"Proof in the Pudding": Designing IoT Plants for Wellbeing

Sarah Martindale◆, Ben Bedwell◆, Robert Phillips°, Micaella Pedros°

◆Horizon Digital Economy Research,
The University of Nottingham,
Nottingham, United Kingdom
{sarah.martindale, benjamin.bedwell}
@nottingham.ac.uk

°Royal College of Art,
Design Products
London, United Kingdom
robert.phillips@rca.ac.uk,
micaella.pedros@network.rca.ac.uk

ABSTRACT

This paper contributes a participatory design case study that used workshops and ideation frameworks to scaffold a conceptualisation of 'user data-actuated' plants. The framework combines ideation cards, worksheets and facilitated co-design, guiding non-experts to conceptually connect personal data, health/wellbeing goals, plants and people. We demonstrate how the framework enabled participants to envisage 'connected' plants, linking personal data outputs with inputs to actuated growing environments, creating biofeedback.

From the results of design work carried out by participants, we synthesise and present four themes. The themes provide a spectrum of values that participants embedded in their connected plants, and in the act of gifting their connected plants to other people. The results of these workshops sign-post a new design space for personal data embodied in plants that could be taken forward by the DIS community.

Author Keywords

Internet-of-things; IoT; plants; growing; wellbeing; health; participatory design; ideation.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; H.5.2. User interfaces: User-centered design.

INTRODUCTION

An ever-increasing range of Internet-of-Things (IoT) products aim to enrich our personal environments by collecting, representing and repurposing personal data. Wearables (e.g. Fitbit), our mobiles (especially through frameworks such as HealthKit), and our homes (e.g. when enhanced with ecosystems such as SmartThings) provide an ecosystem of sensors and feedback devices than can be embedded and connected by non-technical users. However, the creation of a homogeneous environment where we are sensed everywhere and have access to data everywhere, may reduce our opportunities to retreat from persistent pressures, restore our stamina, and make positive plans.

Many IoT products are sold with the promise of revealing insights into the user's activity through quantified measurement and informatics [2,32]. Allied to this data collection capacity, these devices also make the promise of helping to change users' behaviour for the better [22,25]. However, the successful conversion of information and intention into positive action relies on confluence with contextual and social factors. Thus, some products attempt to capitalise on social effects to improve the potential for IoT to change behaviour.

Our research focuses on the potential to use plants as a new interface for personal data. Plants are already integrated into our private and public environments, and growing is shown to improve mental health [4,10,11,24,44] and provide tangible rewards in the form of aesthetically pleasing plants and healthy food [18]. Linking the wellbeing of plants to streams of personal data has the potential to make plants salient in non-"green" settings, abstract data into organic forms, and move our relationship with plants towards one that is more explicitly symbiotic, i.e. where positive behaviour generates positive data, which is mapped to positive growing conditions, and where negative behaviour creates negative growing conditions.

In this paper, we present a case study of co-designing concepts for 'connected' plants using a design framework to explore the possibility of closely coupling plants to personal data and wellbeing. The research questions we set out to investigate through this process were threefold: 1) what data would users appropriate to quantify their wellbeing goals; 2) would they see value in connecting those goals to the growth of plants; and 3) how could that new interaction be meaningful in their social contexts?

The participatory design framework was created specifically to enable members of the public without experience of growing or IoT to generate design concepts. Based on our experience of running participatory design workshops we present an emerging design space for personal data embodied in plants, representing new user-

oriented opportunities to motivate health behaviours and increase a sense of connectedness. We end by reflecting on our method, and opportunities for future work.

BACKGROUND AND RELATED WORK

Our research focuses on the potential for plants to allow end-users - members of the public who produce and consume personal data - to appropriate personal data in ways that enable positive changes to their wellbeing. In particular, we approach this as an opportunity to design systems that place human values, not technology, at the heart of behaviour change. In this section we consider how our three research questions relate to existing work.

Personal data and wellbeing goals

There are many examples of readily available IoT products that seek to enrich environments, changing the way we track our physical activity (e.g. Fitbit[1], HealthKit[2]), shop (e.g. Amazon Dash[3]), and customise our surroundings (e.g. SmartThings[4]). Some of these are designed with the aim of improving health and wellbeing by self-monitoring physical activity (e.g. number of steps), biorhythms (e.g. heart rate), and consumption (e.g. calorific intake), and feeding back this personal data to the user. As a result, the notions of Quantified Self (QS) and Personal Informatics (PI) have emerged [2,32]. Design issues around current IoT devices are well-known, e.g. how to easily connect them to infrastructures [17], but the key challenges have moved up the stack, from low-level device development towards how to present personal data so that it is intelligible and actionable.

Personal IoT devices can generate huge amounts of data, but on-screen visualisations that provide great detail and accuracy may not be best suited to representing personal behaviour: it can be difficult for users to understand numerical data and graphs and to separate the data from its context [39]. More abstract representations of personal data in "natural" form have been explored: Roo et al. present *Inner Garden* - an ambient artefact that provides a representation of the user's mood [33]. The artefact is data-driven yet organic and speaks to some of the same values as small-scale growing: the user can invest effort in tending their garden, or leave it to evolve in response to data. Others also note that physical naturalistic embodiments of personal data may be better placed than numerical visualisations to encourage users to self-reflect [3]. Studies have also demonstrated that infrequent reflections on health data can be effective and reduce the chance of data "fatigue" associated with more detailed persistent feedback

[31]. Aipperspach et al. argue for considering strategic and sparing placement of feedback technology in the home to create heterogeneous, restorative environments [1]. We believe that there is a compelling opportunity to explore plants as a particular class of abstract interface to personal data, offering naturalistic representations of complex data that are well integrated into home settings and demand occasional rather than persistent attention.

Fundamental behavioural challenges have also become salient, in particular how IoT devices can effectively help users to move from "good intentions" to actually taking positive action (the value-action gap). Research has shown that users can change their behaviour as a result of recording their behaviour [22] or by becoming more self-aware [25], but IoT devices have been criticised for building on "naïve change theory" [14 p.251]: relying on individual users making rational decisions (e.g. smart meters and in-home displays [38]) with a focus on utility [27], or assuming users as "data scientists" [34]. There is evidently value in generating and collecting personal data that can be related to wellbeing goals, but research shows that some people may struggle to positively appropriate 'rational' quantifications of their behaviour. In practice, a range of contextual and social factors, not least social pressure by our family, friends and community, influence decisions about our behaviour. Our participatory design method caters for 'rational' and social motivations, encouraging participants to generate designs that include private and social feedback loops of personal data.

Connecting plant growth and personal wellbeing

In the previous section we identify plants as a potentially valuable naturalistic representation of personal data. However, we approach plants and growing as a site for new design, not as professional growers or horticulturalists. To this end we build on existing understandings of the links between plants, growing and wellbeing drawn from health and environmental psychology.

Growing processes, e.g. gardening and farming, have been the site of previous research by the sustainable HCI movement, e.g. [26], which has sought to address environmental as well as social concerns, such as health and wellbeing [9,13]. Traditionally, small-scale growing has played an important role in food production around the world. In an organised fashion, allotments and community gardens were at one time vital in providing the poor with fresh produce in Europe and North America [16], and were re-characterised as "victory gardens" following WW2, providing food security and physical activity for returning soldiers and their communities. In the UK there are currently estimated to be over 300,000 allotments [30], with long waiting lists in many cities [7].

Our interest is in the relationship between contemporary small-scale growing and health and wellbeing, and in bringing these positive effects into the design of new products. From a physical health point of view, obesity and
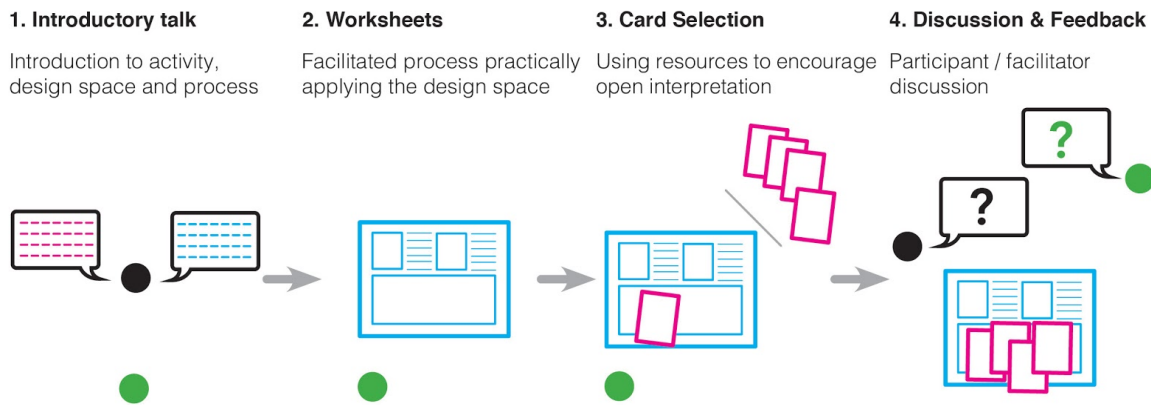
---

1. Introductory talk

Introduction to activity, design space and process

2. Worksheets

Facilitated process practically applying the design space

3. Card Selection

Using resources to encourage open interpretation

4. Discussion & Feedback

Participant / facilitator discussion

Figure 1. PD workshop process

related illnesses such as diabetes have been linked with increasing consumption of processed foods over fresh foods [36]. The physical health benefits of including "grow your own" produce in our diet, as well as the exercise involved in growing, are well established [18] yet only a small proportion of the population engage in small-scale growing. This can be partly attributed to the spread of urban space and a lack of private gardens [8], and to a fear of the risks of "non-professional" food production [18].

Beyond the physical benefits, plants and the process of growing play an important role in a holistic view of wellbeing. The particular qualities of plant-person relationships promote a closely coupled relationship with the grower's environment and their subjective wellbeing [11]. Steiner et al. have explored ways to interface with plants through natural language to allow plants and humans to have a heightened, possibly more harmonious understanding of their shared environment[5]. Studies in Europe have demonstrated the inclusionary value of community gardening for older people, as a place for growers to develop new social connections [24] as well as an opportunity for physical activity [5]. Others have shown that sessions spent caring for plants provide a positive "antidote to urban living" and to the work day [10], with growers exhibiting less depression and fatigue and more vigour [44]. Even very short amounts of "green exercise" - tending to plants or green spaces - provide significant benefits to mental health [4].

We see opportunities in design that makes key qualities of plants and growing more salient, to encourage people to reflect on and act on their wellbeing. Literature points to qualities of the plant-person relationship that we are interested in surfacing: the achievement and self-esteem associated with caring for a living plant, and the sense of connectedness with the environment and others that can emerge by growing with or for others.

---

[5] https://msrstudio99.wordpress.com/2015/11/05/project-florence/

IoT devices as socially embedded artefacts

In order to bridge the value-action gap and incorporate the benefits of the plant-person relationship, we believe that the design of connected plants should account for and be adaptable to users' values and circumstances. Ohlin & Olsson reflect on the tendency for QS and PI to focus on utility and call for HCI researchers to draw on their traditions of postphenomenology to design IoT that fits with and responds to the "whole life-world context" of users [27], pointing towards the community's "maturing confidence in human-centred design" [40].

Previously, design research had to make "insider tools" that enabled designers to view through the participant's eyes; whilst this is still relevant, it is easier to include users in the design process [ibid.]. Empathetic or co-design is a process of "getting people personally, emotionally engaged so they can reflect on a process they are designing for" [42]. Co-design helps designers gather "information about the contexts of people's interactions with products" to understand how these could be adapted or simplified [ibid.]. The practise of co-design is often built around "tools that create a fluency" and engagement [37]. Whilst very "few high-street designers will have the time to engage in these sorts of activities", they are important for getting wider perspectives from, or with, intended audiences [19]. Co-design is a means to understand people's "behaviours and perceptions" placing them centrally in the design process [40]. The process of co-design can "be creative for all stakeholders involved" if there is targeted involvement and a clear strategy [19]. The practice implies that users can act as idea creators but also be involved as "detectors of value-in-context" [43].

Traditionally, participatory design (PD) has involved users in "evaluative research: testing existing products or prototypes of developed concepts" [42]. PD is different to co-design as it has more "open-ended outputs to look for [design] opportunities" [6]. The often-non-linear process of PD explores users' either "existing or possible contexts of use, aiding the design team to have a more empathetic approach" [6].
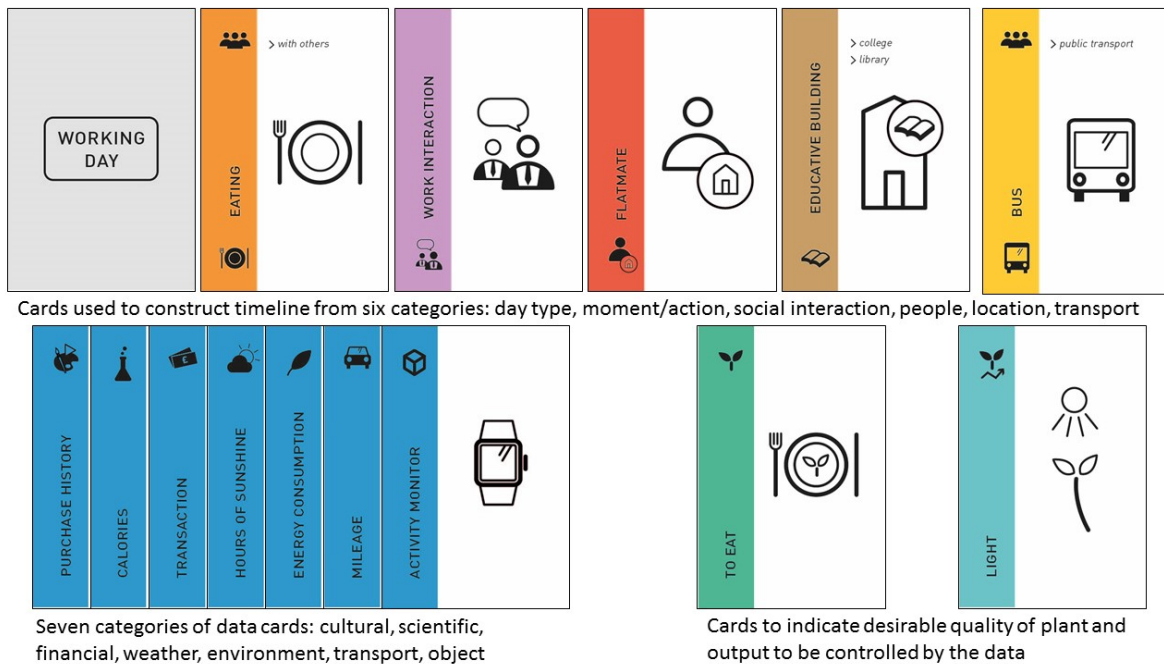
Cards used to construct timeline from six categories: day type, moment/action, social interaction, people, location, transport

Seven categories of data cards: cultural, scientific, financial, weather, environment, transport, object

Cards to indicate desirable quality of plant and output to be controlled by the data

Figure 2. A selection of the PD workshop ideation cards

This practice can often create a "rich setting" to discuss and work within [6]. The PD process should take participants through "small steps" of a process, without overwhelming them [42]. Including users in PD processes should situate audiences in a "context, actively involving [them to] try things" [40]. Our intention was to use PD to clearly create a place for people to have a conversation about how they could make interaction with plants as IoT devices engaging, rich and applicable to themselves.

METHODOLOGY
To help end-users understand the new concept of appropriating their data in the form of plant growth, a workshop was designed involving a four-stage process (Figure 1). Workshop resources comprised worksheets and a flexible ideation card system[6]. The two worksheets guided participants through a thirteen-step task. Worksheet A collected some background information (step 1) then invited participants to use ideation cards to consider their own daily routines (steps 2-5) and the data that they generate - purposefully and incidentally - associated with those patterns of behaviour (steps 6 & 7). Worksheet B provided a framework for imagining, step-by-step, how a connected growing system embedded in the user's social context could support them to achieve a goal. Participants were asked to identify: one aspect of the day they mapped that could be changed to improve their health and wellbeing (step 8); data to measure progress (step 9); a type of plant to connect (step 10); the effect of data on the plant (step 11); a person to whom the plant could be given (step 12); and the impact of giving the plant to that person (step 13). To aid

completion of the worksheets participants could utilise a bespoke deck of 96 pictogram cards that represented daily interactions, types of personal data and attributes of a connected plant (Figure 2). Participants used the worksheets and cards in combination to complete the workshop process (Figures 3 & 4). This section describes firstly how the workshop method was designed and implemented on 2 occasions and secondly how PD was documented and subsequently analysed in this case.

Design Method
As highlighted in the related work, we expected our participants to have differing responses to personal data, and differing goals and motivations. The "key to running successful [workshops] is preparation" so our resources directed participants and stakeholders [21]. The inclusion of end-users within design workshops can develop either "convergent conversation[s], narrow[ing] discussion or divergent conversation[s], expand[ing] discussion by allowing for a multiplicity of perspectives" [12]. To create effective design outputs, "designers must have an understanding of the characteristics and diversity of those" they design for [23], and so while the worksheets directed the participants the cards offered flexibility. This combination encourages convergent and divergent thinking, ultimately offering new but appropriate designs.

The worksheets and cards drew inspiration from the noun project[7], a repository of pictograms. These pictograms communicate complex activities through visual representation, and are nondescript so they still encourage convergent and divergent thinking, because they are open to

---

[6] https://www.horizon.ac.uk/project/growing-data/

[7] https://www.thenounproject.com/

interpretation. The team built on their previous experience of design projects [28], open design principles [41] and running workshops for understanding [29]. If the team had created a prototype or physical technology response it could have steered the participants, resulting in either approval or complete lack understanding and alienation. It was also the goal of the design team to scope the area, and too early to use a Research Through Design approach.

To challenge the participants and develop their understanding of the connected plant concept they needed to be facilitated. To help make this concept understandable to a lay audience the process involved storyboarding. Storyboarding is the act of documenting scenarios "illustrating a character-rich story line describing the context of use for a product or service", as scenarios can "help to communicate and test the essence of a design idea within its probable context of use" [15]. Storyboarding helps participants to contextualise and get "a grip on context and time by forcing them to attend to diverse aspects, integrate these aspects and confront the implications that could be postponed with abstract considerations" [20]. The worksheet and cards built on Sampaio et al's scenario constructing techniques to "enhance a situation with a concrete and precise goal inside a scenario and provide a means of communicating among stakeholders" [35]. Scenario building helps users perceive situations beyond their existing knowledge or perception, highlighting "possible features, functions or design attributes" [15]. The structure of the resources (worksheets and cards) provided a framework for the participants to work within and expand from.

Workshop 1
The Victoria and Albert Museum in London annually hosts a 'digital design weekend', coinciding with a major design festival. As one of the largest museums in the capital, this is a vibrant space to attract technology minded participants that are already motivated to engage in design. The theme in 2016 was *the future of engineering and making*. Members of the public visiting the museum could interact with installations and hands-on activities delivered by invited artists, designer, engineers and technologists. A free publication about the work presented was also distributed at the event (and subsequently online[8]). In total across Saturday and Sunday 24,487 people visited the festival.

During the two days of the event 151 members of the public took part in our workshop; 26 completed the PD process using our worksheets and ideation cards. Some participants enrolled through an online platform, but were also supplemented by passers-by. Because of the open nature of the event it was necessary to offer several levels of engagement for participants. The entry-level introduction offered on arrival was a description (with supporting images to illustrate) of the basic design space being

explored: the potential to actuate a controlled indoor growing system using some form of personal data. At the next level, participants (especially those with children) were invited to engage with the idea of growing plants indoors, using household materials and open source 3D printed components[9] to make a simple hydroponic system to take away. Finally, those visitors who could invest more time in exploration of the design concept could undertake our full PD process.

All those who undertook the PD task gave their informed consent to form part of our research. Working through the two worksheets was a relatively contemplative activity for individual participants, although researchers were on hand to offer explication or advice about the ideation process itself, and to probe decisions at different stages. Some participants were content to work through the sheets independently, examining and choosing cards that represented their experiences with minimal prompting and support; while others enjoyed verbalising their thought processes for the benefit of researchers. In either case, a facilitator would re-join a participant at the end of the process and ask to be guided through the completed worksheets (e.g. Figures 3 & 4). As the activity was largely self-directed, the amount of time participants devoted to it was variable; although all devoted their sustained attention for a period of between 15 and 30 minutes.

Workshop 2
Shortly after the London workshop, members of the research team ran another workshop elsewhere in the UK to gather additional responses from an alternative audience. For the second workshop, we deliberately set out to recruit participants with an established interest in growing plants, but not necessarily in design and technology innovation. To do this we worked with an existing research partner – a large allotment association in the UK Midlands - utilising their visitor centre and connections with communities of local growers. The much smaller sample size (5) from workshop 2 is unsurprising given the relatively small pool of potential participants available from the locality at a given time on a weekday. Like workshop 1 at the museum, participants were self-selecting volunteers and the process of the sessions was identical.

Because all participants at workshop 2 undertook the PD activity simultaneously, there was opportunity for group discussion and feedback; unlike at the museum workshop, where participation took place on an ad hoc basis over the course of two days. Nevertheless the common aim in both workshops was to enable participants to step through the worksheets based on their individual circumstances, considering the value of data about their everyday lives and

---

[8] https://lguariento.github.io/Engineering-the-Future/

[9] https://www.3dponics.com/wiki/download-parts-3dponics-mini/

how that could be harnessed for their own benefit through the design of a data-driven plant.

Analysis

In London 26 people completed the PD process using our worksheets and ideation cards. We asked all participants to provide some basic demographic information, from which we learned that most of the museum sample were female (16/22), living in an urban environment (21/25) and in the age range 25-35 (13/25). Workshop 2 involved 5 participants. Like those in London, most of the participants were female (4/5) and city-dwelling (4/5), but they were distributed across a wider age range, with 2/5 participants in the over 55 year-old category. In the following section, results from both workshops are presented together. The results do not compare groups of participants but consider the variety among responses to the ideation activity.

All participants' contributions were carefully documented in situ at the workshops through overhead photographs of completed worksheets, because these were transient artefacts, which had to be disassembled so that participants could return the cards to the decks for use by others. Photographs from both workshops were subsequently collated, transcribed and analysed as a data set. This analysis attended to the particularities of each individual response and also sought to identify emergent themes that applied across the data set. The first stage of analysis involved quantifying information about the participants and their use of the workshop resources. Next all the qualitative data participants provided about their goals, connected plants and plant recipients were coded. Once coding of the entire data set was complete, data were grouped into emergent themes. Codes and thematic groupings were checked for interrater reliability by members of the research team. A characterisation of each theme was then produced based on the underlying data. Finally the team selected two exemplars to illustrate the themes expressed in participants' conceptual designs for connected plants.

RESULTS

In this section, we report the results of this PD study, describing how the resources were utilised in the workshops. Firstly, we present an overview of participant responses to the ideation process and observable patterns within those responses. Secondly we draw out emergent themes from the workshop materials, in terms of the participants' design goals and the values embodied in the products they envisaged. Finally, we look in detail at some exemplars to illustrate how the PD process worked as a scaffolded, sequential task producing conceptual designs.

Worksheet A

In step 1 of the PD process we asked participants for a couple of free text responses to the general subject of growing and wellbeing, in addition to demographic information. In general, participants expressed an abstract concept of growth as development and change, rather than a literal association with plants and the natural world.

However, perhaps unsurprisingly, 3/5 participants at workshop 2 specifically associated the concept of growth with the cultivation of edible plants. Taken as a whole, participants' statements about wellbeing acknowledge both physical and psychological aspects.

Prior to any product design, worksheet A foregrounded individual contexts of use: the initial choice for participants was whether to focus on a working day or a day off. Overwhelmingly, our participants focused upon their activities during a working day: only 5/31 participants concentrated on leisure time. Participants also made quite extensive use of the ideation cards in constructing their timelines, on average selecting 13/48 activity cards available for this purpose. In terms of the types of features detailed in the timelines, cards relating to people and actions were more prominent than those relating to space and movement. When asked to indicate personal data associated with the activities depicted in their timeline, participants on average identified 12/39 different types of data depicted on cards. The data cards were split into 7 categories: financial, cultural, scientific, weather, transport, object and environment data. Participants selected data types from across these groupings, on average utilising data cards from more than 4 of the categories.

Worksheet B

The design of worksheet B allowed for cards used previously to be transferred into this second stage of the process. However, 90% of participants described the underpinning objective in their own words. Participants were more likely to make use of the cards to specify the data input used to calculate their achievement, but two thirds of those who completed the task still jotted down ideas without reference to the cards, tailoring the parameters of their system per the circumstances they had in mind. Some indicators unanticipated by the ideation deck included a sewing machine being switched on, silence and free (i.e. unscheduled) time. 4 ideation cards were provided to highlight qualities of plants that users might appreciate: fragrance, visual appeal, tactility and edibility. These seem to have encompassed the opinions participants wanted to express, as they were utilised by all bar one. Where a few participants added to the resources it was to specify a plant, thus providing additional insight into the characteristics of value to them, e.g. the aroma when lemon verbena is rubbed. Many of the participants appreciated multiple qualities of plants: averaging across the sample, participants wanted their plant to exhibit more than 1 desirable feature.

Emergent themes

Bringing together data of participants from the two workshops revealed four high level themes. Imagined affordances of a connected plant as a living product are intrinsic to all four of the themes. Quotes are taken directly from notes and sketches on the worksheets.

Caring for yourself
Understandably, many of the changes that participants wanted to make in their lives related to taking better care of themselves. What was interesting was the variety of ways in which participants wanted to go about achieving an improvement in their wellbeing. In some cases, the focus was on physical changes: taking exercise (p10, p14, p16, p24, p26, p29), playing sport (p12, p13, p15) and/or eating a healthier diet (p5, p6, p8, p10, p25, p29). Others focused instead on steps to support their mental wellbeing by: being more organised about work commitments ("do less things but better" p30); pursuing hobbies ("more personal creative time" p22); relaxing ("more me-time" p11) and resting ("get more sleep" p31). One participant (p6) pointed out that "fun" might be another reason to interact with the growing system. Despite the introspective starting point, almost all participants situated the goal embodied by their plant in wider social contexts; only one person couldn't see the value in giving the plant to someone else ("because I'm the only one that matters, right?" p25). In direct contrast, another participant (p10) identified that concern for the plant's health might be more motivating than personal wellbeing: "maybe I'll be responsible to take care of the plant, and indirectly care for my health". Here the incorporation of effect on another organism into an IoT system explicitly influences interaction. Coding participants' responses revealed that self-care was often discussed in conjunction with tangibility, connection and discovery. Most obviously, participants identified how a virtuous development cycle would be established between their behaviour, the plant's health and the experience of the plant by others: "It will make our space prettier. A happy home is going to improve my wellbeing" (p26).

Tangible feedback
The physical presence of the plant within a space as a tangible reflection of their behaviour was something that participants considered from several perspectives. As an organic object the plant provides a visual status update and its existence within an environment provides constant feedback about progress ("it is a tangible indication of my goal each day" p14). Good progress can be translated into a uniquely botanical outcome that serves as a reward for good behaviour: "every time I engage with people [by messaging old friends], the plant will shake to liberate the smell" (p9). For two of the growers who participated in workshop 2, the intrinsic value of plants as plants took precedence over any symbolic or embodied connection to a user. One of these participants focused on plants within a natural ecosystem in terms of the benefits "to help bees and pollinators to survive and continue" (p27). The other participant saw the system as an opportunity to "assist" and "benefit" someone else, who would otherwise be unable to grow plants, "a stranger who lives in a flat with no outside space" (p30). This brings us back to the idea of a virtuous cycle from behaviour, to growth, to shared experience. For several participants, the ultimate outcome of the cycle was tied to the possibility of coming together for a meal of healthy, home-grown produce. For example, p7 imagined giving her plant to a friend who then "has some vegetables" which taste "more delicious" and "we can eat together".

(Re)connecting people
The idea that connected plants would draw on and/or reinforce a significant bond between people was common among participants, for several reasons, many of which revolve around additional levels of meaning. This might be creating a sense of proximity to "a foreign friend" through the plant, which "will keep communication alive - even if we don't have time to catch up each day, progress is visible" (p28). In this example the two friends are working in tandem towards "similar goals" and monitoring/ supporting each other's efforts, and other participants likewise expressed the value of being made "more
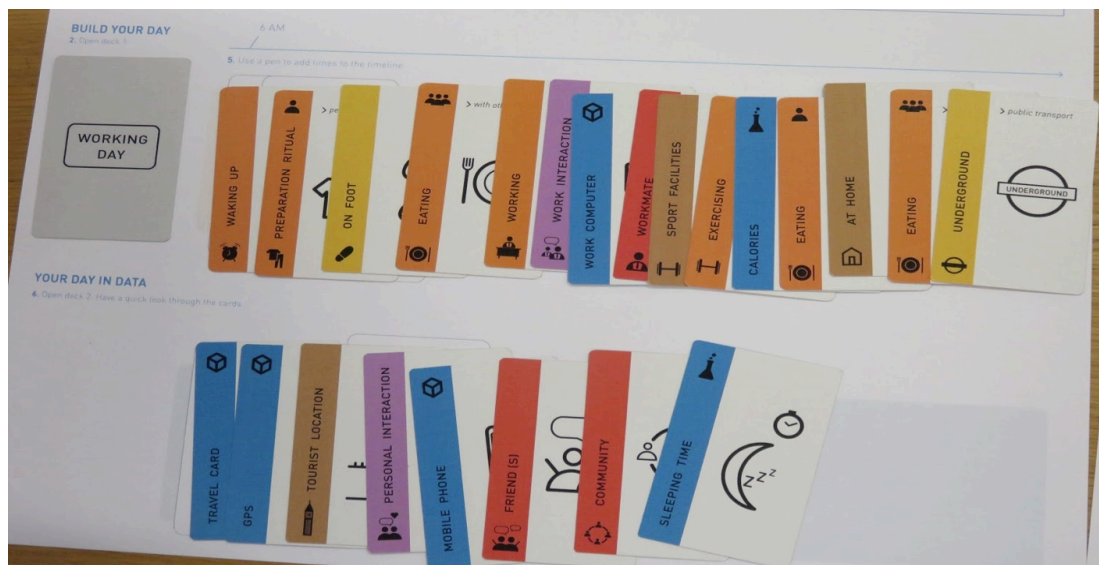

Figure 3. P20's worksheet A showing interspersed activity and data cards

accountable with each other's activities" (p19). One participant felt the plant could serve to reaffirm the love between partners - "I love her and she loves plants" (p23) - meaning that the goal is pursued as a gesture of care for both something and someone else. Similarly, the goal could be used to demonstrate that another person's views are being taken seriously, e.g. p29, who would give the plant to a brother who "lives far away and is passionate about healthy living". Some participants also emphasised the trust placed in the custodian of the plant, who is in a powerful position of supervision: "we will hate/love him" but ultimately want "to please, and get him a good taste with the plant" (p4). In some cases, when participants would give the plant to family the choice was apparently motivated by convenience, rather than deeper meaning, because they live together (p13, p15). However, in other cases, the plant was identified as a simple mechanism for assuaging worry among family: "My sister always worries about me! If she had the plant, she might not check in with me so much! Perhaps our contact with each other would evolve beyond a checklist of 'how are you?'!" (p16).

Discovery
All of which indicates that participants' decision to share their plant and its significance with someone else is bound up in considerable socio-cultural complexity. In the process of thinking through this complexity a couple of participants envisioned negative consequences. One mother who would entrust the plant to her kids, could foresee that they might nag her to achieve a better growth rate for the cabbage, which "could be annoying" (p12). Under these circumstances, the participant felt that her motivation "may not last"; with the conceivable consequence that the cabbage would wither like any other neglected houseplant, giving the children even greater ammunition against her.

A different participant, who chose a flatmate as "convenient" recipient of the connected plant, acknowledged that this might in fact be an unwanted gift: "he's gonna complain because the plant will be in his room" (p11). For some other participants, however, the novel interpersonal challenges posed by giving a data-driven plant to someone else were opportunities, which could serve a valuable forcing function to stimulate and maintain behaviour change. Some goals listed were exploratory, such as "seeing new places and meeting people" (p2). This participant described the plant as a potential conversation starter because its fruit could be given to or shared with others. P21 had a similar idea that the act of gifting the plant could instigate a new relationship with an "unknown person". One participant saw the plant as a more roundabout route to new social interactions because it would improve her relationship with her best friend and consequently build her self-confidence to make new friends too: "feeling secured with good friends helps me to go for more interaction with different people" (p18).

Exemplars
To demonstrate how the themes overlapped and interconnected for individual participants, we briefly work through two exemplars of designs produced by p20 & p24.

"Reclaiming home" plant
P20 - a marketing assistant - mapped out her working day using worksheet A resulting in a routine that contained only 6 data cards, but - unlike all other participants - interspersed these into her timeline (see Figure 3). The emphasis in her map is on actions and places, and the map demonstrates that she spends only the briefest moment at home in between work, fitness and social activities.

Reflecting on this routine, her health and wellbeing goal stated on worksheet B focused on carving out more time from this packed schedule for "personal projects", e.g. "artwork; reading; meditating", and conceived a plant that
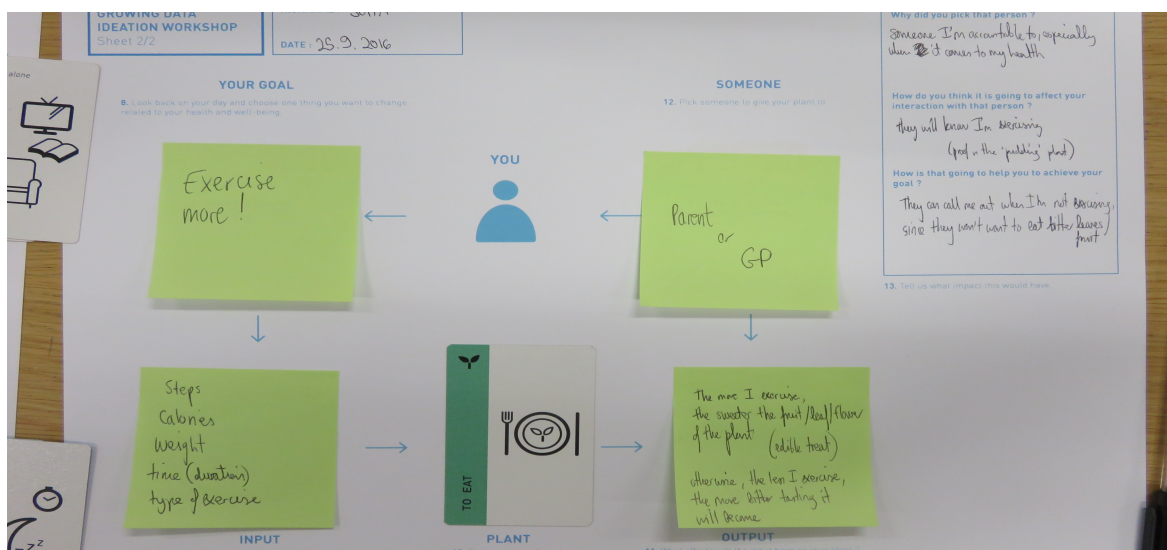

Figure 4. P24's worksheet B, showing connections between goal, data, output and relationships in conceptual design

will receive light whenever she spends time at home, becoming more attractive as home time increases (*tangible feedback*). This inwards-facing goal is typical of the *caring for yourself* theme, but developed as the participant translated it to her plant: in notes on the worksheet, the participant suggests that she would gift her plant to her mother. In doing so, the plant provides social value: on one hand knowing that her child is spending more personal time at home would "be good for her [the mother's] peace of mind" (*connecting people*), and on the other it would encourage the participant to visit her mother more often to see the plant ((re)*connecting people*). In this way, "my mum and I could help each other to achieve my goal".

"Proof in the pudding" plant

P24 - a customer experience consultant - used many data cards when mapping her working day, and split these into two rows on the worksheet to express both the data she is "using now" and data she would "like to have".

Having reflected on her day, the participant focused on the physical goal to "exercise more" (*caring for yourself*). From her existing and desired pool of generated data the participant specified 5 data types, from number of steps to her weight, which would be fed to her plant. Her connected "proof in the 'pudding' plant" would then produce *tangible feedback* in the form of sweeter fruit in response to her physical activity or bitter fruit from lack of activity (see Figure 4). To increase the chance of this motivating her, she suggested that the plant could be given to her parent or doctor ("someone I'm accountable to"; *connecting people*).

These exemplars are not outliers compared to other concepts from the workshops, but demonstrate how the worksheets and cards allowed participants to produce rich, contrasting designs. While participants' designs shared common features - motivating healthy behaviour, nourishing people and enhancing the living environment - the mechanisms selected were idiosyncratic. Both exemplars align with *caring for yourself*, however p20's design promotes wellbeing in terms of relaxation and peace of mind - physical activity is already part of her mapped daily routine - while p24's design focuses on bringing more physical activity into her day. Although both exemplars are designed to foster *connectedness*, p24 conceptualises the possible benefits of "accountability" to an external authority figure (her doctor), as well as (like p20) to a parent.

DISCUSSION

Reflecting on the results presented above, there appear to be three broad positive conclusions that we can make about personal data embodied in plants as a new design space. These points relate to our original research questions: 1) what data would users appropriate to quantify their wellbeing goals; 2) would they see value in connecting those goals to the growth of plants; and 3) how could that new interaction be meaningful in their social contexts? Although our reflections relate to connected plants as a

particular novel case of IoT, our results also sign-post wider issues of interest to the DIS community.

Appropriating personal data

Firstly, participants were able to envisage ways in which data derived from their everyday routines could be repurposed in order to measure progress towards a desired life change. These data might come from diverse sources and might not, taken in isolation, have any obvious connection with the goal being pursued. Secondly, participants could conceptualize a connected indoor actuated environmental system that used the data they specified to control the growing conditions of a plant. They liked the idea that this plant would provide tangible feedback about their behavior through its physical presence, and its natural development and vigor, which would result in sensory reward (flower, scent, fruit). In summary, our results suggest that participants without technical or plant growing experience can appropriate personal data as a component of a value-driven design process.

When IoT is sold as a concept to a public still unsure what the term means and what the technology has to offer, the examples of products often illustrate an instrumental connection between sensing capability, data collected by those sensors, and automated processes triggered by those data. In terms of IoT products to promote health and wellbeing the underpinning paradigm is quantified self, the longitudinal collection of physiological information in order to identify patterns and changes, with the potential to introduce an element of comparison between users. Our PD approach, however, started with a human goal and encouraged participants to leverage the value inherent in that goal to determine what data would be collected and how it would be utilized. The data that participants chose do not necessarily have an obvious causal relationship with their goal. For example, in our study p11 would use silence as an indicator of caring for yourself. Establishing a link between an individual and another living organism complements both the personal character of the data and the underlying health and wellbeing goal. This promotes meaningful interaction that fits naturally with the user's established daily routines.

Designing embodied remote presence/healthcare

The value in the connected plants concept is revealed in our participants' designs, which often overlapped with a concept familiar to the interaction community: remote presence. In this case, the medium – growing plants – is novel. Additionally, the designs point to an interesting variety of external situations in which the plant might use personal data to create presence, including some that are particularly sensitive such as medical or insurance providers. We believe that the connected plants concept has particular value when considering opportunities for new products in remote wellbeing and healthcare. From a design perspective this application area presents product, service and system opportunities and challenges, not least how

personal data can be revealed to a third party in a way that is informative, but privacy-preserving. Ode[10] is a dementia product designed for sensitive communal environments – care homes – that releases food aromas to coincide with the ideal mealtime schedule of a resident to help stimulate appetite. Like our connected plants, Ode is designed to fade into the environment such that it draws attention only from those intended to be influenced, and is an abstract representation of personal data, in this case hiding the precise details of the resident's meal plan. Remote wellbeing and healthcare design applications demand sensitivity around personal data: secure and abstract representations of data in the form of naturalistic interfaces – such as connected plants – are ideally suited to underpin such opportunities.

Making personal data public

Participants negotiated the final imaginative leap in the process, which we had anticipated might present a challenge, identifying circumstances in which it might be valuable to entrust the plant (and its personal significance) to someone else. In making their choices of recipient, participants considered how interactions with the plant would intertwine with interpersonal interactions, in ways that might allow them to reinforce existing close relationships or form meaningful new bonds.

Although our worksheets encouraged participants to consider whether they would benefit by sharing their connected plant, the resources did not suggest whom they might share it with. In practice - except p25, who did not want to share their plant - participants decided on a broad range of recipients, including close social connections (e.g. family and friends) and acquaintances (e.g. doctors), as well as unknown recipients. The participants easily created gifts for these recipients from the combination of personal data and plants. In some cases the personal data *enhanced the plant*, making it a more interesting, surprising or emotive artefact; in other cases, the plant *enhanced the personal data*, putting it in a form that would be attended to (not ignored) or be more meaningful.

In most cases, the data chosen by the participants was sensitive, including a variety of health indicators and home presence. Given the focus of our workshops on creativity rather than critique, it is unsurprising that issues of trust, privacy and security were rarely raised. Instead, some participants did focus on accountability, i.e. the ability of their plant to reveal just enough of their data to the recipient to embarrass or encourage them to work towards their goals. Worksheet B enabled participants to pick and choose how explicitly and precisely their plant responded to data, and participants designed biofeedback that ranged from the abstract and continuous (fruit flavor changes as behavior indicators) to discrete (plants that move when behavior occurs). We believe that our results implicitly highlight

valuable qualities of plants as privacy-preserving data interfaces: in comparison with digital devices plants respond more slowly to stimuli (at least at the level where the results are perceivable by the human owner), hence plant feedback is a cumulative, delayed representation of the underlying data in which individual data points are lost. Unless grown in a tightly controlled environment, plants are also susceptible to a range of other environmental stimuli – sometimes serendipitous (e.g. draughts or shade), sometimes deliberate (e.g. intervention by the owner and other passers-by). Generally speaking, plants offer potential for a representative, yet imprecise and organic view of personal data that might be gifted to others to reveal a representation of self that does not compromise personal privacy and security.

Reflection on method

This study was conducted at a small scale in two different places with self-selecting participants available at the workshop time. The participants' responses were guided by the ideation tools provided, although they always had the opportunity to substitute cards with notes of their own devising. In the main, participants used the cards for Worksheet A, but expressed more of their own ideas when completing Worksheet B. The authors would repeat the activity with an actual artefact/prototype to see impact and insights over time. The work did yield the validation of its users through the process and therefore, we believe, warrants this design space as something of value.

CONCLUSION

In this paper we presented a participatory design process in which 31 participants without technical backgrounds designed new forms of biofeedback - plants driven by personal data - with the aim of motivating themselves to achieve a health and wellbeing goal. We demonstrated how our worksheets, ideation cards and step-by-step method allowed the participants to creatively tackle a challenging design task, appropriating personal data and producing a range of "connected plant" concepts. This process demonstrated that incorporating living products into IoT systems could create affordances for self-care, tangible feedback, social connection and discovery. Our findings suggest that biohacking to connect IoT sensors with digital hydroponics would produce new opportunities for meaningful forms of tangible and embedded interaction.

We believe that this is a fruitful design space, and sign-post ways that the DIS community can take this exploration forward. Our participants' designs show how value-driven IoT can allow designers to break out of the "rational" constraints of quantified self and utilitarian actuation applications; they also demonstrate that plants can be a useful form of privacy-preserving, socially embedded feedback for sharing and representing personal data. With this in mind, we suggest "connected plants" may have a valuable role in embodied remote presence and healthcare.

---

[10] http://www.myode.org/

REFERENCES

1. Ryan Aipperspach, Ben Hooker, and Allison Woodruff. 2008. The heterogeneous home. In *Proceedings of the International conference on Ubiquitous computing (UbiComp '08)*. ACM, New York, NY, USA, 222-231.

2. Manal Almalki, Kathleen Gray, and Fernando Martin Sanchez. 2015. The use of self-quantification systems for personal health information: big data management activities and prospects. *Health Information Science and Systems* 3, 1: 1–11.

3. Ilhan Aslan, Hadrian Burkhardt, Julian Kraus, and Elisabeth André. 2016. Hold my Heart and Breathe with Me: Tangible Somaesthetic Designs. In *Proceedings of the Nordic Conference on Human-Computer Interaction (NordiCHI '16)*. ACM, New York, NY, USA.

4. Jo Barton and Jules Pretty. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Journal of Environmental Science Technology* 10, 3947: 55.

5. Agnes E van den Berg, Marijke van Winsum-Westra, Sjerp de Vries and Sonja ME van Dillen. 2010. Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment. *Environmental Health* 9, 74.

6. Erling Björgvinsson, Pelle Ehn, and Per-Anders Hillgren. 2010. Participatory design and "democratizing innovation". In *Proceedings of the Biennial Participatory Design Conference (PDC '10)*. ACM, New York, NY, USA, 41-50.

7. Campbell M, and Campbell I. 2013. *Allotment Waiting Lists in England 2013*. Transition Town West Kirby and The National Allotment Society.

8. Department for Communities and Local Government (DCLG). 2010. *English Housing Survey*. London: Crown, 1999.

9. Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the landscape of sustainable HCI. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 1975-1984.

10. Marion Ericsson Nolan. 2012. *Allotments, health and well-being*. Doctoral dissertation, University of Essex.

11. Jon Fieldhouse. 2016. The Impact of an Allotment Group on Mental Health Clients' Health, Wellbeing and Social Networking. *British Journal of Occupational Therapy* 66, 7: 286-296.

12. Derek Greenly and Colin Carnall. 2010. Workshops as a technique for strategic change. *Journal of Change Management* 2, 1: 33-46.

13. Tad Hirsch, Phoebe Sengers, Eli Blevis, Richard Beckwith, and Tapan Parikh. 2010. Making food, producing sustainability. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10)*. ACM, New York, NY, USA, 3147-3150.

14. Huang, M.L. and Huang, W. 2013. Innovative Approaches of Data Visualization and Visual Analytics. IGI Global.

15. IDEO. 2013. Design Thinking for Educators. Available via http://www.designthinkingforeducators.com/toolkit [accessed 1/15/17].

16. Seana Irvine, Lorraine Johnson, and Kim Peters. 1999. Community gardens and sustainable land use planning: A case study of the Alex Wilson community garden. *Local Environment* 4, 1.

17. Michael O. Jewell, Enrico Costanza, and Jacob Kittley-Davies. 2015. Connecting the things to the internet: an evaluation of four configuration strategies for wi-fi devices with minimal user interfaces. In *Proceedings of the International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 767-778.

18. Jonathan R Leake, Andrew Adam-Bradford, and Janette E Rigby. 2009. Health benefits of 'grow your own' food in urban areas: implications for contaminated land risk assessment and risk management? *Environmental Health* 8(1), 6.

19. Yanki Lee. 2008. Design participation tactics: the challenges and new roles for designers in the co-design process. *International Journal of CoCreation in Design and the Arts* 4, 1: 31-50.

20. Corrie van der Lelie. 2006. The value of storyboards in the product design process. *Personal and Ubiquitous Computing* 10, 2: 159-162.

21. Vicky A Lofthouse and D. Lilley. 2006. What they really, really want: user centred research methods for design. In *Proceedings of International Design Conference*. Dubrovnik.

22. Alessandro Marcengo and Amon Rapp. 2014. Visualization of Human Behavior Data: The Quantified Self. In *Innovative Approaches of Data Visualization and Visual Analytics*, Mao Li Huang. and Weidong Huang (Eds.). IGI Global, Hershey, PA, 236-265.

23. Chris McGinley and Hua Dong. 2011. Designing with Information and Empathy: Delivering Human Information to Designers. *The Design Journal* 14, 2: 187-206.

24. Christine Milligan, Anthony Gatrell, Amanda Bingley. 2004. 'Cultivating health': therapeutic landscapes and older people in northern England. *Social Science & Medicine* 58, 9: 1781-1793.

25. Raymond G. Miltenberger. 2008. *Behavior modification: Principles and procedures* (4th ed.) Wadsworth, Belmont, MA.

26. William Odom. 2010. "Mate, we don't need a chip to tell us the soil's dry": opportunities for designing interactive systems to support urban food production. In *Proceedings of the ACM Conference on Designing Interactive Systems (DIS '10)*. ACM, New York, NY, USA, 232-235.

27. Fredrik Ohlin and Carl Magnus Olsson. 2015. Beyond a utility view of personal informatics: a postphenomenological framework. In *Adjunct Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing and ACM International Symposium on Wearable Computers (UbiComp/ISWC'15 Adjunct)*. ACM, New York, NY, USA, 1087-1092.

28. Robert Daniel Phillips, Jesse Michael Blum, Michael A. Brown, and Sharon L. Baurley. 2014. Testing a grassroots citizen science venture using open design, "the bee lab project". In *CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14)*. ACM, New York, NY, USA, 1951-1956.

29. Robert Phillips, Dan Lockton, Sharon Baurley, and Sarah Silve. 2013. Making instructions for others: exploring mental models through a simple exercise. *Interactions* 20, 5: 74-79.

30. Tanja Pless-Mulloli, Vivienne Air, Catherine Vizard, and Phillip Hartley. 2004. The legacy of historic land-use in allotment gardens in industrial urban settings: Walker Road allotment in Newcastle upon Tyne, UK. *Land Contamination and Reclamation* 12: 239-251.

31. Nithya Ramanathan, Dallas Swendeman, W. Scott Comulada, Deborah Estrin, Mary Jane Rotheram-Borus. 2013. Identifying preferences for mobile health applications for self-monitoring and self-management: Focus group findings from HIV-positive persons and young mothers. *International Journal of Medical Informatics* 82, 4: 38–46.

32. Amon Rapp, Federica Cena, Judy Kay, Bob Kummerfeld, Frank Hopfgartner, Till Plumbaum, and Jakob Eg Larsen. 2015. New frontiers of quantified self: finding new ways for engaging users in collecting and using personal data. In *Adjunct Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing and International Symposium on Wearable Computers (UbiComp/ISWC'15 Adjunct)*. ACM, New York, NY, USA, 969-972.

33. Joan Sol Roo, Renaud Gervais, and Martin Hachet. 2016. Inner Garden: an Augmented Sandbox Designed for Self-Reflection. In *Proceedings of the International Conference on Tangible, Embedded, and Embodied Interaction (TEI '16)*. ACM, New York, NY, USA, 570-576.

34. John Rooksby, Mattias Rost, Alistair Morrison, and Matthew Chalmers. 2014. Personal tracking as lived informatics. In *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 1163-1172.

35. Julio Cesar Sampaio do Prado Leite, Graciela D. S. Hadad, Jorge Horacio Doorn, and Gladys N. Kaplan. 2000. A Scenario Construction Process. *Requirements Engineering* 5, 1: 38-61.

36. Jac Smit, Annu Ratta, Joe Nasr, G. Shabbir Cheema. 1996. *Urban Agriculture: Food, Jobs, and Sustainable Cities*. United Nations Development Programme (UNDP), New York, NY.

37. Pieter Jan Stappers. 2006. Creative connections: user, designer, context, and tools. *Personal and Ubiquitous Computing* 10, 2: 95-100.

38. Yolande Strengers. 2011. Negotiating everyday life: The role of energy and water consumption feedback. *Journal of Consumer Culture* 11, 3: 319-338.

39. Hariharan Subramonyam. 2015. SIGCHI: Magic Mirror - Embodied Interactions for the Quantified Self. In *CHI'15 Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*. ACM, New York, NY, USA, 1699-1704.

40. Jane Fulton Suri. 2003. The Experience of Evolution: Developments in Design Practice. *The Design Journal* 6, 2: 39-48.

41. James Tooze, Sharon Baurley, Robert Phillips, Paul Smith, Edwin Foote, and Sarah Silve. 2014. Open Design: Contributions, Solutions, Processes and Projects. *The Design Journal* 17, 4: 538-559.

42. Kirsikka Vaajakallio and Tuuli Mattelmäki. 2007. Collaborative design exploration: envisioning future practices with make tools. In *Proceedings of the ACM Conference on Designing Pleasurable Products and Interfaces (DPPI '07)*. ACM, New York, NY, USA, 223-238.

43. Lars Witell, Per Kristensson, Anders Gustafsson, and Martin Löfgren. 2011. Idea generation: customer co-creation versus traditional market research techniques. *Journal of Service Management* 22, 2: 140-159.

44. Carly J. Wood, Jules Pretty, and Murray Griffin. 2016. A case–control study of the health and well-being benefits of allotment gardening. *Journal of Public Health* 38, 3: 336-344.