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Obstacles to wearable computing

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Katherine Helen Oliver

Summary

In the year 2021, wearable technology could look beautiful and feel magical, but instead is exemplified by a plain wristband that looks suspiciously like a prison monitor.

How can we make wearable technology that respects our privacy, enhances our daily lives, integrates with our other connected devices without leashing us to a smartphone, and visually expresses who we are?

This study uses a novel method of participatory design fiction (PDFi) to understand potential users of everyday wearable technology through storytelling. I recruited participants from the general public and gave them a five-point prompt to create a design fiction (DF), which inspired the user-centred design of an everyday connected wearable device. The participants each received a technology probe to wear in the wild for a year. They then updated their DFs as a way to reflect on the implications of the technology. For the purposes of privacy, augmenting device functionality through interoperability, and integration into an Internet of Things (IoT) ecosystem, I used the Hub-of-All-Things personal data store to provide the software infrastructure.

By listening to their stories, we can elicit design concepts directly from the users, to help us create wearable IoT devices that put the wearer at the centre of the design process, and are satisfying both functionally and emotionally.

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I have spent eight happy years at the Department of Computer Science and Technology at the University of Cambridge, first in the Systems Research Group (SRG) and, for the last year, in Security. I started working for the SRG in 2013 and it soon became obvious that there was no better place in the world for me to do my PhD. I am especially grateful to Lise Gough for her concrete support and calming presence. I give thanks to the Department of Computer Science and Technology for supporting my research activity, and to the Kenneth Hayter Memorial Fund for getting me through the second quarter of 2020 as I struggled across the slough of escalated caring responsibilities. I thank Hatice Gunes and Andy Rice for critique and advice at important turning points. Thank you to Alan Blackwell and Dinah Pounds for helping me navigate the ethics of this unique participatory research. Thank you to Eiko Yoneki and Anil Madhavapeddy for wise counsel when I was in a tough spot. Huge thanks to Poonam Yadav for insightful and attentive critique, and for her supportive collaborative friendship. Thanks to Andrés

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Above all I must thank my mother, Katherine Oliver, who lives for art, and lives for love, and never harmed a living soul. This thesis is dedicated to her and to the memory of my father, Ben Oliver... silly old bear.

Contents

Chapter 1

Introduction

This is the whole of the story and we might have left it at that had there not been profit and pleasure in the telling; and although there is plenty of space on a gravestone to contain, bound in moss, the abridged version of a man's life, detail is always welcome. [194, p1]

Wearable computing has great potential to enhance its wearers' everyday lives. By nature of being worn on the body, it also has potential to enhance the wearer's expression of personal style. However, this potential remains largely unrealized. There is a number of identified obstacles to adoption of wearable computing. According to a 2015 European Commission case study on the IoT, some of these obstacles - besides cost, which I will not be dealing with - are [87, p10]:

- **O1:** privacy;
- **O2:** impracticality of single use-case devices; and
- **O3:** integration into an IoT ecosystem.

Besides these four obstacles, experts [59] have accused the sector of:

- **O4:** designing for the smartphone rather than the wearer, thus failing to innovate [168] [178, p21]; and
- **O5:** failure to engage wearers emotionally ([185], quoted in [59]).

A wearable device which addressed all of these obstacles would:

- **O1:** protect user privacy;
- **O2:** enable multiple functions within or between devices [168];
- **O3:** be integrated into an IoT ecosystem [87, p10] [168];
- **O4:** serve as an extension of the wearer rather than the smartphone [168] [178]; and
- **O5:** appeal to the wearer's emotional as well as functional needs ([185], quoted in [59]).

This thesis describes a research through design (RtD) [103] of everyday IoT wearables [208] which tries to find ways of overcoming each of these five obstacles to varying degrees. The obstacles are signposted throughout the text.

Primarily, I use a novel method of PDFi, with independent adult volunteers, to inspire everyday IoT wearables that (O4) go beyond "black-slab incrementalism" [226, p21] and (O5) appeal to emotional as well as functional needs. Secondarily, I use the Hub-of-All-Things (HAT) [1] for the project's software infrastructure, thereby providing a (O1) private platform which makes it possible to (O2) augment the devices' functionality by contextualizing data from multiple sources; and to (O3) integrate the devices into an IoT ecosystem.

There are three research questions I sought to answer:

1. **RQ1:** Can participatory design fiction help us to create wearable IoT devices that add value to everyday life? (O1, O2, O3, O4, O5)
2. **RQ2:** Can we translate participatory design fictions into feasible real-world designs for everyday IoT wearables? (O1, O2, O3)
3. **RQ3:** Can we implement everyday IoT wearables based on participatory design fictions in a way that sustains user engagement in the wild? (O2, O3, O4, O5)

I will revisit the research questions at the end of the thesis.

In the next section, I describe the state of everyday connected wearables in mainstream use (section 1.1). I then provide some background information on user-centred design and participatory design in terms of their potential to overcome some of the obstacles to wearable computing (section 1.2). I contrast the prevailing, computer science-based approach to wearable computing with the work of the contemporary jeweller Jayne Wallace on the personal significance of digital objects (section 1.3). Next, I introduce the discipline of DF which is central to this study (section 1.4). Then, I show how DF relates to questions of privacy and provides a context in which to consider those questions; and I describe some practical implementations of solutions for data ownership (section 1.5). Next I show how the use of the HAT as the project's software infrastructure allows for a single use-case wearable device to augment its functionality through integration into an IoT ecosystem and contextualization with data from other sources (section 1.6). Next, I introduce my methodology (section 1.7) and highlight the contributions made as a result (section 1.8).

1.1 State of the art

1.1.1 Most popular everyday wearables

The stereotypical everyday connected wearable [208, p1] is a wrist-worn device - an activity tracker or smartwatch - which remained the most popular form as of mid-2019 [78]. Also gaining popularity are ear-worn devices or "hearables", partly because they replace wired headphones for newer smartphone models with no headphone jack [78]. These consumer

[1] *Hub of All Things:* https://www.hubofallthings.com

devices provide or support multiple functions (O2), and integrate with smartphones (O4). Hearables may be invisible in use [215, p8], while wrist-worn devices, which are expected to be worn continuously, typically fit a "normcore" [2] (section 3.6.3) aesthetic intended to suit everyone and go with every outfit (O5). Despite their relative popularity, these wrist-worn devices are still often abandoned [240].

The choice of wearable technology on the mass market has depended on what manufacturers have wished to convince us we want [126, p2]. Consumer wearables are dominated by miniature smartphones, and accessories to smartphones (O4). The functionality of fitness bands and smartwatches has been limited, literally and figuratively, to pedestrian use cases: activity monitoring for the Quantified Self [3], or managing notifications from the smartphone [168] [178, p21].

However, Hunn [126, p18] identified the potential of hearables to "use new technology to enhance an existing experience". In early 2019, consumer wearables enjoyed a surge in popularity [78], much of it attributed to the entry of hearables into the mainstream, not only as replacements for wired headphones, but as a means of using smart assistants [77] [78]. This can be seen as progress, because of the possibilities that hearables hold for new applications in context-awareness [215, p2]. Maciocci [168] saw context awareness as an area for wearables to fulfil their potential as an extension of the wearer, rather than of the smartphone (O4); though at present most hearables rely on paired devices for computational power [215, p10].

Despite the "push" of wearables from manufacturer to consumer - and although this is not a work of market research - it would be unreasonable to say the mass market tells us nothing about what users want from everyday wearables. No user pays good money for a consumer wearable unless it has something desirable about it. Although activity monitors and smartwatches are often abandoned, they also are often put to use.

Nevertheless, the heart's desire cannot be bought off the shelf. Out of all the studies reviewed in [240], the 2015 study by Lazar et al [153] had the most in common with this thesis: it studied everyday connected wearables, the volunteers were all independent adults, the users chose their own wearables, and they wore them in the wild for a period of months.

Lazar et al.'s 17 volunteers [153] received a budget to buy their choice of smart consumer devices, to use in-the-wild for two months to facilitate a self-defined personal goal. It was a study of smart devices rather than wearables, but wearables were what the users wanted: three-quarters of the 48 devices selected turned out to be wearables. Most of the personal goals were about health and fitness, probably because that is what the products supported, not necessarily goals the participants would have set on their own. Over two-thirds (25 of 35) of the wearables were fitness bands and smartwatches, of which a quarter (six) were not newly bought but already owned by the participants. Of the 10 devices that were not wrist-worn, six were posture monitors worn under clothing on the lower back (O4). Two participants chose a health sensor tank top (O4). The other two items were a biofeedback headband for meditation, and a biofeedback ear/collar clip sensor (O4).

After two months, nearly 80% of the devices had been abandoned, which the study defined as wearing them less than four days per week (and questioned that definition: did they give up on the wearables, or were they just done with them?). Devices were abandoned

[2] *Wikipedia:* **Normcore** https://en.wikipedia.org/wiki/Normcore
[3] *Wikipedia:* **Quantified Self** https://en.wikipedia.org/wiki/Quantified_self

if they were uncomfortable or obtrusive, were too effortful to maintain or did not fit with routines - all unsurprising reasons to reject a wearable item of any kind, technological or not. However, a major reason for abandonment was that the devices' functionality **did not fit with the wearers' conceptions of themselves** (O5) - they saw them as better suited to some other, more normative user, such as an "avid fitness freak", or "older adults" with greater health needs. Meanwhile, the avid fitness freaks were rejecting the wearables because **the data collected was not useful**. The avid fitness freaks did not need a pedometer because, they said, walking is not exercise; as expert users, they said a fitness band did not know how they should eat and train.

So it seems the consumer wearables in [153] were designed for a normative user, who is someone else.

1.1.2 Fashion tech

The European Commission case study [87, p9] points out that, because wearable technology is worn on the body, it is more personal than other smart daily carry devices such as phones or tablets: "two characteristics that usually do not feature in the decision making process for other tech products play a significant role here: fashionability and uniqueness." Engineers are stereotypically anti-fashion [221] or not fashion conscious; one criticism of Computer Engineer Barbie was that her appearance was over-styled [71]. Fashion designers do not commonly have advanced engineering skills, but those who do may be found in the subdiscipline of "fashion tech", which covers the intersection of fashion with all forms of technology, ranging from nonwearable applications such as software [4] to illuminated garments [5] (O4) to smart textiles [6] (O4). Only a subset of fashion tech consists of connected garments and accessories, of which the work of CuteCircuit [7] is exemplary (O5).

Despite some extremely beautiful outputs, fashion tech has yet to insinuate new kinds of connected wearables into the mainstream. Silina and Hsu [243] reviewed the tradition of sentimental jewellery (O5), and the potential and emergence of social wearables in jewellery form factors [8] that might still function as jewellery after their technological components become obsolete (O4, O5). However, they noted "the interaction explorations within industry are stifled by market factors and practicalities" [243, p4].

CuteCircuit produces high design with prices beginning at GBP 250.00 (for a t-shirt with app-controllable lights) and rising into the thousands for couture items that are exclusive by nature (O5). In contrast, Levi's Jacquard by Google^{TM} Commuter jacket, for urban bike commuters, is intended to be a mainstream product but is also highly priced at USD 350.00. An equivalent nontechnical jacket from the same brand would cost much less, and the added value of the smart functionality has been questioned by product reviewers [152]. The jacket controls smartphone apps by a set of gestures over touch-sensitive fabric (O2, O4). Whereas implementation issues are to be expected, as is improvement in future iterations, more important are the inherent benefits and limits of the use case. Langley [152] appreciated being able to use apps while staying focussed on the road, which is the

[4] *Farfetch Blog:* https://www.farfetchtechblog.com/xen/farfetch/
[5] *Elektrocouture:* https://elektrocouture.com
[6] *Jacquard^{TM} by Google:* https://atap.google.com/jacquard/
[7] *CuteCircuit:* http://cutecircuit.com
[8] Such as Ringly (https://ringly.com) which closed in 2018 and reopened in 2021.

jacket's core function. Hall [114] found that the jacket fit his routine well at first: "After having worn the jacket for a couple weeks, there have been many times that I've forgotten it's a smart jacket entirely." Two years later, Hall had some criticisms: "to really get your money's worth and live out a rhythm of the Jacquard technology actually making the ways we interact with devices better, you had to wear the jacket every day." [115] This brings up a possible inherent limitation of any one smart garment: "regionality and seasonality", but also "I don't know anyone that wears the same jacket on every single cold-ish day." (Another limiting factor is that the jacket can be washed only 10 times in its lifetime.) "In my testing of the jacket, I found it hard to make using it part of my daily flow, because I just didn't wear the jacket enough. And reminder: I was - am - literally the ideal customer for that thing." [115]

Langley [152] saw the jacket as a replacement for a smartwatch (O4), but Hall's experience [115] shows it would actually take a wardrobe of jackets, and winter coats, and summer shirts to replace a smartwatch. The wrist-worn device is the most popular because it is the most versatile (O2).

Hall [114] spotted the real conceptual breakthrough of the jacket: it is a means of controlling smartphone apps, rather than vice versa, which brings it closer to Maciocci's [168] desired state of being an extension of the wearer (O4). "In a world of smartwatches and smartphones, it's a real, working consumer product that everyone can actually buy that breaks the mold. Just on that merit alone, I'm a huge fan [...] **it's meant to be philosophically different from a smartwatch or any other wearable you might compare it to** [emphasis mine]." Hall [115] was more optimistic about the dailiness of the jacket's successor product, the (even more expensive) Yves Saint Laurent Cit-E Backpack with touch sensitive fabric on the shoulder straps. Previously, Langley [152] noted that "The team also want to add more features [to the jacket] based on user feedback." This brings us to the issue of user-centred design.

1.2 User-centred and participatory design

The need for user-centred design of wearables is widely acknowledged [126] [189]. Alongside fashionability and uniqueness, the European Commission case study [87, p9] recommends human-centred design. The context, however, suggests that they really mean user-centred design. Although the two terms are often treated as interchangeable, the difference is that human-centred design seeks to balance and question the technical and social aspects of the system being designed, including the effects on stakeholders who are not users [100, pp. 30-31]; whereas user-centred design focuses on solutions for more specific target groups of users.

Of the consumer market considered in section 1.1, Hunn [126] wrote "The problem is that [major companies'] model for wearable technology is built around technology push, trying to shape their technology to fit consumers. It is a strategy that is likely to fail, as wearable technology is more, rather than less, personal [O5]." Of the research literature, Motti & Caine [189, p1820] write: "[...] most of these works focuses on the feasibility of individual solutions. As such, the human aspects are often neglected, which can decrease not only the acceptance levels for novel devices, but also their sustained engagement [O5]." In the foreword to Motti's much-needed book on wearable interaction [191], Zancanaro

wrote: "innovation seems largely focused on technical aspects rather than on how people appropriate and use wearable devices in the long term" [285, pvii].

User-centred design is design for users [231], focusing on user needs throughout the design process [129]. Participatory design is design with users [231], in which users play a critical role in the design process [235] and is a human-centred approach [100, p38].

In the research of user-centred and participatory design of everyday wearables, the "push" approach of individual solutions [212], and the focus on specialist use cases [248] or predefined types of technologies [190] or materials [142] are also dominant. Participatory studies invite stakeholders to focus on a design exemplar [100, p34]: How would you style your fitness monitor [212], how would you design these Augmented Reality (AR) glasses [49]? Whether dealing with established forms and functions, or novel ones [88], positive responses from participants do not necessarily mean they would want the devices outside of the laboratory setting.

One study that took the device beyond the laboratory is by Lo et al. [165], who pushed a premade device, but offered it for wear in the wild. 10 users received electronic temporary tattoos to wear for a day (O4), after which most wanted to keep them and enthusiastically proffered ideas for applications of the technology (O5). One user-centred study that proposed a unified approach to advance the state of wearables as a whole, is Smelik et al. [245], who proposed an interdisciplinary framework of "embodied design". Using Van Dongen's "Solar Dress" as a case study, the embodied framework was used to reiterate the dress into the more practically wearable "Solar Shirt" (O4), very successfully: "To [the user's] own surprise, she was willing to wear solar fashion. [245, p298]"

1.2.1 "WHAT DO WE WANT???" "[. . .]"

Still, the question "what kind of everyday wearable do you want?" is not often asked. On the contrary, the prevailing worldview is that the question should not be asked. A rare study which elicited concepts for everyday wearables from adult users without predefinition of form or function was Mueller et al [192, p1675]. All of the users' ideas were rejected as derivative of popular media or existing products, and the researchers reached conclusions consistent with the advice of van Erp [270]: "Think like the user... but not too much". Users, van Erp explains, can critique existing designs but otherwise their imagination is "terrifyingly limited". What evidence can we find to challenge this view?

The maker movement is an emerging source of contributions at grassroots level, and opportunities for wearers to implement their own concepts might be found there. FabLabs [72] provide community space for fashion innovation between users and designers. Hackathons such as StitchFest [223] give participants a chance to make their own devices, but going by the details that are published, these often seem to involve predefined themes and materials, and/or the items made are not necessarily for real-world use or development. Fashioning Circuits [9] is a public humanities project that combines university research and teaching with community workshops [37], proactively recruiting underrepresented students to a critical design course where the brief is to create an item of wearable technology that makes a statement or solves a social problem.

[9] *The University of Texas at Dallas, ATEC School of Arts and Emerging Communication:* **Fashioning Circuits** https://atec.utdallas.edu/content/fashioning-circuits/

Li et al. [156] elicited concepts for stress-management wearables from a small group of participants, using video diaries and experience mapping as well as paper prototyping to understand what kinds of interventions are helpful. Although their cohort was veterans with post-traumatic stress disorder, and taking into account their expressed concerns about generalizability, the results may be informative towards development of the Positivity Patch (section 5.4).

Ananthanarayan et al. [9] (section 3.5.1) got their participants to make the casing for a connected UV sensor, preselected by the researchers, to be worn in-the-wild for seven days. This resulted in varied form factors such as a headband and a bag charm.

Tsekleves et al. [269] (section 3.8.1) describe a participatory design workshop where participants generated the concepts for a DF that resulted in a wearable "euthanasia watch", but the fictional watch was created by professionals; the topic was future healthcare technologies rather than wearables. Another group in Malaysia worked on the DFs as well as the concepts for the fictions, but no wearables were involved.

Andersen and Wilde [10] (section 3.8.2) elicited concepts in both form and function by inviting workshop participants to use an embodied method to create paper prototypes of fictional wearable technology. The prototypes were not for real-world use or development; but they did provide evidence that users can be imaginative about designs that do not exist yet.

Another strong challenge to van Erpism [270] came from Jones et al. [136] (section 3.5.2). They used the "magic thing" prototype, an imaginary (therefore unconstrained by its ostensible form factor) wristband which could have any function the participant desired, to elicit insights from emergent users to inform development of a technology roadmap with a five- to 10-year horizon. This study found the participants' ideas "fresh", "stimulating", "challenges to the orthodox", and "potentially realisable".

So the lesson learned from Jones et al. [136] is that the way to elicit concepts from wearers is by magic. This approach seems more practical than dismissing users as unimaginative.

1.3 Motivation

1.3.1 The computer science approach

Hunn [126, p4] wrote: "Throughout, the desire is to identify what a consumer would want to buy rather than what is thrust at them, which is likely to mean that successful products must have a significant degree of emotional attachment [O5]." Unlike this thesis, [126] is a work of consumer research, and is concerned with solutions at an industrial level. If consumer wearables are for the normative user, and the normative user is someone else (section 1.1.1), how can I as a non-normative user find something that I want to wear? As ten Bhömer [259, px] put it: "While wearing my activity tracker during the day and clipping my sleep tracker to my pillow by night, I personally still have not found the compelling reason to keep using these systems [...] Can these mass-produced products take an intimate role in our lives, and are the design processes traditionally used for consumer products still sufficient?"

The smartwatch is one of the fruits of a philosophy that defines a wearable as "a small body-worn computer system that is always on and always ready and accessible" [169,

p1]. Steve Mann (section 3.3.1) lives this philosophy to the extreme, as a cyborg rather than like one [170], but as the "father of wearable computing" [112] his definition of wearable technology, combined with the philosophy of the MIT Wearable Computing Lab [10], dominate the genre as we know it. Mann's commitment to the cyborg life is something I admire, but not something I share. I want something different for myself.

1.3.2 The digital jeweller's approach

Wallace [274, p40] (section 3.6.4) challenges the "computer science" philosophy of wearable technology, and its treatment of the body as a place to locate ubiquitous computing. Wallace crafted digital objects not as a cyborg but as a contemporary jeweller, primarily concerned with personal and emotional significance and not with producing "gadgets": "[...] there is a paucity of approaches that consider emotional and intimate attachments people form with and around objects [...] the qualities that we have come to associate with the digital are born from a predominantly consumer electronics field and are both narrow and hindering if we wish to consider digital technologies having wider, more emotional scope in our lives [...] I maintain that there is a need to extend our understanding and vision of digital experience into ones ripe for enchantment [O5]."

Wallace worked with a small number of individuals, building up her understanding of them by using a variety of objects and questionnaires as stimuli, including a detailed prompt for a "communication fairytale". The digital objects Wallace crafted included a flower made of postage stamps, with a rain sensor that triggered the flower to blossom only once, in response to rain falling in the recipient's homeland.

The flower's functionality has none of the practical utility typical of smart consumer devices, and it achieved the goal of emotional resonance with the recipient. Wallace's study [274] shows how it is possible to work closely with individuals to produce digital objects that do not conform to the "terminal world" of black slabs [226, pxiii] (O4) and do appeal to emotional needs (O5), while questioning the premise that any functional needs must be met at all.

The one actually wearable object in [274, p127] was a neckpiece made of copper, enamel and synthetic silk. As the wearer passed by displays around the city, the neckpiece triggered film clips inspired by her responses to the design stimuli. The recipient of the neckpiece did not understand it at first; and in an effort to make sense of it, imagined a backstory in which the neckpiece had fallen to earth in a spacecraft, then been found by a Mongolian herdsman who attached it to his saddle unaware of its digital functionality [274, p149] (O5). This backstory could be described as a DF after the fact (section 1.4.2).

1.4 Design fiction

1.4.1 Science fiction before and after the fact

Section 1.2.1 refers to Mueller et al. [192, p1675], in which participants' concepts were rejected for being too derivative of popular media. This may have been a missed opportunity (O5). Dourish and Bell [76, p1] point out how openly NASA have been influenced

[10] *MIT Wearable Computing Lab:* https://www.media.mit.edu/wearables/ cited in [274, p40]

by *Star Trek* [11], and how Arthur C. Clarke speculatively invented the communications satellite. Science fiction's (SF's) influence on science is an obvious reality, widely acknowledged in the research literature [234] [239] [150], and has been intentionally deployed to influence public policy and fund real technology development [145].

Dourish and Bell [76, p3] analyze five very popular SF TV and book series - *Doctor Who* [12], *Star Trek, Blake's 7* [13], *Planet of the Apes* [14] and *The Hitchhiker's Guide to the Galaxy* [15] to show how particularly relevant SF is to design research in ubiquitous computing, because of its "explicit focus not only on the extrapolation of current technological opportunities, but the imaginative and speculative figuring of a world in which new technologies can be applied". The technologies in these series are always portrayed in the context of a society in which questions of democracy and totalitarianism, or of equality and diversity, feature in the narrative (O1, O5). "Technological problems [...] are problems for today, and problems of cultural context are ones that come into play later, once our technological infrastructure rolls out into the world. [...] these questions are ones that arise not in the deployment of technologies but in the imagining of them - an imagining that arises before design."

1.4.2 Design fiction and related disciplines

All of the series analyzed in [76] can be seen as examples of **design fiction**. The root text on DF is Bleecker's *Design Fiction* [29], but it is influenced by Dourish and Bell [76] which had been circulating informally at that time. The best definition of DF is Sterling's: "the deliberate use of diegetic prototypes to suspend disbelief about change" [33]. Kirby [145] defines a "diegetic prototype" as a portrayal of a technological possibility in a fictional context such as a popular movie.

There is no formal definition of the necessary and sufficient attributes of a DF, nor is such a definition considered desirable [163], though Coulton et al. [54] argue, justifiably in light of Dourish and Bell [76], that DF is primarily a worldbuilding activity. DFs can take many forms besides the popular media series described in [76] and the films in [29]. Just a few examples are: imaginary product catalogues [40] for real companies; imaginary marketing materials and imaginary technical standards for imaginary products [53, p24]; realistic illustrations for fictional products and interfaces in existing media [281]; fictional abstracts [31], research papers [164] and conferences [146]; stories of life in imaginary cities [284]; "pastiche scenarios" inspired by existing media [30]; and many more, some of whose creators never thought of their works as DFs nor ever heard of the genre. Closely related is **speculative [and critical] design (SCD)** [82] which presents unreal design scenarios, in order to provoke discussion, sometimes too successfully [14]. SCDs can "present more plausible depictions of near-future technological applications. By stepping out of the normative relationship that ties technological development to commercial markets, speculative design opens a space for alternative perspectives, critical reflection and an examination of contemporary and near-future technological application." [13, p6] As with DF, some creators produce SCDs without necessarily applying that label

[11] *Wikipedia:* **Star Trek** https://en.wikipedia.org/wiki/Star_Trek
[12] *Wikipedia:* **Doctor Who** https://en.wikipedia.org/wiki/Doctor_Who
[13] *Wikipedia:* **Blake's 7** https://en.wikipedia.org/wiki/Blake%27s_7
[14] *Wikipedia:* **Planet of the Apes** https://en.wikipedia.org/wiki/Planet_of_the_Apes
[15] *Wikipedia:* **The Hitchhiker's Guide to the Galaxy** https://tinyurl.com/yn28zsnb

to their work; the hamartia robots of Giertz are an example [16]. Devendorf et al. [70, p8] opened the concept of the *design memoir*, in which they acknowledge that autobiography inevitably contains an element of fiction.

A DF is usually an imaginative exercise with no intent to produce a real-world design artefact, but the genre of "science fiction prototyping" [135, p3] is closely related. A SF prototype is a media artefact such as a comic, film or story; which may be speculative but may also be a step in the development process of a real product. Thus a DF may sometimes produce more than a thought experiment. Can a DF ever be less than a thought experiment? Corporate promotional videos for designs-in-progress such as the Google Glass [113] [32], or as promotions of the future vision of the corporation, have been classed as DFs by some [108]. As promotional videos, these works seek to persuade (at least) as much as speculate. Narrative formats can be used not only to suspend the disbelief of, but to induce temporary credulity in the audience [109, p719].

1.5 Privacy

1.5.1 Privacy in society

A 2016 study of the data security of fitness trackers [123] painted a dubious picture (section 3.3.5), and there is an identified research gap [34, p3422] regarding responsible design of IoT data (O1, O3).

Responsible handling of personal data is not only owed to the individual who generates the data, but has wider implications for society. The works analyzed by Dourish and Bell [76] raise questions of democracy and totalitarianism which loom even larger today [89]. Dourish and Bell [76, p12] point out that, in considering the privacy implications of a pervasive computing use case such as location monitoring, those considerations are already embedded in cultural assumptions about the individual's relationships to commercial entities and the state. The example of location monitoring in [76] was in a context of commercial exchange with a service provider. Since [76] was published, the Investigatory Powers Act was passed in the UK, permitting bulk surveillance of the digital communications of the country's entire population, without suspicion of a crime being committed [17]. In surveillance states, the context of that kind of commercial data exchange is inexorably expanded into the context of state power [219]; to say nothing of potential misuse by nonstate actors [63, p25]. Underlying the cultural assumptions about commercial data exchange is another layer of cultural assumptions about "the current model where users have to hand over personal data to digital giants in exchange for perceived value. As we've all discovered, this hasn't been in our best interests." [27] Berners-Lee, known as "the" inventor of the World Wide Web [18], was so alarmed that he is attempting, via the Solid open-source project [19], to remake the World Wide Web with a decentralized system

[16] *Y Combinator,* 5 June 2019: **Interview with Simone Giertz** *https://www.youtube.com/watch?v=WmFJpv7-VyY*

[17] *Liberty,* 17 June 2019: **People vs. Snoopers' Charter: Liberty's landmark challenge to mass surveillance powers heard in high court** https://www.libertyhumanrights.org.uk/issue/people-vs-snoopers-charter-libertys-landmark-challenge-to-mass-surveillance-powers-heard-in-high-court/

[18] *Wikipedia:* **Tim Berners-Lee** https://en.wikipedia.org/wiki/Tim_Berners-Lee

[19] *Inrupt,* 22 October 2018: **One Small Step for the Web** https://inrupt.com/blog/one-small-step-for-the-web

in which the user owns and controls their own data [20].

1.5.2 Privacy in the Internet of Things

Solid is not the first or the only initiative to return control of personal data to the user (O1). For the IoT (O3), Databox provides an ecosystem for processing personal data within the user's equipment, and performs computations locally, circumventing the loss of control incurred when using cloud services [188] and "making the IoT accountable to individuals" [58]. The HAT project [21], conceived as a platform for commercial data exchange, is a microserver the current version of which is commonly hosted in the cloud.

The HAT "confers intellectual property rights of personal data to individuals through their ownership of a dedicated database, wrapped with containerised microservices" and operates on a framework of trust between organizations. Because this study builds on work previously done for the HAT project [205], and because the HAT was already on public release as a software product, it is the HAT that provides the software infrastructure for the current study, being the endpoint to which the wearable device sends its data (O4).

Talk of data "ownership" is a euphemism, as there is no way of legally owning data. It is possible to have ownership rights to a database, and thus to its data and contents, which is the model provided by the HAT. Ng [196] lists the rights given by the General Data Protection Regulation (GDPR) [104] to our personal data that is held by firms:

1. **right to be informed** [of how our data might be used];
2. **right of access**;
3. **right to rectification**;
4. **right to erasure**;
5. **right to restrict processing** [in particular ways, such as how a firm profiles us];
6. **right to data portability** [the firm must provide our data in a machine readable format];
7. **right to object**;
8. **rights in relation to automated decision making and profiling**.

Ng points out that the reason we do not have *more* rights under the GDPR is because our personal data, held by firms within applications such as Facebook, Alexa, Amazon, Spotify etc., cannot be isolated in the same way it is isolated within the HAT. The article goes on to list five more "ownership" rights, that is, rights that are made possible by ownership of data:

1. **"Right of possession** - Having our data stored in a place where we are the only one who have access to the data.

[20] *Inrupt:* **How It Works** https://solid.inrupt.com/how-it-works
[21] *Hub of All Things:* https://www.hubofallthings.com

2. **"Right of control** - Being the only one deciding who gets to use our data and when.

3. **"Right of exclusion** - Deciding who doesn't get to use or see our data.

4. **"Right of enjoyment** - Being able to use our data for our own purposes whenever we wish to.

5. **"Right of disposition** - Being able to monetise, exchange, profit, license our own data because we own the rights to it." [196]

Ng explains how the HAT's data sharing model affords ownership rights to the user: rather than sharing data directly from Facebook, tools are provided for a user to import their Facebook data into the HAT through subject access. Ownership rights can have limits [22], for example, Facebook would not permit that data to be sold for cash [197].

1.6 Internet of Things ecosystem integration and augmentation of device functionality

The European Commission case study [87, p10] describes single use-case wearables as impractical because it is hard to find an occasion for usefully wearing them, and because no-one would want to wear multiple single use-case devices at once (O2). The answer according to [87, p10] and [168] is greater integration into the IoT to contextualize the user experience across devices (O3).

This study builds upon previous work in building a smart cabinet, the Automagic Box of Beauty (Beautybox), as a use case for the HAT [205]. The Beautybox used a barcode scanner and a kitchen scale to track the depletion rate of grooming products, inspired by a beauty blogger [23] who used a scientific scale to estimate the number of applications in an eyeshadow palette. Parry et al. [211] contextualized the Beautybox data for shower gel with a flood sensor and diary entries, and found that the depletion rate doubled and shower time increased when one of the householders had been running. Because of the HAT's data ownership model, this analysis can be done without fear of being spied on in the bathroom (at least, not because of anything the HAT is doing) (O1). The same kind of contextualization could be used to augment the functionality of a single-use wearable device.

[22] *Hat Community Foundation - Resources:* **Building on HAT** https://www.hatcommunity.org/resources#building-on-the-hat

[23] *Brightest Bulb in the Box: Beauty for Critical Minds,* 10 March 2014 (via Wayback Machine:) **How Many Eyeshadow Applications Are In A Palette?** https://web.archive.org/web/20160316093103/http://www.brightestbulbinthebox.com/2014/03/how-many-eyeshadow-applications-are-in.html

1.7 Approach

1.7.1 Design fiction

The main focus of this thesis is on obstacles O4 (designing wearables as an extension of the wearer) and O5 (meeting emotional as well as functional needs). To confront these obstacles, besides using the HAT as the software infrastructure (O1, O2, O3, O4), I used **participatory design fiction (PDFi)** to elicit concepts from volunteers for everyday wearable IoT devices. By PDFi, I mean DFs elicited directly from participants - in other words, asking wearers to tell stories about the wearables they would have, if they could have anything.

The hope, in using DFs in this way, was to unlock the imaginations of participants through narrative transportation [109], to free their minds from real-world constraints, and let their emotions, values and desires shine through. By presenting their thoughts in a narrative, I hoped to get the participants to express ideas, details and nuances that I would not have thought to ask for. Ahmadpour et al. [7, p219] asked their participants to critique the researchers' DFs: "We found that the participants had responded to some contextual elements of the fiction that were unrelated to any specific concept."

Ahmadpour et al. [7, p219] favourably compare DFs to scenarios, which are more goal-oriented (section 3.7.3). The participants' remarks highlighted concerns of the cohort of older adults in unexpected ways: for example, that a character uses a car that would be hard for a senior to get in and out of. Kim et al. [144] used a method of group storytelling as a way of better empathizing with unfamiliar target groups.

I also wanted to create a particular kind of atmosphere and imaginative space, to make room for the enchantment that characterizes what Rose calls "enchanted objects" [226] - connected objects (O3, O4), embedded in our everyday lives, using technology to perform functions with a glamour of magic (O5) (sections 2.2 and 3.6.5) .

1.7.2 Participants

Because this study focuses on understanding wearers at the individual level (O4, O5), and is influenced by the work of Wallace (section 1.3.2) and Wright et al. (section 3.6.5), the number of participants was kept small. I planned to recruit six volunteers and work with them over a period of two years.

I recruited members of the general public through events at Makespace in Cambridge [24]. The target cohort was independent adults, and I hoped to recruit an even split between men and women, with technical ability ranging from "can use my smartphone" to "I made my smartphone", and ranging in fashion-consciousness from J. Random Hacker [221] to Computer Engineer Barbie [71] and beyond.

Recruiting independent adults was important to me because participatory studies often recruit minors or care home residents; or "older people" who are nearly always quasi-medicalized [50] or stereotyped by a "deficit" model of ageing [61, p1]. Many studies entail a power differential between stakeholder and user which I wished to avoid to the extent possible [97]. Although [247] is not about wearables, it is a cautionary tale about

[24] *Makespace:* https://web.makespace.org

science-fiction prototyping with ideas elicited from disadvantaged users, only for those ideas to be overridden by more powerful stakeholders and the users alienated as a result. Another study [83], which focused on eliciting ideas from teenagers for fitness trackers that would motivate them to exercise, did not end so badly; but it did conflate the question of device design with the more intractable problem of behaviour change, and on a cohort of minors with relatively little control over their own lives.

1.7.3 Implementation

The participatory process followed three iterative phases based on IDEO's [39, p5] model: Inspiration (the user's situation), Ideation (creating prototypes) and Implementation (analysis).

1. **Inspiration** I began with a series of storytelling workshops (O4, O5) (Appendices H, I and K), and gave participants a five-point prompt (Appendix H.5.3; Table H.1) based on Johnson's [135, p25] "Five Steps" for creating a SF prototype. I used the term "design fiction" instead of "SF prototype" in all communications, and emphasized that the stories could be in any genre or time period; and could be original or derivative of existing media. After each participant told their story to the group, the rest of the session was spent on paper prototyping (Appendices H.6.4, H.7.8 to H.7.11, H.10.4 to H.10.8, H.11.3 and I.3) to visualize the concepts, using creative toolkits [232] (Appendix H.5) developed for the workshops.

2. **Ideation** Over several iterations of workshops, I recruited the volunteers for the longitudinal study, who finalized their DFs (Appendix K). I then analyzed the stories and created a proposal for a real-world technology probe for each one, and the group selected their favourite idea by ranked majority (Chapter 4).

3. **Implementation** After releasing the technology probes (section 4.6), and issuing each participant with their own HAT (O1, O2, O3, O4) (section 3.3.5), the participants wore the probes in-the-wild and fed back their impressions and critiques (O4, O5) (Chapter 5). During this time they also updated their DFs to reflect on the experience (Chapter 6), and I began development of a prototype (section 5.4.1). [25]

1.8 Contribution

This is the first study of PDFi to elicit DFs from users as a way of directly inspiring real designs for everyday wearable IoT devices - wearables that function as accessories for the wearer, not for the smartphone (O4, O5). The study takes a generative [287] whole-systems view that follows the design process from inspiration to adoption, considering software infrastructure from the start rather than making the implementation details "someone else's problem" [22]. It is the first study of participatory design of everyday IoT wearables to elicit immediately actionable design concepts from independent adult users with no predefinition of form, function or materials; issue the wearable devices to the participants for in-the-wild study; and revisit the DFs to reflect on the lessons learned

[25] No prototypes were completed because of the COVID-19 shutdown.

and envision what we want the future of everyday IoT wearables to be in our lives and in society (section 3.1.1).

1.8.1 Publications

The research in this thesis has yielded the following peer-reviewed publications:

Helen Oliver and Richard Mortier, 2021: How not to be seen: privacy and security considerations in the design of everyday wearable technology. In *Proceedings of the 7th Conference on Competitive Advantage in the Digital Economy* (in press). IET, 2021. CADE 2021, 2-3 June 2021, Virtual Venice.

Helen Oliver, 2019: Design fiction for real-world connected wearables. In *Proceedings of The 5th ACM Workshop on Wearable Systems and Applications*, pp. 59-64. ACM Press, 2019. WearSys '19, 21 June 2019, Seoul. DOI: 10.1145/3325424.3329664.

Helen Oliver, 2019: Demo abstract: Participatory design fiction for innovation in everyday wearable IoT systems. In *Proceedings of the International Conference on Internet of Things Design and Implementation*, pp. 285-286. ACM Press, 2019. IoTDI '19, 15-18 April 2019, Montreal. DOI: 10.1145/3302505.3312597.

Conference presentations

Helen Oliver, 2017: That HAT really ties your outfit together: Integrating wearables into an IoT ecosystem to augment device functionality and increase utility. In *Proceedings of the Competitive Advantage in the Digital Economy Forum 2017,* p. 16. CADE 2017, 1-3 June 2017, Venice.

1.8.2 Follow-up research

This study is the first stage of my research on everyday IoT wearables that enhance the wearer's everyday life while overcoming the obstacles that currently stand in the way of acceptance. Depending on opportunity, possible next steps are:

1. Develop HAT software applications for user-centred decision support [205] (O1, O2, O3, O4, O5) (section 3.4).
2. Replace the microcontroller with a Lax-driven sensor [250] (O2, O3, O4) (section 5.3).
3. Collaborate with a product designer to scale the design process for more users (O5) (section 3.7.2).
4. Complete the Positivity Patch/Gallery Badge prototype (O2, O3, O4, O5) (section 5.4.1) and collaborate with a jewellery designer for more polished design artefacts.
5. Validate the DF method with a control group (section 1.9.2) using more classic methods for inspiration, such as brainstorming (sections 3.1.2 and 3.7.3); and counterbalancing the workshop groups with a second facilitator (O5).

6. Extend the workshop to a remote format for housebound participant groups (O4, O5) (Appendix I.1).
7. Explore the comparative importance of community and narrative in participatory design of wearable IoT technology (O5) (section 6.5.2).
8. Collaborate with colleagues to develop a new Positivity Patch with privacy-preserved federated learning [283] for context-aware sentiment analysis (O1, O3, O4, O5) (section 5.4.2).
9. Start a folksonomy wiki for practitioners of all genres of imaginary design (Appendix M.1).
10. Conduct a participatory research through design of "Good Enough" Artificial Intelligence (AI) (section 3.4.2) with a user evaluation in the style of [203] comparing at least three IoT and/or personal data platforms such as HAT, Databox, Solid and Adafruit.io. In the process, compare narrative accounts and formal specifications of each platform's support for contextual integrity (O1, O2, O3) (section 3.4.3).
11. Make a start on implementing spimes (O3) (section 3.7.2).

1.9 Scope & limitations

1.9.1 Scope

Devices

Whereas the forms and functions of the wearable devices were tabula rasa at the start of the study, their scope was limited to **everyday wearable IoT devices**.

1. By **wearable IoT devices**, I mean wearable devices that are connected to an ecosystem of networked devices within the IoT (O3).
2. By **everyday wearable IoT devices** or **everyday wearables**, I mean wearable IoT devices (O3) for daily, regular or occasional use in **everyday situations** - routine, non-safety-critical, non-occupational situations - by **independent adults**.
3. By **independent adults**, I mean individuals over the age of majority, who are able to volunteer and participate on their own initiative.

As explained in section 1.7.2, I recruited independent adults rather than targeting cohorts that often feature in participatory design studies, such as care homes and schools. I would not have approached a care home for recruitment, but a care home resident aged over 18 who volunteered on their own initiative would have been eligible, as would an 18-year-old who was still in school.

Besides wearable devices that are *not* connected (i.e. do not send or receive data to or from an endpoint), the following use cases are outside the scope of this study: medical, safety-critical, assistive, specialist (including gaming), educational or occupational applications. All of these use cases entail an extrinsic motive for wearing the device: you cannot hear without the hearing aid, the boss makes everyone wear the smartwatch. **This thesis is about wearables that users *want* to wear, even when they don't *have* to (O5)**.

Participants and assistive technology

Many participatory studies feature assistive technology and/or design for specific disabilities [277]. I have been asked whether the technology probe (Chapter 4) is assistive technology. The answer is no, with some explanation.

No volunteer for this study was going to receive any kind of medical or safety-critical device. Had I built a non-medical, non-safety-critical device that arguably functioned as assistive technology for some participants, the research would still not be *about* assistive technology because all participants would wear it, not just the ones with the relevant disability.

The winning DF (Appendices E.7 and I.3.7), on which the technology probe (Chapter 4) was based, was about feeling excluded partly because of autistic spectrum disorder and hearing loss. The technology probe functioned as part of the storyteller's proactive lifestyle, not by compensating directly for any disability-related deficits, so it is not assistive. Contrast this with the Empathy-In Glasses/Empathy-Out Gloves (Appendices E.4 and I.3.4), which directly compensate for a communication deficit. When the *character* wore the technology it was assistive, but the technology probe would be worn by the *storyteller*, who, in that story, was a different person from the character (O5). If the storyteller were expecting a wearable for her character rather than herself, *Empathy-In Glasses/Empathy-Out Gloves* would read differently [279]. Also, and importantly, the main character is not the only one who needs the technology - the bullies need it too [278, p4] (Appendix M.3.5).

1.9.2 Limitations

Maker skills

Although there was no limit on the form or function of the devices imposed on the DFs, the real-world implementation of the designs they inspired was constrained by reality, including the limitations of my maker skills. I am a software engineer, not an electrical engineer; I have minimal jewellery making skills and can design and sew clothing patterns, but the execution is clumsy (O4).

When proposing the designs to put to the vote, I as the maker also had a vote, based on what I thought would a) be feasible, b) for me, c) in the time available (O5).

Demographics

The goal was to recruit a group of half men and half women. In the end, five of the six final volunteers were women, even though recruitment efforts were concentrated on Cambridge's Makespace, where men abound. I resolved to make an extra effort to recruit men if any participants dropped out. However, perhaps more women are needed for wearables research: [125] describes the target market for smart wearables as "West Coast, large wrist, male, geek" (O4, O5).

Additionally, all the volunteers for the longitudinal study were white British, even though a large minority of attendees of the pilot workshops were from other demographics. Al-

though WEIRDness [26] [119] may be difficult to avoid in Cambridge [220], I had hoped to be able to adjust the levels (O5). The political atmosphere in the UK since 2016 could have discouraged volunteers of other nationalities from long-term commitments, and the small size of the group might explain why everyone is white (though the Cambridge pilot studies were only 75% white).

All the volunteers for the longitudinal study were artists, writers or designers. I did not target these occupations, but those were the ones that turned up to otherwise poorly attended public workshops, and stayed for the duration. A small number of participants is not a barrier to generalization [56] on its own (O5), but there is reasonable doubt as to how well a study of six artists and designers generalizes to the rest of the population (though the work's appeal to this group is encouraging).

Control group

I considered running the workshops with a control group using more classic methods for inspiration, such as brainstorming. However, using a control group would not have been a meaningful test of the validity of PDFi, considering the inherent subjectivity of the process [157, p183] (O5). As the workshop facilitator, it would have been too easy for me to bias the results, so a control group would have doubled costs and time to no good effect. For future work (section 1.8.2), it would be good to counterbalance control group workshops with a second facilitator. However, the goal would not be to prove the superiority of PDFi over any other method; as I say, it is subjective. I only seek to show that PDFi can be one fruitful method among many, for those to whom it appeals (sections 2.1 and 3.1.1).

Scale

The current method can only be done with a small number of participants because it involves detailed individual attention (O5). This means the method would have to change in order to scale up for use by a product designer. Although I hold the opposite of Norman's [201] view on human-centred design as far as the current state of wearables is concerned, his point about scalability [201, p16] is well taken. The need for further study, in collaboration with a product designer, is indicated (O4).

Software

Each participant received a HAT (O1, O2, O3, O4) and an introduction to its use. However, due to time constraints, iteration focussed on hardware refinement; possible applications to combine personal data were discussed (O2, O3) but not developed. Based on past work [203], the user experience would be worsened by asking them to use a partially-developed software application.

[26] Western, Educated, Industrialized, Rich, Democratic

1.10 Conclusion

In this chapter, I identified six obstacles to wearable computing, five of which I address in this research. I posed three research questions about the possibility of using PDFi to address these obstacles.

In section 1.1, I described the state of everyday connected wearables in mainstream use. In section 1.2 I provided some background information on user-centred design and participatory design in terms of their potential to overcome some of the obstacles to wearable computing. In section 1.3 I contrasted the prevailing, computer science-based approach to wearable computing with the work of the contemporary jeweller Jayne Wallace on the personal significance of digital objects. In section 1.4 I introduced the discipline of DF which is central to this study. In section 1.5 I showed how DF relates to questions of privacy and provides a context in which to consider those questions; and I described some practical implementations of solutions for data ownership. In section 1.6 I showed how the use of the HAT as the project's software infrastructure allows for a single use-case wearable device to augment its functionality through integration into an IoT ecosystem and contextualization with data from other sources. In section 1.7 I introduced my methodology, and in section 1.8 I highlighted the contributions made as a result. In section 1.9 I specified the scope and limitations of the study.

In the next chapter I will describe my methodology in more detail.

Chapter 2

Methodology

In the previous chapter, I identified five obstacles to wearable computing which I address in this research (O1, O2, O3, O4, O5), and on two of which this chapter focuses: wearables that function as an extension of the wearer (O4) and appeal to emotional as well as functional needs (O5). I posed three research questions about the possibility of using PDFi to address these obstacles.

I also described the main issues that have driven me to carry out this research: the state of everyday connected wearables in mainstream use (section 1.1); the potential of user-centred and participatory design to overcome some of the obstacles to wearable computing (section 1.2); the computer science-based approach that dominates consumer wearables and the contrasting approach of the contemporary jeweller Wallace (section 1.3); DF (section 1.4), its relationship to privacy, and some practical solutions (section 1.5); and the HAT as the project's software infrastructure and how it facilitates IoT integration (section 1.6). I introduced my methodology (section 1.7), its contributions (section 1.8), and the scope and limitations of this study (section 1.9).

The current state of the art (sections 1.1 and 1.3) is dominated by the "computer science" paradigm of consumer wearables. I seek to balance this with the "digital jeweller's" approach, based in craft practice, which [274, p5] describes.

My aim was to create a research study that would increase understanding of what kinds of wearables potential users really want, while balancing utility and emotional appeal in the **same** digital object. To do this, I would have to develop a new methodology which supported potential users within the right kind of imaginative space. In this chapter I will explain my methodological choices in more detail.

In section 2.1 I discuss considerations about participation and participants appropriate to this kind of RtD. In section 2.2 I briefly review the literature on enchantment in wearable technology. In section 2.3 I explain my choice of DF as a form of participation in designing for enchantment. In section 2.4 I argue the case for narrative immersion as a way of increasing participation in the ethics of wearable computing. In section 2.5 I argue the case for refocusing on the texts as worthy artefacts of participatory design; and for taking participants of narrative-centric research at their word. In section 2.6 I place the study in its frame of RtD. In section 2.7 I explain my methods of capturing data. In section 2.8 I explain my use of creative toolkits.

2.1 Participatory design

Vines et al. [273] reaffirmed and challenged the purpose of participation in design. A purpose of participatory design is listening to stakeholders who are normally disenfranchised. Vines et al. [273, p429] call out accountability for "the agency of researchers, funders and the locations of engagement as contributing factors to the quality of participation". They echo Redström's concern [222, p129] that "user design" is overly controlling of users' behaviour and experience.

Vines et al. [273, p432] raise three key issues about participation:

- Forms of participation: what do participants actually do?
- Initiators and beneficiaries: who initiates and who benefits from user involvement?
- Sharing control: we must not gloss over the researcher's agency in a way that exaggerates how much control the users really had.

Regarding forms of participation, I describe the participants' activities in Chapters 5 and 6; and Appendices H, I and K.

Regarding sharing control, my own input and framing of the activities are specified in sections 1, 1.3, 1.5.2, 1.6, 1.7, 1.8 and 1.9; sections 2, 2.1.1, 2.2, 2.3, 2.4, 2.7 and 2.8; Chapters 3 and 4; sections 5, 5.1.7, 5.2, 5.3, 5.4 and 5.6; sections 6, 6.1.1 and 6.5; Appendix H sections H, H.1, H.2, H.3, H.4, H.5, H.6.3, H.7, H.7.1, H.9, H.10.1, H.10.3, H.11, H.11.1, H.13 and H.14; Appendix I sections I, I.1, I.2 and I.5; and Appendix K sections K and K.1.

Light, 2010 [157, p184] points out how unseriously the concept of participants' "ownership" of their ideas was treated in common practice. By the time I embarked on this study in 2016, the ethical policies of the University of Cambridge required me to explain intellectual property (IP) rights in the participant information documents; in a nutshell, researchers and participants share ownership of IP, and I did remind participants more than once that they owned their own contributions when they asked about publishing them elsewhere (the only issue was respecting others' anonymity).

Light also points out that micro-interactions are as important as methodology: "What is under-reported is who is executing these techniques and what they bring that would have been different in another's hands." This introduces an element of subjectivity (sections 1.9.2, 2.5 and 3.2.2) which seems to threaten repeatability and risk being labelled "unscientific", which may be why it is not as much talked about. I was mindful of the issues Light describes about how to maintain engagement with people who owe me nothing and could be spending their time differently. I do not claim to have excelled at hospitality, but neither was it an afterthought.

Initiators and beneficiaries: I was conscious that I was the one seeking help from my volunteers, not offering potential benefit to a putative population at this early stage of the research. Besides reimbursing travel and compensating each participant with a voucher for GBP 30.00 per workshop or interview, I did my best to make sure they would benefit from an enjoyable creative process (they did) and, ideally, from the technology itself (some did). This project is the first step in a larger agenda to develop user-centred wearable

systems, and future work will develop technology that has progressively more to offer to participants as well as other stakeholders. As development continues, the participants will have the satisfaction of seeing the impact of their ideas.

2.1.1 Participants

My goal was to recruit members of the public who would be interested enough and capable enough to contribute to a two-year longitudinal study. Because Cambridge has a large maker community based at the hardware lab Makespace (members-only, but with some free public events), that was the obvious focal point.

By focussing on the maker community in a well-resourced university city, I was more likely to recruit a privileged cohort, and I was not, at this stage, trying to target what Harrington [117] calls the "forgotten margins". Harrington's use of storytelling and refusal of "damage-centered" research has shown me a path I could follow towards democratization of my own methods, and reaffirmation that having something to offer as a researcher is not simply about solutionism and gadgets: "'We don't always want to talk about health as what's wrong; sometimes we want to talk about the fun things we do to take care of ourselves [O5]."'

One objection I have received is that I was only recruiting enthusiastic participants, rather than trying to evangelize reluctant users (O5). My response is that this was by design. A show of hands at a Cambridge Wireless specialist group meeting in 2014 [1] indicated that few attendees owned any wearable technology, and fewer were wearing theirs. The first challenge is to make something enthusiasts will wear, and then maybe I can persuade reluctant users.

Details of recruitment and publicity are in Appendices H.4, I.1 and I.4. I did succeed in recruiting exactly the right number of volunteers. Most (all but two) were over 35. All were white, British, and native English speakers. The occupational profile was strikingly expert:

- three costume designers
- three artists (two with day jobs)
- one academic (with a non-academic day job)
- one person not employed due to disability

Vines et al. [273, p434] tells of an occasion when they tried to recruit for inclusiveness, only to discover that the recruits had a long history of volunteering for university studies, which called their status as "representatives of their peers" into question. If I avoided convenience sampling of computer scientists because they are not representative users, but got mostly artists and designers - are they representative users? Or should I just feel validated to see designers and artists enjoying the process, some of whom found, with us, the kinds of inclusion they sought? "Grace" joined in part because she wanted more involvement with the University; to which, like most of the participants, she had no ties. "Rachel" rarely got to participate in group projects because her health problems often force her to miss meetings.

[1] *Cambridge Wireless - Connected Devices Group,* 9 October 2014: **Wearables: The Internet of Us.** https://www.cambridgewireless.co.uk/events/46845-connected-devices-sig-event-wearables-the-in/

2.2 Enchantment

McCarthy et al. [177] refer to the "charm, delight, and pleasure" that enchantment connotes (O5). They conclude: "[. . .] in order to support a lasting enchantment, an interactive system has to have depth". They offered a set of "sensibilities" (not "guidelines") for "designing for enchantment" (numbered for convenience):

1. "The specific sensuousness of each particular thing
2. "The whole person with desires, feelings, and anxieties
3. "A sense of being-in-play
4. "Paradox, openness, and ambiguity
5. "The transformational character of experience"

All of these guidelines come into play in the methodology I applied to my study, but at this stage the second, third and fourth sensibilities in particular drove the design of the workshops.

Storytelling was the format I chose for the participants to frame their desires, feelings and anxieties (second sensibility). Whereas the prompt for the storytelling was well defined, I emphasized to the participants that they had freedom to move within that format (fourth sensibility). The relative openness of the DF format (compared to a more goal-oriented format [7, p222]) allowed "the possibility for complex, layered interpretation" [177] and depth of the wearable system. To give workshop participants the right conditions for creativity and open expression, the workshops would have to provide a welcoming and emotionally safe atmosphere for a sense of "being-in-play" (third sensibility).

Another researcher who has explored enchantment and wearable technology is Wilde [275] who focuses on body movement. Wilde's 2009 article [275] mostly discusses "performative" art pieces that are thought-provoking or surprising. Wilde is critical of the blandness of consumer wearables: "They still, predominantly, focus on technological development - enhancing functionality and increasing efficiency, and largely ignore broader aesthetic concerns." [275, p184] As a maker working alone with off-the-shelf components, I was not striving for technical innovation this time, and unlike Mueller et al. [192, p1675] I do not rule out ideas that already exist as concepts or products. The main design concept to emerge from this study, a Gallery Shirt, has been made before, but not for the same purpose of *designing for enchantment* for an individual storyteller.

On the other hand, my intention was to design items for everyday or perhaps occasion wear - nothing as performative as the works Wilde [275] describes, or as questioning as Wallace's [177] false eyelashes made of silver so heavy that the eyelid cannot open. Wilde [275, pp. 185-186] offers the most useful categorization of (non-medical, non-safety-critical) wearables I have found (numbered for convenience):

1. "works that literally transfer non-body-based technology to the body, transferring button to sleeve, for example, hiding elements in pockets

2. "works that are closely aligned to traditional approaches to fashion, treating the body as a moving, biomechanically complex coathanger, whose purpose is to transport a body-based artwork, garment or device through space
3. "works that capitalize on the body's capacity for movement
4. "architectural explorations of the extended body space
5. "socially and critically engaged works
6. "conceptually challenging/stimulating works
7. "works destined for everyday life
8. "works destined for performance and dance
9. "works that sit in a hybrid space in-between art, design and everyday life
10. "works with an ongoing narrative
11. "one-liners - works that perhaps show technical prowess or conceptual acuity but may not be engaging over time
12. "works that truly capture us, transport us, challenge the way we think about things beyond the immediacy of the work itself."

As well as categories 10 and 12, my aim was to produce works in category seven, though in reality they were likely to end up in category nine and, in the worst case, category 11. Besides being less performative than Wilde's [275] (section 3.6.5) I also wanted to make something more purposeful than Gaver's "curious things for curious people" [102], smart objects that were predominantly playful. My moth dress [206] is the best example to show what I am driving at.

2.2.1 The moth dress

Figures 2.1 and 2.2 show a death's head moth costume with an Artcode [2] - a machine-readable illustration [261] on the back, in retroreflective ink. The dress is a costume, but it is also a day dress, appropriate for many everyday situations. Compare this with Mainstone and V2_'s *ShareWear* [3] which also adds a twist to conventional garment forms, resulting in a much less conventional appearance than the moth dress.

We tried, but failed, to make the ink invisible except under a camera flash; the dress is not plain-looking, but if we could have made the ink invisible the dress would seem to have nothing unusual about it until the twist is revealed. It has an ongoing narrative (Wilde's category 10, section 2.2), being inspired by the moths in *The Silence of the Lambs* [64]. It has a carefully selected colour scheme (first sensibility of McCarthy et al. [177], section 2.2), represents one of my lifetime artistic influences (second sensibility), has a sense of "being-in-play" (third sensibility), and plays with the ambiguity in the hidden functionality of the hyperlinked two-dimensional image that appeared and disappeared

[2] *Artcodes.co.uk:* https://www.artcodes.co.uk
[3] *V2_ Lab:* **Sharewear** https://preview.tinyurl.com/s7xfsmq

Figure 2.1: *Artcode in retroreflective paint on back of death's head moth costume. Artcode by Liz Jeal, art direction and inking by Emily-Clare Thorn.*

Figure 2.2: *Front view of death's head moth costume.*

under different lights (fourth sensibility). As well as Wilde's 10th category, the dress fits her second, seventh and ninth categories; and I hope to get it to category 12 with further work, possibly in an implementation of distributed performance.

Rose [226] defines "enchanted objects" as "ordinary things that have the same functionality that they had before, except now they can talk, they're connected. These are ordinary things that have extraordinary capabilities." [4] Rose sees enchanted objects as "atomized" in comparison to the "black slab" of the multipurpose smartphone (O3, O4).

Rose defined a "Ladder of Enchantment":

1. Take an ordinary object [like a trashcan].
2. Connect it.
3. Personalize it [e.g. connect it to your Amazon account].
4. Socialization
5. Gamification
6. Storyfication [create a story that lives in the object; e.g. a grouch [5] lives in the trashcan and nags you about your dietary habits if you throw away too many cookie boxes.]

What if "storyfication" were on the first rung of the ladder?

2.3 Design fiction

Rose argues that enchanted objects (O3) appeal to these six human desires:

1. omniscience
2. telepathy [connection with others]
3. safekeeping
4. immortality [health]
5. teleportation
6. expression

Appendices J.7 and L.7 evaluate the DFs in terms of Rose's six desires (O5).

There are other formats I could have chosen besides storytelling. Knutz et al. [148, p1] note that, besides Blythe and Wright [30] and Dindler and Iversen [73], "the question of the relationship between fiction and participation remains largely unexplored." Tsekleves

[4] *TEDxBeaconStreet,* 9 December 2014: **Enchanted Objects: Design, Human Desire, and the Internet of Things |David Rose** https://tinyurl.com/y7rwvxpy

[5] *Wikipedia:* **Sesame Street** https://tinyurl.com/zzh3np5

et al. [268] have since investigated co-design of DFs for healthcare, with elderly volunteers generating the narratives which were then developed into a tangible fictional prototype by consultants (section 3.8.1).

Knutz et al. consider DF, "discursive design", and SCD all together. They identify six strategies that may be relevant to participation and which could be used to, among other things, involve users more directly in product development:

1. **Value Fiction** [79] [80], to prompt discussion of technology, social values, and wishes for the future. The participation is in the user's response to a real, usually subversive, design artefact.

2. **Perceptual Bridge** [13, p140] [12], to make SCDs relatable by rooting them in everyday life. Auger and Loizeau [12] gathered written responses from colleagues to a shocking design proposal - which can be seen as PDFis to a specific brief. More recently, Beattie et al. [21] took inspiration from a child's use of Minecraft [6] to redesign the space in his orphanage.

3. **Digital Anthropomorphism** [187]. Anthropomorphizing technology such as a drone or a WiFi-enabled cow [186] to understand the complexity of its ecology.

4. **Pastiche Scenarios** [30] [62] [281]. Taking existing characters and fictional universes to improve the quality of the DF and increase user involvement. Blythe and Wright [30] use Alex from the film of "A Clockwork Orange" [149]. They argue for better characterization in narrative-based HCI research in order to get a better feel of the user experience. Using existing characters and worlds is more effective than starting from scratch with a short original text.

5. **Fictional Space As Design Space** [73] [35]. Fictional spaces are created when participants play games of make-believe, assisted by props.

6. **Fictional Re-Framing of Social Innovation** [85]. This method questions assumptions about design and its effects on society and sustainability. Emilson [85] held extensive workshops with a variety of stakeholders, involving community organizations and local authorities, using the narrative strategies of "dark and soft fiction" to reframe debate on sustainability.

Of these methods, it was Pastiche Scenarios that resonated with me [30]. In everyday life, people often use existing media as a common point of reference to describe concepts across disciplines. A storytelling format that allowed derivative works would increase the accessibility of the exercise, without excluding those who wanted to write original stories.

2.4 Narrative immersion and ethics

Casey Fiesler [93], a technology lawyer, points out that "in law school, 'hypos' [hypotheticals] are a dominant pedagogy". Fiesler, like the computer scientists Burton et al., [43] use SF to teach computer ethics and train students to speculate about the possible

[6] *Minecraft:* https://www.minecraft.net/en-us/

consequences of the technology they develop. There is an argument for narrative methods as a way to increase participation in the ethics of wearable technology (O1).

Although suspension of disbelief about change [33] seems to be widely accepted as the defining characteristic of DF, Jensen and Vistisen [133] argue that the role of narrative immersion (O5) has been neglected by the literature, which has focussed on art-based design. As someone with a background in literary analysis [204] [207] I have also noticed this blind spot. Jensen and Vistisen [133] developed a framework for narrative ethics in DF, based on the assumption that a DF is written by a designer for a corporation; and distinguishing apathy, sympathy and empathy with the user as ethical stances on how the company should behave.

Jensen and Vistisen argue that focussing on narrative immersion is necessary to bring DF to maturity, which they define as broadening it into a strategic as well as a critical approach so it can be used in near-future design. There is controversy about the ethics of using DF for current or near-future design rather than just critique. Brown et al. [40] realized that it was difficult to be outright critical in an industrial partnership. MIT Technology Review published a scathing article [175] about the commercialization of DF, citing Google's 2012 video about Project Glass [7] as an example. The article ends with faint praise for Bleecker's [29] involvement in real product development for a company producing luxury cycling accessories.

2.5 Words

Rereading the cited works in [148] I realized some of them were quite difficult to read, because they used obfuscated or roundabout language. For example, in [187, p46] I had trouble pinning down specific details I was looking for about forms of participation: were the girls in the opening section real or (as it seems) fictional? How did/would the authors know about the girls' reaction?

Jensen and Vistisen's paper [133], arguing that narrative immersion is important for the ethics of product design, was easier to read, not quite so easy to summarize. At that point I came across Fiesler's [93] *Medium* article which states its case very bluntly.

The main design artefacts of this research are the PDFis and the technology probes. However, almost all critiques of my work so far, including favourable ones, have glossed over the texts. Objections have focussed on the rudimentary quality of the paper prototypes, as if the texts were supporting material for the paper prototypes and not the other way around. This is why I refer to the participants' contributions as *stories* more often than *design fictions*: to keep the focus on the texts. After reading [133] I now understand that the reason I have struggled to articulate a justification for my choice of PDFi via storytelling, with words, is that not everyone shares my *unspoken* assumptions about *paying attention to the words*.

Sir Anthony Hopkins [8] prepares for a role by thoroughly learning his lines, ritualistically reading each script 250 times. He needs minimal rehearsal time as a result. While Foucauldian discourse analysis may assist, incorporating the words is the most direct

[7] *Google,* 5 April 2012: **Google Project Glass: Official Concept Walkthrough Video, "One Day" [HD]** https://www.youtube.com/watch?v=5R1snVxGNVs

[8] *Wikipedia:* **Anthony Hopkins** https://tinyurl.com/ty675a4

route to understanding the character. Words are a very efficient way of telling us things about the person saying the words (O5).

Some of the more suspicious reactions to my work have begun with the exact phrase "the paper reads well". If the subject matter were highly technical and it were easy to read, that would be welcomed. If the subject matter could be (has been) accused of being "fun", *and* is easy to read, how can the reader trust they have read something serious?

The art critic Berger [26, 24:35] calls out "mystification" in a critique of a Hals portrait. "It's as though the author wants to mask the images, as though he fears their directness and accessibility. [...] It's as though he doesn't want us to make sense of it in our terms. And when he sums up, he resorts to meaningless generalisations [...] This is mystification."

Like grounded theory [107], my research is concerned with emergence from the data. It does not, however, follow the methods of grounded theory, which Tolhurst [263] forcefully argued:

"GTM [grounded theory method] has been shaped by the endeavor to attain the sense of exactitude associated with positivism, whilst also seeking exclusive referents of inquiry that are distinct from the empirical realm of the natural sciences. [...] eschewing the perceived requirement to define and defend an academic niche could help to facilitate the development of a more useful and pragmatic orientation to qualitative social research."

I have received objections about the lack of a "scientific" (i.e. positivist) method for analyzing the DFs. Tolhurst has some choice words for this shame-based approach to methodology, and the effect it has had on the language used to communicate about it:

"It can perhaps be queried why such a contrived lexicon has been developed in response to a task which is likely to be highly explicable to the layperson. With regard to a qualitative method such as semi-structured interviews, the process involves a researcher speaking to research subjects and then attempting to make sense of what has been said by reviewing the transcript of the conversation. The explicability of this process does not mean that it is easy and that it does not require substantial skill."

It is true that I did not use any specific technique of narrative analysis, because the DFs are straightforward texts, to be taken at face value, and reading comprehension was enough. If my method of PDFi is useful, it should be adopted by others, and it needs to be *usable* in order to achieve that. I am not arguing that no other narrative analysis techniques should ever be used with the method elucidated in this thesis; only that mystification discourages participation for researchers and designers as well as for users.

2.6 Research through design

RtD deals in wicked problems [225, p155] (section 3.2.2). A wicked problem is "difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize." [9] A wicked problem is "a problem whose social complexity means that it has no determinable stopping point." [266] As Brandt et al.

[9] *Wikipedia:* **Wicked problem** https://en.wikipedia.org/wiki/Wicked_problem

[35, p171] put it: "Design is not decision-making in a well-known space of opportunities but an exploration of what may be envisioned through the coming together of a network of actors."

I planned this study with the four criteria of Zimmerman et al. [286, pp. 7-8] in mind, for evaluating the contribution of a RtD. These are:

1. **Process:** the methods must be rigorous and the rationale well justified; this is what I have striven for. The process must be well documented enough that someone else could repeat it.

2. **Invention:** the contribution must be a significant invention, defined as a "novel integration of various subject matters to address a specific situation." No study of the participatory design of everyday wearable IoT devices has done what this study has done (sections 1.8 and 3.1.1), using PDFi to elicit concepts from, and reflect with, users; and design everyday wearables based on PDFis for in-the-wild study.

3. **Relevance:** the research changes or helps to change the world "from its current state to a preferred state" and explains why the preferred state is preferred. The current state is that wearables are not being worn, are stuck in a rut of "black-slab incrementalism" [226, p21] and are implicated in an IoT which threatens users' privacy [123] (O1). The preferred state is that wearables are being worn, have more variable form factors (O4), protect the users' privacy within an IoT ecosystem (O1, O2, O3), and appeal to their emotional needs (O5). The preferred state is preferred because in the current state, wearables risk being lost to their great potential [24].

4. **Extensibility** "means that the design research has been described and documented in a way that the community can leverage the knowledge derived from the work." This thesis fully documents my process from end to end.

2.7 Note-taking

During most of the early workshops and interviews, I took notes using designVUE [65]. For privacy reasons, audio or video recording was ruled out and I typed all notes in real time, editing them afterwards for clarity. In sessions where I used designVUE, all of the main points and many of the details were captured despite the lossiness of the note-taking process.

The designVUE concept maps use Issue-Based Information Systems (IBIS) notation [224], for reasoning about design, including wicked problems [225, p155], with quick and continuous capture of design rationale.

At the inaugural workshop (Appendix I), the laptop was unexpectedly needed for a Skype attendee so I took handwritten notes instead.

After the second workshop, designVUE became incompatible with my operating system, and I no longer had access to the code base. The best alternative I found was SimpleMind [10] which, like designVUE, has bidirectional hyperlinking; but I never found it as usable as designVUE and reverted to plain text after the second workshop.

[10] *SimpleMind:* https://simplemind.eu

2.8 Creative toolkits

Wallace [274, p113] used a probe [101] method, which she adapted: "I found that probes centred on gaining short answers, sound-bytes almost and I wanted to allow space for longer story telling through text based answers [O5]". Sanders and Stappers [233, p9] distinguish the applicability of toolkits, probes and prototypes to different modes of co-design. In their framework, toolkits are for making "artefacts about or for the future", and are to be used in generative research as a way to involve users in the co-design process of artefacts that may go on to be developed. They position probes within a pre-design process [11] for the purpose of empathizing with users, not for further development. Creative toolkits may be used in a more structured and facilitated process than would be suitable for probes.

According to [232, p70] "Toolkits are made of 2D or 3D components such as pictures, words, phrases, blocks, shapes, buttons, pipe cleaners, wires, etc." The contents and usage of a creative toolkit should be improvisational and not be allowed to calcify into routine. Suggested contents include photos, systematic sets, words, puppets, symbolic shapes, cartoonlike expressions, raw scraps, and construction kits like Lego.

I excluded systematic sets because they seemed too directive. I included an abundance of "raw" craft materials (card, paints, glue, felt-tips), to maximize creative freedom. Some of the embellishments were already fashioned to representational shapes - felt birds, metal charms, etc. - but instead of words and phrases, I included letters and numerals as a less directive choice.

Sanders and Stappers' suggestion of puppets seemed like a poor fit for this use case, but I included some children's toy costume items, as well as some real but characteristic clothing items in a dressing-up box.

As well as tangible items, the creative toolkit included a story prompt based on Johnson's [135, p25] "Five Steps" of creating a SF prototype. As [232, p60] put it: "we cannot ask people to become instantly creative. They need time for immersion". Therefore, the first workshop of the longitudinal study would introduce the format, and the second workshop would bring out the real story.

With these materials, the composition of the creative toolkits was, as recommended by [232], varied in content, abstraction, levels of ambiguity and openness, aesthetics and form.

2.9 Conclusion

In this chapter I have gone into greater depth about the methodology of this study. I discussed considerations about participation and participants for this RtD; briefly reviewed the literature on enchantment in wearable technology; explained my choice of narrative fiction as a form of participation in designing for enchantment; argued the case for narrative immersion as a way of increasing participation in the ethics of wearable computing (section 2.4). I have argued the case for refocusing on the texts as worthy artefacts of participatory design, and for taking participants of narrative-centric research at their word

[11] My technology probe (Chapter 4) would be a prototype in Sanders and Stappers' framework.

(section 2.5). I have placed the study in its frame of RtD (section 2.6). I have explained my methods of capturing data (section 2.7) and my use of creative toolkits (section 2.8).

In the next chapter I will contextualize the research contributions of this thesis to the wider community.

Chapter 3

Comparative Methodology

*The patient sleeps on the steps of the temple and dreams. What matters is the **right** dream, and the right dream cannot be planned for. Whether it was the right dream is only known after the fact, when the patient wakes up. Incubations cannot be repeated, planned or standardised. In incubations the expert does not so much apply her superior knowledge, but rather accompanies a lay person on an experimental path. [111, p73]*

In the previous chapter I explained my methodological choices for this study. In this chapter I will contextualize the research contributions of this thesis to the wider community.

I recommend turning to the appendices before reading any further.

Appendices A through G contain the full texts of the PDFis. Appendices H through M contain descriptions of the PDFi workshops, and analysis of the stories. To contextualize the PDFis with the workshops in which they were developed, I suggest reading the appendices in the following order:

1. Appendix H, interleaved with the stories in appendices A through D
2. Appendix I, interleaved with the stories in Appendix E
3. Appendix J, initial analysis of the stories so far
4. Appendix K, interleaved with the stories in Appendix F
5. Appendix L, initial analysis of final stories
6. Appendix G, final story updates
7. Appendix M, analysis of stories in greater depth

Sections 3.1 and 3.2 explain the study as a whole: 3.1 explains the contribution and novelty of the study, and 3.2 explains my fundamental methodological choices. Section 3.3 relates this study to the existing literature on privacy, and explains how the software infrastructure supported or constrained privacy and affected design decisions (O1). Section 3.4 relates this study to existing research on the IoT (O2, O3) and discusses missed opportunities and possibilities for future work. Section 3.5 positions this study within

the literature on participatory design of wearable technology (O4, O5); 3.6 provides a detailed comparison of this thesis with related research on aesthetics (O4, O5). 3.7 relates the thesis to past and current work in design fiction and other fictional design methods, and identifies the target audience (O4, O5). Finally, in section 3.8, I compare this thesis to related work in participatory design fiction (O4, O5).

3.1 Contribution and context

Nägele et al. [195] acknowledged a question that is not often asked - the contribution of the PDFis: "Although effectiveness of a DF is difficult to quantify there is promise that the PDFi method can surface insights that effect and inspire developers of medical device technologies and rightfully give voice to people in vulnerable positions." PDFi has value as a method of listening to participants and facilitating them in telling their own stories on their own terms.

I have been asked how I know it was the PDFis, rather than the participation and co-creation, that contributed to emotional engagement in my own study. The implication "method in →results out →success!" is commonly found in the literature, usually (as in [195] above) supported by argument, but not proven. As Dindler [74, p36] elucidated:

> "Obviously, arguments suggesting a change in design practice or concepts for reflecting on the issue of engagement cannot be true or false. They can be more or less useful in any given context. My experiments cannot in a traditional scientific terminology prove an argument, as this would suggest that we are dealing with matters of truth. Experiments can however improve the quality of that argument by showing its strength within a particular program. This is in essence similar to relating arguments to established theoretical notions thus strengthening the position. Experiments may thus substantiate an argument in the form of a concept or a technique by showing the breath of its applicability and by delineating its boundaries."

In my case, the PDFi *was* the participation, and the PDFi *was* the co-creation, so in a way, asking how the PDFi's contribution can be distinguished is like asking "How do you know it's six of one - what if it's half a dozen of the other?"

Storytelling is inherently emotionally expressive, therefore a participatory and consequential (section 3.8.2) storytelling process could be expected to be emotionally engaging. The emotional engagement of PDFi contrasts with "affective computing" for wearables in the current paradigm which, as Ryan [229, pp.99-100] elucidates, becomes simply another way of treating the body as a data source. "Emotional design" [200] usually means designing to elicit a particular emotional response from a user. Both of these things are different from trying to design for *emotional engagement with an everyday wearable inspired by a diegetic prototype in a story told by the wearer, to express what the wearer finds meaningful.*

In the first two cases, the designer leads. In "affective computing", the wearer-generated data is processed to provide the value a programmer knows how to provide. "Emotional design" is on a continuum of "designing the user" [222, p127]. With PDFi, the wearer/storyteller's expressed values may be within the gift of the programmer, the designer, or both to provide for *in relation* with the wearer. The purpose of *Gallery Jacket*

is social, and a programmer's first thought would be to turn it into a a Social Proximity Application (SPA) with social media integration, but it is actually about artistic expression and socializing face-to-face. The minimum viable functionality requires little or no computation of user data, so little that the resulting technology is not so much a wearable computer as a wearable item with computational capacity. Its functionality comes from the emotional investment and social interactions of its wearer and of bystanders, not from data inputs or outputs. Of course, there are many possible enhancements, but the core functionality already works as its author intended.

Another implication of the question as it was put to me, was: how can I show that PDFis are *more* effective than some other method of concept elicitation? The question was about emotional engagement, but I will extend its scope to all five obstacles (section 1).

3.1.1 Novelty

I never did claim that PDFi was *more* effective than other methods; I only ever claimed it was *a possible way* of addressing the five identified obstacles (section 1), and that the appeal of PDFi depends on the psychology of the individual (sections 1.9.2 and 2.1).

To be fair on its own terms, the question needs to be recontextualized to the entire study, like this:

How can I support my argument that using PDFi for concept elicitation

- from independent adult participants,
- of real wearable technology probes,
- for everyday connected wearables,
- with an open-ended brief,
- for in-the-wild study,
- and for co-imagining sociotechnical futures for everyday connected wearables,

is more effective than using something *other* than PDFi to address the same obstacles?

The answer is that **there is no way to know until somebody else tries to do the same thing using *any* method, and so far, no-one has.**

3.1.2 Related work

Were someone to repeat this method, it is important to remember the epistemic limits and value of replication of a DF study [74, p36]:

"Doing multiple experiments to support an argument is not a way of proving its truth-value, but a matter of unfolding the richness and boundaries of what it suggests. As an example, both P1 and P2 address multiple experiments in developing the notions of fictional inquiry and staging imaginative places. However, these multiple experiments are used to substantiate the propositions made through these concepts and not as repeated experiments that show their truth-value."

This is *not* a participatory design study that happens to use everyday connected wearables as a motivating example. It *is* a study of everyday connected wearables using PDFi. The PDFi is used for inspiration, consequential speculation [84, p5391], co-imagining, and reflection.

If any other study did *all* those things, designing everyday connected wearables, using PDFi or not using PDFi, to address concerns overlapping with any of the five obstacles in this study (section 1) then we might learn something about the comparative contribution of PDFi.

Spiel et al. [249] studied co-design of "companion" technologies for autistic children with an open brief. That article is out of scope for this thesis because the cohort was minors with a specific disability, and because it was not about wearables. Otherwise it is a good example of what a comparable study without PDFi would look like.

Key similarities between [249] and this thesis are:

1. First, they approached the children with a holistic rather than a 'deficit' attitude: "With few exceptions, technology for autistic children tends to be focused on the regulation of perceived deficits" [249, p245].

2. Second, they had a small number of participants - four to six children per school year.

3. Third, they had an open design brief with "only two requirements: the technology should afford positive experiences in a meaningful way to the child and the child should be supported in sharing those experiences with their social environment." [249, p245] This is comparable to the brief in this study which prompted for stories about wearables to enhance everyday life.

4. Fourth, they let the children lead the co-creative iteration of their inventions: "Such technologies are then not driven by an outsider's perspective of what an autistic child needs, but rather are intrinsically valuable to them as a user." [249, p245]

5. Fifth, they expected that letting the children lead with an open design brief would result in innovation: "Furthermore, we expect the final objects to be radically different from existing technologies." [249, p245] The innovation they sought was not new technical solutions, but assemblies of already available components into inventions that cut across stereotypes.

6. Sixth, they actually made the childrens' inventions. (Unlike my own study, the participants were involved in the making.)

7. Seventh, they deployed working prototypes to the children [249, p247], though they did not have results at the time of publication.

The rest of this chapter will unpack the theoretical implications of this study and position it in relation to the existing literature. The section topics are not discrete; there are enjambments [179, p51] which would be better represented by free verse, and bidirectional links better suited to hypermedia [65], but the thesis format does not accommodate either.

3.2 Design research

3.2.1 Research without design

The "opposite" methodology to in-person participatory RtD for researching everyday wearables would be online surveys and questionnaires. Liao et al. [158] tried to address emotional engagement (O5) with a two-axis interactive collage tool, for the general public, to evaluate perceptions of comfort and delight in response to pictures and descriptions of multiple wearable products. One of their findings was that clothing form factors were perceived as the most pleasant.

Fortmann et al. [94] had an open-ended brief: they asked respondents to imagine a "digital jewel" with any function, then answer questions about requirements. Similarly to this study, [94] focussed on "everyday consumer products, i.e. products that are typically just worn for fun". They found differences in the perceived importance of requirements according to gender and age; that "functionality, form factor, and interaction and display design" including "long battery life, an aesthetic and unobtrusive appearance, and a quick operation" are more important than "body location, context awareness and customisability".

3.2.2 Inspiration: research through design

Instead of getting people to tell stories, I could have used online survey methods as a quicker and cheaper way to get results that would have been statistically significant. Why do in-person participatory RtD?

- First, because the responses in [158] were not to real wearables, but to pictures and text; the respondents in [94] answered survey questions about wearables that stayed in their imagination. In real life, wearables are experienced by wearing [139].
- Second, because at the time I started the research I had not identified the obstacles that the research was trying to address [225, p159].

The unsatisfying state of everyday wearables is a "wicked problem" [225, p155] (section 2.6), a problem "complex enough that no correct solutions exist a priori and for which formulating the situation is integral to addressing it." [103, p4] The five obstacles this work tries to address (section 1) are not set as objectives the overcoming of which results in a binary or even partial solution to a well-defined problem, but as signposts pointing in the direction of a preferred state for everyday connected wearables.

Gaver et al. [101], in their work on "cultural probes", explained their approach to "Design as Research": "Unlike much research, we don't emphasize precise analyses or carefully controlled methodologies; instead, we concentrate on aesthetic control, the cultural implications of our designs, and ways to open new spaces for design."

3.3 Privacy, security, and making wearables in the Internet of Things (O1)

The axiom of privacy in this thesis is encapsulated in Anderson's definition [11, p31]: my privacy is breached "If my neighbour cuts down some ivy at our common fence with the result that his kids can look into my garden and tease my dogs". Part of the breach involves someone else's altering the boundaries so that my personal space is observable to those outside it; the other part is invasive behaviour into my personal space and directed at its rightful occupants. A simple definition of privacy would be "the ability and/or right to protect your personal information and extends to the ability and/or right to prevent invasions of your personal space" [11, p32].

Any given definition of privacy is too narrow [25, p3] but in this thesis it means "don't [you |let them] look at me [like that |here |now |from that angle |when she's around |etc]". But there are two sides to every story, especially if I say "If you can see me, I can see you".

3.3.1 Inspiration without imitation: Digital Eye Glass

The last attempt at a "killer app" wearable, before hearables, was Google Glass, which foundered on bystanders' visceral objections to being observed and perhaps recorded. To understand the wearer's side, we need to understand "sousveillance".

Steve Mann, the inventor of smart glasses, has been wearing some version of his Digital Eye Glass since his school days, and this thesis would be incomplete without paying proper respects to a genuine radical.

Ryan [229, p7] put her finger on the problem: designers of wearables pursue innovation through noncommercial work with a significant component of critique or commentary; which is reduced to mere gadgetry when the work is commercialized, a case of "disappearing esthetics". Although the smartwatch is Mann's invention and although this thesis challenges the dominance of "cyborg" wearables, I am not opposed to smartwatches or cyborgs or self-quantification. I am opposed to *surveillance*, as is the inventor of the smartwatch.

Steve Mann conceives "sousveillance" as a way to make "veillance" two-sided and thereby equalize power: Big Brother watches, Little Sister stares back.

The logic of Mann's "Digital Eye Glass" is: a camera mounted at eye level is "the least privacy-invasive camera. Hundreds of years ago, before the invention of photography and video surveillance, the human eye was the only camera and the human mind the only recording device [...] People developed protocols for privacy based on an expectation of eye-level veillance. Clothing, such as skirts, as well as window blinds, such as Venetian blinds, were designed to provide privacy from eye-level." [171]

Surveillance cameras operate from a high vantage point and see into spaces that humans are not meant to. The "Digital Eye Glass" merely augments the memory of what the eye naturally sees; if someone witnesses a crime, "telling someone not to remember something will be tantamount to destruction of evidence". We accept security cameras to protect merchandise and prevent shoplifting, so, Mann argues, we object to eye-level cameras because things are more valued than people: "bodily integrity certainly should be more

sacred than the integrity of a lamp post or ceiling. Yet how often do security guards strip-search a building, like what happens to just about every airport passenger?"

Mann acknowledges the fear that an eye-level camera is always recording, but points out that "We already have technology to have completely hidden cameras. It is only the seeing-aid part that is visible." He dismantles the logic of accepting surveillance cameras but objecting to smart glasses. The feeling of unease does not melt away in the face of this logic, but if I turn away I only bump into the logic again: we have grown too accustomed to being surveilled, so why pick a fight with the one person who can look Big Brother in the eye?

3.3.2 Contextual integrity

Probably because those in the camera's sights feel that their contextual integrity is threatened. Contextual integrity, the "benchmark of privacy" [199, p101], is breached when either of two norms posited by Nissenbaum [199, p106] is violated: norms of appropriateness, or norms of distribution.

In the context of a public place with many people and transient interactions, such as an airport, it would be confrontational to turn my phone camera on a stranger who expects to pass unnoticed through my life. A well-mannered person would try not to appear to be pointing the camera at anyone in particular, and it is already rude to stare without smart glasses. But using a phone camera may be less disconcerting than an eye-level camera because I am filming openly. Filming openly may also be ethically better than filming covertly, but a camera wielded at eye level by a stranger feels more personal than being filmed by a surveillance camera from a high vantage point in the periphery of my awareness. Is she filming me? Why is she filming me - why does she want my image? She must be planning to do something with it, but what? Maybe nothing worse than the fishmonger did with your daughter (section 3.3.6), but a norm of appropriateness is broken just by raising the uncertainty that an image from one context may be transferred to another that its subject does not know. The subject's lack of control over the flow of the information captured by the camera breaks the norm of distribution.

Looking into the eye of a camera embedded in a place where it should not be, in a public place where we already know everyone can see us, and that cameras are on us at all times - this is a reminder that we are even more seen than we thought we were, and the tension may break through the surface [198].

The branding of Mann's "Digital Eye Glass" into the commercial *Google Glass,* and consequent association with the world's most omniscient corporation, was probably not reassuring to bystanders.

That bystanders have explicable reasons for reacting as they do, does not negate the logic of Mann's arguments for sousveillance. Legally, [199, p128] states, "A presumption in favor of status quo does not, however, rule out the possibility of a successful challenge where adequate reasons exist." Technologies do exert pressure on social norms, and Mann's argument is that social norms should change to accommodate eye-level cameras as a means for Little Sister to protect herself and her rights.

Mann argues that the pressure of norms will produce eye-level cameras that are invisible to bystanders, and that the uncertainty about who looks through a camera and who does

not will end in acquiescence to the technology. Hearables also trend towards invisibility, though I am not aware of anyone's lashing out at the mere possibility that a hearable is recording their sounds.

The purpose of the Gallery Necklace – even if styled very plainly – was display. It existed to be seen, in an alterity relation to the wearer (section 3.6.2). This is what the participants wanted, when they could (theoretically) have any wearable item they could imagine (subject to reality).

3.3.3 Nondisruptiveness

Among several reasons for backgrounding wearables (section 1.1.1) is the nondisruptiveness of the device functionality; for example, the earliest function of a smartwatch was to show notifications from the smartphone in situations where handling a phone would be inappropriate. Jacob and Dumas [131] considered the privacy aspects of wearables using a hug-from-a-distance device for couples. Making sure the remote hug message was only detectable to the couple, and not to bystanders, was important not only for nondisruptiveness and social acceptability (sections 3.6.2, 5.1 and 5.2), but to preserve the intimacy and thus the emotional quality of the communication.

Body-worn devices are inherently bound to the wearer's personal space, that which is breached when privacy is breached. How might the privacy of a hug-from-a-distance system be threatened? By leakage of the personal data from the device or from an app; by an attacker tampering with messages to the unsuspecting partner; by the hug system's usage being exposed to bystanders, by network activity or by attention's being drawn to its physical presence.

Dourish and Anderson [75, p331] observe that risk is perceived differently based on the different experiences of epistemic communities. The Gallery wearable concept was primarily intended as a conversation piece for instigating in-person relationships. I also felt a need to design defensively against the wrong kind of relational outcome. The author of the PDFi that inspired Gallery Necklace was the only male in the group; I gave his necklace a minimalist style in keeping with the style of his paper prototypes, but also to avert the risk of hostile reactions from other men. Though several of the PDFis involve wearables as protection from physical assault (*Agent X, Leaf Me Alone, Wooden Horse* in particular) Warren's Gallery Necklace - that is, Lanyard (section 4.5.7) - was the first time I designed defensively against hostile reactions to the wearable. The incident in which Warren lost his hearing is told in *Gallery Jacket* (Appendix E.7) - he was assaulted by a hypermasculine man, a demographic one might also anticipate could react aggressively to the sight of another man wearing an outsized item of avant-garde jewellery. Suggestions from male colleagues during my hallway usability test (section 5.1.7) of Warren's lanyard gave further insight into how I might avoid inadvertently subjecting him to unwelcome appraisal.

Mood Bracelet (Appendix F.4) supports the proposal of [57, p453] that "'privacy' has little utility as a focus for design [...] a more productive way forward would be to concentrate on supporting people's evident interest in managing their relationships in and with the networked world." Crabtree et al. [57], like [69] have converged on the truth that privacy is a polymorphous, pervasive, continuously negotiated and improvisational feature of relationships that is better captured by narrative than analysis.

The PDFis include many unforced narratives of tensions about what to show or hide, and how what is seen or hidden affects relationships. IronWoman's (Appendix A.1) invisibility suit clashes with George Clooney's, and she nearly misses their meet cute because she is not seen when she wants to be. The Wooden Horse (Appendices B.3 and F.1) is worn inside a concealed sleeve pocket; the orphan boy has to hide the only entity in his world that cares for him; but much later, long after the Wooden Horse has helped the boy grow into a man and the man's life is over, the Wooden Horse becomes known to all, a product available to protect anyone who needs it.

3.3.4 Project infrastructure

I used the HAT as the software infrastructure not as a panacea, but as a start in addressing the obstacle of privacy in wearable computing. This approach was informed by lessons learned during the HAT project about legibility of sensor data [264] and the subjective and idiosyncratic effects on the experience of privacy within households, which is best conveyed through narrative description, as demonstrated by Nippert-Eng 2010 [198], Tolmie et al. [264], Crabtree et al. [57], and in both directions by Desjardins et al. [66] [67] [69].

My study took a whole-system view of wearable computing as ubiquitous computing, to be envisioned by the participants within the sociotechnical systems of their respective storyworlds. In [75, p337] Dourish and Anderson conceptualized privacy as a cultural practice, "support for effective privacy protection cannot be grafted onto a system because it is a pervasive aspect of how that system is designed [...] how the system will be used, the context in which it is put to use, the values that it is used to support, the interpretations that others will make of its use, and so forth." This study was about making wearables, not just speculating about them, and practical decisions about system architecture had to be made.

Given my experience of the HAT and knowledge of its rights-based model of data ownership it would have been almost negligent not to use it as an endpoint, and time-inefficient to switch to a comparable system had one been available. According to Dataswift's terms and conditions the participants would own the rights to their personal data store and the data held in it. I could have required them to share their data with me, but I wanted to send the clear message that their data was theirs. Because HAT developers wishing to push sensitive data (like location) must undergo a risk review, I did consider switching to Databox to save time [188] but that would also have taken too long. Application development was out of scope, but I had hoped to build a proof-of-concept. Setting up my own microserver and hosting it on the university's systems would have incurred compliance risk, whereas regulatory compliance, including GDPR [104], is a feature of the HAT, which was a mature product on public release. Benthall et al. [25, p61] warn that "sometimes merely holding data (sometimes for great durations) can pose privacy threats". The Solid project (section 1.5.1) was announced in 2018, and in 2019 Candle (section 3.3.5) was released, but neither was available in time for me to implement them in this study.

I resolved the difficulty by downloading a free HAT for each participant, which would be deleted after 12 months' inactivity (as I understood at the time, though I cannot find any confirmation in the current documentation [1]), or at the request of the account holder.

[1] *Dataswift Ltd (Dataswift)* 3 January 2021: **Personal Data Account (PDA) Owner Agreement** https://www.dataswift.io/legal/pda-owner-agreement-en and *Dataswift Ltd (Dataswift)* 26 January 2021: **Privacy Policy** https://www.dataswift.io/legal/privacy-policy-en

Participants could also have gone on to keep their accounts and connect other data sources and HAT apps to them.

3.3.5 Security of the Gallery Necklace

Unlike Bluetooth connectivity, which is the default for wearables, by connecting the Gallery Necklace to the HAT I could only transmit over HTTPS. This requires the Transport Layer Security (TLS) cryptographic protocol [2] which prevents message modification and eavesdropping. Bluetooth is not secure, so even commercial wearables are less secure than one might assume. Bada and von Solms [15, p2] identify Fitbit's four main types of security risk:

1. Lack of authentication and physical security control, making devices and networks highly vulnerable;
2. Disadvantages of Bluetooth connections, which are vulnerable to "message modification, denial of service (DDoS), and eavesdropping attacks";
3. Location/tracking and biometric leakage either through its own GPS or that of a paired smartphone;
4. Third-party related attacks, for example an attack in 2015 in which hackers gained access to Fitbit users' online accounts and made false claims for replacements, as well as accessing personal data.

Connectivity

While no networked object is ever completely secure, I tried at least to avoid the obvious pitfalls for the Gallery Necklace, which used the Adafruit M0 WiFi Feather microcontroller with the required WPA2 standard [3] (now superseded by WPA3).

Authentication

The classic IoT attack scenario is leaving a device on default authentication settings [4], another obvious pitfall for researchers to avoid.

The Gallery Necklace required two sets of credentials: one for connecting to WiFi in provisioning mode, which saves known networks (in practice this was unreliable); and one for connecting to the HAT (section 4.4).

The HAT credentials were awkward because the Feather M0 WiFi, unlike other microcontrollers in the range, has no way to write it into device memory, which would have made it possible to set up a password management interface. Instead, the HAT credentials had to be saved as constants in the source code, which lay users cannot reasonably be asked to update; so they would be unable to change their HAT passwords without in-person help from me.

[2] *Wikipedia:* **Transport Layer Security** https://en.wikipedia.org/wiki/Transport_Layer_Security
[3] *Wikipedia:* **WiFi Protected Access** https://en.wikipedia.org/wiki/Wi-Fi_Protected_Access
[4] *Wikipedia:* **Mirai (malware)** https://en.wikipedia.org/wiki/Mirai_(malware)

Accepting the situation for the moment, I set up each HAT account with a sequentially-numbered username, a throwaway email account, and a complex password for which I kept a cryptic handwritten reminder which I destroyed after the handover.

At the handover I got each participant to log into their HAT with the given credentials, then change the email to their own, then change the password to something memorable but hard (hoping for compliance). Then I connected their Gallery Necklace to my laptop, opened the settings file in the source code, and positioned the cursor at the start of the empty string where they were to type their new HAT password. When they were ready I asked them to click to another tab in the Arduino window so the tab with their new password would not be on top where I might see it. I saved the files, then uploaded them to the hardware. I repeated this process with all six participants.

Provisioning

Provisioning the WiFi was a security hole that opened up every time the device checked its network connection and did not find one. This will happen repeatedly on a mobile device which moves in and out of range of known networks. Hron [5] presents an insecure coffee machine as a case study of manufacturers' carelessness, but what the coffee machine has in common with the Gallery Necklace is that it becomes its own wireless access point (AP) in order to provision the connection. At least the coffee machine is rarely worn around the neck. For the headless Gallery Necklace, setting credentials required the wearer to open a web browser on a separate device, find the necklace in the list of available networks, and enter the credentials (section 4.4).

Every time the image changed, the necklace checked for an existing network connection, and if none was found the AP stayed open for two minutes (section 4.4). Obviously, the frequency needs to be reduced to improve program flow, reduce the vulnerability, and reduce the risk of damage to the screen which should not be redrawn more than once every three minutes. On the technology probe there is no functionality yet for the user to control when to enter provisioning mode. A smartphone hotspot would provide a relatively reliable connection, but some downtime is inevitable. To discreetly inform the wearer that the necklace is in provisioning mode, selected images are shown (Figure 4.5); this only works because of the obscurity of the handmade device. The more frequently the screen shows an image that is not in the gallery, the less the necklace is performing its core function, and also the greater the opportunity for a bystander to catch on.

Hosting

At the outset of the HAT project, the plan was for the microserver to be available with varying levels of security, the default (and the one available during this study) being the Straw HAT, which is hosted in the cloud, by Amazon AWS. The more secure level will be the Hard HAT. Databox would typically be a local device with Cloud-Assisted Networking. It is not obvious from the documentation where Adafruit.io servers are hosted; I infer that they are Adafruit's own. Solid also host their own servers.

[5] *Decoded.avast.io* 25 September 2020: **The Fresh Smell of Ransomed Coffee** https://decoded.avast.io/martinhron/the-fresh-smell-of-ransomed-coffee/

I remain disappointed that my suggestion of a Tinfoil HAT, with no connectivity and funded by a separately-sold wearable Faraday cage, has seemingly slipped down Dataswift's to-do list. Since its release in 2019, an alternative is offered by the SHERPA project's *Candle,* [6] a DIY smart home system which is hosted in the user's home and is disconnected by default. I have not tried Candle but it is a home-based system, not mobile; and is intended as a proof of concept for a 100% private smart home. Candle grudgingly tolerates connection of almost any smart home device, but strongly disapproves, especially of WiFi-based devices.

Candle never sends the user's voice to its servers, and questions the rationale for learning every word in the language to listen to everything said in the household (section 3.4.2) – what is the benefit of such omniscience, and for whom? The customer probably just wants to turn the TV off at 11pm, and only so much vocabulary is needed to achieve that.

Things vs. Internet

Using Candle, or another locally-networked home-based system as the endpoint for a mobile device like the Gallery Necklace, would require a change of tempo in input-output, caching and syncing. At a certain point, some would object that the asynchrony results in too much Thing and not enough Internet.

Turning off Bluetooth and relying on WiFi also entails some asynchrony because known WiFi networks will only be intermittently available when the wearer is out and about. Using a smartphone as a WiFi hotspot improves availability, but does not guarantee it. However, according to participants' feedback (section 5.2), a tempo change is needed to improve the display functionality of the Gallery Necklace. It should increase the intervals between attempts to connect to a network and to send records; increase the cache to hold every record that cannot be sent; and, when the SD card is full or records have been in the cache for over 24 hours, the user should be alerted to transfer them explicitly (even manually if need be) or delete them. The Gallery Necklace is not always-on, it is only for occasional wear, so should be able to tolerate some asynchrony.

Future iterations of the Gallery Necklace/Positivity Patch hybrid (section 5.4.2) will include Adafruit's clock and GPS (Global Positioning System) components on the base unit, to enable more on-device event-driven functionality and less dependency on pairing with a smartphone.

Adding things to the Hub-of-All Things ecosystem

Whereas it was simple to connect a DIY device to send a "Hello World" message to the free version of the HAT, data from other sources such as Fitbit or Facebook requires a data plug. In the case of Facebook and others, the data plug does a Subject Access Request [7] to acquire the data and capture it into the HAT personal data store, where it is contained in a space to which the user owns the rights to everything held within. Sending Facebook data to the HAT does not undo the effects of your questionable decision to use

[6] *Candle Smart Home:* **How "Good Enough" AI Could Make Voice Assistants More Ethical** https://www.candlesmarthome.com/good-enough-voice-assistants

[7] *Information Commissioner's Office:* **Right of access** https://ico.org.uk/for-organisations/guide-to-data-protection/guide-to-the-general-data-protection-regulation-gdpr/individual-rights/right-of-access/

Facebook, but once the data is in your HAT, you have control over it until you choose to share it with approved applications or other approved HAT users [8].

Dataswift apps and data plugs have granular ratings indicating their privacy tradeoffs: for example, if an app takes data from a HAT and stores it, that would be rated 'B' for privacy [9]. This attention to privacy limits the HAT's interoperability, as Dataswift governance reviews third-party data for risk and requires an impact assessment for certain actions such as pushing sensitive data, including location data, into the PDA.

3.3.6 Collective information practice

By running away with the technicalities of security as the implied means of preserving privacy, I have left collective information practice behind. Dourish and Anderson [75, p323] made the point: "we may be able to engage in more effective design interventions by moving our focus away from information and its regulation and looking instead at what we term collective information practice - for ways in which social action is sustained and reproduced through the formulation and flow of information." They distinguish three "programs of work", the first of which is "empirical examinations of security practice".

Regarding wearables, [15, p1] point out "Guidelines do exist for securing such devices, but most of such guidance is directed towards device manufacturers, IoT providers and more. One good example is the Code of Practice for consumer IoT security by the UK Department of Culture Media and Sport. Very little, if any such guidance does exist for the real end user, the ordinary citizen, who makes use of fitness devices and other smart home devices."

Participatory security

The re:CONFIGURE project report [244, p6] describes a pilot study of participatory community workshops on cybersecurity: "Although such community action is effective, cybersecurity cannot be limited to individuals changing passwords or downloading VPNs." And the arms race against cybercrime means, as [11, p110] describes in detail, that in a domain such as online banking which affects millions of people in the UK, specific advice (look for the lock symbol in your browser, don't click this or that kind of link) becomes weaponized in favour of the criminal as fast as it is issued, with the customer held responsible for the results.

Dourish and Anderson [75, p325] examined three approaches to privacy, one of which was "Privacy as Economic Rationality". The HAT is primarily a market platform for the trading of personal data, but with "ownership" of the data returned to the individual user, who can selectively disclose subsets of data to counterparties that have signed up to HAT community standards; that is, it facilitates the individual in managing those relationships (sections 3.3.4 and 3.3.5).

[8] *Dataswift Docs:* **Data Exchange Service** https://docs.dataswift.io/reference/data-exchange-services-dex

[9] *Technical:* **Application choices** https://tinyurl.com/245k9s5x

Creepy

I have not emphasized the marketing aspect of the HAT because I am not interested in it (in contrast to [51] I am not forcing myself to use functionality I do not want), but one important analogy from the HAT's founder, Irene Ng, explains why the HAT's economic model of data was necessary: imagine you are at a fish market and you point out the fish you want, and try to hand over the money. The fishmonger says you will have to hand over your daughter for the duration of the transaction. You protest and ask why this is necessary. The fishmonger assures you he will not do anything untoward with your daughter, you can feel perfectly safe handing her over. You half believe him, though he seems to be missing the point. But you need the fish, so you hand over your daughter, hand over the money, get your fish, and get your daughter back, seemingly unharmed; and this is how your personal data is handled in every online transaction. Technically you could say that is a story about economic rationality; it explains why it is economically rational to give the fishmonger control of your daughter - because those are the terms on which trade is conducted.

The analogy pushes the right emotional buttons, the feeling of unease [241] about obvious yet hypothetical and undefined threats that you have to subject yourself to in order to complete a mundane and necessary transaction. The reconceptualization of "ownership" of personal data, and the enormous amount of legal analysis that went into developing the HAT, was *justified* in terms of economic rationality, but it is not only about that. As Palen and Dourish [210, p136] make explicit, "what technology enables is as important as how it is actually used; it is the possibilities, rather than the actual practice, around which privacy regulation is performed."

Security and making for research in the Internet of Things

There are other points in the system where security could be improved, including the microcontroller itself via federated learning (section 5.4.2), which would also improve sustainability [10]. But even with its flaws, the security of the Gallery Necklace compares favourably with the most popular consumer fitness tracker. It takes unexceptional programming skill to connect to the HAT, which forces the choice of a microcontroller with encrypted WiFi, of which Adafruit provided a simple choice of two models, one in beta release. **If we can expect basic security from a decent programmer working with off-the-shelf hobbyist hardware, why would we expect less from the leading consumer wearable?**

Adafruit's IoT endpoint [11] prioritizes individual ownership of personal data and comes with a draft Internet of Things Bill of Rights (https://www.adafruit.com/iotbor/) as a living document. I have not used adafruit.io but it may be worth investigating if the HAT does not suit (for example, because of Dataswift's governance processes). Tim Berners-Lee's Semantic Web-based Solid [12] project (section 1.5.1) is another possibility (which I also have not tried). The difference between Inrupt's Solid privacy model and that of Dataswift's privacy model for the HAT is that the latter is personally identifiable to the

[10] *Flower:* **What Is The Carbon Footprint of Federated Learning?** https://flower.dev/blog/2021-07-01-what-is-the-carbon-footprint-of-federated-learning

[11] *Adafruit:* **The Internet of Things for Everyone** https://io.adafruit.com/

[12] *Solid:* **Solid Apps** https://solidproject.org/apps

individual owner, whereas Solid apps, in more traditional style, may identify users only when necessary.

3.4 Internet of Things (O2, O3)

3.4.1 Inspiration: non-stereotypical participatory design fiction for non-stereotypical people

As discussed in section 1.1, the participants in [153] had a reasonable variety of consumer wearables to choose from, but they still felt that these wearables were for some other, more normative user. As Desjardins et al. [66] described, IoT design is equivalently limited by a stereotypical view of what a home is. The researchers visited a number of participants in a variety of non-stereotypical homes, some conventional (apartments) and others less so (a carriage house). They made each participant a booklet with concept sketches of IoT devices overlaid onto pictures of their own homes, and space for them to write their insights and add sketches of their own ideas. By turning to participants in other housing than that which resembles a child's crayon drawing (a detached two-storey single-family dwelling), the researchers' concept of a home was reconfigured to become a system with boundaries extending to the outside world. For a participant in a shared house, they offered the concept of a camera on their plum tree which would send photos to all the housemates when birds ate the plums, prompting the householders to eat their share.

By recruiting from a cohort of "adults who want to be here," and setting an open brief for writing the design fiction, my participants had space to bring whichever experiences and aspects of themselves they thought were important. Warren joined out of his own interest as an art and technology enthusiast whose artistic side had been suppressed by his environment. He also brought his experiences on the autism spectrum and of hearing loss. The wearable he actually wanted, the *Gallery Jacket* (Appendix E.7), which won the group vote by a landslide, has the simple function of displaying artwork, which superficially has nothing to do with either deafness or autism, but has very much to do with Warren's ongoing quest to connect with people in person. The *Gallery Jacket* is not something that anyone would necessarily have thought of for assistive technology or "social" wearables, including the relevance of IoT data. I sent a "Hello World" message to the HAT from the Gallery Necklace as minimum functionality for the technology probe (Chapter 4), but also because it was not obvious what to send. If a Gallery device could not send data (which, when no network is available, it cannot) it would still be performing its core function; whether or not it *needs* to send data is a relevant question, but that it *would* was part of the brief from the beginning, so by voting for *Gallery Jacket* the group pushed that problem back to me. As a social wearable, the Gallery Necklace defies assumptions because it is not a Social Proximity Application (SPA), and the feedback shows little interest in making it into an SPA. It is a social wearable *for meeting people in person, without functionality for connecting with their social media.* It also goes against the stereotype of what wearables are supposed to be for, being in an alterity relationship (section 3.6.2) that aims to draw the outside world's attention first to it, and then to its wearer [209].

Serena wanted the gallery functionality in bracelet form, and preferred the air quality sensor from a selection of possible upgrades. So why not a smartwatch, with more than

two functions? And why combine those two functions - conceptually, what does a gallery screen have to do with air quality sensing? In Serena's Gallery Bracelet, the screen would go where a watch-face would go, but it would be in an alterity relation, like a jewel or embellishment; it would be the thing for others, more than the wearer, to look at. The hermeneutic relation of displaying air quality readings would be secondary. That would make Serena's Gallery Bracelet conceptually different from a smartwatch which tries to display information to the wearer while not drawing too much attention from bystanders [209].

While the Gallery Necklace left me actively looking for reasons to generate data from it, its heir apparent, the Positivity Patch, offered more obvious ways to go. Section 5.4.1 talks about ways of combining calendar and location data with user input for sentiment analysis. However, the idea for that combination did not come from this study; I had thought of it before.

L'esprit de l'escalier: IoT PDFiclets

A weakness of this study is my failure to find a way to elicit thoughts about IoT data specifically during the in-the-wild phase, beyond what was already present in the PDFis. Part of the problem is that I had less contact with the participants during the in-the-wild study than expected. I planned for repeated RITE [181] testing, because I expected the technology probes to malfunction; as both developer and tester, I expected to miss some bugs. But the necklaces worked as expected, so did not need to be fixed, so there were no occasions for visits and conversations other than with Grace, who needed training to connect her necklace to WiFi. I planned for ethnographic sessions observing the Gallery Necklace in use, but because it was an occasion piece there were no realistic opportunities to do so. I planned to request experience reports at regular intervals, but the participants' time and attention were overloaded and I stayed quiet so as not to wear out my welcome.

Because of all this, I was leaving the participants alone with their Gallery Necklaces and their HATs and encouraging them to think about them both together, but not doing much to stimulate their imagination besides asking their opinion on potential upgrades (section 5.3). This was a wasted opportunity, especially after learning the lessons of the HAT project about the illegibility of data generated by IoT sensors, and the necessity of context and insider knowledge to interpret them.

Tolmie et al. [264, p491] wrote: "It is largely presumed that understandings of people's everyday interactions will be relatively easy to 'read off' of such data and that this, in turn, poses a privacy threat." We have all heard stories about activity trackers that testify against their wearers [13] and, without presuming to comment on any individual case, in the back of one's mind, the assumption of data legibility to third parties naturally transfers to any networked device within range. In reality, "The study reveals that personal data generated through this networked sensing system is opaque when considered in isolation." [264, p491] The activity tracker performs its hermeneutic function of displaying your biodata to you ready-interpreted; as a software engineer I think of modelling data into tables, graphs, trees, tuples; but what about the end user of an IoT prototype looking at spikes on a graph? "Something else that becomes visible in the way people account

[13] *BBC News,* 4 October 2018: **Fitbit Data Used to Charge US Man with Murder** https://www.bbc.co.uk/news/technology-45745366

for the data relates to what they know, as members of the household, of one another's routine doings and who might therefore be responsible for some particular piece of data looking the way it does [...] [and] just who might be responsible for unusual activity in a bathroom at a time when there are guests and whose data might look like what as a consequence of how long they routinely stay in the shower [...] None of this is visible in the output of the sensors [...] the challenge for sensing is [...] not just cooking (etc.) but how the cooking (etc.) is indexical to specific people and their routines."

Interpreting data output from sensors looks like an art. The "scientific estrangement" of mundane situations makes them harder to model because they are so close, whereas "trivial and alienating" situations "(e.g. bidding in a blind auction)" are more "meaningful and controllable" to a scientist [193, p199]. The *Black Mirror* [38] episode "The Entire History of You" tells a story about a man who understood too much, after focusing too much on raw, but legible, data from his own domestic life. Raw and inscrutable sensor data might offer opportunities for the more traditional plot device of *mis*understanding. Desjardins and Biggs [69] took the output from a household's IoT sensors and novelized the raw data into stories told *from the point of view of the sensors*.

In hindsight, I see how I could have created short pastiche scenarios (ficlets), with polls, and circulated them as stimuli to help the participants think about IoT data without burdening their time or attention. I could have invited participants to contribute their own, ad hoc. These could be patterned after the three main types of network anxieties defined by Pierce and DiSalvo [213, p1]: *troubling edge cases*, about what could go wrong and how far-reaching connections could turn out to be; *pervasive fields* about being surrounded by networks and sensors we cannot see; and *unique personal identifiers* which express the fear of being personally targeted. [264, p496] wrote: "Andrew has been 'found out' in wanton consumption of electricity. The deeper point here is that sensor data has the potential to make visible to others with whom you are quite specifically related matters that might otherwise be invisible to them," - a deeper point about privacy and pervasiveness, but also a sitcom waiting to happen.

For example, a *Red Dragon* [118] romcom featuring a classic *edge case* of misunderstanding:

Reba decides that Frank is The One, so she meets her casual squeeze Allen Shlemiel for a breakup date. But unbeknownst to Reba, Frank sees the footage from her doorbell cam of her giving Allen one last smooch for the road. Investigating the horrible murder tableau featuring Allen as the centrepiece, it looks like Allen's fridge door was opened *after* he was killed. Where should the detectives look first?

- check Allen's shopping list and see if his smart fridge added Babybel after the door was opened, even though he just had some delivered
- check Frank's washing machine sensor for the night in question, and did he use extra stain remover?
- bag the little red wax dragon mini-sculpture Reba is fiddling with to calm her nerves, and send it for trace analysis
- other (please specify)

3.4.2 Future work: "Good Enough" AI

I should clarify what "sentiment analysis" would mean in terms of AI for this project, had I had time to implement it. Tijmen Schep, for the Sherpa EU project [14], says, "I'd argue it would be healthy to refer to 'AI' as statistics in fancy clothes". It is important not to mystify the task at hand, which only needs what the Candle project (section 3.3.5) calls "good enough" AI.

All the Positivity Patch (section 5.4) needs to do is choose, from a finite gallery, an image or slogan that is statistically likely to appeal to whatever emotion the wearer is statistically likely to be feeling, given their current time and location. The full thesaurus of human emotion need not be incorporated; a small controlled vocabulary will do (see also Trudy's idea in Appendix K.6). Some of the gallery images would be added by the participants, who could tag them manually in the process, and if a proffered image does not suit a particular occasion, the user can feed that back via the touchscreen (section 5.4.2). This is a non-safety-critical task, within a system that has regulatory compliance with GDPR and all other applicable regulations, and has access to the personal data of only one wearer, who chooses whether to share that data and with whom. Campolo and Crawford's [45] well-founded concerns about "enchanted determinism" are mitigated by the existing constraints of the system.

I wonder if I could provide enough sentiment- and context-awareness to be useful, and at what point wearers would give up and manually override it, and whether a manual Positivity Patch would be useful. Could we do better at sentiment analysis than Schep's misadventures in Body Mass Index (BMI)? The only way to make sense of the Positivity Patch would be to make it, sentiment analysis and all [139] and that would be another project, this time with expert collaboration (section 5.4). Besides co-designing the system with participants, the wearer will always be "in on" [84, p5387] the sentiment analysis functionality, in a human-in-the-loop partnership.

Like the rest of the system, the sentiment analysis might not be innovative on a technical level: "The discourse of enchanted determinism has the effect of covering over these problems, suggesting that if we want 'superhuman' accuracy and performance from deep learning systems, we may need to give up the types of rational, causal explanations that Weber associated with disenchanted modernity" [45, p15]. Like the Wooden Horse (Appendices B.3 and F.1), the Mood Bracelet (Appendix F.4) and Mr. X (Appendices E.5 and F.5), the Positivity Patch (Appendices F.2 and G.2) is an artificial intuition device. Like Vasilisa's doll [214], it is a projection of the wearer's inner wisdom; the doll's preternatural proficiency at completing Baba-Yaga's tasks is a *fictionalization* of Vasilisa's increasing self-mastery. However, part of the enchantment of the Wooden Horse, the Mood Bracelet and Mr. X is in the fact or appearance that these devices have minds of their own. To be enchanting in real life, the Positivity Patch will need to surprise the wearer every so often with serendipitous accuracy. The question is whether "good enough" sentiment analysis can support this kind of enchantment, and if not, whether it is "good enough" without it.

[14] *Sherpa Pieces:* **Making My Own "AI" Made Me Feel Dirty** https://www.sherpapieces.eu/overview/making-my-own-ai-made-me-feel-dirty

3.4.3 Future work: formal and informal representation of contextual integrity

While Nippert-Eng [198], Tolmie et al. [264] and Crabtree et al. [57] showed that privacy is best understood through narrative, Benthall et al. [25, p12] point out that contextual integrity (CI) "bridges two worlds. In one [...] CI posits contextual informational norms to model privacy expectations and explains when such expectations are morally legitimate and warrant societal protection. In the other, CI offers a formal structure for expressing rules of information flow (informational norms) and for building computational models of people's privacy expectations in well-defined settings (contexts.)" To properly understand how participants would live out the combination of wearable-generated and other data within a personal data platform like the HAT that promises privacy via rights-based individual ownership of data, it would be necessary to do another participatory study dedicated to ethnography like [264] and contextualization in practice like Parry et al. [211] and, at the same time, compare the participants' desired data combinations and privacy behaviours to the reality of how the HAT, compared to other platforms like Adafruit.io [203] supports or inhibits that behaviour.

3.5 Participatory design of wearable technology (O4, O5)

3.5.1 Participation and making

Customized prototyping to a narrow brief

In Pateman et al. [212, p1], designers fabricated custom 3D-printed, low-fidelity, dummy "activity trackers" to 15 existing users (of whom nine were female), based on the participants' own workshopped designs, for five days' in-the-wild evaluation. "We found that aesthetics plays an important, and currently underappreciated, role in use and continued engagement, particularly when the context of use is considered."

Participants found their prototypes uncomfortable and compared them unfavourably to real products: "to actually see something that you designed and went through to prototyping - that was great. To actually wear that and realise actually the idea is not so great after all - so enlightening".

Pateman et al. found that requirements change with context and occasion. "Frequently, participants simply desired for their wearable technology to be *less visible* - either through designing it to look like an everyday piece of jewellery, or by literally hiding it beneath other items of clothing."

The authors recommend a higher standard of prototyping so as not to lose the engagement of volunteers. They offer a solution to the problem of boring wearables: "We suggest that manufacturers should embrace adaptability and DIY cultures, allowing end-users to customise their wearables and support them in appropriately choosing, and creating their own designs."

Inspiration: participatory crafting to a more open brief

Pateman et al. [212] built on the work of Ananthanarayan et al. [9] (section 1.2.1) who used participatory crafting to make wearable health technologies more individually meaningful.

Given a preselected technology in the form of a UV (ultra-violet) sensor, the participants crafted a casing to an open-ended brief for appearance and body placement, then wore the device in-the-wild for a week. The authors prioritized aesthetics: although the sole female participant produced the most flamboyant casing (a felt fox headband) and none of the males saw themselves as fashion-conscious, even the one who thought he was not good at crafts managed to create a tree-and-mountain felt casing in an afternoon.

Their study shows that both the maker movement, and personal health technologies, have advanced to the point where making a device like this is feasible for end users. Ananthanarayan et al. suggest craft practice as the path to personalization of health wearables, and personalization as a possible path to increased adoption.

Ananthanarayan et al. is in the same spirit as my own study. As they put it: "We envision a goal where users are not limited by the ideas of researchers and designers." They also point out the "sentimental or autobiographical significance" that crafts can have for the maker.

3.5.2 Participation and democratization

Anti-inspiration: One Laptop Per Child

Though HCI for Development is beyond the scope of this thesis, it is worth contrasting the participatory approach of [136] with the "push" approach of "One Laptop Per Child" (OLPC) led by Nicholas Negroponte of the MIT Media Lab (section 1.3.1).

Ames [8, Introduction] describes a 2005 meeting at the World Summit on the Information Society in Tunis, where Negroponte joined United Nations General Secretary Kofi Annan in presenting a mock-up of the proposed laptop with a hand crank to charge the battery; the crank broke off. Later versions of the proposed laptop not only doubled the price but reverted to a wired power adapter, "collapsing the vision of the laptop leapfrogging past regional infrastructural deficiencies".

Meanwhile in 2005, mobile phone use in Africa grew 66% [47, p24] and African users were working around lack of infrastructure by "repurposing phones" [47, p31]. Without making the assumption, which [47] questions, that mobile phone use was a net positive for development in Africa or in poorer countries elsewhere: OLPC is an example of a "push" project that failed to democratize the technology it was trying to promote.

Dead end: the "Killer App" for wearables

The obstacle of cost, though outside the scope of this thesis (section 1), has been decisive for mainstream wearables. As [229] shows, designers have created innovative wearables again and again, and they disappear from public consciousness again and again. Margaret Orth's experience with the MIT Media Lab's "Beauty and the Bits" project, and its

commercial aftermath with her company IFM (International Fashion Machines) which she founded in 2001, is described in [229, pp. 84-86]: "once an electronic module was tooled, hundreds of thousands would have to be sold to realize a profit, whereas clothing producers projected on a scale of tens of thousands of units". Besides this, each fashion house wanted proprietary technology. IFM soon fell victim to the dot-com bubble of 2001, and innovative wearables became a risk the market no longer wished to take. Other promising intiatives like van Beirendonck's modular "i-Wear" [229, p109] fell into the same abyss. Armani once said that, in fashion, "timing is everything"; as [229, p94] observed, fashion and technology have never quite been in sync, and any "killer app," besides the wristbands and earbuds we already have, remains elusive.

Wearables designers are part of the audience to whom this thesis is addressed. However, this problem of commercialization is beyond my expertise. Taking Ryan's [229, p217] differentiation that "design is customarily thought of as a professionalized social practice and craft viewed as more personal", I am neither a designer nor a marketer and thus not qualified to suggest next steps for designers. Where design and craft practice meet, there may be markets for small-scale and bespoke production. My own actionable next steps would be towards craft practice, specifically, participation in maker groups, where the process is as important as the product. Neither path leads to a "killer app," but Warren's modest utopia featured increased recognition of "niche creators" (Appendix G.1.1). Any one wearable created by a maker group will have niche appeal, but many diegetic wearables created by many maker groups would be a movement (sections 3.7.3 and 6.5.2). I also draw the reader's attention to Appendix M.3.5, which discusses a PDFi that shows the value of the technique to wearables researchers seeking "situated knowledges" [278, p2].

Inspiration: participatory speculative wearables

Jones et al [136] (section 1.2.1) worked with groups of emergent users in Bangalore, Nairobi and Cape Town, investigating mobile and ubiquitous technologies, and using a fitness tracker as a "magic thing" as a prompt to imagine the participants' desired technologies for the future.

The Bangalore group was a domestic workers' collective, and a break from the normcore (sections 1.1.1 and 3.6.3): "Wearable designs dominated the discussions and drawings. As well as the earpiece, rings and necklaces mentioned above, there were also pendants and bracelets. The ladies in the workshops all wore many items of jewellery, from ankle bracelets and toe rings to necklaces and earrings, as is the norm in India. They saw future mobiles as being an additional adornment—becoming part of their identity—and mentioning too the importance of personalisation (such as colour choices)."

In Nairobi, *in*activity trackers were de rigueur: "The magic thing probe stimulated much discussion in this group focused on wearables to enhance personal emotional wellbeing and health" including clothing to prompt the lifestyle-overexerted wearer to do *less* exercise.

In Cape Town, the issue of physical security, not just cybersecurity, of wearable devices was raised (section 3.3.3): "Participants said they liked the idea of wearable devices as they are more secure, especially in unsafe areas. In addition, they indicated that the device should be able to be hidden under clothes in such places."

3.6 Aesthetics (O5)

My first words in this thesis asserted that "wearable technology could look beautiful and feel magical", but that the aesthetics of current wearables, exemplified by "a plain wristband", fall short.

What support do I have for this assertion? As discussed in section 1.1.1, the wristband form factor is practical for continuous daily wear, and its plain appearance contributes to its practicality. The "any color so long as it is black" [15] approach was already well thought out in 1909: "when the suggestion is only as to style, one has to make sure whether it is not merely a personal whim that is being voiced."

How do we know that my approach to aesthetics is not merely the voicing of my personal whim?

3.6.1 Aesthetics are fundamental

Aesthetics and research through design

The importance of aesthetics was recognized in Gaver's work on cultural probes in RtD [101] which influenced this study (sections 2.6 and 3.2.2): "Throughout the project, we have viewed aesthetic and conceptual pleasure as a right rather than a luxury [...] we believe aesthetics to be an integral part of functionality, with pleasure a criterion for design equal to efficiency or usability."

Aesthetics of wearable technology

Motti and Caine [189, pp. 1821-1822] (section 1.2) identified 20 wearability principles, including aesthetics (attractiveness) and fashion (stylishness and conventionality).

But why are aesthetics *of wearables* important? Fairburn et al. [88, p92] wrote "It is difficult to quantify the impact of aesthetics, however Norman (2002) notes that as emotional beings, we all judge the appearance of products, whether consciously or unconsciously, and aesthetics should be considered an important function because of this alone." A wearable that fails to meet a minimum aesthetic standard is not wearable at all. Khaorapapong and Purver [143] created an "Icebreaker T-Shirt," a Social Proximity Application (SPA) to help shy people in face-to-face interactions (somewhat like *Gallery Jacket*). As they recognized, "most SPAs are deployed in unsophisticated objects causing low aesthetic value in 'wear-ability' that can limit the usefulness in sensitive social situations."

Aesthetics as respect

Although this thesis is about wearables worn out of preference, not necessity (section 1.9.1), the experience of ten Bhömer [259] emphasizes a principle that is relevant to my own work. In a RtD of a service system for dementia patients, ten Bhömer prioritized aesthetics as an essential part of respecting his users, and of the acceptability of the garments he made for them. Aesthetics are not a frivolity that are only applicable to inconsequential application areas.

[15] Henry Ford in collaboration with Samuel Crowther in My Life and Work, 1922; p.72.

3.6.2 Aesthetics and social acceptability

Techno-aesthetic innovation

Since many people prefer not to stand out, even a sophisticated aesthetic design, like the first version of van Dongen's Solar Shirt [245, p300] drew attention that its wearer may not have wanted: "the shiny cells express a look that invites social interaction. Fashionable technology thus underscores that clothes - like the body itself - are a highly social phenomenon."

Kelly and Gilbert [141, p1030] evaluated the social acceptability of wearables and noted that "a major roadblock for earbuds may be that people are reluctant to be a member of the 'group' that wears this type of device." For example, people who wore Bluetooth headsets were seen as self-important by some respondents.

The risk of social judgments is one reason why invisibility is a selling point for some hearables [215, p8]. Conversely "hearables can also be designed as high-tech fashion pieces [...] but come with a potential risk for social judgments." Meyer et al. [182, p332] did a two-week in-the-wild study of five lifelogging devices, four of which were wearable, and found that the preferences of their 12 participants varied between inconspicuousness and fashionable display. "We conclude that 'the universal' all-purpose activity tracking device does not exist".

The occupational profile of my participants (section 2.1.1), and their location in a major university town, meant they were all members of the "group" that would be willing to wear experimental art jewellery at least once; it would be consistent with their self-image and might get positive reactions from their peers [237, p2].

Postphenomenology

The postphenomenologist Ihde [128, Ch5] regarded clothing as being on the borderline of background and embodiment relations. In the embodiment relation, the human connects to the world *through* the technology: for example, the human talks to the world through the phone without paying attention to the phone:

$$(\text{human - technology}) \rightarrow \text{world}$$ [16]

Ihde uses an example of perfectly invisible clothing [128, p76]. That would probably be J. Random Hacker's [221] ideal outfit (section 3.6.3), because it would then be in a *background* relation with him:

$$\text{human (technology / world)}$$

The fitness band is also in a *hermeneutic* relationship with the wearer, by making their biodata visible:

[16] *FutureLearn* **Philosophy of Technology and Design: Shaping the Relations between Humans and Technologies** - What can we learn from Don Ihde? https://www.futurelearn.com/info/courses/philosophy-of-technology/0/steps/26324

human →(technology - world)

Ryan [229, p103] articulates the assumptions implied by the invisible clothing example: "WT [wearable technology] rehearses an age-old dialogue between society and the body that proposes a process of invisibility based on an ideal of pure functionality and pure information, and ultimately a uniformity of dress. Historically, the technological view of wearable computing is anti-dress and essentially modernist in its cultural viewpoint, in accordance with traditional science." (section 3.6.3)

The alterity relation, in which the human pays attention to the technology and not the world around it (as when using a cash machine, or a toy) is neglected by mainstream wearables, as it is in [128].

human →technology (world)

The importance of clothing as presentation of self is observable in the earliest known wearable items [116]. A style-conscious person would usually want to be in an embodiment relationship with their clothing, because fine feathers make fine birds. But a clothing item could be in an alterity relation with the wearer if it drew enough attention [209]. A negative example is the incident in which Steve Mann, the "father of wearable computing" [112], was assaulted by a fast food employee who objected to his sousveillance glasses [171] (section 3.3.1). A positive example is the Gallery Necklace (Chapter 4), which serves as a conversation piece and icebreaker in social situations. By displaying the wearer's artwork, the Gallery Necklace draws attention to itself first and holds attention, albeit as a step in the process of introducing the wearer to the one who looks.

3.6.3 The hacker aesthetic

Anti-inspiration: the hacker aesthetic as functional anti-fashion

Plain is also an aesthetic. [221] asserts: "Hackers dress for comfort, function, and minimal maintenance hassles rather than for appearance." We should be grateful to the hacker aesthetic for setting the bar; imagine the discomfort, malfunction and high maintenance if wearable technology were made by women's shoe designers.

The hacker aesthetic is specific. Even as [221] deprecates appearances, the New Hacker's Dictionary describes a very *particular* aesthetic: "Casual, vaguely post-hippie", with "outdoorsy" or "punk, goth and rave" as alternatives, as long as they are black: "Hackers appear to wear black more because it goes with everything and hides dirt than because they want to look like goths." This explains why [226, p21] complains about "black-slab incrementalism" instead of fuchsia-polyhedron incrementalism.

Because of the hacker aesthetic, the normcore (section 1.1.1) look of mass-market wearables manifests in sporty or space-age [267, p1] styles, even though the range of classic "go-with-everything" styles is much wider: "[Hackers] have a very low tolerance of suits and other 'business' attire; in fact, it is not uncommon for hackers to quit a job rather than conform to a dress code." It follows that a fashion tribe that hates suits would make black-slab smartwatches the default style, and smartwatches resembling traditional timepieces would become the alternative.

Silina and Haddadi [242] confirmed: "The common point of view expressed in popular media is that current *wearables* largely appeal to people already engaged with technology".

The hacker aesthetic is exclusive. Not everyone is, or wants to look like, a hacker. Gaver [102, p1] was concerned that the increased integration of computers in everyday life was also incorporating some distortions, including "technologies' tendency to insist on telling us what to do and who to be. Through the functionality they offer, their aesthetics, and the ways they are marketed, technologies convey a narrative of use that entangles our imagination and self-image."

Not even every hacker wants to look like a hacker [17]. What J. Random Hacker insists on as personal preference, his female colleague must conform to as a professional standard. A young woman developer's question about dress codes on the preeminent hackers' forum, Stack Exchange [18] elicited a variety of answers. The highest-rated answers urge conformity, of which the second-highest confirms: "The guys wearing jeans and t-shirts look like a common stereotype of a developer. That's why they 'get away with it' [19]. You, on the other hand, are a woman which means that you **already** don't match the stereotype. The more you deviate from it the harder it will be for you to get people to take you seriously as a developer."

The hacker aesthetic is strongly defined by what it is not, and one thing it is not is FOR GIRLS [8, Ch1].

Or at least, not the wrong kind of girl: "giggly cuties in mini-skirts", for example, who "stop the younger men from working" and "cause rivalry and mating rituals". Ryan [229, p105] wrote: "The idea that clothing must be minimized, standardized, and muted reflects a tendency among fashion historians as 'functional anti-fashion.' [...] nearly all modernist utopias [...] [including] George Orwell's Nineteen Eighty-Four (1949), and even Mao Zedong's Chinese Cultural Revolution [...] envision functional universal dress, often blocky suits or overalls with little or no difference between individuals." The anti-cutie enforcer on Stack Exchange is also a woman, preserving her power in the system by denouncing the original poster as the enemy of the hacker people.

3.6.4 Anti-hacker aesthetics and MAYA

YA: the case against casings

Perhaps a personalized casing will help, like the Tory Burch casing for Fitbit [20]. Now the hackband looks like a bracelet. I would buy several casings like these if I wore a Fitbit. Silina and Haddadi [242] count the Tory Burch bracelet among the best examples of *fashionable technology,* along with Swarovski's Shine (a solar-powered tracker) and the

[17] *The Guardian*, 18 May 2015: **The video-game industry has a dress code - driven by a lack of diversity** https://www.theguardian.com/technology/2015/may/18/video-game-industry-dress-code-plaid-denim

[18] *workplace.stackexchange.com*, 14 July 2018: **Is there a dress code for women in software industry?** https://workplace.stackexchange.com/questions/30533/is-there-a-dress-code-for-women-in-software-industry/30657

[19] With breaking corporate dress codes.

[20] *Tory Burch:* **Tory Burch for Fitbit Metal Hinged Bracelet** https://www.toryburch.com/en-gb/jewelry/bracelets/tory-burch-for-fitbit-metal-hinged-bracelet/35112.html

Cuff emergency-contact bracelet: "most fruitful aesthetical and technological pieces occur when engineers and jewelers collaborate."

Sterling distinguishes a stylist from a designer by citing Loewy's [21] acronym MAYA (Most Advanced, Yet Acceptable) [252, p61]: "Most Advanced would be ivory-tower scientific researchers. Yet Acceptable would be crass mass manufacturers. A designer is neither MA or YA, but MAYA, with all that implies."

A bracelet casing for a Fitbit, though useful, provides no Advancement, as it is merely disguising the hackband. Advancement involves redesigning the whole unit, not just the casing [252, p62].

YA: the feminine normcore

Cifor and Garcia [51] (section 4.5.7) did a six-month duoethnographic study of the Jawbone UP3 tracker, a model which is no longer available but which paid particular attention to aesthetics.

The authors [51, p15:2] criticize the dominance of the "quantified self" view of fitness trackers which they argue "perpetuate an ideal of an always adherent genderless healthy user" and that "when gender is addressed explicitly in design decisions, the devices are produced in ways that promote highly normative conceptions of women and femininity" while ignoring non-masculine wearers' actual needs (section 1.1).

Cifor and Garcia [51] seem to have disliked everything that the Jawbone stands for at the outset, but forced themselves to use it continuously for six months. People who dislike fitness trackers would not normally be the ones to wear them, but the Jawbone did not win over the authors during those six months.

One of the authors liked that the UP3 blended in with feminine clothing, looked like vintage jewellery and not obviously like a fitness tracker. The other side of this coin is the normative femininity of its appearance: "a thinner strap, smaller face, more subtle styling, and colorways that include white, gold, and other colors associated with femininity". This is the feminine version of "normcore".

The other author felt exposed and embarrassed wearing her Jawbone, even before considering data security [131] (section 3.3.5): "I start to have shaming thoughts like 'Look at her. She wears two fitness trackers and she still can't lose weight."'

Having selected weight loss as a goal, the target weight could not be personalized [153]; a basic failure of usability. The "one size" device did not fit; its clasp scratched and caught; the user interface offered only two genders at setup, with no options for nonbinary wearers; and the "Smart Coach" accompanying app "was highly repetitive and general", with inadequate recognition of women's health concerns.

The authors disliked the social network functionality's emphasis on competition and comparing biodata (another stereotypically masculine value). Although they knew and trusted each other already and were sharing data for the purpose of study, the researchers still experienced tension from the mutual exposure [198] [264] [66] [67].

The feminine normcore is YA.

[21] The self-styled "father of industrial design".

MAYA: the LilyPad and inclusive education

Buechley et al. [42] exploited the Arduino LilyPad's usability characteristics to attract women and girls to education in "embedded computing, which women usually shun" through the gateway of textiles and fashion. They write: "Most famous Renaissance figures [...] were renowned for - often intertwined - artistic and engineering accomplishments [...] We believe that the divorcing of aesthetics from engineering contributes to its lack of diversity."

They picture designs by a girl (a bag with electronic appliqué) and a woman (a top with electronic appliqué) who attended their courses, remarking on "just how different these artifacts look from any other technology-related student projects. [...] Five out of eight students mentioned fashion, or a related theme, in their explanation of why they signed up for our class" which attracted "overwhelming majorities of young women".

The LilyPad was an important component of the crafting movement in wearable technology, but Ryan [229, p220] critiques wearable crafting for its "lack of semantic depth and irony" and risk of "enclosing female techno-crafters in nostalgic but preposterous stereotypes". Ryan also critiques wearable crafting for reinforcing consumerism: "The proliferation of rudimentary abilities to wire and program simple microcontrollers expands the population of users more than it does programmers" (p. 220).

I suggest that collaborative PDFi maker groups that share skills might advance the state of the art (sections 3.7.3 and 6.5.2). Ryan [229, Ch5] overviews the landscape of craft practice in a frame of critical design, and in so doing, gives an impression of holding wearable craft innovators up to an impossible standard: yes, dress is "bound up with capitalism" (p. 215), not as much as fish are bound up with water, but enough that it is a big problem to ask craft innovators to solve. If we just want to make something, we use the tools we have to hand [108, p37].

In my study, the majority of volunteers were women (section 1.9.2) recruited via workshops for creating *imaginary* wearables through DF, compared to [42] where the students made *real* wearables themselves. Three of my volunteers (of whom two women) were experienced in creating wearable technology already. Any one of us would not be able to attain MAYA, but together we might.

Inspiration: the jewellery aesthetic

MAYA: Tsaknaki et al. [267] are among those that have sought new forms and functions, approaching wearables as a whole through jewellery design and craft practice. All the items in [267] were created by designers without nonexpert participants. Like [242] they critique the normcore with its "industrial-, sports- and spaceship aesthetics", and define jewellery as "adornments," as well as "strong signifiers of local social hierarchies and customs, but also reflecting cultural values." They see a future in the handmade rather than mass market: "With increasing popularity in maker practices around electronic products, and also significant improvements in terms of easy-to-use tools, the arena for handmade and uniquely produced interactive accessories will potentially grow significantly in the upcoming years" (sections 3.7.3 and 6.5.2).

In particular, [267, p7] talk about "ensoulment": "both a design principle and a mechanism to promote sustainable interaction design by increasing the psychological attachment

to electronic products. The idea of ensoulment is described as 'a feeling of deeply moved and as a consequence, a feeling of being significantly changed, by a meaning and value of a design' (Blevis & Stolterman 2007) and implies deeper engagement with a product as a way to create longevity." Silina and Hsu [243] argue for jewellery items that remain wearable after their technological components break down or become obsolete, and refer to Ahde-Deal's [6] work on women's use of sentimental jewellery to understand how women invest jewellery items with interpersonal significance.

I fear the Gallery Necklaces would not be destined to last very long; wiring connections come loose and must be resoldered; acrylic scuffs; WiFi protocols are superseded (section 3.3.5); components become obsolete. Acrylic is cold and rigid and is not evocative of sentimentality. But perhaps the acrylic pieces could be polished and reassembled, or the circuit boards themselves could be treated as jewellery materials.

More MA than YA: Wallace [274, p80] provided the main inspiration for my own work. Like Wallace, I engaged with a small number of individuals in order to understand their "felt life". Wallace took an approach similar to [101], and used 10 different probes or "stimuli" [274, p114] to gain insights that "take the form of narratives about interactions, relationships, places, events, and memories of significance and value." [282, p13] She then crafted a digital (not necessarily wearable) object for each participant, as an indirect representation of their responses to the stimuli. The ambiguity was important to the development of "sensibilities" for enchantment [177] (section 2.2).

Compared with Wallace's fey intricacy, with its sensibility of "unfinalizability and ambiguity" [282, p16] my own set of prompts was simple, comprising the story prompt (Appendix H.3.1) and the creative toolkits (Appendix H.5). The story prompt was the most direct way of asking the participants what wearables they wanted, short of asking point-blank which would not help them to think of ideas for wearables that did not exist yet [10, p60]. I followed up the workshops with 1-1 interviews (Appendices K.2.2, K.3.3, K.4.1, K.5.3, K.6.1, K.7.3 and K.8.3) and and to make sure I had properly understood what the participants communicated through their storytelling, paper prototypes and illustrations (Figures H.8 to H.15, I.1 to I.13 and K.1 to K.8). After that, I tried to realize the stories as literally as I was physically capable of doing (section 4.1), trusting reality itself to coerce the designs into less direct interpretations. "It is a dialogical reflection; experiences of significance to one individual are understood through the eyes and hands of another and returned to them. [...] In so doing, it not only transforms these experiences, but also transforms pre-existing conceptions, both of the digital and of jewelery". [282, p12]

Wallace's work [274] was user-centred rather than participatory; but like Wallace I unveiled the digital objects as a surprise, followed by an in-the-wild study. Wallace [274] gathered feedback with "a range of techniques including photograph-taking, drawing, diary-keeping, and verbal reflection" [282, p14]; I requested feedback less often than I planned: firstly, because I did not want to burden my participants; secondly, because a special-occasion piece is worn in settings a researcher cannot observe directly, and too rarely to generate frequent comment. I requested feedback once or twice over the course of a year, by emailing a prompt in the form of "I like/I wish/what if?" (section 5.2). Like [274, Ch7], I included a final reflection stage; with workshops to update the PDFis and 1-1 interviews to discuss them (Chapter 6).

The biggest difference between [274, p131] and mine is that Wallace was more concerned with art than wearability (with MA than YA): "I did not want to force the piece to be wearable or for the study to be a challenge for me to make something that she would

wear, these issues were not my interest." Indeed, only one of the three digital objects Wallace crafted was meant to be worn.

3.6.5 Aesthetics as enchantment

Performativity and poetics

Wearable computing has not always been this plain. As [275, p184] pointed out, "early images of scientists wearing computers are quite theatrical. They hook into images from SF, and connect to our collective dreams of the future". The designs of this period are described and pictured in [229, pp. 39-41] and include the "Sword of Damocles", the first heads-up display, too heavy to be worn, which was developed by Bob Sproull in 1968 for the US Department of Defense's Advanced Research Projects Agency (ARPA).

Wilde, citing [177] complained that, despite increasing efforts by companies like Philips, IDEO and Levi's, wearables were "often not 'enchanting"' (section 2.2). Wilde sought a quality of "performativity" (section 2.2) for devices worn on the moving body, through a lens of "poetics", that is, a transposition of the "aesthetic and evocative" language used in poetry onto the design characteristics of a body-worn device. An example of this performativity was the hipDisk [275, p188] [276] resembling a cross between a tutu and a hula hoop, which made sounds if the wearer gyrated their hips with substantial effort.

The hipDisk looks avant-garde and functions solely to extend the enjoyment of movement - art for art's sake.

Inspiration: the enchanted middle

There is a wide middle ground between normcore wristbands and performative sonic tutus, which is where this study is located (though I would have gone to either extreme if my participants had desired it).

Ryan [229, p191] put her finger on a point where I can further divide-and-conquer the range of available design space: "some designers still seek to go beyond academic research and see their work integrated with everyday life. They aim toward the naturalization of technology, which will enable it to be, not invisible, but rather part of an evolving language of dress (rather than a commercial prototype, art work, or oddity)."

Alongside [267] in this middle ground are Ferraro and Ugur [90], another of the studies that considered user-centred design of wearables as a whole (section 1.2) by giving design students an open brief to connect with nature through the five senses (a sensibility shared by [226, pp. 157-165]). The potentially realizable prototypes resulting from this open-ended brief included a scarf of natural materials incorporating an audio system; and a helmet resembling a peapod, that incorporated both an audio system and a visual display over one eye. Future-oriented prototypes included a kinetically-powered GPS cyclist's glove with conductive ink.

Inspiration: enchantment, advancement and aesthetics as experience

Perhaps I should have said wearables could "be beautiful" rather than "look beautiful" (Summary).

Wright et al. [282, p11] explain Wallace's [274] prior work in craft practice and digital making, in which "beauty is a form of enchantment (a relation between user/viewer and artifact) and is the key to personally meaningful engagements with digital technology. However, beauty and enchantment cannot be added as a 'layer' to the functionality of the digital, rather it has to be at the heart of the process of conception and making".

Wright et al. [282, p1] conceive of aesthetics as an experience, in particular their "holistic approach wherein the person with feelings, emotions, and thoughts is the focus of design". They contrast an "analytical" - appearance-based - approach to aesthetics with their "pragmatic" approach: "[...] pragmatism sees aesthetics as a particular kind of experience that emerges [...] in the construction of relations between artifact and viewer, subject and object, user and tool."

Though Sterling [253, p3] is cantankerous about the nebulous term "experience design", [282, p3] provides the definition that applies to this study: "Etymologically, 'experience' stands for an orientation toward life as lived and felt in all its particulars. It tries to accommodate both the intensity of a moment of awe and the journey that is a lifetime. These origins suggest the aesthetic potential in all experience." As a wise storyteller once said, "All sorrows can be borne if you put them in a story" [98], and the same is true for all joys and all particulars of felt life in between.

3.6.6 Aesthetics and design fiction

Top-down diegetic prototypes

Kirby [145] discusses the work of Brett Leonard, a film director and a technological entrepreneur who used the film *The Lawnmower Man* to "create a modern 'technological mythology' featuring interactive technologies. He worked with Nicholas Negroponte, Steve Wozniak and Sun Microsystems, among others, to create a compelling vision of virtual reality. According to Leonard, a film director acts like a 'tribal shaman' who creates visions of the future that can define a culture's shared desires." Žižek puts it another way, that cinema tells us what we desire [92]. This is the power of DF from the "top down", and it does start with appearances.

Aesthetics and worldbuilding

As Sturdee et al. [255] argued, appearances in DFs are a necessary part of the worldbuilding, and worldbuilding is the distinguishing feature of DF that creates a "magic circle" where disbelief can be suspended.

Sturdee et al. [255] developed imaginary resources, images and documentation for a Voight-Kampff machine [22], including a realistic-looking crowdfunding campaign. They succeeded in suspending disbelief, because a documentary filmmaker approached them on the misunderstanding that the product was real - a feat also achieved by Auger and Loizeau [14] with their 2001 audio tooth implant [23] which was essentially a media hoax.

[22] *Wikipedia:* **Blade Runner** https://en.wikipedia.org/wiki/Blade_Runner

[23] *Wired*, 4 November 2006: **Lying Through Their Teeth** https://www.wired.com/2006/04/lying-through-their-teeth/

Gonzatto et al. [108, p39] called out the aesthetics of corporate futurology, which do not consider social change and "typically avoid the negative facets of their proposals with seductive imagery, borrowing from SF language. The aestheticisation of technology works to naturalise them".

Inspiration: aesthetics as perceptual bridge

For this study, the paper prototypes and illustrations (Appendices H, I and K) communicated the participants' storyworlds and informed the styling choices for each device. For her spacefaring heroine (Figures I.6, I.7 and I.8), Ursula the steampunk jeweller received a wide metal collar with decorative "rivets" (Figure 4.19), resembling an astronaut's or early diver's collar; with a silvertone acrylic frame and casing engraved with an antique astrological illustration, inspired by one of Ursula's published books.

By styling the technology probes this way, I hoped to create a perceptual bridge [13, p140] (section 2.3) that would help the participants to imagine themselves in their storyworlds while they wore their Gallery Necklaces in the real world, experiencing the positive and negative details of using the technology probes, and thinking about how the devices would progress towards possible, plausible or probable futures in their storyworlds.

Reality always scarifies fantasy. The assembly of each device was fragile, felt even more fragile (Table 5.7), skewed off-center, and exposed the device's innards (section 5.1.7; Figure 5.1). Some necklaces failed at representing their recipients' tastes and/or lifestyles (section 5.1). Each one, successful or not, was visibly made especially for the one person who would wear it and the storyworld it came from. A series of identical plain plastic casings might have been better and faster executed, but less fit for purpose.

3.7 Genres of fictional design

3.7.1 Anti-inspiration: the worst of speculative and critical design

Among the most influential researchers in SCD (section 1.4.2), a genre of fictional design which is closely related to DF, are Dunne and Raby (DnR), who argue for designing futures that are *possible*, not just *marketable*. Wallace [274] was heavily influenced by DnR and this study is heavily influenced by [274] (sections 1.3.2 and 3.6.4). Tonkinwise [265, p170], in his review of [82], articulates SCD's central question: "How to take responsibility for the futures we are designing toward even when we cannot take charge of that designing?" Since I am trying to answer the same question using PDFi, I should be hanging on DnR's every word. Instead, I find myself agreeing with [265].

In [82, p96] DnR specify in detail the aesthetic of an SCD, including that it should be "glitchy", not too realistic, just sufficiently "off" to challenge or disturb.

Tonkinwise's critique includes DnR's "Foragers" in which citizens, neglected by their governments, are left to deal with food shortages using "DIY digestive devices" in the form of

wearable external bird gizzards that can digest nonedible items from the environment [24] [25]. DnR costume these foragers not in rags, which are "obvious", but in "outdoor, sporty clothes" (the costumes are neon and the gizzards look like sousaphones) in order to "challenge expectations of them being organic and anti-technology" and to remind us that we are viewing "ideas, not products".

Tonkinwise calls this out as a misuse of aesthetics: the premise of *Foragers* is a starving working class (a present reality in the UK for some time now [26] [27] [28]). If the Foragers were dressed in "obvious" rags it is unlikely anyone would mistake them for a product, any more than anyone would mistake a neon outfit with a sousaphone-looking external gizzard for a product. It is more likely that rags would foreground the Foragers' status as members of a starving working class, whereas the neon costumes deflect attention away from the premise of the work at the moment the audience looks at it. So this is not a *real* starving working class, but a cartoon version? It hardly seems to matter, because the solution is not a real solution (which is the premise of SCD after all); but also, **the problem is not presented as if it were a real problem; and yet it *is* a real problem affecting people amongst or known to the audience.**

DnR explain the purpose of the *Foragers* project: "This is somewhere between commentary, which we're not interested in, and problem solving, which we think is impossible [...] As designers we lean towards the optimism of thinking that there has got to be a way of sorting this out, but we love the kind of aesthetic, poetry and irony that comes with comment." While I cannot claim to be trying to solve serious social problems in my own work, and I certainly consider amusement to be a worthy goal, this amounts to an acknowledgement by DnR that they will commit to nothing *but* amusement, and *Foragers* can be understood in that light.

This implied attitude is openly expressed in the comments on a review of a similar SCD, Burton and Nitta's "Republic of Salivation" [260]. Prominent practitioners, including Auger and Parsons, argue that accusations of trivializing the subject matter misunderstand the speculative nature of SCD, the purpose of which is to provoke debate: they are debating, so it must be working.

But I understand and am inspired by SCD, I am in the same privileged demographic as these Northern European practitioners, my subject matter is the "problem" of boring wearables, and I also find these speculations decadent and fatuous. Admittedly, they got me thinking, and with a little effort I might manage to feel disturbed. What would that disturbance achieve?

[24] *Icon,* 28 August 2011: **Dunne and Raby's Future Foragers** https://www.iconeye.com/design/features/dunne-raby-s-future-foragers

[25] *Clot,* 2 May 2016: **Dunne & Raby, Using Design as a Tool to Critique, Debate, and Speculate** https://www.clotmag.com/design/dunne-raby

[26] *Trussell Trust:* **Regional Breakdown 2011-12** https://www.trusselltrust.org/news-and-blog/regional-breakdown-2011-12/

[27] *The Guardian*, 16 December 2020: **Unicef to Feed Hungry Children in UK for First Time in 70-Year History** https://www.theguardian.com/society/2020/dec/16/unicef-feed-hungry-children-uk-first-time-history

[28] *The Big Issue*, 29 March 2019: **Urban Foraging: if Brexit Bites, Dig for Victory** https://www.bigissue.com/latest/urban-foraging-if-brexit-bites-dig-for-victory/

Speculation and democratization

A foundational goal of participatory design was "striving for democracy" [110, p62]. Though Knutz et al. [148, pp. 2-3] see potential for participation in some of these same SCD projects, the speculations of DnR and of Auger and Loizeau are top-down (section 3.6.6).

Tonkinwise [265, p185] argues that "our modernist forms of democracy are not up for this kind of debate"; indeed as an audience member, my participation is limited to a vague feeling of suspicion of being trolled. Tonkinwise argues that, to the extent these speculations were consequential, DnR are denying responsibility for those consequences. "By contrast, if the designer is sitting alongside the scientific researcher, sketching amoral or even immoral implications, then the scientific research expert is the audience."

3.7.2 Who is my target audience?

In this study, I am the designer sitting alongside myself as the researcher; but I am designing as a maker, which anyone can be; and not as a product designer, which is a professional discipline.

Product designers are discouraged from taking individual users' creativity as seriously as I do [270]; the pressures of productivity make individual users a distraction to real-world professionals: "Sometimes what is needed is a design dictator who says, 'Ignore what users say: I know what's best for them."' [201, p17]

But this is the problem, this is where we came in: commercial wearables are made for some normative - other - user [153] (section 1.1.1). The way out might not be through commercial product design; although an OEM company in the USA has taken an interest in my methods, it remains to be seen whether or how they will scale them up for industrial use. Companies have expressed interest but focussed on the design artefact while overlooking the methods; the Gallery Necklace looks like a failed digital photo frame to them, which is not even in colour, which anyone could already buy as a keyring and hang around their neck (they don't, but they could). This is what the Gallery Necklace is reduced to without its backstory: "disappearing esthetics" [229, p7], which the mass customization advocated by [212, p5] might or might not overcome, but a maker movement could (sections 1.2.1, 3.5.1, 3.7.3 and 6.5.2).

What do I take seriously?

In section 3.7.1 I criticized certain works of SCD for their unseriousness. What do I take seriously?

I take all things wearable seriously. I take technology seriously. I take the wearers and users of that technology seriously in general, and in particular I take my participants seriously. I care very much that the technological systems I am building should, to the small extent that it is within my power, enhance their lives and contribute to a world in which they may exercise their vital powers into the future.

It sounds grandiose to claim I am striving to democratize everyday wearables through participatory design, but a nationwide electoral majority is not necessary to get started; half a dozen will do.

I do not believe I have much influence, but the worst case shows me the direction I want to move away from: inventing a technology that causes harm and never even trying to anticipate that harm.

I am serious about my participants' inherent creativity, and the credibility of their contributions. If they had wanted me to build something ludicrous in the literal sense, I would have done that. If they had wanted to go on being cyborgs but with different devices than they can buy in a shop, I would have facilitated that.

What is important is that users are not just bodies available to firms as locations to place ubiquitous computing; and that users have the right to wear and enjoy technology on their own terms; and (if data is capital) to own the... am I going to say "means of production"?

Disappointing Marxists

In the MOMA debate [260] (section 3.7.1), "Matt" threw down the gauntlet: "Against indulging in 'anti-market' fetishisation, I want to know what SCDs current strategy is for actually abolishing the capitalist market system." How remiss of me to have forgotten this task. Muniesa [193, p206] explained it all: "'Design' is a new word for politics - especially when connected to other crucial notions of our economic cosmology, such as that of innovation - but with politics understood as the modern art of the informed fix." That sounds more tactical than strategic, but I digress.

Insinuating Georgists

I am not taking a Marxist position. I am taking a position based on vulgar Henry Georgism [105].

I am not a critical theorist, so I will not overemphasize my ideological worldview, but I do need to state it.

To answer "Matt", my strategy for "actually abolishing the capitalist market system" would be: "Through the collection of the rental value of all natural and community resources - from whomever holds and monopolises them - and the application of the revenue raised for public purposes *in lieu* of traditional taxation" [29].

In vulgar Georgist terms I would say that in a wearable technological system, the body plays the role of land (an unimproved artefact of nature), and data is labour (the product of human effort), as are the wearables that collect data about the body [280]. In the world I am trying to make, the wearer chooses which data to collect and whether to convert it into capital (wealth in the process of exchange) or keep it for personal consumption (like breakfast, which has an exchange value, but is not capital for the one who eats it [105, pp. 29-33]). These choices are not decided for them by a technology billionaire, or a cybercriminal. And for the purpose of this study we are not capitalizing the data, though the possibility of doing so is inherent to the software infrastructure (section 1.5.2): "your data, your way," and by extension "your wearables, your way". I mean this not as a mere

[29] *The Henry George Foundation:* **Our Approach** https://www.henrygeorgefoundation.org/about-the-foundation/our-approach.html

anaphora of a marketing slogan, any more than Tonkinwise's critique of DnR's use of the classic vanilla "Cone of Futures" is "a cheap identity politics criticism" [265, p174].

The HAT was not developed as a Georgist system, but by returning ownership rights to personal data to the individual, it coincidentally has that in common with one.

L'esprit de l'escalier: sustainability

One of the natural resources a Georgist would tax is "pollution emissions capacity". Production per se is not to be taxed, but unsustainable production is to be taxed in proportion to its unsustainability. My omission of the issue of *sustainability* is a weakness of this study, considering the open goal afforded by the software infrastructure.

Sterling [252, p11] proposed that the IoT should enable sustainability by connecting an audit trail, or *metahistory*, of information about every component of every material instantiation of every product: "Spimes are sustainable, enhanceable, uniquely identifiable, and made of substances that can and will be folded back into the production stream of future Spimes". Adding RFID (radio frequency identification) tags to the technology probes would have been unfeasible, but I could have set up device metahistory on the HAT.

Spimes are foundational to the IoT and to DF, and [251] imagine the practicalities of democratized innovation in three DF prototypes: the repairable *Toaster for Life* [251, pp. 7-9], the DIY clinical *HealthBand* [251, pp. 10-13] whose makers must be licensed with an "NDHS Domestic Fabrication Permit" [251, p13], and *The Future Is Metahistory* [251, pp. 14-17] data design fiction. Since everyday (nonclinical) wearables can be made without a license, there is already a path to their democratized innovation through the maker movement, as well as increased sustainability through resharing of discarded materials. The Cambridge Makespace has a "trove" which sometimes becomes overwhelmed with excess materials. Any headway that could be made on implementation of "spimes" could make it possible to inventory some reshared materials (not all; it is difficult to apply RFID tags to metal substrates) and eventually build a network for trading materials with other makerspaces, thereby increasing both sustainability and affordability for the entire makerspace as well as the wider maker community.

Sterling and Gibson vs. Dunne and Raby

More than one Latin American designer [99, p8] [216] has criticized Northern European speculative dystopias that match present realities in less privileged regions. Howell et al. [124] fleshed out a set of proposals for a plurality of models for futuring that acknowledge the complexity, situatedness and nonlinearity of "progress". DnR's manifesto for SCD is "ambiguous, but not deliberately" [265, p180]; the "un-manifesto" of [124] chooses "not to commit to a unifed set of claims, but rather to highlight a plurality of perspectives for design futuring."

Both [124] and [265, p174] quote William Gibson: "The future is already here - it is just not evenly distributed." Tonkinwise points to the DESIS Network [30] for social innovation through service design with communities.

[30] *DESIS Network:* **Our Goals** https://www.desisnetwork.org/our-goals/

My target audience includes the research community in computing systems design, including those in digital economy and in service systems design [209], from which Dataswift and the HAT Community Foundation originated [196] [197], and which led me to this study from the original HAT project [205] [211] [264].

As described in section 6.5.2, my audience also includes wearable technologists in making and craft practice [9] [37] [42] [70] [223] [243] [267] [274] [277] [282].

Another audience I wish to address is the emerging PDFi community. In 2018 at NordiCHI, Lyckvi et al. [167] called for a workshop to inquire "if, when and how to combine Participatory Design and design fiction", and to establish a new PDFi process. This is the most obvious audience to whom I wish to address this study, and I had hoped to attend, but was prevented by personal circumstances. I expanded on participatory design of wearables in section 3.5 and will say more about PDFi in section 3.8.

3.7.3 The boundaries of design fiction

I have been working on the assumption that the participants' stories constitute DFs, but do they?

A reviewer, who claimed expert knowledge of DF, argued that the PDFis are *not* DFs, but rather part of a process of human-centred design. They gave the following reasons in support of that argument:

- That the texts are brainstorming or scenarios, not DFs.
- That the texts are used to understand what participants would want in the present, whereas DFs are for imagining other worlds and comparing them to our own.

The ambiguity around the definition of DF [163] demands a considered answer to the reviewer's objection. Lindley and Coulton [163] "posit that design fiction is inherently flexible, and it is this flexibility that causes the ambiguity".

They offer the following minimal definition: "So a design fiction is (1) something that creates a story world, (2) has something being prototyped within that story world, (3) does so in order to create a discursive space." They warn not to gloss over the complexity of considerations about the diversity of media used to create storyworlds and the diversity of diegetic prototypes within those worlds.

Lindley and Coulton [163] are clear that this flexibility does not imply that anything goes. In the same year, Lindley [162, p2] stated "design fiction is, in Kuhnian terms (Kuhn 1962) in a crisis period". The software engineer in me protests that "we look for things that make us go" [31], and that if the DF community will not accept it, I will call it something else and keep going. The HCI researcher in me asks: what *doesn't* go?

According to the reviewer, brainstorming and scenarios don't go, but do the participants' stories fall into either category?

[31] *Memory Alpha:* Species - **Pakled** https://memory-alpha.fandom.com/wiki/Pakled

Brainstorming and design fiction

It is true that *IronWoman* (Appendix A.1), *Fertility Ring* (Appendix B.2), the first version of *Wooden Horse* (Appendix B.3), *Leaf Me Alone* (Appendix B.4), *Wearable Plant* (Appendix E.1), *Freedom Hat* (Appendix E.2), *Mood Shirt* (Appendix E.3) and *Wearable Life Support* (Appendix E.6) read more like brainstorming - each is the product of divergent discussion of an idea with contributions from the whole group. The first four are from the pilot workshops (Appendix H), and the others are from the inaugural workshop (Appendix I), when the concept and methods were still being introduced. The sequence of workshops was structured that way because it is unrealistic to expect a finished product from each participant immediately, and reading the first drafts can still help us to understand the authors [20]. These PDFis are *unfinished*.

That leaves: *The Hermit and the Shepherd Boy* (Appendix B.1), all of the stories from the Edinburgh groups (Appendices C and D), *Empathy-In Glasses/Empathy-Out Gloves* (Appendix E.4), *Jacinda Dragonfly and Mr. X* (Appendices E.5 and F.5), *Gallery Jacket* (Appendices E.7 and G.1), *Wooden Horse* (Appendix F.1), *Amelia and the 8 Inventions* (Appendices F.2 and G.2), *Hat-of-All-Assistance* (Appendix F.3) and *Mood Bracelet* (Appendix F.4). All of these stories constitute completed narratives. These PDFis are *finished*. They do not read like brainstorming. Are they scenarios? Rosson and Carroll [227, p5] define scenarios as "work-oriented design objects". They have certain things in common with DFs.

Scenarios and design fiction

Rosson and Carroll [227, p1] begin their definition of scenarios as follows: "Scenarios are stories." In this, they differ from DFs, which may or may not involve stories [52, p172].

Another reviewer on a different occasion said "design fiction is not storytelling", and [52, p166] argue that storytelling and narrative are not necessary to DF, because the primary task of worldbuilding can be accomplished in many other media. However, [52, p172] do not go so far as to say storytelling *cannot* be DF. Sterling may have said "it tells worlds not stories" [33], but he described his own writings as "design fictions" and if [254] is not a story, what is it? There is, in any case, no consensus that storytelling and DF are mutually exclusive; and if there were I would challenge it.

Rosson and Carroll [227, p1] continue their definition of scenarios: "They consist of a setting, or situation state, one or more actors with personal motivations, knowledge, and capabilities". A "setting, or situation state" is less than a world, and "one or more actors with personal motivations, knowledge, and capabilities" is less than a character. Except for Jacinda Dragonfly (Appendices E.5 and F.5), the Hermit, and the Shepherd Boy (Appendix B.1), who already exist as characters outside of the PDFis, characterization in the PDFis is limited in practice by space, but not in principle by genre.

Back to Rosson and Carroll's [227, p1] definition of scenarios: "and various tools and objects that the actors encounter and manipulate." The equivalent step in the story prompt (Table H.1) is Minute 2: introducing the wearable technology.

"The scenario describes a sequence of actions and events that lead to an outcome. These actions and events are related in a usage context that includes the goals, plans, and

reactions of the people taking part in the episode." The equivalent steps in the story prompt are Minutes 1 ("and build your world") and 3 ("a day in the life").

The scenarios are narrative rehearsals of specific user interactions. Rosson and Carroll [227, p2] walk us through a visit by "Sharon", a fourth-year Virginia Tech undergraduate, to the SF club's webpage. Sharon:

- "stops by the computer lab to visit the science fiction club [online]"
- "opens a Web browser"
- "realizes that this computer will not have her bookmarks stored, so she starts at the homepage of the Blacksburg Electronic Village"
- "sees local news and links to categories of community resources (businesses, town government, civic organizations)"
- "selects 'Organizations', and sees an alphabetical list of community groups"
- "is attracted by a new one, the Orchid Society, so she quickly examines their Web page before going back to select the Science Fiction Club page"
- "gets to the club page"
- "sees that there are two new comments in the discussion on Asimov's Robots and Empire, one from Bill and one from Sara"
- "browses each comment in turn"
- "submits a reply to Bill's comment, arguing that he has the wrong date associated with discovery of the Zeroth Law"

That describes Sharon's interactions with the webpage on a single hour-long occasion. What is Sharon's history with Bill? Is there a triangle with Sara? These and many other questions about Sharon will never be answered, because Sharon is not a character.

We can compare this with Rita's interaction with the Mood Bracelet (Appendix F.4). Rita's interactions with the bracelet are described over a period of time; her emotional responses to her bracelet are described, with the tension of her mounting suspicion that the interaction was a two-way process, that the bracelet had information about her that she did not realize it was capable of receiving or processing [198] (sections 1.5.2 and 3.3.3). We learn about the reactions of Rita's husband, how it affected their life and relationships, and how they learned to adjust their reactions to keep the bracelet's influence on their lives healthy and proportionate.

Arguably the Mood Bracelet is an example of emotional design [200] in that its purpose is to manage Rita's emotions, therefore the interaction as described would be equivalent to Sharon's, making *Mood Bracelet* equivalent to a scenario.

Narrative detail, convergence, and divergence

How then to distinguish a scenario from a DF?

We can use [254], a text we know to be a DF, as a benchmark. According to Lindley and Coulton's [163] definition of a DF, it:

1. **"creates a story world"** - *Mood Bracelet* does, but so do the scenarios in [227], however minimally. *Mood Bracelet* is set in present-day but magical-realist England in the home of a middle-class married couple; [254] in contemporary Italy with design pundits in alternate timelines.

   In [254], details are provided not to accomplish a task but to differentiate worlds: the blonde television presenter from present-day Italy with her swaying gait, curvaceous figure "upholstered in Gucci", her "dainty crocodile purse" and her "big pair of sunglasses"; versus her counterpart "Svetlana" in Yugoslav Italy with her "impressive bust", her "hand-knitted peasant sweater" that was "gaudy, complex and aggressively gorgeous", her "smouldering eyes thick with mascara", her "talon-like red painted nails", and her "thick gold watch that could have doubled as brass knuckles".

   Rosson and Carroll [227, p2] give Sharon three scenarios, with no details that are not task-oriented: even the branding (Newcastle Brown) on the pitcher of beer that her friends are "drinking" in the MOO is not characterization but an indication of the level of detail to be portrayed to the user.

2. **"has something being prototyped within that story world"** - True in all three cases: a mood bracelet, a web page, a dimension-jumping memristor.

3. **"does so in order to create a discursive space"** - *Black Swan* [254] and *Mood Bracelet* were written for that purpose, but so were the scenarios. *Black Swan* was written to create a discursive space within literature and design simultaneously. *Mood Bracelet* created a discursive space in order to co-imagine a concept based on an open-ended brief.

   The PDFi is **more convergent** than brainstorming, in that it helped the participant to close in on an actionable concept more quickly. The PDFi is **more divergent** than the scenario, which is a basis for discussion of ways to accomplish a preselected task within a closed design brief.

Based on this comparison between a "known good" DF [254], a contested PDFi, and a scenario, I conclude that scenarios can be distinguished from DFs by task-orientation and level of detail; a distinction appreciated by [7, p223].

Sterling uses details to create and differentiate worlds - familiar worlds get slightly less detail, alternate worlds get more. *Mood Bracelet* is qualitatively more similar to [254] than to Sharon's scenarios because it is discursive (written for group discussion of a design concept), whereas the scenarios were task-oriented (written to script a concrete task). Sharon is qualitatively more similar to Alice and Bob exchanging cryptographic keys [32].

[32] *Wikipedia:* **Diffie-Hellman Key Exchange** https://tinyurl.com/hysy3ywm

Design fictions and storyworlds

The next part of the reviewer's objection is that DFs are about imagining other worlds. They did not specify what would make a world "other" enough: is a near-future version of this world "other"? If not, that excludes a large body of work about near-future systems, among them [29, p8] on "new possible near future worlds" and [252, p76] whose *spimes* (section 3.7.2) Hales' [113] tentative taxonomy of DF described as "a near-future rhetorically futuristic and ecotopian imaginary object."

Coulton et al. [53, p17] write: "rather than trying to make Middle Earth's Elves, dragons and magic accessible and relatable, we're interested in an alternative and near-future version of *our world* where the IoT has become more widely adopted". They go to such lengths to ground "Polly, the world's first truly smart kettle" in the present world through graphic design and faux-marketing that including Polly but excluding *Agent X* (Appendix C.2), *Little Strawberry* (Appendix C.3), *Amelia-8* (Appendix F.2), *Hat-of-All-Assistance* (Appendix F.3) and *Empathy-In Glasses/Empathy-Out Gloves* (Appendix E.4) seems hard to justify.

The world of *Leaf Me Alone* (Appendix B.4) is based on frustrations with the current world, but it brainstorms the age-old Cloak of Invisibility (Appendix H.7.7); *Mood Bracelet* (Appendix F.4) is mundane except for the magical realism of the bracelet, which is technologically in the near-future; *Gallery Jacket* (Appendix E.7) is autobiographical, but tucks magical realism into a tiny detail.

A number of the stories *are* set in other worlds - *Flower* (Appendix C.1), *GodSon* (Appendix C.4), *Green* (Appendix C.5), *MirrorMask* (Appendix D.1) *Wooden Horse* (Appendices B.3 and F.1), *Jacinda Dragonfly and Mr. X* (Appendices E.5 and F.5) or past worlds (*The Hermit and the Shepherd Boy*, Appendix B.1).

The existing literature deals with DFs set in other worlds [21] [73] [147] [256] [257], alternate histories [254], and future or near-future versions of this world [7] [12] [40] [53] [55] [136] [147] [159] [160] [161] [174] [176] [255], including and especially [29].

Bleecker wrote: "Not all science fact is about the near future, but enough is. Perhaps the more pragmatic sort of science fact that is close enough in its matters-of-concern to help out in any worldly crisis. Neither is all science fiction about the near future, but there is some that is specifically about the near future, and so that's good enough for me."

Inspiration: design fiction and the grammar of time travel

The reviewer implied that using PDFis as part of a human-centred design process negates their status as DFs. Lindley [162, p4] wrote: "An interesting quirk of design fiction in this mode is that its focus is never a material end product (in contrast to research through industrial design, for instance)."

My response is is that "All the important changes have happened before the things they were supposed to change" [2, p80]. The present is - was - the only possible time to give participants anything; "The proximate future is a future infinitely postponed," [22] - it is a matter of "handiness" [108, p36].

SF prototyping is distinguished from DF by its role in industrial design, which this study is not driving at. I based the story prompt (Appendix H.5.3) on Johnson's "Five Steps"

for creating a SF prototype (Table H.1) not for theoretical reasons, but simply because I thought it would work: it offers a clear sequence [151, p81] that would help participants to improvise in public. Each step prompts for inclusion of elements that help to mould the story into DF [20].

As Bell [23], one of the authors of [76] which influenced this study which influenced [29] recently wrote, in an article looking back over her involvement with the history of artificial intelligence: "Of course, it is not enough to tell stories about some distant or unevenly distributed future; we need to find ways of disrupting the present too. It might be less important to have a compelling and coherent vision of the future than an active and considered approach to building possible futures. It is as much about critical doing as critical thinking. One approach to the future might be to focus less on the instruments of technologies per se and more on the broader systems that will be necessary to bring those futures into existence."

Sterling [252, p62] wrote: "Designers mine raw bits of tomorrow. They shape them for the present day. Designers act as gatekeepers between status quo objects and objects from the time to come." The only way to get to tomorrow is through today.

As Jasanoff [132, p2] points out, fiction understands sociotechnical context *better* than nonfiction: "many nonfictional accounts of how technology develops still treat the material apart from the social, as if the design of tools and machines, cars and computers, pharmaceutical drugs and nuclear weapons were not in constant interplay with the social arrangements that inspire and sustain their production." The real is just as imagined (co-produced) as the imaginary.

Evaluating design fiction

The participants had complete editorial control over their stories, except at the workshop for reflection at the end, when I contributed to the brainstorming of a resolution of Warren's dystopia (Appendix G.1.2; section 6.1.1). Interference before that point would have undermined the purpose of the PDFis: to understand the users [20].

Baumer et al. [20] analyze HCI's state of confusion about how to evaluate a DF. There have been multiple attempts to define and categorize DF [256] [113] [159] [162] [163] [258] [32]. The most hopeful is [32] which grapples momentarily with semiotic methods of analysis before abandoning them in favour of whimsy: a medieval-style map which connotes that DF is an undiscovered country, and the map itself a work-in-progress.

Why does defining and categorizing DF and its subtypes matter *this much?* Does DF exist for the purpose of arguing about what it is?

Baumer et al. [20] argue that just as the different methods within HCI - "controlled laboratory experiments, ethnographic field studies, analyses of usage log data, RtD" - have developed their own evaluative frameworks, DF "should similarly be evaluated based on its epistemic function, i.e. the kinds of knowledge it seeks to create."

They then portray a series of fictional reviews which do not always place the fictional paper in the authors' intended epistemic frame. Mine would be "User Studies", but the reviewer whose assertions I have been contesting is treating it as "Critical, Adversarial, and Speculative Design". Baumer et al. [20] center the question: "what is the value that members of a community wish to take from design fiction?"

Inspiration: design fiction and consequential enactment

To gatekeep DF within purely speculative limits is to ignore the momentum in the literature over the last few years towards *doing,* as well as thinking [133] [84] [96]. It seems unnatural to stimulate thought and debate, but stifle any resulting impulse to action.

Elsden et al. [84, p5386] (section 3.8.2) argue: "beyond generating discourse, there is a need to 'engage people more viscerally in futures conversations'. Practically, there is more we can learn from the way people can interact with, and experience, speculation." They contend that complementing speculation with enactment matters because HCI is "a fundamentally applied, participatory and experience-centered field."

Inspiration: making and design fiction at hand

The main venue for recruitment and networking in this project was a makerspace, with a paid membership base (but many free public events), in a well-resourced and privileged Northern European university town. I was simply using the resource that was put in front of me. Rachel pointed out the potential value of similar activities to housebound disabled communities (Appendix I.1), and thus the next step is put in front of me.

Gonzatto et al. [108, p37] ask: "Despite dealing with the future, what are the origins and consequences of design fictions in the present?" They talk about Vieira Pinto's concept of *amanualidade*, or "handiness", of using what is "at hand":

Gonzatto et al. [108, p37] contrast the assumption expressed in [81, p84] that SCD should make the fictional more real than the reality, and reveal real products as limited artefacts of consumerist ideology. "While in Dunne ideology is the legitimation of alienation from the means of production, as in the tradition of critical Frankfurt School, in Vieira Pinto it can also be a collective effort towards autonomy and self-consciousness."

Gonzatto et al. [108, p43] compare the handiness of three different kinds of DFs: "Each fiction was constructed from the resources each actor had available and transformed according to its own approach (the concept) towards technology: Microsoft Office Labs [corporate futurology] put technology as a requirement for new actions; the RCA [SCD] find the controversies around new technologies; while Faber-Ludens strives for new appropriation of current technologies. The handiness property, thus, helps us to understand how the concept of technology is embedded in action, in this case, the action of posing design fictions to the public."

The Faber-Ludens approach, "inspired by Gilberto Gil's notion of usopy—the future that is already in use (Savazoni and Cohn 2009) - tries to develop design fictions that are constructed at the same time they are used, relying on participation to keep the future open-ended."

I do not wish to appropriate that definition of a Brazilian DF practice, which I do not have enough information to understand; but as [99, p56] describe it, the Faber-Ludens approach and mine have some things in common: "[Usopy] challenges one common notion of Design Fictions that typically takes place in the future. The existence of this 'time' or fiction comes alive while it is been used and moves away when it isn't anymore."

3.8 Participatory fictional and speculative methods

3.8.1 An example of problematic participation

Tsekleves et al. [268] describe a use of PDFi to explore issues of public policy on ageing with elderly volunteers. A 2019 paper [269] also covers the project, called *ProtoPolicy*. [268] is the paper that is most often cited to question the novelty of my own study, because the resulting DF took the form of a euthanasia smartwatch.

The difference between my study and *ProtoPolicy* is that *ProtoPolicy* was not *about* wearables, it was about public policy and simply happened to produce a DF in the form of a wearable. Also, the "Soulaje" smartwatch does not meet the definition of an everyday wearable (section 1.9.1), because self-euthanasia is not a routine, nonthreatening activity. Finally, the researchers were not offering a real-world implementation of the DF.

At first glance, *ProtoPolicy* looks like an exciting example of a use of PDFi for democratization, but further examination raises questions.

The study, as described, went like this: they carried out participatory workshops in which elderly people co-created DFs. The researchers then took these "co-designed speculations" [269, p5] from the workshops, and collaborated with a DF consultancy to produce another DF based on the participants' co-creations. This new DF was the "Soulaje" smartwatch [269, p6], with a built-in poison capsule for self-administered euthanasia. The researchers presented the watch to the elderly participants for discussion; then presented their findings at the House of Commons in London, to promote PDFi as a method for shaping public policy.

What concerns me is this: I wanted to know what the elderly participants expressed, during the participatory design fiction workshops, or in the "co-designed design fictions", that led the researchers to believe that a euthanasia watch was the best way to represent their participation. But the paper does not include any direct quotes from the participants until *after* the researchers presented the euthanasia watch.

Section 2 of [268] goes into considerable detail about workshop attendance, the wide variety of participatory activities, the large amount of data collected in various formats, and the scrupulous conformity to their institution's ethical standards.

I was expecting to see an extract from the large volume of data collected at the participatory workshops, but this never appears in [268] or [269].

In section 2.3 of [268], they go straight to the euthanasia watch, and only then, for the first time, are direct quotes included from the participants' reactions to the researcher-created DF. With so much detail provided about the activities that led to this point, the casual reader might not notice that data about the participation is missing. Or perhaps the information was omitted because it was not considered important enough to include. From my point of view, this was the *most* important information, and I could not find it.

In section 2.1 they describe how they went into the workshops basing their discussion on secondary research, bringing with them extracts from government policy documents on ageing. This delineates a clear agenda for discussion, which is unremarkable in itself; but combined with the absence of data about the "co-designed designed fictions" produced during those workshops, there is a lack of clarity about the link between the participation and the euthanasia smartwatch DF presented as a result.

There are multiple hyperlinks in [268] to data and supplementary materials. These links are years old and are broken by now, so I had to search for a while before I found the documents. The casual reader would not even look for them.

The first place I looked was an early news bulletin about the "microfictions" [33] generated at the participatory workshop. However, there are no actual microfictions in the article, just promotion of their potential.

There was also a project report [60, p24], describing the presentation of the findings in the House of Commons in London, and the reactions of civil servants about using participatory design fiction in policymaking. Below are two quotes that seem to confirm my doubts:

> "A further challenge that was raised was the link between the design fictions and the research question and how they relate to evidence that can inform policy-making. One interviewee stressed that: 'You must ensure a connection to the research question. It's a really strong technique but the important thing is working out exactly what you want to understand."'

> "The design fictions and the subsequent data collection exercise must be developed to ensure that users focus on the questions and issues under investigation. For example, there could be a risk that the SOULAJE design fiction would lead only to a debate on whether euthanasia should be legalised or not rather than the broader research question. As one civil servant pointed out: 'As a non-specialist coming to speculative design for the first time my lesson would be that developing the design fiction is important but facilitating the interaction with the design fictions is as important for generating meaningful data."'

Although Tsekleves et al. [268] may have *done* PDFi, what the paper *describes* is user-centred, not participatory, design fiction. In order to believe that it was participatory or co-designed rather than user-centred, I would need to see direct quotes from the participants from *before* the researchers developed the euthanasia smartwatch DF. Nägele et al. [195] did not directly quote their participants' DFs either, which is understandable because their participants were patients; what they did do was convincingly account for the participants' contribution when describing their methodology.

Another quote from [60, p26], from an attendee at the presentation:

> "I gave the design fiction on euthanasia to my researcher - it hit a nerve. It was shocking and distressing. The Smart Objective Therapist was not as ambitious as the euthanasia wearable. It was in effect an extension of sales engineer. It's not beyond the realms of possibility anymore. Many ideas that seemed far-fetched a decade ago are now a reality. I think there's a real opportunity for using technology for health in a very customisable way, which not too long ago would have been a design fiction."

[33] *Imagination Lancaster:* **Interesting Design Micro-Fictions Emerge from our 1st Co-Design Workshop** https://imagination.lancaster.ac.uk/update/interesting-design-micro-fictions-emerge-from-our-1st-co-design-workshop/

Of course, the researchers were promoting PDFi as a method for shaping public policy, not promoting euthanasia smartwatches as public policy. However, considering the sensitivity of the euthanasia smartwatch DF, it is troubling not to have an explanation of the link between the "microfictions" and data generated by the participants at the initial workshops, and the DF created by the researchers and consultants. Elderly people are a vulnerable and marginalised group, and speculations attributed to them as representations of their concerns should be explainable.

3.8.2 Inspiration: speculative enactment

Elsden et al. [84] prescribe multiple guidelines for speculative enactments, and space does not permit a point-by-point comparison here; but the first three distinctions are particularly relevant to my own work.

Firstly, speculative enactments are *consequential*. In *Metadating*, a real speed dating event that played with the idea of Quantified Self data (also characteristically rooting the speculation in the "future mundane" of an existing routine activity), the *consequence* was the real-life meeting of what would become a long-term couple. In my study, the *consequence* was that each participant would get a real-world wearable based on one of their PDFis.

Secondly, speculative enactments "invite a study of experience". According to [20] , the first use of the term "design fiction" in the literature was not from Sterling, but by Milton [184], who presented a Hitchcockian pastiche script as a basis for arguing for more narratively engaging design. The article [184] is impressionistic rather than specific, but its proposed level of user involvement does not seem to go beyond a consumer experience of narrative transportation with which the product should be imbued by the design process somehow. The next level of participation is in the example provided by [84, p5387] of Lindley's "anticipatory ethnography" [161], which involved capturing ethnographic insights from an audience that had just watched a DF-type Hollywood film, as if they could "somehow skip ahead of time, and become vicarious participants in the futures represented." Elsden et al. [84, p5387] compare this to the more active, yet scripted, participation in [202], which however was scripted in detail. But detailed scripting limits the contributions of participants.

Thirdly, participants' experience is further limited when the speculation does not go beyond the laboratory, which is why I built the technology probes (Chapters 4 and 5): "Further, the lab setting (however disguised) and rapid shift between multiple potential futures, risks breaking the suspension of disbelief, upon which the method partially relies [...] this is fieldwork for how-people-react-to- and-talk-about futures - rather than their experience of these futures." Compare this to Andersen and Wilde [10], one of the few studies besides this one to elicit concepts for wearables from (rather than with, as in [277]) users [34]. Even though the paper prototypes made by the users were never meant to be realized, the methods - listing a set of desires, and asking where in the body that desire was located - and then building and putting on the paper prototype - is an experience through embodiment, not just talk. The one paper prototype that is pictured, the "Mastication Amplifier" with plastic cups over the ears, probably even has some mechanical function.

[34] Jones et al. [138] used card methods to elicit concepts for wearables from users. They shared my goal of breaking the creative impasse, though the cards constrained the choices to a predefined set.

I would never have thought of that and cannot imagine why anyone would want it, but that is the wonder of letting the participants write the scripts from an open-ended brief.

Related work in participatory design fiction

A third characteristic of speculative enactments is that "Participants are 'in' on and co-construct the fiction" - there have been a number of studies of PDFi, giving the participants varying degrees of editorial control.

In 2015 Prost et al. [217] used PDFi to explore sustainable energy, asking participants to imagine the energy consumption habits of a family named Gruber in 2039. This is a very specific stipulation of scenario, set of characters, and time period.

In 2019 Candello et al. [46] used PDFis for a study of robot guides for museum tours. The design brief was specific: "AI robots to work as floor guides in a science museum". All 47 participants were museum guides, who were given the start of a fictional story and asked to write the end. Although the participants did contribute some writing, they were adding to partially prewritten stories, and the brief was narrower.

A personal favourite is [19] on urban planning with residents of an African-American neighbourhood in Los Angeles. The DF is a video tour of the community's own vision of their neighbourhood's future, and is the product of a group brainstorming process. Although the work was not about wearables, it did involve some workshops with rapid prototyping of wearables [17, p4] [19, p1]. Not much detail is provided about the wearables, but an example after my own heart is the high schooler who "imagined sneakers [...] that would notify the wearer - through vibrations - whenever their friends were having a nearby pop-up basketball game." [18, p292]

More recently in Afrofuturism, Bray and Harrington [36, p1793] used card methods for participatory speculation in Black and brown communities: "Participatory design is positioned as an approach to address community challenges and reimagine potential futures by decentralizing systems of power and centering the marginalized, moving away from designers as experts and framing design as being community-driven. Methods of speculative participatory design are useful in imagining futures among marginalized groups while negotiating existing societal constructs."

Comparison: participatory design fiction for medical devices

In 2018, Nägele et al. [195] worked with a medical device company to imagine product design 20-25 years into the future for patients with urinary tract infections. They emphasized how their PDFi process was rooted in the egalitarianism of participatory design: "Many well-meaning technology experts seek to 'solve' the 'problem of disability' through tech fixes by (re)making disabled bodies. The resulting technologies may conform well to medical needs, but they often neglect complex aesthetic and social needs of the individual. PDFi attends to this problematic by giving voice—first and foremost—to the individuals who need the medical devices."

Their participants had a similar amount of editorial control as mine. They sent their writing prompt to 12 women aged 23-33 from Europe, North America, and South America, giving them a timeframe of 2028-2043, and inviting them to write a "personal narrative,

diary entry, or describe an ordinary scene in which you are the narrator or main character in this future [...] Think SCIENCE FICTION and be creative!" As I did in my own study, they emphasized to their participants that they were not bound by reality and had full editorial control. They added a series of questions about the storyworld to help to guide the narratives, emphasizing that they were option. The design brief was of course specific to the purpose of the inquiry, but [195] made it as open as possible within that brief.

The participants in [195] were geographically dispersed, so participation was fully remote, and it is not clear whether there were any group meetings or with the researchers interacted 1-1 with them throughout. They were asked to supply their own materials for paper prototyping (Appendix H.5) but did not always do so. In-person group creativity was an important part of my own study, whereas it is not discussed in [195].

The researchers took the participants' narratives, categorized them into themes, and created a storyboard; then worked co-creatively with each participant and in workshops, followed up with (longer and more structured than mine) 1-1 interviews. Each of the 12 participants received a different fictional device made specially for them by the researchers.

The final stage of [195] was the "PDFi Showroom": "The facilitator completes the storyboard, verifying changes with the participant and develops conceptually resolved diegetic artefacts [...] A prologue is added to the narrative to give further context. The original narrative, the newly created storyboard, diegetic artefacts, and the participant's profile, along with values and design considerations uncovered in Part Three, are then presented to the initial design team."

It is difficult to determine the exact balance of participation described in RtD papers because even the most detailed account is condensed, and "human-data entanglements" are messy [68, p2133]; the divergent discussions at my early pilot workshops (Appendix H) were easy to capture as concept maps in designVUE [65] but the software became incompatible with age. The authors appear to have tried to balance the co-creation continuously, compared to my own study where participants held creative control throughout the inspiration phase and 1-1 interviews, after which I took most of the control at the point of developing the design proposals.

One participant in [195] wrote: "I would say that this is the first time I have ever been even asked about UTIs by anyone other than like my parents and my doctors, and I definitely think my story reflects how I really want there to be a focus on women's health problems in the future". The researchers concluded "By opening future visionary quests to people who are most impacted by those futures, researchers, designers, organizations and others with large influence over the future, can help in shaping preferable futures."

3.9 Conclusion

In this chapter I have contextualized the research contributions of this thesis to the wider community.

Sections 3.1 and 3.2 explained the methodological basis of the study as a whole: 3.1 explained the contribution and novelty of the study, and 3.2 explained my fundamental methodological choices. Section 3.3 related this study to the existing literature on privacy,

and explained how the software infrastructure supported or constrained privacy and affected design decisions (O1). Section 3.4 related this study to existing research on the IoT (O2, O3) and discussed missed opportunities and possibilities for future work. Section 3.5 positioned this study within the literature on participatory design of wearable technology (O4, O5); 3.6 provided a detailed comparison of this thesis with related research on aesthetics (O4, O5); 3.7 related the thesis to past and current work in design fiction and other fictional design methods, and identified the target audience for this study (O4, O5). Finally, in section 3.8, I compared this thesis to related work in participatory design fiction.

In the next chapter I will describe the user-centred design of the technology probe based on one of the participants' DFs.

Chapter 4

User-Centred Design of the Technology Probe

In the previous chapter I contextualized the research contributions of this thesis to the wider community. In this chapter I will describe the user-centred design of the technology probe based on one of the PDFis.

In order to get to the point of knowing what to make of the technology probe, I gathered a large amount of data between October 2017 and July 2018.

- In October 2017 I held four pilot studies (CFI1 and CFI2; Edinburgh Group 1 and Edinburgh Group 2) to test the format of the PDFi workshops and recruit participants. Details of the planning, execution and outcomes of the pilot studies can be found in Appendix H.
- In January 2018 I held the inaugural workshop of the longitudinal study at Cambridge Makespace. Details of the planning, execution and outcomes of the inaugural workshop can be found in Appendix I.
- A preliminary analysis of the PDFis from the pilot workshops can be found in Appendix J.
- In March 2018 I held a second workshop to finalize the PDFis, and in the first half of 2018 I conducted 1-1 interviews with the participants. This process and its outcomes are described in Appendix K.
- A preliminary analysis of the finalized PDFis can be found in Appendix L.
- An analysis of the full set of PDFis as design fiction can be found in Appendix M.

The PDFis themselves can be found in Appendices A through G.

In June 2018, after the second workshop and 1-1 interviews (Appendix K) I took the volunteers' finalized stories and worked out proposals for a real-world technology probe of each one.

Of course, it is not participatory design to take the participants' ideas and go off and design something without their input. If the volunteers had contributed any more, I

would have had to employ them, so ending the participatory phase, and switching to a user-centred design phase, was appropriate. Besides, the wearable technology needed to be substantially my own work.

As the maker, and an end user, at this point my opinions started to count in design decisions.

According to Hutchinson et al. [127], a technology probe balances "the social science goal of collecting data about the use of the technology in a real-world setting, the engineering goal of field testing the technology and the design goal of inspiring users (and designers) to think of new kinds of technology."

- To meet the first goal, the technology probe must be one that the volunteers would wear (O4, O5).
- To meet the second goal, Hutchinson et al. got their technology to collect usage data. For a HAT device, requiring volunteers to share data would undermine the third goal (O1), so I relied on self-reporting.
- The third goal being to get users thinking about the HAT and what kinds of data they would like to collect and combine (O2, O3).

A probe is not for future iteration, whereas a prototype is. I admit that, for the sake of time, I did plan the probe with future iteration in mind.

4.1 From design fictions to design proposals

The first task was to analyze each story to discern what the storyteller wanted, and what I could build to match that in spirit (O5). Besides my skills (section 1.9.2), another constraint was that the device must connect to the HAT (O2, O3, O4) via SSL (O1) (section 3.3) [1].

Accepting those constraints, I considered each story in turn. I will start with the Wish Spell Bottle, which is a good example of the thought process. I presented the proposed designs at the third workshop, after which the group voted on which one to build.

4.1.1 Thought process: Wish Spell Bottle

Ostensibly, it is no longer feasible to build a Wish Spell Bottle when no-one believes in sympathetic magic [2]; if we did, it would work as well as it did in the past. Supposing I could build a Wish Spell Bottle that worked by technology. What would it do? The original bottle protected the Shepherd Boy from aggression at home (Appendix H.7.8). Is the solution a wearable panic button? Such things exist, some of them quite stylish [3] and not all requiring the proximity of a smartphone [4] (O4). Such a safety-critical device would be outside the scope of this project, but would it be in spirit?

[1] *Wikipedia:* **HTTPS** https://en.wikipedia.org/wiki/HTTPS
[2] But we do. [228]
[3] *Invisawear:* https://www.invisawear.com
[4] *MyLifeline:* https://www.mylifeline.co.za

The Wish Spell Bottle is a Self-Protection device (Appendix J.3). The purpose of sympathetic magic is to exert control over aspects of the external world, using an object that represents those aspects of the world. A panic button would accomplish that by summoning help. But is pressing a button and summoning emergency services anything like what the Shepherd Boy experiences when he uses the Wish Spell Bottle? In sympathetic magic, "action taken on an object affects similar objects" [228, p703]. What the Shepherd Boy does is take an insect wing out of the bottle and wish for protection. A wing represents flight, freedom, escape; when the Shepherd Boy turns his ankle, the Hermit appears and shelters him under his cloak, takes him under his wing. This is comfort and companionship, which is why the Wish Spell Bottle is also classed as a comfort object: "a way of honouring intent, and collecting hope" as the author put it (O5).

Proposed design: Wish Spell Bottle

I considered taking a recordable voice module from a greeting card and placing it inside a bottle. But how to transmit the message to the HAT? I was building with Arduino components for ease of use, as I already had experience with the platform. An Adafruit FONA cellular Feather [5] might work with HTTPS redirect (O1, O3, O4), but is over two inches long, so the bottle would be too big. I kept the proposal, but with low confidence and low enthusiasm.

4.1.2 Proposed design: Hermit's Cloak

The Hermit carries supplies in his interior cloak pockets, secured by the buttons. His character is known for being well prepared and abundantly supplied for every situation.

Tsaknaki et al. [267, p4] made a disembodied button that can do an action on a computer or smartphone over Bluetooth, but that did not seem to fit this use case.

For a technological version, I proposed a tactical garment (realistically a handbag, but a reach target is a garment) [6] with an RFID [7] reader in range of each pocket. Every item of an everyday carry (EDC) would be labelled with an RFID tag, so the system would know what is in each pocket and alerts the wearer if something is missing (O4).

Even the realistic handbag version was a low-confidence, low-enthusiasm proposal. I wanted to use RFID tags for the Beautybox [205] and found them more difficult to work with than expected. A chunky microcontroller (O3) would be harder to fit into a garment than a bag, though I might have reduced the bulk with conductive fabrics.

4.1.3 Proposed design: Empathy-Out T-Shirt

The Empathy-In Glasses read another person's mood and tell you what it is. It is technically possible to attempt this [8], but it requires monitoring bystanders who cannot consent by definition, so is ruled out on ethical grounds (O1).

[5] *Adafruit:* Adafruit Feather 32u4 Fona - **Overview** https://learn.adafruit.com/adafruit-feather-32u4-fona/overview

[6] *Scott eVest:* **Women's Daphne Dress** https://tinyurl.com/yb477v5m

[7] *Wikipedia:* **Radio-frequency Identification** https://tinyurl.com/op2vs2y

[8] *Microsoft Azure:* **Face API** https://azure.microsoft.com/en-us/services/cognitive-services/face/

That left the Empathy-Out Gloves. Many electronic glove projects have been published, but I could not think of a way of making them reliably communicate mood to bystanders, and gloves pose problems with comfort and hand hygiene.

A generally understandable system might be an emoticon t-shirt [9], using a flexible LED sheet [10], to represent current mood (O4, O5). Reading the mood would require more sensors and take more time, but we could start with manual user input with a soft switch (O3).

4.1.4 Proposed design: Mr. X Artcodes Kimono

Animated figures move across the surface of the kimono that Mr. X inhabits when he goes on missions with Jacinda (O3). Imagine an Artcodes kimono (section 2.2.1) (O5). Layering colours allows you to multiply the content [261]. Scanning different images and colours could bring up different, predefined information searches, and the system could learn context awareness to improve relevance.

The nagging doubt is that, being passive, Artcodes have to be scanned through a smartphone app; the only way to use it is to pull out your phone. That gets dangerously close to making the kimono an accessory for the smartphone. If you displayed search results on an eInk panel, everyone would see them (O1).

4.1.5 Proposed design: Gallery Shirt

Warren devised a jacket that dynamically displays his own artwork, for a conversation piece to connect socially (O4, O5).

eInk shirts have been feasible for over a decade [11], and plausible-seeming commercial implementations surface from time to time (as do vapourware crowdfunded projects).

A problem is that eInk is very expensive. A colour display module costs thousands. Smaller, monochrome kits were available to start with, but some of the driving boards are very bulky.

4.1.6 Proposed design: eInk Visor of Visdom

Rachel describes going to sleep in the woodland and waking up to find that some moss has miraculously healed her.

Rachel has to wear a hat all the time. A visor could passively display the most important alerts from her Polar smartwatch (O3, O4), inside the brim in her sightline. It could learn context awareness to show her, or speak, the words she needed to say (O5).

This idea inches closer to mobile health, which is out of scope and raises the ethical bar. However, had the group voted for it, I would have found a way to make it.

[9] *Lumen Couture:* **LED Matrix LBD** http://www.lumencouture.com/buy-led-light-up-dresses/shop-led-matrix-black-dress/

[10] *Adafruit:* **Flexible 8x8 NeoPixel RGB LED Matrix** https://www.adafruit.com/product/2612

[11] *Instructables:* **World's First E-Ink Shirt (Ghetto Version)** https://www.instructables.com/id/Worlds-First-E-Ink-Shirt-Ghetto-Version/

4.1.7 Participant-suggested design: Visor of Verdant Vistas

At the third workshop, Ursula's interpretation was that a display of vital signs would give too many reminders of symptoms and illness. Ursula suggested an adapted Google Cardboard VR visor [12] to display idyllic scenes whenever you need ten minutes of escapism (O4, O5).

I suggested both to Rachel, who had not been at the workshop, and she preferred the Visor of Visdom. This was her explanation:

> "My device would actually work in the opposite way to how you described it; rather than a constant reminder of symptoms and illness, it would remove the need to think about it, because instead of having to check when heart rate is getting too high and need to rest, it would tell the wearer when that is happening [O3]. That way they can relax and get on with what they are doing without having to worry about whether they are overdoing things [O5]. I suppose, a bit like the latest devices for diabetics that constantly monitor blood sugar, so they don't have to stop and do a blood test. [...]
>
> "The idea of the forest is that a forest environment contains more oxygen and recent research has shown that trees reduce heart rate. So it is about lying down near trees and that physically reducing heart rate. Looking at screens, in contrast, strains the eyes and induces physical tension so the alternative idea of a visor with a pleasing image, while it would be distracting and might work in a psychologically relaxing way, wouldn't fit with my story."

4.1.8 Proposed design: Wooden Horse

The Wooden Horse is an intuition doll that tells a bullied boy what to say and do to get through a situation safely. A realization of this would be artificial intuition in a human-in-the-loop partnership (O3).

For now, this device could be in two parts, both of them in a wooden horse-shaped casing. One could be an ear cuff over an earbud, that speaks the right words into your ear (O4, O5). The pocket could have an eInk panel with context-appropriate words inside the top flap, so bystanders would not see (O4, O5).

4.1.9 Proposed design: Amelia-8's Positivity Patch

After discarding a number of inventions, Amelia invents the Positivity Patch, the Badge that Boosts your Mood (O4, O5).

This could be attempted as-is: a little eInk, LCD or TFT badge with context-awareness to show you the right image or slogan at the right time: say, you are stressed about to go into a meeting (contextualizing with location and calendar data) (O3).

[12] *Google VR:* **Cardboard** https://arvr.google.com/cardboard/

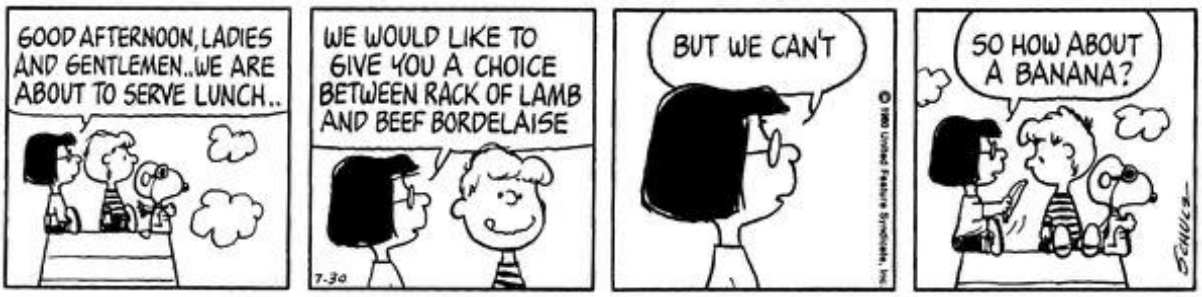

Figure 4.1: Peanuts *cartoon for managing volunteers' expectations of what they would receive.*

4.1.10 Proposed design: Mood Bracelet

This is a bracelet or ring with a simple three-colour display in red, blue or green, that detects your mood and gives you visual feedback about it (O4, O5). This could be attempted almost as-is with a pulse and/or motion sensor, some addressable LEDs and a 3D-printed bangle casing. Even if the mood sensing was inaccurate, the colour changes could refocus the wearer's attention on their mood and remind them to check in with themselves.

4.2 Voting

I held a third workshop at Makespace on Saturday 7 July 2018 where I presented all the proposals. Attending were Grace, Hunter, Serena, Warren and Ursula. I emailed descriptions of all 10 proposed designs to all participants and asked them to rank their preferences.

Grace, Hunter, Rachel, Serena, Warren, Ursula and I all voted. The Gallery Shirt was by far the most popular with six out of seven first-place rankings (O5). There was wide variance on all the other rankings, with the only majority being the Wish Spell Bottle, which had four votes for ninth place.

4.3 Setting expectations

I used a *Peanuts* cartoon [236] (Figure 4.1) to set expectations (O5):

1. *The roof of Snoopy's doghouse. Left to right: Marcie (as stewardess), Schroeder (as passenger) and Snoopy (as pilot).* MARCIE: Good afternoon, ladies and gentlemen. We are about to serve lunch...

2. *Left to right: Marcie, Schroeder.* MARCIE: We would like to give you a choice between rack of lamb and beef bordelaise *[SCHROEDER licks his lips.]*

3. *Centre: Marcie.* MARCIE: But we can't

4. *Left to right: Marcie, Schroeder, Snoopy.* MARCIE: So how about a banana? *[offers banana to Schroeder]*

Marcie wants to offer gourmet meals, but what she has is a single piece of fruit. The gap between aspiration and reality can be disappointing.

On the other hand, Marcie is an eight-year-old on the roof of a doghouse piloted by a sapient beagle dressed as a World War I flying ace. By focusing on the quality of in-flight catering, we may miss a larger point about the power of imagination.

4.4 Functionality and mechanical assembly

For the quickest implementation, I selected Adafruit's eInk breakout board and Feather M0 WiFi microcontroller to enable HTTPS requests to the HAT (O1, O3, O4). The eInk screen is laid on a rigid circuit board and is just over two inches square. The microcontroller measures 53.65mm x 23mm x 8mm. For power, a rechargeable Lithium Ion Polymer Battery at the recommended 3.7v 500mAh, sized 29mm x 36mm x 4.75mm, connected to an on/off switch large enough for the wearer to locate and operate without fiddling (Figure 4.4).

A two-inch square screen is large compared to most jewellery, but is appropriate for displaying artwork. The size would fit a necklace or badge, possibly a bracelet (O4).

I was naïve about how bulky the device would be once the wiring and casing were in place. Pins take up space, and just one millimetre of thickness makes a small device proportionately much larger. There was no way to connect the screen to the microcontroller without a wire assembly; I thought - wrongly - that I could fold the wires to hide the microcontroller behind the screen, possibly sandwiching a battery in between. There followed an odyssey of soldering and breaking connectors, laser-cutting and gluing and breaking box casings, and "saving time" by not persevering beyond a cursory attempt to rotate the image in Adafruit's sample code [13] so the wire connectors could be straight instead of at right angles.

Once the fragile wire connectors were in place, I found myself with an assembly that was much bigger than the sum of its parts. How to make visual sense of such a bulky device? There was precedent in the Tibetan Gau pendant [14], a prayer-box sometimes worn around the neck. There are contemporary jewellers making statement necklaces with large pendants [15], so that was an aesthetic on which I could base a design that would at least make visual sense. I settled on a large bib or collar style necklace, to which the eInk screen would be attached as a pendant, with the smaller microcontroller assembly below it.

I sandwiched the wired microcontroller between two rectangles of acrylic held together with chrome spacers (Figure 4.2). The sides would be exposed, but I had not managed to make box casings that could withstand removal and reinsertion of the microcontroller.

This worked, so I did the same thing with the frames (Figure 4.3).

Because the bent wire connectors threatened to show beyond the edges of the screens, I had to make the frames even wider to conceal them.

[13] *Adafruit:* Adafruit eInk Display Breakouts and FeatherWing - **Arduino Code** https://tinyurl.com/y7pteqox

[14] *Best Himalaya:* **Tibetan Ghau Pendant-Buddhist Prayer Box Nepal** https://www.besthimalaya.com/collections/tibetan-ghau

[15] *Caprilicious Jewellery:* **Statement Necklaces** https://tinyurl.com/yaobknnh

Figure 4.2: *Microcontroller in acrylic casing.*

I ordered a variety of bib necklaces. The only one of the neckpieces I made by hand was for *Wooden Horse*, because the ones I purchased kept breaking. I lashed each neckpiece to a suspension of cord, wire or ribbon. The frame and microcontroller hang off the suspension, which is the part that bears the weight. Each frame was attached to the suspension by wire or cord threaded under the top spacers. In turn, the microcontroller component was attached to the frame by wire threaded around the spacers.

I wrapped each battery in silicone baking paper so it would not be too hot against the skin, and hid it behind the neckpiece (the *Wooden Horse* battery was on the back of the frame). The on/off switch (Figure 4.4) was hidden in an easy-to-reach spot behind the neckpiece, with the red-and-black power wires run up from the top of the microcontroller through the inside of the frame sandwich, and then lashed to the back of the neckpiece out of sight.

The battery is recharged with the USB cable which I supplied with each necklace. The charging socket is open to the side of the microcontroller component.

When the power is on, the image changes about every three minutes. More frequent changes would damage the screen. The longest recommended time between image changes is 24 hours. When the power is off, the eInk display still shows the current image. Because the image blinks when it changes, there had to be an option to turn it off lest the blinking cause distraction.

1. Switch on with the on/off switch.
2. The necklace looks for the SD card (located behind the frame at the top), which the wearer should have preloaded with correctly formatted 24-bit bitmaps no larger

Figure 4.3: *Frame, with Adafruit test image on eInk screen.*

than 150x150 pixels. If the SD card is missing or not working, an X-pattern appears on the screen (Figure 4.5) and the process ends.

3. The necklace connects to a known WiFi network, or the wearer must connect it during an interval when it is available in provisioning mode (Figure 4.6). This availability is indicated by one of several patterns on the screen, which changes so as not to advertise the open access point to a malicious bystander. The necklace checks the connection, and tries to connect if necessary, before each of the remaining steps.

4. The necklace tries to get the time from an NTP server.

5. A gallery image displays.

Figure 4.4: *On/off switch.*

6. The necklace tries to send a record with the filename, “Hello World”, and the datetime to the wearer’s HAT.

7. The necklace tries to send any cached records to the HAT. Failed attempts remain in the cache file up to a capacity of six records, whereupon the cache is emptied and saved to an archive file.

8. After about three minutes, the next image displays.

9. Repeat until powered off.

I placed the images in a folder named ”gallery” on the SD card (Figures 4.7 and 4.8) and programmed the Feather to cycle through each bitmap file on the folder. The images sometimes displayed backwards and had to be flipped. Filenames containing more than eight characters, or special characters, would not display.

The first file is BLINKA.BMP (Figure 4.3), a cartoon snake, Adafruit’s test image. If it does not display correctly, the screen is malfunctioning.

I included my Artcode logo, but it is too small to scan (Figure 4.9). Simple line drawings display well (Figure 4.10).

Photographs need to be rendered a certain way to look good. Figures 4.11 and 4.12 show a portrait of a woman wearing a flower crown, rendered two different ways.

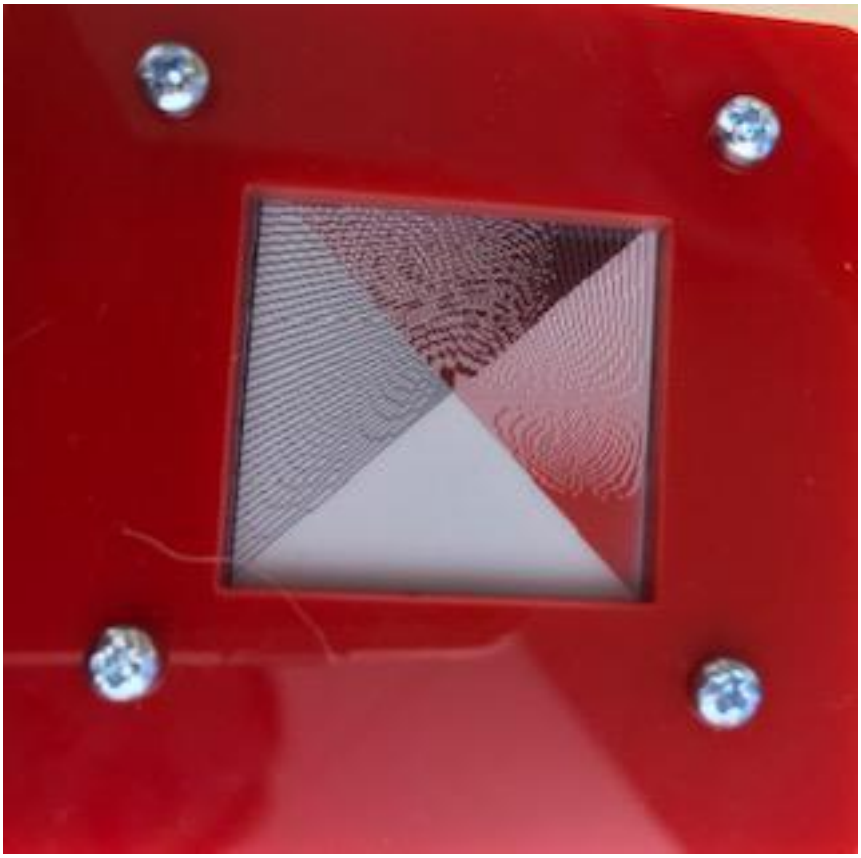

Figure 4.5: *Screen display when SD card is unavailable.*

There is no way to preview an image; the only test is to view it onscreen. This meant inserting and removing the SD card repeatedly, which wore out my cheap SD cards. I supplied better quality cards to the participants.

Converting an image to a 24-bit Microsoft bitmap is easily done in Microsoft Paint; Mac users must use Photoshop or a free image editor such as Gimp.

4.4.1 Hub-of-All-Things

After connecting to WiFi the Gallery Necklace tries to connect to the user's HAT (O1, O3, O4). Unlike other Adafruit microcontrollers I had used, it turned out that the Feather M0 WiFi cannot write to EEPROM, so there was no good option for storing the HAT login credentials except by editing the header files directly. Because the necklace is a headless device, most of the volunteers would need my in-person help if they needed to change their HAT password.

The dummy message, which the necklace tries to send to the HAT with every image change, contains the filename, datetime, and "Hello World":

{"data": {"eink": {"image": "BLINKA.BMP", "message": "Hello world!", "datetime": "2019-01-15T20:46:12+0000"}}}

The dummy record is a technology probe for the sole purpose of getting the wearer thinking about combining data in the HAT (O2, O3). There is no user-friendly way to

Figure 4.6: *Arduino login screen to join a new network. Along the top of the window, the words "Join wifi101-0DO8" (the name of the device). Top left, the Arduino logo. Below it, one box labelled "SSID:". Below that, one box labelled "PASSWORD:" Below the boxes, a button labelled "CONNECT". Under that, the caption "Please enter your WiFi network credentials. Then the board will attempt to connect to your WiFi network." At the centre bottom of the window, the label "wifi101". Bottom right, a button labelled "Cancel".*

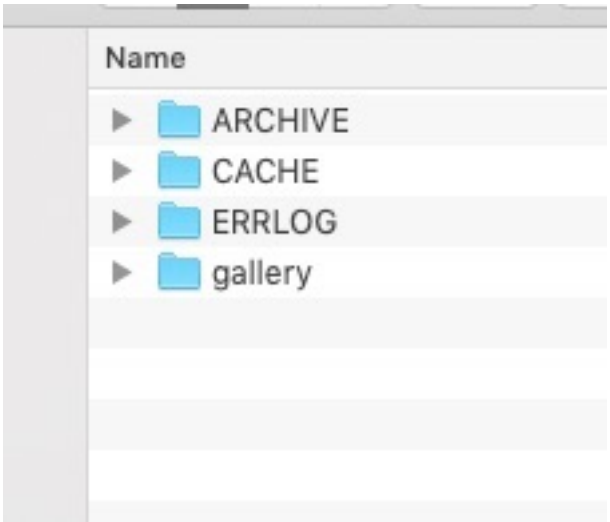

Figure 4.7: *File structure of the SD card. A folder named "ARCHIVE", one named "CACHE", one named "ERRLOG" and one named "gallery".*

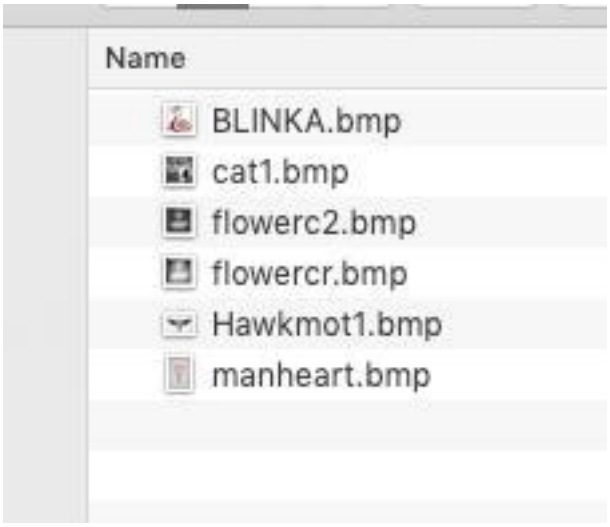

Figure 4.8: *Gallery folder with example images.*

Figure 4.9: *My personal logo, a hawkmoth Artcode by Liz Jeal.*

Figure 4.10: *A simple line drawing (public domain) which displays well.*

retrieve the records, but the volunteers did not need to see them at this stage (though I offered to write a utility on request). The disadvantage of not building a user interface to view records was that it would have made it easier for volunteers to think about ways of combining HAT data.

Hub-of-All Things data contextualization

In early 2019 the HAT could display the user's location history; display a weekly overview of digital activity; apply a sentiment tracker to social media data; post and display permanent or ephemeral, public or private text, image and social media notes with the Notables app; and plug in data from Google Calendar, Facebook, Fitbit, Spotify, Twitter and Instagram (O3). Application development was outside the scope of this study; at most I might have implemented some proof-of-concept functionality.

4.5 Necklaces

I personalized each necklace to its story and paper prototype (O5).

Figure 4.11: *Portrait photo of a woman in a flower crown (public domain).*

4.5.1 Grace's necklace

The *Wooden Horse* necklace (Figure 4.13) had to look like the orphan boy had made it himself out of forbidden materials. The frame and casing are lightly varnished wood panels. The engraving on the microcontroller component is taken from Muybridge's famous photography [16]. The neckpiece is braided hessian ribbon. On the back of the frame, out of sight, is a laser-cut wooden horse shape, affixed with magnetic tape (not strong enough to affect the electronics).

4.5.2 Hunter's necklace

Because Hunter's paper prototypes had been so colourful, and because she had worn a memorable red outfit to the most recent workshop, I made her necklace red, accenting it with braided ribbons inspired by Ukrainian traditional costume (Figure 4.14). The microcontroller casing is engraved with a Baltic folk pattern. The neckpiece is fabric appliqué on metal. I infer that this style was not generally liked, and Hunter never wore it.

Figure 4.12: *The same portrait, rendered differently.*

4.5.3 Rachel's necklace

For Rachel I selected a goldtone collar necklace engraved with a Celtic design (Figure 4.15). The casing was made of wood engraved with another Celtic design. I bought doll's house climbing roses and moss for embellishments. However, I could not make the assembly hold together and at the last minute substituted the one I had been making for myself (Figure 4.16), which had a neckpiece of braided strands of silvertone rocaille beads, a silvertone mirrored frame, and a microcontroller casing engraved with a floral pattern.

4.5.4 Serena's necklace

Based on Serena's illustrations, I searched for a goldtone neckpiece with coloured glass or translucent material. Her casing was yellow acrylic with no engraving. I do not have a photo of the completed assembly, but it is affixed to the neckpiece in the seller's photo of the set in Figure 4.17.

4.5.5 Trudy's necklace

Because of the rainbow/spectrum symbolism embedded in Trudy's story, I looked for a rainbow neckpiece for her, but could not find a suitable one. I settled for a braided red

[16] *Wikipedia:* **Eadweard Muybridge** https://tinyurl.com/zbs9tc2

Figure 4.13: *Grace's* Wooden Horse *necklace.*

Figure 4.14: *Hunter's Gallery Necklace.*

bead neckpiece to rhyme with the waves of Trudy's hair (Figure 4.18).

When I did not hear from Trudy I reallocated her necklace to myself.

4.5.6 Ursula's necklace

For Jacinda's steampunk spacefaring, I found an astronautical collar neckpiece (Figure 4.19). In choosing the engraving, I looked at the illustrations in one of Ursula's books for inspiration. The engraving is an illustration from an old astronomy text.

The construction felt flimsy because the electronic assembly was suspended from a single wire stretched taut across the back of the neckpiece. It was secure, but felt like it was hanging by a thread.

4.5.7 Warren's lanyard

In section 1.1.1 I was critical of the "normcore" aesthetic of mass market wearables. Cifor and Garcia [51, p15:1] wrote "The intentional design of fitness trackers as genderless or universal is predicated on masculinist design values and assumptions that do not result in 'neutral' devices and systems."

Whatever the shortcomings of my Gallery Necklace designs, they could not be accused of conforming to masculinist design values. However, when designing the device for the

Figure 4.15: *Failed version of Rachel's Gallery Necklace.*

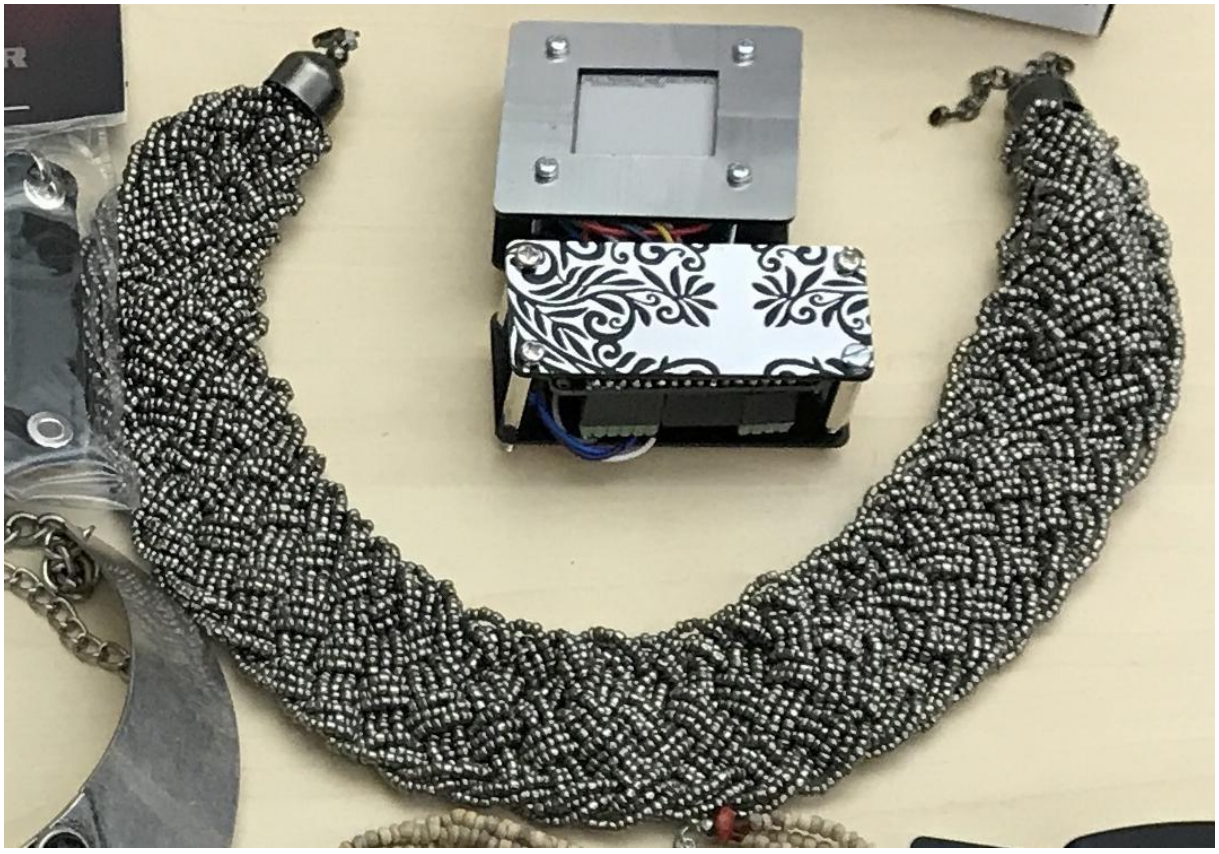

Figure 4.16: *Progress picture of my Gallery Necklace, which I reissued to Rachel.*

Figure 4.17: *Seller's photo of the necklace set, with bracelet and earrings, that I used for Serena's Gallery Necklace.*

one man in the group - the group member who came up with the concept the Gallery Necklace was based on - I had to stop and think about how to do it differently.

I did not want to make Warren's assembly (Figure 4.20) too flamboyant, for two reasons. First, it might get hostile reactions from other men. Second, his paper prototypes confirmed his minimalist style of dressing.

Instead of a necklace, I used a badge lanyard (Figure 5.1). The frame was black acrylic and the microcontroller casing was unengraved silver acrylic. During a hallway test (section 5.1.7), a male colleague suggested I make the cord length adjustable because an issue men have with badge lanyards is that they draw attention to the genitals. . . .

Figure 4.18: *Trudy's necklace, reallocated to me.*

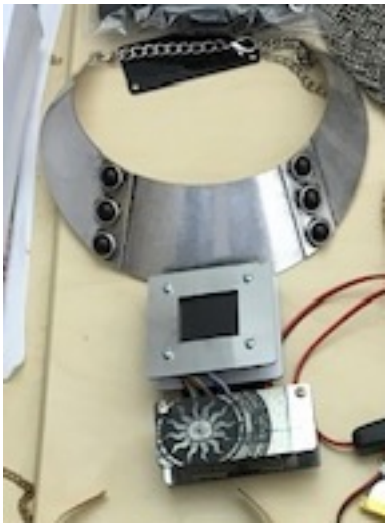

Figure 4.19: *Ursula's necklace, with the black suspension wire running along the inside edge of each beaded decorative plate. The wire is stretched taut across the inside of the neckpiece, as a straight line between the two beaded plates.*

4.6 Fourth workshop: releasing the technology probes

On 4 January 2019 I met Ursula at the Computer Laboratory to give her her necklace and connect it to her HAT (O1, O2, O3, O4). On 11 January 2019 I had a meeting with Grace, Hunter, Rachel, Serena and Warren at the Computer Laboratory. They had no prior knowledge of the form or function of the devices they would receive.

Grace's and Hunter's neckpieces kept breaking and I was not able to complete them before the second meeting. I delivered them to Grace's home on 29 January 2019.

I had explained the core concepts of the HAT throughout the project, but sent some explanatory links and privacy policies ahead of these meetings. The participants were thorough about reading and understanding such a large amount of documentation, which many people would have glossed over.

4.6.1 Ursula

Ursula's reaction, on unboxing, was an immediate "wow!" (O5). I connected her necklace to her HAT (O3, O4) and walked her through the documentation.

4.6.2 Grace, Hunter, Rachel, Serena and Warren

I set up three necklaces (O4) and five HAT accounts (O3, O4), walking everyone through the documentation.

At the suggestion of Dr. Andrew Rice, before the big reveal I conducted a tiny experiment. I went to my office to fetch the boxes and came back wearing a transparent badge-holder around my neck, with some magazine pictures inside, which I shuffled to simulate a gallery effect. "What would you think if I said I was going to give you something like this?"

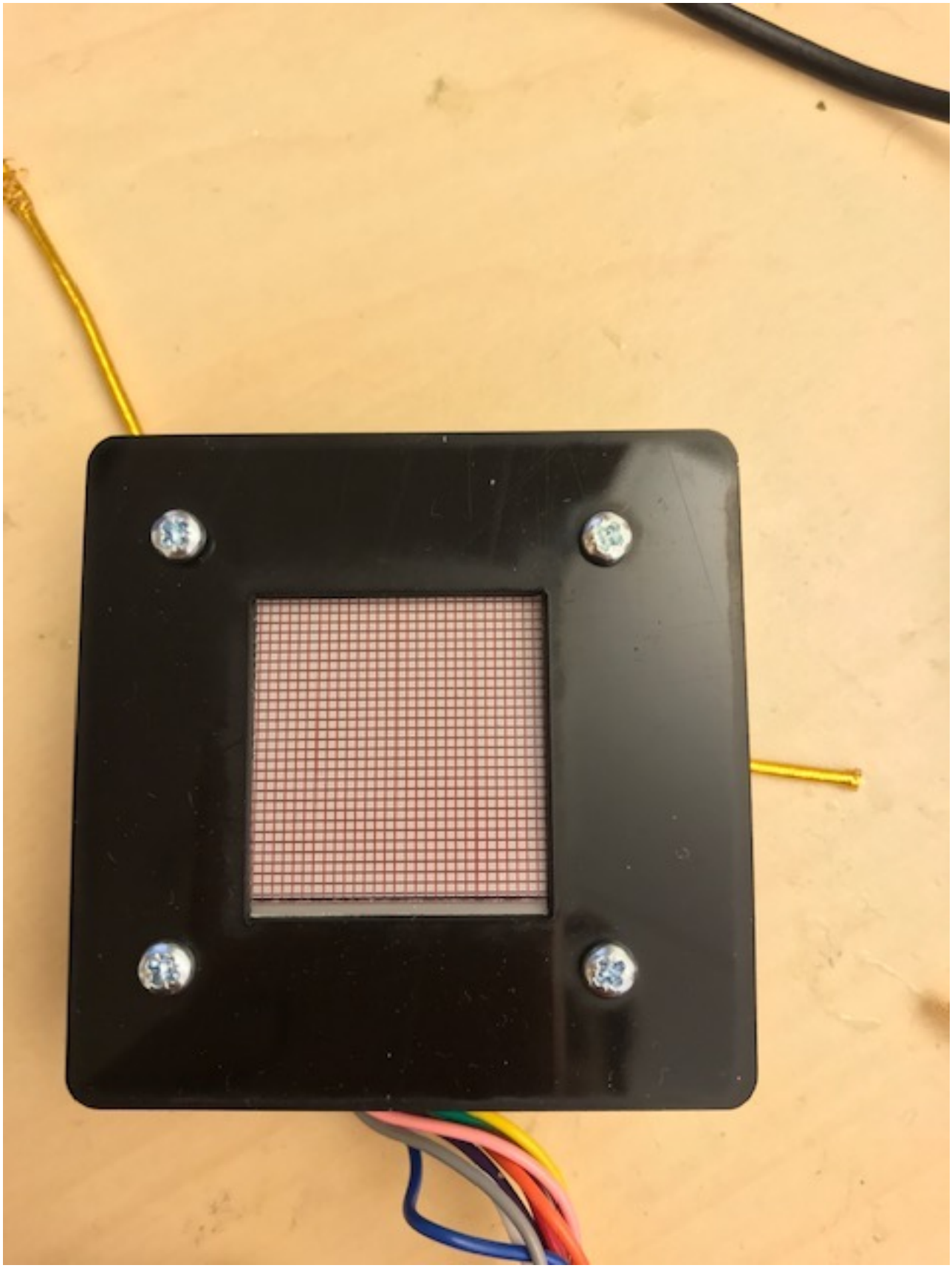

Figure 4.20: *Progress photo of Warren's lanyard. The full assembly is shown in Figures 5.1 and 5.2.*

There was a politely dubious silence. Finally, Warren replied, "I would think you were a business software salesperson."

Next, I presented a smartphone hanging from my neck, and scrolled through the photo gallery. "And what would you think if I said I was giving you this?"

After a pause, Serena politely replied that she felt it would be rather basic.

At that point I unboxed the necklaces, and the real festivities began. For all their flaws, the Gallery Necklaces were much more enthusiastically received than their low-fidelity alternatives.

4.6.3 Usability

Whereas the functionality of a technology probe should be "easily accessible", usability is not a primary concern [127]. I made the Gallery Necklaces to be easy to use after setup (O4), but setup was a manual process requiring some explanation. The final user guide ran to 48 pages, with an explanation of each aspect of the Gallery Necklace's setup and functionality that assumed no prior technical knowledge. I circulated the completed user guide on 16 January 2019.

4.7 Conclusion

In this chapter I have described the user-centred design of the technology probe, the Gallery Necklace, based on Warren's DF, *Gallery Jacket*. After explaining the nature and goals of the technology probe, in section 4.1 I described each proposed design and the thought process behind it; in section 4.2 I described the vote, at the third workshop, for which design to build; in section 4.3 I described how I set the users' expectations; in section 4.4 I described the functionality and mechanical assembly of the probe; in section 4.5 I described the personalization of each technology probe; and in section 4.6, the release of the probes at the fourth workshop.

In the next chapter I will describe the in-the-wild study.

Chapter 5

Into the Wild

In the previous chapter I described the user-centred design of the technology probe, the Gallery Necklace (O4), based on one of the PDFis (Appendices E.7 and I.3.7).

In this chapter I will describe the in-the-wild study, which ran from 4 January 2019 to 3 January 2020. I report on each participant's (including my own) usage of, and response to, the Gallery Necklace (section 5.1); the participants' feedback from an "I Like/I Wish/What If?" prompt (section 5.2); a possible upgrade and the participants' responses to it (section 5.3); the improved Positivity Patch/Gallery Badge hybrid prototype (section 5.4.1) and efforts to move forward with a full-colour, interactive Positivity Patch/Gallery Badge with privacy-preserved federated sentiment analysis (section 5.4.2); and participants' further thoughts about upgrades, changes and HAT contextualization (section 5.5).

I had planned for a lot of interaction with users during the in-the-wild phase, including 1-1 interviews, in-person observation and Rapid Iterative Testing and Evaluation (RITE) [181]. This was to be interleaved with a lightweight adaptation of user experience reporting and diary studies, kept infrequent so as not to burden the volunteers.

I did less of this than planned, for several reasons. First, four out of six volunteers were coping with unusually high workload. Second, the necklace is obviously not "normcore" and not expected to be worn with every outfit [153], so there would be fewer naturally-arising occasions for me to observe it without obtruding. Third, no RITE testing was needed because the necklaces worked correctly and did not need any troubleshooting.

The setup process, which in theory does not count at the technology probe stage, did cause some problems for Grace, who needed a home visit. Grace had a lot of anxiety about needing help with the setup, so much so that she was tempted to drop out. On the other hand, "nontechnical" Grace mastered image formatting within seconds.

As a visual artist, Grace had no shortage of material for her gallery. Serena, a costume designer, could not find time to create one. I offered technical help, but preparing the images was not the problem - selecting them was. "It's just finding time to find the pics I want. [...] At this rate I'm just going to have pictures of my cat if I can't get anything else sorted soon!" If the Internet is for cat pictures, surely the Internet of wearable Things should also be for cat pictures.

5.1 Usage

5.1.1 Grace

On 27 March 2019, Grace wrote:

> "I have now used the wearable at [university venue]. Also at my own home and in my friend's home and at [local] college. Data is downloaded to the HAT too [O1, O3]. The device was on for half an hour for three of the occasions and an hour for one occasion."

Grace was using her necklace for professional and personal networking, and was giving a lot of thought to which occasions were or were not appropriate (O5). In the summer, Grace said she wanted to pause her participation until at least September, because she had been wearing the necklace at professional gatherings, and now her career was accelerating dramatically. At high-stakes events, she did not want to take sartorial risks or split her attention.

5.1.2 Hunter

Hunter did not like her necklace and seemingly never wore it (O5). She does not wear necklaces and would have preferred a badge.

5.1.3 Rachel

On 14 January 2019, Rachel wrote: "I think all the devices look amazing, and am looking forward to getting my head wrapped round it all." On 22 February Rachel sent live text messages from a public lecture she was attending: "necklace has garnered some interesting glances, I'm expecting questions later on!" (O5)

I asked Rachel if it was comfortable. "Yes it's OK maybe but heavy, but my neck is stiff anyway." The acrylic version was a few grams heavier than the light plywood version Grace had.

"The necklace looks good and is comfortable worn outside clothing. Not sure it would be next to skin, but I have very sensitive skin and it could be mounted on a soft fabric, for example. [...] that was more an observation than a request for action, it's fine and liveable with [...] very fine weave microfibre viscose, like lens cleaners are made from, prewashed to remove chemicals, might be safest? [...]"

5.1.4 Serena

By 27 August 2019 Serena still had not had an occasion to wear her necklace: "I'm afraid I'm working 6 day weeks [...] No point wearing an exciting necklace on [worksite] :-(" By 31 December: "I'm afraid I've been very poor at wearing my necklace. Partly due to work commitments and partly the size/comfort of the item".

On 3 January 2020 I conducted a 1-1 interview with Serena (section 5.3.1). Besides the flamboyant style and the setup, Serena found that the wire caught on her hair at the back. She does not usually wear necklaces that large.

I asked if she would have worn a smaller necklace with preloaded images. She said she would have worn it, and worn it at work interacting with many other professionals (O4). This is significant, knowing that behind-the-scenes workers in Serena's industry usually dress very plainly.

Serena said that despite her necklace's not working out, creating wearable technology was a process she found fascinating, with its multiple and various considerations. In her experience a wearable device is really difficult to build unless it is incredibly simple: for example, with a powered patch, they had to find a reasonable way to hide the power supply elsewhere on the costume.

I emphasized that I had never expected Serena to wear such a flamboyant necklace continuously, only from time to time. "Yes, that's probably more realistic, you would wear it for special occasions. I've made light-up things for festivals etc. I wouldn't wear things to work because that would be odd. It's nice to have someone come and talk to you about what you're wearing. Making interactions with other people more likely [O5]."

I asked why, if she would not wear light-up things to work, she would wear a version of the Gallery Necklace. She replied that she does not habitually wear necklaces, but it would be interesting as a bracelet. We went on to discuss further development (section 5.5.2).

5.1.5 Warren

Warren wore his lanyard straight out of the box and on several occasions, never with the same group of people so as not to repeat himself. Warren reported no difficulty with setup and said the lanyard had functioned basically as he had hoped in social settings (O5). On 21 February 2019, he wrote: "[The lanyard] has worked fine the times I have used it so far, done what it needs to so far [...] Photos were lovely and easy [to upload]."

On 31 August 2019 I held a 1-1 interview with Warren. He showed how he had been wearing the lanyard over one shoulder rather than hanging from the front, which kept its position more stable (O4). He fitted it over his camera bag so it was like one unit (Figures 5.1 and 5.2).

When he travels he has a jacket and it just goes neatly under the jacket, untroubled by rain. Once he arrives at a meeting, he can take the bag off and prop it up so it is still on display, but is not distracting him by being on the body.

Whether or not he would repeat himself with the same audience, depends on the audience. He goes to one group every two weeks, then a different one, so repetition is not always an issue.

5.1.6 Ursula

On 3 January 2020, I conducted a 1-1 interview with Ursula (section 5.5.3).

RESEARCHER: So the implementation I gave you was quite fragile and clumsy...

Figure 5.1: *How Warren wears his lanyard, front view. Note how the connecting wires are visible from an angle.*

Figure 5.2: *Side view of Warren's lanyard fitted over his bag.*

URSULA: I haven't worn it again but I've taken it out and looked at it [O5]. But not worn it [O4].

RESEARCHER: Is it too flamboyant or just too fragile?

URSULA: It's a little too flamboyant for everyday use but I liked wearing it as a statement piece. It had good style [O4, O5].

5.1.7 Ethics become aesthetics

Like Serena, I confronted the problem of what to put in the gallery when I had no art of my own. The best occasion was an upcoming fan event, so fanart seemed the best choice. Plain line art worked well on the screen. The creator of the Cannimal Sanctuary comics [1], featuring Hannibal [98] characters as cartoon animals, granted permission to use her artwork (Figures 4.18 and 5.3).

The HAT is a personal data store that I felt confident about the ethics of asking participants to use (O1, O3). They own the data in their HAT; they get to choose who, if anyone, sees the data. The aesthetics of the piece affect how participants will wear it, whether they wear it at all, and are inseparable from the entire way we think about the eventual product and its function, including what data it generates and for what purpose.

Rationally, there is no reason for me to feel negatively about the Gallery Necklace; it is a good basis for an experiment. As a human, I am not always rational; but I can appreciate a polite fiction. I will use Kelly and Gilbert's [141] WEAR scale to present my own experience of wearing the Gallery Necklace with a figleaf of "modern objectivity" [278, p3] (Tables 5.1 and 5.2).

[1] *Hannipenguin Comic:* **Cannimal Sanctuary Full Cast!**
https://hannipenguin.tumblr.com/post/175163095375/cannimal-sanctuary-full-cast-from-left-to-right

Table 5.1: WEAR Scale Factor 1: Fulfillment of aspirational desires

Q	A
I like what this device communicates about its wearer.	I feel like the fool character in a discomfort comedy sketch.
I could imagine aspiring to be like the wearer of such a device.	I am the wearer. I feel intense shame.
This device is consistent with my self-image.	I can't deny that.
The wearer of this device would get a positive reaction from others.	See the subsection of 5.1.7 on **hallway testing**.
I like how this device shows membership to a certain social group.	Yes. See the subsection of 5.1.7 on the **first outing**.
This device seems to be useful and easy to use.	It is not utilitarian. It is very easy to use.
This device could help people.	Apparently it has (Tables 5.3 and 5.5).

Table 5.2: WEAR Scale Factor 2: Absence of social fears

Q	A
This device could allow its wearer to take advantage of people.	No.
Use of this device raises privacy issues.	No.
The wearer of this device could be considered rude.	Not in this setting (see the subsection of 5.1.7 on the **first outing**).
Wearing this device could be considered inappropriate.	Not in this setting.
People would not be offended by the wearing of this device.	Not with these pictures and not in this setting.
This device would be distracting when driving.	It is too fragile to wear while driving.

Hallway testing

For a wearable device, the responses of bystanders constitute indispensable feedback (O5). The difficulty is getting an honest opinion.

Only once (at a conference, between sessions) did I ever receive an overtly negative remark, of the kind that poses as refreshing honesty and therefore cannot be taken at face value. The worst feedback I was realistically likely to get was polite dubiousness. I wanted the necklace to make a good first impression, and polite dubiousness indicates the opposite of that.

I did some hallway tests at the University of Cambridge Computer Laboratory and the Alan Turing Institute, and polite dubiousness was the trend.

First outing: fan event

Before the fan event on 5 February 2019, I did not publicize the necklace because I wanted gut reactions (O5).

I previewed the device to "Alice", a friend, but a perfectionist in matters of appearance. Alice understood the style of necklace at first glance, immediately pulling up photos of similar styles by her favourite designer. She was critical of the quality of the assembly: the frame opening is off-centre, the bottom piece is not properly aligned with the frame, and she disapproved of the off-centre engraving on the microcontroller faceplate. Despite the flaws, she gave the necklace a 78% score and encouraged me to proceed with my field test.

Putting the necklace on, I expected it to be painfully heavy; it was just right. I expected the wiring under the neckpiece to feel scratchy; it did not. Once powered on, the necklace worked without a hitch (O4).

I wore the necklace for 90 minutes. It blended well with the right outfit (Figure 5.3).

Because of the timing of activities during that interval, I spoke to only one person. They immediately recognized the artwork, and also immediately saw the connection between the necklace and the moth dress (section 2.2.1).

I texted photos to "Betty", an artist and special needs teacher. She had a philosophical difference about the execution of the necklace. Her first reaction was "intrigued". Betty said:

> "I sell stuff made by obviously limited skilled kids to teachers who [...] nitpick. 78% probably translates to 95% in the world of 'well it's handmade so that's a feature not a fault'. Some people think hand stuff should look like a machine made it. They've lost the point."

Betty's point is relevant to the intersection of PDFi and maker culture. Her final evaluation was "It looks good [...] I'd wear it... an art piece."

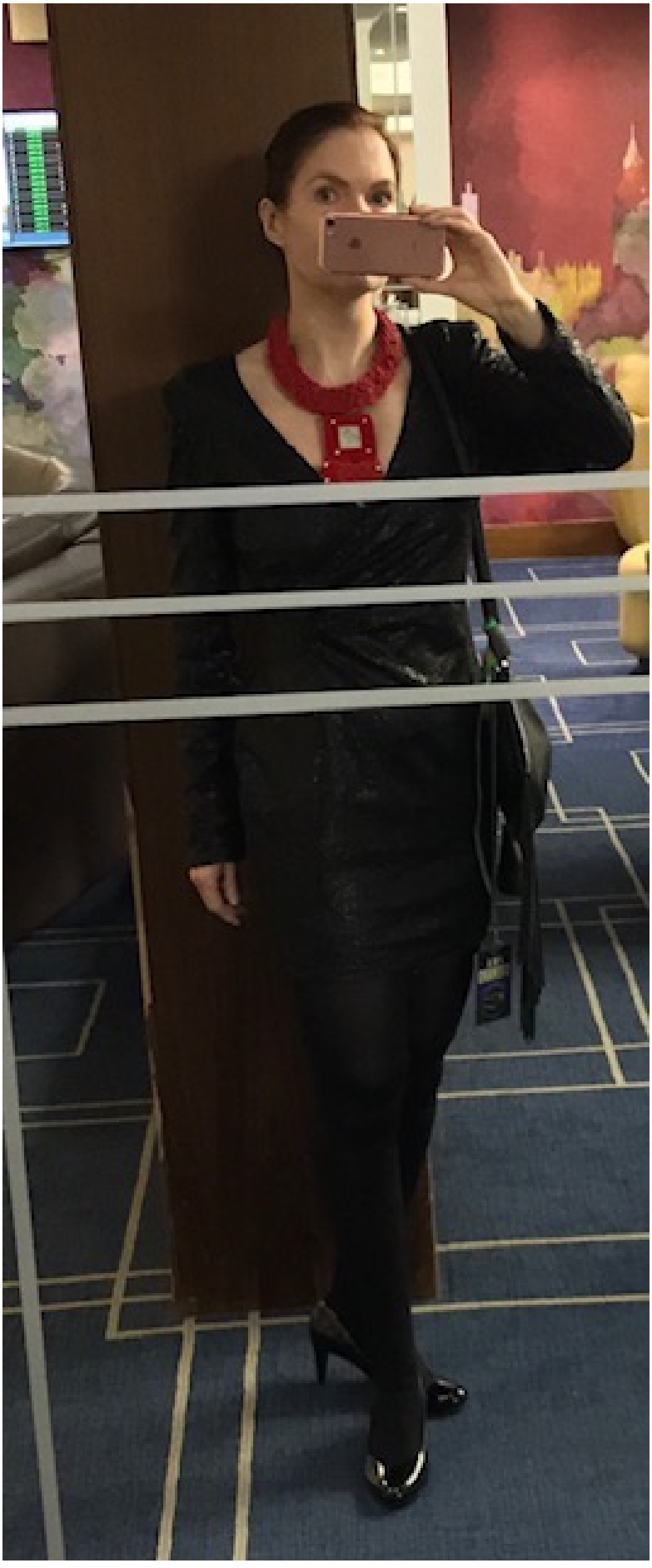

Figure 5.3: *Full-length outfit incorporating Gallery Necklace.*

Second outing: poster presentation

On 9 March 2019 I wore the necklace for a poster presentation at the Oxbridge Women in Computer Science Conference. The poster was well frequented and the necklace well received. One attendee said she would definitely wear it if the microcontroller were smaller. Another said that both Hunter's necklace (on the poster) and mine were "very beautiful" (O5).

Third outing: WearSys 2019

Nevertheless I felt that Grace's necklace was a better example, and borrowed it for several conferences, including WearSys 2019 [208], where the study received the blessing of the father of modern wearable computing Steve Mann [172], who also asked the question about assistive technology (section 1.9.1).

5.2 I like, I wish, What if?

On 8 February 2019, I requested feedback using an emailed "I like/I wish/What if?" prompt [2] (O5). Only Rachel did not respond; I have incorporated her feedback from section 5.1.3.

Now that I have my Gallery Necklace,

1. I like (Table 5.3):
2. I wish (Tables 5.5 and 5.6):
3. What if? (Table 5.7)

5.2.1 I Like

Although Hunter and Serena did not like the implementation of their necklaces (Table 5.4), their enthusiasm remained high and they were still committed to the idea.

Because the Gallery Necklace was supposed to satisfy the need for telepathy [226, pp. 85-99], it was good news that it worked as it should according to Warren's story, and that all four of those who wore it in public said it was a good conversation piece (O4, O5).

Dislikes

Although four volunteers wore their necklaces and liked many things about them, for Hunter and Serena the execution missed the mark. I left off a fabric backing because I anticipated having to adjust the wiring, but Grace and Rachel found their neckpieces scratchy.

[2] *Ideo:* **Build Your Creative Confidence: I Like, I Wish** https://www.ideo.com/blog/build-your-creative-confidence-i-like-i-wish

Table 5.3: Likes

Theme	Name	Remarks
Impressiveness	Grace	I like that I can show it off. (O5)
Attracts Attention	Grace	It looks really intriguing and people are interested in your necklace so it draws attention to what I am doing. (O5)
	Rachel	necklace has garnered some interesting glances (O5)
Networking	Grace	I like that I have an excuse to talk about my paintings to strangers. (O5)
	Warren	makes a great talking point/ marketing point for networking. (O5)
Comfort	Grace	The necklace was comfortable and not too heavy which I like.
	Rachel	comfortable worn outside clothing
Gallery	Grace	I like that the paintings are cropped to a square. I like the simplified images.
	Warren	simple design, have found adding new photos easy and a statement (O5)
Concept	Hunter	I like the idea of it.
	Serena	I like the overall concept, it's brilliant.
Conversation Piece	Grace	I like that I have an excuse to talk about my paintings to strangers. (O5)
	Rachel	I'm expecting questions later on! (O5)
	Ursula	I like the conversations I've had with people while wearing the necklace, it's been an interesting ice-breaker. (O5)
	Warren	makes a great talking point/ marketing point for networking. (O5)
Appearance	Rachel	The necklace looks good (O5)

Table 5.4: Dislikes

Theme	Name	Remarks
Discomfort	Grace	the scratchy feeling of the string
	Rachel	Not sure it would be [comfortable] next to skin
	Serena	size/comfort of the item
Execution	Hunter	[...] but [I] am not convinced by the practicality of it.
Weight	Rachel	OK maybe but heavy

5.2.2 I Wish

Most of the participants' expressed wishes - easier setup and image upload, control of the timing, an image library - would be provided by an application with a user interface, which would be part of the development process towards a viable product.

It is encouraging that all the wishes were for a more mature product and/or different styling; nobody was wishing for an entirely different device or functionality (O4).

Table 5.5: Wishes

Theme	Name	Remarks
Timing	Grace	I wish I could control how long the images could come up for (pause for). I wish they came up quicker. It searched for the next picture for ages (about 10 minutes) [*Author's note: probably trying to connect to a network*] As a result not all of my pictures were shown to the other artists as we ran out of time.
	Warren	I wish there was a simple GUI on a computer/phone to change speed of change, without the use of any WiFi.
Mobility	Grace	I wish I could wear it when riding my bike.
Setup	Grace	I wish that it had been easier to set up.
	Hunter	I'd like it if it came with an app so I could perhaps create my own slogans and images easily and quickly to go on it (maybe the possibility to take a pic on my phone or create a slogan or QR code on my phone and then somehow scan it to the device instead of having to go to a laptop and change the image size or use Photoshop etc and add it to the memory card etc. For example I'd love to have some slogans on there, feminist things like 'Girls just wanna have FUNdamental human rights', picture of Rosie the Riveter etc. Right now I'd love to work out how to get a picture of the European flag with the stars on to show solidarity with Europe but I'm afraid I'm not technically proficient enough to work that out quickly.
	Warren	I wish there was a simple GUI on a computer/phone to upload pictures

5.2.3 What if?

Besides colour, software support, and suggestions for sturdier or more comfortable construction, there were some new suggestions. Grace wanted animations and annotations, and Serena wanted a modular microcontroller unit compatible with multiple display components with different form factors (O4).

Table 5.6: Wishes, cont'd

Theme	Name	Remarks
Size	Hunter	A smaller entire device (not the screen, just the rest of it) would be useful
	Serena	I wish that maybe it was smaller.
	Ursula	I wish the screen were larger [...] and the necklace smaller
Weight	Ursula	[I wish the necklace were] lighter.
Form Factor	Hunter	I'd personally prefer it if this could be worn as a badge and not a necklace as I very rarely wear necklaces anyway and do not feel confident enough to wear this in public most of the time.
Colour	Hunter	I wish it had more display colours.
	Ursula	I wish the screen were [...] in colour
Appearance	Serena	It's a serious statement piece that only goes with certain outfits!

Table 5.7: What If?

Theme	Name	Remarks
Colour	Grace	What if the images were in more colours?
Animation	Grace	What if I could download a moving image [O3].
Annotation	Grace	What if we could put text over the images like the name of the painting? The year it was painted? [O3]
Setup	Hunter	What if there was an app so you could quickly and easily add standard images (ready made) and slogans to the device instead of having to create your own. (I know most people wanted to add their own but as a busy mum of three it might be nice to have say fifty ready-made images or cheerful slogans "Have a nice day!" to choose from so you can add to your device in a more easy way...
	Warren	What if this could be attached in a format to "patch" this.
Modularity	Serena	What if you could have a bottom unit that was self contained and could be moved to different necklaces, or worn on my bag, or as a brooch? [O3]
Construction	Rachel	What if it were mounted on a soft fabric like very fine microfibre viscose?
	Ursula	What if the necklace was a sturdier vac-formed or 3D printed shape - more like a solid collar?

5.3 Upgrade possibilities

On 26 March 2019 I circulated an update in light of a discussion with Phillip Stanley-Marbell [250] about the Lax Warp miniature low mass sensor system. Adafruit's components are designed for ease of use, so are much larger than technically necessary. The finished Lax sensor weighs 0.62g, including two AgO batteries, with debug and expansion provided by a miniature expansion connector. The hardware with integrated battery holder is 15mm wide, compared to 53.65mm for the Adafruit Feather M0 WiFi. One unit can incorporate an environmental sensor for temperature, humidity, pressure, and carbon monoxide/volatile organic compounds (CO/VOCs).

A disadvantage is that the sensor uses Bluetooth Low Energy [3], which has doubtful security (O1) and a range so short it would have to be paired with a smartphone app (O4) or replaced with a WiFi antenna (O3). Besides this, I would have to port the code to C and re-pin the Adafruit breakout to fit, which would probably take too long.

The question of whether the participants would like to a) swap the microcontroller for this smaller component and/or b) add one of the available sensors was worth asking, even as a hypothetical. The choice was any one of the following (O2):

- temperature
- humidity
- atmospheric pressure/equivalent to elevation
- acceleration
- angular rotation
- magnetic flux density/compass direction
- ambient light intensity and ambient light colour
- air quality

5.3.1 Responses

Grace: "No thanks to suggestions to change it [...]. No need. I don't need any of those extra applications. Not for my wearable." (O4, O5)

Hunter: "Off the top of my head, I don't need it to do any of those extras you've listed, (and honestly can't see why any of them would be useful for us, but perhaps that's just me)." (O4)

Serena: "1.a) yes, in a perfect world the necklace would have a smaller bottom unit.

"b) I would initially have said that the extra feature I'd like most would be a compass, however, waking up each morning coughing from travelling around in London makes me think an air quality sensor would be good. Either of those..." (O2, O3, O4)

[3] *Wikipedia:* **Bluetooth Low Energy** https://tinyurl.com/y8v8zaqa

Figure 5.4: *Base unit of the Positivity Patch, using Adafruit's quote display tutorial.*

At our interview on 3 January 2020, Serena affirmed her strong interest in the air quality sensor. I asked Serena how she would like to combine HAT contextualization with the data. "Well with an air quality sensor and Google Maps I would know where definite trigger points for me are."

Ursula: "I would choose a compass personally, I enjoy knowing my direction." (O2, O4, O5)

Warren: "1.a) sensor: wouldn't want that at this stage

"b) given the options if I were expected to, acceleration - although would have a preference to sound detection (dB sensor)" (O2, O4)

5.4 Positivity Patch and further development

5.4.1 Prototype development: eInk badge

In August 2019 I discovered that Adafruit had released a FeatherWing version of the eInk screen: https://www.adafruit.com/product/4128. A FeatherWing pins directly into a Feather microcontroller, eliminating the wire connector assembly that made the technology probe so fragile and bulky (O4).

I implemented a test setup from Adafruit's quote display tutorial [4] and started work on connecting it to the Notables HAT app so that users could enter their own quotes as a Positivity Patch proof of concept (Figure 5.4) (O2, O3, O4, O5).

Unfortunately I waited too long to get back to it, and development was definitively halted by the COVID-19 pandemic shutdown. Using shorter connecting pins and a smaller

[4] *Adafruit:* ePaper FeatherWing Quote Display - **Overview** https://learn.adafruit.com/epaper-display-featherwing-quote-display

battery, I was on my way to developing the much-requested smaller unit for at least one or two participants. With simple tagging for sentiment analysis, and contextualization with location data and the Google Calendar data plug, I could see a path to context-awareness; but the gallery function would have been enough.

5.4.2 Next project: full-colour privacy-preserved Positivity Patch

With Dr. Poonam Yadav, we have explored options for building a Positivity Patch (O5) with privacy-preserved federated learning [283] (O1). This would provide on-device sentiment analysis functionality which is consistent with or without network availability (O2). Although data ownership, as provided by the HAT (O3), is necessary for user control and agency, it is only meaningful in combination with data privacy and security of the wearable IoT devices. [5] [16].

This version of the Positivity Patch (O4) would incorporate the Gallery functionality using the full-colour Adafruit TFT Featherwing Touchscreen [5] and the Adafruit Ultimate GPS FeatherWing [6] to provide accurate timestamping as well as location data for the federated sentiment analysis model. The device would get GPS data every time the picture display changes and/or user input is received via the TFT screen.

Inputs on the TFT screen would indicate the user's mood: simplified emojis, tick or cross, frown or smile, etc. Using on-device location and time data combined with user inputs and scrolling through galleries, the Positivity Patch would develop context awareness: at this time of day/in this location the user feels anxious/angry, wants to look at this picture/slogan, and so on. On-device data and user inputs/scrolling through galleries would be used to develop context awareness: at this time of day/in this location the user feels anxious/bad, wants to look at this picture/slogan, etc.

This implementation would provide the colour screens that several participants wanted, and probably would not need a separate power switch. Shorter pins might compensate for the added bulk of the GPS FeatherWing.

5.5 Further responses and reflections

5.5.1 Hunter

Hunter wrote on 9 November 2019:

"Wow, the new e-ink screen looks awesome! If you could turn it into a badge for me that would be great [O4]. Or if the weight would be too heavy on a pin I could wear it on a lanyard like Warren?

"I really liked the wooden style frame like Grace's as it would go with any outfit and blend in more, and I absolutely LOVE the idea of adding quotes. That would be perfect for me, thank you.

[5] *Adafruit:* **TFT FeatherWing - 2.4" 320x240 Touchscreen For All Feathers** https://www.adafruit.com/product/3315

[6] *Adafruit:* **Adafruit Ultimate GPS FeatherWing** https://www.adafruit.com/product/3133

"Is there a way I can add my own quotes? Maybe you could show me?" (That would be a job for HAT's Notables app (O2, O3).) She included a set of quotes she would like to start with (O5).

5.5.2 Serena

At a previous interview (Appendix K.5.3), Serena had talked about wanting a bracelet form factor. She would have liked to add QR codes, if only for purposes of Rickrolling.

"What would you hope to come out of your interactions with people while wearing it?"

"Just general social-ness, I don't think I'm wanting more than that from it, just interaction for its own sake [O5]." She was not interested in directing people to Facebook, which was "mostly the work of the Devil [O1], yet technology I do love".

Was she still interested in mood and emotion sensing? Serena was skeptical: "it would be nice to think that a piece of tech can solve all kinds of different issues that you might have in life but sometimes it won't be the answer and it's not as simple as that. The air sensor thing sounds much more possible [O2], I wouldn't necessarily know just by walking in somewhere, as I don't have an immediate reaction."

On 5 January 2020, I asked Serena:

"You said you'd like the screen display mounted on a bracelet. A lot of people would probably mistake it for a smartwatch.

"The difference being that it would only do two things (at least, after developing it to what we see as the next level): display pictures, and monitor air quality.

"Would you rather have the Gallery Bracelet, or a smartwatch?

"Or would you want the Gallery Bracelet to evolve into a smartwatch over time?

"Or just still be a Gallery Bracelet but have more and more functionality?

"Or stop there at those two functions?"

Serena replied:

"I still love the idea of a picture/message display. It seems such a shame to completely lose that function as that's the really fun part. Ideally the air quality would be an additional function, making the bracelet both practical and really cool [O2, O3, O4]."

5.5.3 Ursula

At our interview on 3 January 2020, we talked about the differing considerations for wearables that are meant to be worn every day, and those, like the Gallery Necklace, that are not. Ursula had received a Fitbit for Christmas and was getting used to wearing something on her wrist. "It kind of feels like a tag that criminals wear when they go out [see Summary]." She would rather it was an elegant silver bangle than just a "black chunk", but the advantage is that there is nothing on it to catch or get in the way. "They're kind of milled to be smooth and chunky? but it's fine, I've been getting used to being able to read the data off it quickly, that's really what it was for." The experience had been interesting, as it was the first time she had worn such an item continuously. It

did not feel as invasive as she thought it would (O1), but knowing about the functions that are behind paywalls, such as heart rate monitoring, she would rather it did everything (O2).

In contrast, the Gallery Necklace is "A special occasion thing. I like the picture, I like that it is a talking point and that it changes and that you've got that as a thing. I do find the step counter useful, whether that would be sensible to put in the Gallery Necklace. Something that measures temperature might be quite nice, as your moods are often influenced by temperature, and the Gallery Necklace is more about social interaction than health. The Fitbit feels like a health thing, it's OK but it doesn't feel special, it's functional. The Gallery Necklace feels special, when I'm wearing it it's exciting, it would be nice to exchange data with people [O2, O3, O4, O5]"

I speculated about the use of QR codes or Artcodes to scan social profiles, if there were a way to bring up an app with fewer gestures than the process currently involves. Perhaps a blacklight image on the lower part of the necklace that you could turn on quickly to make it appear and disappear?

"It's a thought, you're hoping that as an icebreaker you'd be talking to people so you'd be able to tell them your phone number. The functionalities that you'd want from it would be very much social things."

I raised the possibility of using Facebook data in the HAT for this function.

"Yes, that would be good, mostly the question is what use it would be to have Facebook. Wild imaginary things: it could tell you when your Facebook friends were in the vicinity, do a gentle vibrate. So it would be nice if it could give you a heads-up that there was someone you knew nearby so you could go and find your Facebook friend." I told Ursula about the "Icebreaker shirt" [143] that does a similar thing.

Ursula concluded: "It's been a really fun project to be involved in and I'm intrigued to see the outcome."

5.5.4 Warren

By the time of our interview on 31 August 2019, I had received the new FeatherWing and asked Warren if he would prefer an upgrade to his existing lanyard, or a fresh device. He preferred to tear down the old one and replace the necklace format. We discussed possibilities for a badge format and how best to fit it to a lapel or bag.

"What data would you want to get from a device that you only wear sometimes?" (O2)

Of devices in general, if it were a smartwatch, he might swap a plain watch for a fancier one for an occasion. When he had a Fitbit he always wore it because he wanted that continuity of data (he stopped wearing it because it broke) so when he went to the gym it would detect if there was a problem and an alert showed on his phone.

"Would you want to know who was there at the meeting?"

That would probably be a useful function. One activity has a granular schedule which is reliably adhered to. Sometimes a turn is missed, so a forward/back button might be good. The club that runs this activity has branches worldwide, and every club has unique features, but the schedules are standardized.

"But how would that actually be useful?"

A timekeeper is at the back of the room, and shows a green, yellow and red card as the interval runs out. Clothing would have better visibility than holding up a sign. He could have a traditional colour-changing e-paper jacket, so certain stripes activate and others don't, which would also help colourblind people. This could be a new, traditional timekeeper's jacket (O4).

Also, utility is not the only consideration (O5). People think up new and interesting ways to signal timekeeping. These methods get publicity on social media and attracts new attendees.

So for a HAT application, one could have a generic granular scheduler to control a timed activity with some manual override, such as a slide show (O3).

"Supposing everybody had it, what could happen in society?" Warren had a poster presentation coming up. He suggested an SPA to draw people to relevant posters (O4). Everybody at the event receives clothing, a bag, or visible wearable technology item. When you get close to someone, a much smaller signal or image change is given off by each individual piece, that tells them something about your piece of work.

"Like directing traffic?" I suggested. "And maybe you could flag the attendees you especially wanted to talk to and it could direct you to them."

There could be people you did not want to talk to. "Then you'd have no escape. How do you repel them?" A successful implementation must have a repel-o-person function to send them away (O1).

5.6 Conclusion

In this chapter I have described the in-the-wild study, from 4 January 2019 to 3 January 2020. In section 5.1 I reported each participant's (including my own) usage of, and reaction to, the Gallery Necklace. In section 5.2 I reported the participants' feedback from an "I Like/I Wish/What If?" prompt. In section 5.3 I described a possible upgrade and the participants' thoughts about it; in section 5.4 I describe the improved Positivity Patch/Gallery Badge hybrid prototype, which sadly will not be assembled before the end of the study; as well as efforts to move forward with a full-colour, interactive Positivity Patch/Gallery Badge with privacy-preserved federated sentiment analysis; and in section 5.5, participants' further thoughts and reflections about upgrades, changes and HAT contextualization.

Four out of six participants wore their necklaces; two did not, one because they did not like it, and the other because it was a statement piece they could not find an occasion to wear (nor time to curate a gallery). Everyone liked the concept of the necklace, and most of the feedback expressed a wish for app support and a more mature version of the device; nobody rejected the Gallery Necklace per se, they just wanted it to be developed further. The prospect of an upgrade to a smaller badge format was universally well received. Warren, whose DF inspired the Gallery Necklace, wore it the most and reported that it worked just as he wanted it to.

Given the opportunity to add sensors, every participant had a different idea. The sequel to the Gallery Badge will be a context-aware, full-colour Gallery Badge/Positivity Patch hybrid with privacy-preserved federated learning.

In the next chapter I will present participants' updates to and reflections on their stories, and how they see the future of their characters and their wearables. Finally, I will assemble some concluding thoughts on the findings of the study.

Chapter 6

Resolution. Sequel?

[...] very uncool to actually commit to a particular future, and to argue forcefully for its wider desirability - but that is what we need of design right now. Not speculations that just fuel the market-as-usual, but decisive intents to constitute different futures, especially ones that seem currently impossible. [265, p187]

In the previous chapter I described the in-the-wild study, from January 2019 to January 2020. I reported on each participant's (including my own) usage of, and reaction to, the Gallery Necklace; the feedback; and the participants' thoughts about a possible upgrade. I described an improved Positivity Patch/Gallery Badge hybrid prototype, which unfortunately would not be built in time for the end of the study; as well as efforts to move forward with a full-colour Positivity Patch/Gallery Badge with privacy-preserved federated learning. The chapter finishes with participants' further thoughts and reflections about upgrades, changes and HAT contextualization.

In this chapter I will present participants' updates to and reflections on their stories, and how they see the future of their characters and their wearables. Finally, I will assemble some concluding thoughts on the findings of the study.

On 30 December 2019, I held a workshop to update the stories and reflect. Hunter and Warren attended; Rachel sent apologies. I subsequently conducted 1-1 interviews with Serena and Ursula.

6.1 Addendum to Gallery Jacket, by Warren

Warren provided two alternate endings: one utopian, one dystopian. The full texts of both versions are in Appendix G.1.

6.1.1 Group discussion on possible solutions; by Hunter, Warren and me

The two main obstacles to resolution of the dystopian ending of *Gallery Jacket* (O5) are:

1. Limited power of the individual
2. Fake news and propaganda

1. Limited power of the individual

- An anonymous donor with enough power to drive everything to the top of the page. "Zuckerberg's virtuous twin"... they are a turnip billionaire, and they create the game-changing alternative to Facebook.
- Q. A turnip billionaire? A. The billionaire bred a nutritionally complete version of the humble root vegetable which thrives in British soil. Just one turnip can feed a family of four for a day, and the chemical composition produces a "chameleonic neutral" flavour that dramatically enhances and complements almost any other flavour in existence, such that the selfsame turnip can be transformed into an astonishing variety of dishes with nothing more than herbs and spices.
- The billionaire wanted to donate their turnip to humanity, but they were contractually obliged to sell it for profit and they lost the case against their co-founders in the turnip startup. Unable to live with themselves, they turned to codeine but found its false comforts unsatisfactory and took up coding instead in an effort to simulate the biomarkers of another world-saving root vegetable.
- Little by little, they found themselves so enraged by the fake news about their own case that they tried to create an algorithm to combat it, and one day they realized they had the makings of a new Facebook that would make the world's thumbs beat a path to their app. Which was called Turnipbook, which was compatible with all other platforms but automatically masked every item of fake news with an image of a turnip.
- RESEARCHER: fake news via ambigrams that change their meaning for each audience, like the messages in *They Live* [48].
- WARREN: a turnip logo instead of the apple.

2. Fake news and propaganda

- This didn't solve the human tendency to seek out confirmatory propaganda, and some people never learned, but the time came when a terrible disease swept the continents. [1]
- Of course people tried the fake remedies, and of course they died, so the only ones who survived were Turnipbook users who had a natural tendency to be evidence-based.
- RESEARCHER: OK so what overcomes the human tendency to seek out confirmatory fake news even at death's door?
- HUNTER: Could a revolutionary group take down Facebook?
- HUNTER and WARREN: A disease? So that people really wanted real info?
- WARREN: [Nerve damage leading to atrophy]... people couldn't log in because they don't have any fingers left.

[1] Within a month, the COVID-19 soon-to-be pandemic recorded its first case in the UK.

- HUNTER: Alexa... it's creepy... like a female slave obeying her children's commands - only not, because it can't do anything you ask it to do [O1].

6.2 Amelia and the 8 Inventions, v2, by Hunter

Hunter's story was subtly altered in light of current events. The full text is in Appendix G.2. Note how Amelia's agency in her world has increased, raising her from social entrepreneur to peacemaker:

6.3 Reflections on the Mood Bracelet, from Serena

I conducted an unstructured telephone interview with Serena on 3 January 2020. Serena felt that her story could not be updated except by radically rewriting it, so *Mood Bracelet* stands as canon (O4, O5).

For upgrades, Serena wanted air quality, not mood sensing (O2, O4). She did not believe mood sensing was feasible, and was skeptical of solutionism. One could imagine Margherita Banks learning to trust herself over the bracelet (where the story ends), and eventually wearing the bracelet for aesthetics only.

6.4 Reflections on Jacinda Dragonfly and Mr. X, from Ursula

I conducted an unstructured Skype interview with Ursula on 3 January 2020.

Ursula leaned towards a utopian outcome (O5). "Tech should be widely available to do useful things, rather than the flip side of it. That's the path they would go down, they're kind of good guys." Ursula's characters would try to keep it from people who would use it for war or dystopian purposes, and therefore would make it available to everybody.

RESEARCHER: So Mr. X is open source?

URSULA: Yes. Initially he was created and became an AI of his own character, but the code that created him would generate new AIs with their own personalities.

RESEARCHER: Are they his children?

URSULA: I suppose so, they breed like rabbits. Yes, I think they would be offshoots of his program.

Are the offspring AIs benevolent towards humans? Inevitably, for a good story, there will be one character who has a bad experience with a human; but that could turn them into an interesting antagonist as opposed to a villain. Ursula saw the offspring AIs as reflecting their human contact, enhancing and assisting humans as their function, which they would want to perform to the best of their ability even though they would not necessarily know the ulterior motives of those humans (O4).

RESEARCHER: Like dogs?

URSULA: Yes, there are no bad dogs, just bad owners. It never ceases to amaze me how trusting dogs can be. They can be rehabilitated. But story-wise, it's not very exciting if everyone's very good all the time.

Ursula added that there was scope for viruses to get in and infect the AIs and get them doing different things and manifesting weird behaviours and malfunctioning.

RESEARCHER: So, a society of assistance AIs, all with personalities derived from Mr. X?

URSULA: Yes.

6.5 Conclusion

In Chapter 1 I listed six identified obstacles to wearable computing, five of which (O1-O5) I set out to address in this study, with particular emphasis on the last two. I have addressed all five obstacles in the following ways:

- **O1:** ***protect user privacy*** **-** Each volunteer was issued with a HAT personal data store, which gives them ownership of all the data therein. There was no requirement to share usage data with me; instead, I relied on self-reports. The microcontroller has good SSL support. The next step (section 5.4.2) involves privacy preserved federated learning, which will increase user control and agency over the data.
- **O2:** ***enable multiple functions within or between devices*** **-** Within devices, the prototype (section 5.4.1) would demonstrate a combined Gallery Badge and Positivity Patch, and the next project (section 5.4.2) will incorporate federated sentiment analysis to make the device context aware. The participants also suggested other functions they would like to combine (Chapter 5). Between devices, addressing O3 also addresses O2.
- **O3:** ***be integrated into an IoT ecosystem*** **-** Also provided by the HAT. The technology probe helped the participants to think about ways to combine data from other sources (section 5.5).
- **O4:** ***serve as an extension of the wearer rather than the smartphone*** **-** Another obstacle partly addressed by the HAT, but, with O5, a focus of the study from start to finish. Every wearable device in every one of the PDFis is an extension of the wearer, it was simply a matter of picking one. The Gallery Necklace is not paired with a smartphone, and at most would need one for a WiFi hotspot. Application support is needed for setup, but not for computational power. The Gallery Necklace also functions as an extension of the wearer by becoming an instrument for self-expression as they display their art.
- **O5:** *appeal to the wearer's emotional as well as functional needs* - This was the main purpose of the PDFis, and all the volunteers' feedback indicates that we succeeded. The author of the DF that inspired the Gallery Necklace said that it worked just the way he wanted it to, with similar feedback from other participants. The two participants who did not wear their necklaces had issues with the execution, but remain enthusiastic about the concept, and I still hope to be able to give them the Gallery Badges I started.

These are the three research questions I asked in Chapter 1:

1. **RQ1:** ***Can PDFi help us to create wearable IoT devices that add value to everyday life? (O1, O2, O3, O4, O5)*** Yes. Not only does participants' feedback indicate that we can, the Positivity Patch (section 5.4.2) project would take their ideas even further. Even at this early stage there has been commercial interest in the Positivity Patch, which seems likely to have wider appeal.

2. **RQ2:** ***Can we translate PDFis into feasible real-world designs for everyday IoT wearables? (O1, O2, O3)*** Yes; the Gallery Necklace technology probe is directly inspired by Warren's DF, *Gallery Jacket*, and there are plans to upgrade it to a Gallery Badge/Positivity Patch prototype; and for development into a new context-aware Positivity Patch which incorporates both Warren's and Hunter's DFs.

3. **RQ3:** ***Can we implement everyday IoT wearables based on PDFis in a way that sustains user engagement in the wild? (O2, O3, O4, O5)*** Probably, considering the usage patterns of Warren and Grace. Rachel, who is mostly housebound, managed to find an occasion to wear hers. Ursula wore hers only once, but would have worn it more (instead of just taking it out to admire it) if the assembly had been stronger. She also had fewer occasions to wear such a flamboyant piece of digital jewellery, as did Serena, who also wanted changes to the assembly. Hunter never wore hers but was thrilled at the prospect of the badge prototype. As for my necklace, I am tempted to commission a jewellery maker to improve the build, so I could wear it to more occasions. The size of the Gallery Necklace technology probe is so large, and the aesthetics so extreme, that I had no optimism when I issued it to the volunteers. If they were willing to wear the Gallery Necklace, and wear it on multiple occasions as some of them did, the outlook is good for a smaller and more polished implementation.

By a group effort, we have addressed all five obstacles, and answered "yes", "yes", "probably" to all three research questions. This is the accomplishment of a group of independent adults who did not need wearable technology, but *did* want it. Each of us told everyone a story, *their* story, of the wearable technology they wanted and the world they would like to live in with it. All of us chose one story, and I built the best real-world version of the wearable in that story that I could. I made each participant, and myself, a version of that wearable with the minimum viable functionality, personalized to fit into the storyworld of each one. I left it with them for one year, and at the end of the year I asked them what they would change about their stories, in hopes that we might little by little gain agency to write our own endings and influence technosocial reality through participation and co-imagining. The influence of any small group of individuals is limited, but we must try to do what is in our power to do to shape the technologies and not only let powerful others use them to shape us.

Nobody else has done this. As far as everyday wearables in the IoT are concerned, nobody has ever tried to do all of these things, all in the same way (section 3.1.1). Conventional wisdom says that participants need a design exemplar to compensate for their imaginative deficits. According to my experience, they only need the right kind of prompt - and to be approached as equals. There is nothing wrong with approaching particular cohorts,

as long as the cohorts do not become silos. Any given member of the public may be marginalized in particular ways and less so in others, but every storyteller is a complete person who will tell it like it is for them, in accordance with their own priorities, and often against stereotypes of what a person in that category should want or need.

Furthermore, we were able to answer these research questions while confronting issues of privacy with which mainstream wearables have a poor record [15] (section 3.3.5). I urge researchers in wearable systems to be mindful of these issues and consider whether our solutions may be applicable and extensible in their own work.

The wearables my participants asked for were in a different relation to the wearer, an *alterity* relation, than wearables in the mainstream of product design or, to a large extent, the research literature which mostly are in embodiment and/or hermeneutic relation to the wearer (section 3.6.2). The group's favourite PDFi described a wearable for the purpose of *display*, making it philosophically different from most mainstream wearables, which are designed to pass unnoticed and to show the wearer their biodata, but never to be the centre of attention to bystanders. The Gallery Necklace is a social wearable whose social functionality depends on the wearer's interactions with physically present others, rather than on automation of social networking or other computational functionality.

From this group I learned that self-expression and connecting with others are desired, and not necessarily in ways that are best solved with AI and computation; the relation of the wearer to the device is critical, and the device is used as a tool for in-person interactions in ways the computational part of the system need not even know about.

Another theme emerging from the PDFis was a desire for communication with the self through a comfort object. David Rose [226, Pt2] claimed that enchanted objects could satisfy six human desires, but we discovered a seventh desire: **heart** (Appendix L.7.1) - the desire to have with us, on the body, something we can use to comfort ourselves and stay in tune with our wisest selves. This kind of usage scenario did *not* necessarily involve connecting with others over social networks - it was more about relating to one's self.

There was a lot of luck involved in recruiting such dedicated, talented and open-hearted volunteers. PDFi for everyday wearables is a topic with niche appeal, not mass appeal. But luck is not solely a matter of chance: the storyteller needs someone who will listen, and understand.

6.5.1 An embarrassing sociomaterial positionality

During the difficult fabrication phase I was acutely conscious that three of the recipients of the technology probes were professional costumers, all with experience of wearable technology. My own mechanical assembly was inevitably going to fall short of what they could have built for themselves. If my description of the assembly process (Chapter 4) seems emotional, the first draft was a melodrama. How mockingly the steam did hiss from the soldering iron as I sat, late night after late night, and watered it with my tears.

On the other hand, my pattern cutting, sewing, and jewellery making skills may have been weak, but I had them and was going to use them. I had the ability to take the PDFis and create feasible design proposals (some sublime and others ridiculous) for all of them, build a mechanical assembly out of off-the-shelf electronics and do the laser cutting and soldering and wiring, write two thousand lines of robust and reliable code to make it work

and connect it with a personal IoT data store. Then to take the good common practice of software engineering and "eat your own dogfood", wear your own technology probe, completes the circle of empathy with the authors of the PDFis: "While everyone wears something when they make and communicate research, few of us dress *in* our research. Drawing attention to your own clothed body in this way is rare and sometimes risky. It can be a potentially embarrassing sociomaterial positionality." [140, p66] Arguably, by applying the WEAR scale to myself (Tables 5.1 and 5.2) and not to the participants (because I did not think of it in time) I am breaking the "behavioural shibboleth" [193, p199] which treats *other* agents, but not our own behaviour, as proper objects for our own scientific curiosity.

Being able to work with emerging technologies, as I have done as a software engineer with ontologies, hypermedia mapping and then the IoT, makes it easy to see the near and sometimes further future as if it were already here. Developing a wearable IoT system from end-to-end helps me to avoid treating the problems of IoT "as implementation issues that are, essentially, someone else's problem, to be cleaned up afterwards as part of the broad march of technology" [22]. And as Bell and Dourish laid out [22], it comes as no surprise that this place is such a *mess*.

Jungnickel [139, p494] appreciates the commonly underappreciated details of making as research, and the value of "the desire to engage materially with media, learn from doing, and, in the process, render public the visible and tangible mess, mistakes, and tangential happenings." Reading Jungnickel's account of the collective experience of DIT (Do-It-Together) construction of a WiFi network in an Australian community, makes me think that this study which started in the maker community, should stay in the maker community. In a city like Cambridge it is difficult to recruit a completely nonexpert cohort of volunteers, but makerspaces bring together multiple disciplines by nature. It is not only that the PDFi method produced ideas for wearables that were potentially realizable as viable products (section 5.4.2). It is not only that the PDFi method gave insight that participants wanted wearables in relationships of alterity which are neglected by the mass market (section 3.6.2). It is that the participation and co-creation enable us to use such agency as we have to imagine the sociotechnical futures we want and, to some extent, realize them in our own lives. Of her project recreating the technical clothing worn by early women cyclists: "Similarly, Bikes & Bloomers is fundamentally a project about DIY and DIT sociotechnical cultures. At one level, the women who patented their new cycling costumes did so because what they considered to be appropriate cycle wear did not exist. They had to do it themselves."

6.5.2 Synthesis

In his assessment of the state of HCI in 2020, Frauenberger [96, p2:19] made a radical proposal: "Despite its honourable role in reminding technologists to think about people, I want to argue to abandon user-centred design."

The reasoning behind this proposal is an articulation of what my own experience on this study has been showing me since I started in 2016: "Not because humans do not matter, quite to the contrary: to shape who we want to be in this world, we should be designing meaningful relations, not user experiences. Meaningful Design encompasses the political mattering of things through which we make sense of us in the world, going beyond what we experience, but who we want to be."

Frauenberger proposes a new paradigm of "Entanglement HCI" which draws upon entanglement theories, including postphenomenology (section 3.6.2), which intersect with HCI. He proposes Speculative Enactment [84] (section 3.8.2) and reemphasizes **Participatory Speculation** (section 3.8) towards "mattering of future socio-technical configurations."

This new paradigm of entanglement would also "move beyond the distinction between design and use, and embrace the design-use of things as a continuous process of re-defining and re-enacting our relationship to technology." To which I reply, "Yes, I've been waiting for your call."

Frauenberger's proposal [95] includes *Agonistic Design*, originated by Björgvinsson et al. [28] and "characterised by employing processes and creating spaces where groups of people can passionately engage in vigorous, but tolerant disputes and design that quite literally feeds off the controversies." My experience with PDFi showed how naturally it provided a platform for neurodiverse participation, and this is the least of its potential. Furthermore, the elucidation of this principle [28] shows how close it is in practice to what I was trying to facilitate with personal data in the wearable system: "agonistic struggles which are not suffocated by a compromise in the process can become features in the design".

Entanglement HCI [96, p2:19] covers a wide variety of concerns relevant to this study. One of these is scaling up "Meaningful Design" to suit the needs of industry. Despite some interest from industry (section 3.7.2) I believe my own work will be more relevant to wearables researchers in craft practice and the maker movement (section 3.6.4; Appendix M.3.5 on *Jacinda Dragonfly and Mr. X*).

In her history of wearable technology, [229, p209] writes: "since the mid-2000s a literature and praxis have evolved centered on how to reconfigure not just the relations of power but the ways technology is used to reshape social relations. This involves a grassroots (or 'netroots') approach to creating electronically and digitally enabled dress, one that joins technological and craft practices and tries to accommodate the different cultures proper to each: whereas the technological tends to be masculine, proprietary, and function-oriented, craft is generally distributed, collective, and oriented toward process over, or in addition to, product."

Within engineering, this study has been best received by systems, digital economy, and service systems researchers. IoT researchers are sometimes receptive but do not perceive wearables as being IoT devices. Within HCI, it has been difficult to explain this study in terms that were accepted when I began: my claimed contribution was perceived to be sometimes outsized, sometimes too small, for whichever theoretical nook or cranny was available to force it into (section 3.7.3).

As I complete and reflect on the study in 2020-21, Entanglement HCI puts out a theoretical welcome mat for my research practice. The article summarizes: "I have argued to leave user-centred design behind us, and with it the mantra of user experience. Instead, I suggest to move towards design practices that feed off controversies, that are participatory, involving human and non-human actors, that are speculative to create spaces in which we negotiate desirable futures, that are agonistic to recognise the creation of technology as a political arena and that reach across design and use. I am suggesting to move from optimising user experience to designing meaningful relations that are enacted as part of our ongoing re-configuring the world."

The main target audience for this work has always been designers of everyday wearables, connected or not. The history of wearable technology laid out by [229, p191] is an elu-

cidation of despair for those of us who want to make innovative everyday wearables that are "part of an evolving language of dress (rather than a commercial prototype, art work, or oddity)." The problem of "disappearing esthetics" (section 3.7.2) and the financial failure of otherwise promising commercial ventures (section 3.5.2) imply, to me, that craft practice is the scale at which "Meaningful Design" of everyday connected wearables is achievable at present.

The future I imagine

As for the relevance to researchers in PDFi [167], I imagine a maker subculture of diegetic wearables (sections 3.5.2 and 3.7.2) that will organically expand to other media besides text. At the same time as I worked on this study, I was involved in a number of projects in dance and physical theatre that were influenced by Boal's Theatre of the Oppressed [2]. The participatory process of making theatre produced performances from mixed-ability casts that were more than the sum of our parts [180].

Boal's concept of the "Spect-actor" humanizes the audience as participants in rather than mere spectators – one might also describe them as *users* – of the show. Similarly, the participants in a PDFi workshop are free to tell their own stories in their own voices and according to their values. Maker groups like these are of course not new [223] [72], but a design process based in participatory storytelling is.

Future groups could involve participants in making through skill exchange and leverage of existing activities, as in Jones and Girouard's example [137] of incorporating e-textiles into visible mending workshops. And the design fictions could continue to the point of loss of interest [108, p43], and the PDFis could be expanded from group storytelling into performance, costume and more.

Rather than a test lab for a method to be deployed elsewhere, the PDFi workshops at Makespace seem more like a starting point of "handiness" [108, p37] from which participation in "Meaningful Design" of everyday connected wearables could grow, and most importantly the wearers could make the wearables, as the participation makes the meaning [139].

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Appendix A

Stories from CFI1

A.1 IronWoman, by Aaron, Beate, Ciaran and Dominic. Transcribed from notes.

Selecting a character, the group created Ironwoman [154]. The story fits the Five Steps [135, p25] as shown:

- (1) IRONWOMAN!!! She lives in Cambridge and looks remarkably like Beate and/or the Researcher. She is downtown, walking down the street to Costa Coffee, to meet the man of her life.
- (2) IronWoman has a suit with all the powers [O2, O4]! The suit is adaptable and not to be pinned down to one fixed form factor. However, being wearable, it is swappable from person to person. It can be donned and doffed in one step.
- (4) But - IronWoman is cycling around, and everyone can see she's IronWoman because of her suit! This is problematic [O1]. What if you're invisible? Invisibility affects her fated beloved's ability to see IronWoman, and vice versa. This threatens to undermine the romantic subplot.
- (3) She can't see the man who is her fated beloved. Because she can't see anyone. They are all invisible because they all have the suit, which is all the rage. The air conditioning is too low but, because of her auto-temp-regulating suit, she feels fine! But because of the steam of the coffee that shapes itself around the people, she has a glimpse of another invisible coat-wearing person. It's George Clooney [1], who is having an espresso, because the Starbucks coffee wasn't very good.
- (5) [and she could see the visible thought-waves!] George Clooney has voice distortion to stop people recognizing him by his voice (but not his thought-waves).
- (5) ...all of this will be resolved in the sequel. Spoiler: selective visibility is the solution!

[1] *Wikipedia:* **George Clooney** https://tinyurl.com/zbvbjjx

Appendix B

Stories from CFI2

B.1 The Hermit and the Shepherd Boy, by Erica. Verbatim from author's text.

- (1) The shepherd boy runs barefoot across the open scrub of the hillside. He is nimble and fleet of foot and his small flock of goats and sheep follow him readily. From the mouth of the cave where he stands the hermit watches the boy head for the tree-line. Just before he reaches it the boy turns and sketches a wave to him. The hermit hadn't realised he had been seen but he raises a hand in his own greeting. And then the boy is gone.

- (3) The hermit came to the cave only recently, but it suits his purposes. It is dry, deep enough to keep out the rain and wind that scours the valleys hereabouts, small enough to heat with a fire of juniper and pine branches, sputtering and fragrant. And the view is something to behold. The few people who pass near by sometimes trade with him; for the things he carves from fallen boughs, for a wish-spell, for a letter scribed on a scrap of parchment, for some pocket of wisdom. Sometimes they have money, more often they have food. Either suits him well enough. The boy usually passes twice a day, early in the morning up and over the near by rocky pass, and in the evening when the sun starts to dim. Today though is different. Some time, when the shadows are at their longest and are on their way into gloom it begins to rain. And rain. And then rain some more. The hermit retreats into his cave and lights a small fire and then sets out his supper. There is no sign of the boy.

- (4) When he has eaten and carefully stored the leftovers the hermit hears the clonkle of bells and he skirts round the edge of the fire to look out. In the gloaming he can just make out the aimless descent down the hill of the small flock, untended and wandering, except for the dog the boy favours, nipping at the heels of a reluctant ewe. He frowns, goes back into the depths of the cave, pulls on his cloak and lights a horn lantern.

- (4) Satisfied he lifts the lantern higher, more for the welcome glow than its soft illumination. As he searches at the edge of the trees he calls occasionally. He has never learned the boy's name but his intent is clear. After he calls he stops and

listens. When the lantern begins to spit he considers that he may have to abandon his search, until he hears the faintest cry. Heading towards the sound he repeats his call, listens for the answer and after a short while he finds the shepherd boy propped against a tree stump on the edge of a clearing. The boy looks up and makes an apologetic noise, "I twisted my ankle. I was stupid. I can't put my weight on it."

- (4) The boy's voice is low and tired, and the hermit realises he is older than a child. "I have something you can drink and eat. You must be cold." As the hermit passes him the flask and meat the boy nods, "I thought I might perish out here. Did you see the herd?" "They passed close by. On their way down." The boy nibbles at some meat and sighs, "Well. I shall see trouble for it. If you help me, I can probably hobble."

- (4) The hermit sits beside him and undoes his cloak to wrap around the shepherd. "Eat first. Get a little warmer. Then we shall try." Sighing into the folds of the cloak, still warm from the body of the hermit the shepherd answers, "Thank you. Sometimes something as simple as a little human comfort is a wonderful thing." The hermit smiles at him, and once the boy has eaten, the hermit holds the cloak around them both as he half crutches the boy out of the trees and across the hillside, back to the cave. Once there he settles the boy, "Sit here. We can strap your ankle. Tomorrow we will get you home, but both of us risk more than a twisted bone if we try to make the village in the dark." He looks back over his shoulder out of the lee of the cave and into the darkness beyond.

- (4) In the valley below he can see the glow of the forty or so houses there. When he looks back at the shepherd boy he sees he is already asleep, exhausted by the pain and worry. The hermit goes back into the cave and returns with some long strips of linen. He wraps the shepherd's ankle tightly. It is testimony both to his skill and the boy's wretched state that he doesn't wake.

- (5) The hermit tucks the cloak more closely round the boy and then fetches a blanket of his own from his bed at the back of the cave. He seats himself, and wraps his blanket around his shoulders. He tends the fire until morning.

B.2 Fertility Ring, by Francine. Transcribed from notes.

- (1) Francine works with sensors. Her friends decided to have a baby and tried for IVF. Francine realized her sensors could help them to collect the egg.

- (2) Francine said to her friends, "Hey! I can do something for you but you have to be my sample." She creates a ring to read the wife's body temperature. Various formats were considered for the gem housing the sensor; she decided on an "open sketchbook" shape.

- (3) The sensor is pretty big on the wife's finger. It lights when her body temperature indicates that she is fertile.

- (4) The husband is Francine's friend. He asks her to change the ring to be beautiful, not like a sensor [O5]. Francine wants it to be like a diamond. The wife is nearly 40 and people will see the ring; Francine is trying to make it beautiful.

- (4) The story has not reached step 5 yet. "So how do I make it beautiful?" Francine asks. "I am stuck."

- (4) The woman wants to wear something that nobody will know is a sensor.

B.3 Wooden Horse, by Grace. Transcribed from notes.

- (1) A little boy is an orphan, and the story goes back to the memory of being in the orphanage, where he was bullied.

- (2) He has a tiny wooden horse. Wood is rare, and this wood is valuable. It is also able to resist the heat of fire, so when he picks it up it doesn't get hot. The wooden horse enables him to feel happy and supported by another playmate. One day, other children are chasing him. He puts the warm horse from the fire into a zip-up pocket [O4] so it will equip him for anything. The wooden horse lets him know what to say, how to stand up to a bully with words. It gives him the right words to say back [O5].

- (3) "I'm never going to go to that party," we tell ourselves. "I won't know what to say." Well, now you will know what to say! Harassed on the tube? Boys dominating a class? What to say if you are put down in the next sentence by the guy next to you? The wooden horse is to give you a message to say into your brain, and it always knows the right thing to say. You have scripts for what to say, don't have to look at a book, and nobody can take it away from you once given. Perhaps it could even give you the right facial expression to show!

- (4) Probably, a fight changes things for the boy, because he has the psychological comfort.

- (5) And he carries his toy all the way through his life.

B.4 Leaf Me Alone, by Hunter. Transcribed from notes.

- (1) "Since childhood I've always felt that I'm in a man's world and I can't cut it." Hunter feels that she is always at a disadvantage. When she was 11 years old, on a bus, a man sat next to her behaving obscenely, and nobody intervened. This happened several times with the same man. Occasionally, if someone Hunter knew happened to get that bus home, she'd try and sit with them. But Hunter was never very popular at school, and got bullied. Hunter also picked up on themes in Grace's story, about presenting oneself in such a way as to deflect bullies and belittlement.

- (1) Hunter has a second story about a time she was harassed. This time, she called the police, and they asked "how much have you had to drink?" What happened was: Hunter was walking down a road and a guy grabbed her by the coat. She used a technique of Jiu Jitsu to shed her coat and break away. [This reminds of a concept dress by Amisha Gadani. [1]] Hunter still had to get down the road in order to get away from him - and even after she broke away, he was still waiting for her, undeterred. Hunter's friends and family showed her a newspaper: she had had a near miss. 12 similar assaults had taken place over recent weeks. Hunter said that the police had to know that she had been attacked by the same guy that had done those 12 other assaults, but when she reported it to them, they didn't care.

- (2) In GI Joe [2], there is a mirror suit like a chameleon. A suit like that could help Hunter to walk home in the dark and not be harassed. What Hunter would like is for all women to be invisible. (Well, what she'd really like is for men to stop harassing us. But that problem is beyond the scope of this discussion.) So what should we invent to help women? [O5]

- (2) When Hunter had a car with central locking, it was like a cocoon. This made Hunter think about the idea of a wearable cocoon, almost like an invisible cloak [O4].

- (3) If she wants to be seen, she's seen. If not, she won't get any harassment. She can go to work, take it off when she gets in the door. Then she decided that was "a bit ridiculous".

- (2) So how about a 2nd layer of skin [O4].

- (3) So you can go about your business and deflect harassment. And you can wear it 24 hours a day, and not worry about adjusting your behaviour to reduce yourself so as not to offend men who are targeting you. Then Hunter decided **that** was ridiculous.

- (2) "Leaf Me Alone" leaf camouflage [O4]. Hunter has a skin condition and is combining the second skin idea with the desire to be invisible.

- (3) With "Leaf Me Alone", you can blend in with nature. The drawback is that it would only work if you were in nature.

[1] *Amisha Gadani:* **Skink Defensive Dress** http://www.amishagadani.com/Work/skink/index.html

[2] *Neo Encyclopedia Wiki:* **Baroness (G.I. Joe)** https://tinyurl.com/yactw2du mentions Chameleon Mold

Appendix C

Stories from Edinburgh Group 1

C.1 Flower, by Iris, Katrina and Millie. Transcribed from notes.

1. A young girl with a younger sister, and some parents, Flower has a really hard time at school. She has a history test and really wants to pass it.

2. On her way to school, Flower passes a mad scientist who offers her this special crown. The crown will take her back in time, and she can meet all the people she's been learning about in class, and learn about history.

3. Flower has an amazing experience, meets people from history, passes her test. She tells all her friends about this crown. Her life is great.

4. Flower goes home, and discovers that the crown is missing! Her little sister has taken the crown, and has gone back in time and is missing. So the crown is stuck in the past.

5. Flower meets the scientist, who gives her a new crown to help her find her sister. Flower brings her sister back, and destroys the crown. Flower learns that she must study history, and not use magic. The End.

C.2 Agent X, by Jameson and Opal. Transcribed from notes.

1. Third world war, limited resources. Deadly virus all over the world. Agent X is here to get the virus back from The Company [O5]. In order to get the virus back from The Company he has to get through the safety door.

2. Agent X puts the mask on so he can scan and generate facial information about people and it can shape the mask. The function for the cloak is to make Agent X invisible to everybody.

3. "Only" kills one guy at the start of this mission, now he has access to the base.

4. Wears the cloak because people from The Company find the dead person. All the people in The Company want to kill Agent X. Because this cloak is made of a fabric composed of electronic material, it is not waterproof, and during the battle the cloak gets blood on it and is now visible. Another function of this cloak is it's bulletproof [O2] and he can pump it up like a tent. When the agent is discovered by enemies he can't escape and the cloak becomes a tent and they stab and stab him, which ruins the bulletproofness.

5. He has another suit on underneath, with basic invisible functionality, but he's not bulletproof. Also, the cloak needs to be much larger [than the child's costume cape from the dressing up box], then he can just sneak away by wearing this other invisible suit.

C.3 Little Strawberry, by Leo, Priscilla and Quinn. Transcribed from notes.

1. The character in our story is named Little Strawberry. She is a fashion girl: goes to school, then shopping, then exercise. At night: to the pub and party.

2. A wearable bra that can help her to attend different occasions [O4].

3. When she goes to school, it's cotton and convertible. When she goes shopping, it becomes a beautiful fashion bra that fits her curves. At the gym, it becomes a sports bra. At the pub, it becomes a shining pink bra, that enables her to be the most shining star. All the kinds of functions and materials or shapes for all bras: different colours, materials to fit different occasions. It has the power [O5]!

4. A week or month later, Strawberry gets bored, because she wants to change the pattern, and it's hard to clean this magical bra.

5. Every night she can put the magic bra into the box, and push a button: wash, clean, transform patterns, colours and styles from the screen to do what she wants, so she can still use this magic bra.

C.4 GodSon, by Noah. Transcribed from notes.

1. My name is GodSon.

2. When I wear this mask, I know everything.

3. When I meet a stranger, I know everything. I know what today's weather will be.

4. When I want to make friends with someone, I know he doesn't like me and he hates me. When I fall in love with someone, I know about her past, that she tried to cheat someone. I know everything. And some things, I don't want to know. Because we are in the information society, and maybe sometimes, we know things we don't want to know [O5].

5. So - I throw away the mask.

C.5 Green, by M4. Transcribed from notes.

1. His name is Green.
2. He knows everything in the world.
3. His green shadow can be in every corner of the world. He can be very big, and he can be very small. When he wants to get into the mind of the people, he has the green energy.
4. He's happy. He has no problems [O5].
5. His shadow is green.

Appendix D

Stories from Edinburgh Group 2

D.1 MirrorMask, by Xenia, Yolanda and Zara. Transcribed from notes.

1. A girl who does not like her appearance. She lives in a world where people always judge by appearance. They have a standard judgment of how people should look.

2. And she wears a mirror mask, to reflect people's own faces back at them.

3. One day when she goes out, the sun is shining, and she is reflecting too much light because of the mirror mask. Late at night, she also cannot go outside.

4. So it makes her feel much more lonely [O5]. The reflection from the sun may hurt people. She finds out that the boy she loved, and all of her friends, want to play with this girl because they see only themselves. They like her appearance, but don't care about her personality. They are narcissistic.

5. One day at a Halloween party, she meets a boy. The boy thinks the mask is a costume. The boy takes off her mirror mask, and he is the girl's Mr. Right. So the mask changes into a necklace, and the girl always wears it [O2]. It has the shape of a girl's face. So the boy keeps it in his mind. The boy wants to take this girl to a different world, where there is a different standard of beauty, and different values. And the boy tells the girl that she is the most beautiful girl in his world [O5].

Appendix E

Stories from the Inaugural Workshop

E.1 Wearable Plant, by Hunter. Transcribed from notes.

1. We need something to make us feel better, and we don't get out in nature enough. How about we turn nature into something that you have with you [O5]? If children are out exploring in nature and touching all these things it helps their development [citation needed].

2. A wearable plant! A little air breathing plant for a badge (O4). [Researcher: I saw someone with a little succulent in a necklace once] A sensor that senses the sunlight and measures how much you have had, and signals to go outside when you need to. Seasonal Affective Disorder (SAD) glasses, blue light lamps that make the light hit your eye at the right angle. [Warren: that's what eyelashes are for, to filter light] Type 2 diabetes? Instead of a finger prick, why not a biofeedback t-shirt (O4)? Or a message t-shirt? If a guy jumps you out on the street at night the shirt might tell him you're scared, and you don't need that so how about a shirt to broadcast the message "F** OFF I KNOW JIU JITSU"? For women: amplify your voice in a meeting - the words could flash on your shirt! In a bar, a shirt could go "NO CHANCE [O5]" How about a neurodivergence badge - tech to recognize faces (O4)? A badge with a screen and camera, scans people's facial expression and tell you what it means. Good for anyone, even the neurotypical! It could also read your mood, and give you inspirational messages [O5].

3. People who can't get out much can benefit, and won't have to go outside to water their plants! Old people's homes - [someone known to Hunter] wasn't allowed outside to water the plants.

4. [Ursula: poison ivy feather boa?] [Warren: risk that children may eat the plants and poison themselves] [Hunter: a rare bonsai tree left to her by her grandmother. Plants in her care never survive, she kept the tree alive for six years. In the fifth year it flowered, but in the sixth year it was infested with red spider mites, and she tried to get rid of the infestation but it killed the plant.]

E.2 Freedom Hat, by Rachel. Transcribed from notes.

- (1) Rachel has debilitating fatigue and intermittent cognitive symptoms. One of Rachel's problems is that she often cannot express herself very well. Her condition gradually gets worse and worse, making her life smaller and smaller. There is always a tension between saying "everything's fine" and what's really happening. Speaking to the doctor about what it is like to gradually lose your ability, but we aren't encouraged to talk about it and the decisions you must make, like deciding you won't have a family. If you look fine, people might think you are. This is a problem.

- (2) Rachel always has to wear a hat now - and would like a few more [O4].

- (3) Doing all you can for yourself but also wanting to be normal, and using all the aids you can. It's always a tiny thing that stops her dead, things to do with the outside world. And the hat helps. Just warm enough, and also a lot of people come to talk to her because of the hat. But even if the hat were hideous she would still have worn it because it does the job. As mentioned earlier, hormone levels affect Rachel, and she also has symptoms of POTS where the body wants to be flat - but your heart needs to be at the highest level. She hasn't been tested for POTS because the test itself is debilitating, but she believes she has it.

- (2) What if the hat could read the hormone levels and start pumping the blood up to her brain?

- (2) She always used to drink lots of water, like you're supposed to - but then realized it was making her symptoms worse! [by lowering her blood pressure?] In those days she would have liked to have a hat that had a water pipe so she could drink from a handsfree water container through a straw.

- (2) A hat with little fans, etc., like an Australian cork hat would also be a good idea.

- (2) Rachel used to not eat salt, because salt is Bad... but it's bad because it raises your blood pressure? and when it dawned on her that her problem is low blood pressure... well, maybe I should try eating salt AND IT WOULD BE REALLY NICE IF THE HAT COULD WORK IT OUT! Imagine if the hat could say "get it [the salt tablet] out of your bag" or a hand came down and handed the salt to you, or if it adjusted hormone levels itself somehow!

- (2) OR noise - she gets debilitated quickly - ear plugs? "I detect the pressure on your ears" and show soothing images [on the inside front brim of the hat?] to make it not hurt.

- (3) Rachel cannot form thoughts at times - and so had to stop taking public transport, never knowing when her symptoms would manifest. But she can't always take taxis because she can't think straight to say to the driver where to go.

- (2) Serena: "Could the hat talk? Tell the driver what you need?"

- (2) If Rachel had another person it would help - but she'd be dependent on them - so what about the hat? And other people being aware [because the hat could

indicate it by speaking for her], that helps people listening to know it's a problem, so she would not be scared of going out any more!

- (3) Thinking really big [society-wide]: isolation, loneliness is a problem for many. If everybody had a hat it would make her so normal, creating a domino effect, whereby we would all go out and be lovely to each other. The media portrays us as if we're perfect and have no problems and that is not the truth. If you didn't feel anxiety, wouldn't it be lovely [O5]. If only we had some magical methods of dispelling it.

E.3 Mood Shirt, by Serena. Transcribed from notes.

- (1) A woman aged between 50 and 30.
- (3) This woman is changeable; it's hard to know how she'll feel from one day to the next.
- (2) So if a shirt may change colour, people will know if she is feeling fragile [O4].
- (4) But - maybe you don't want everyone to know how you're feeling [O1].
- (5) Maybe it has to be something that only certain people know [O1]. "Today is not a good day to have that particular conversation [O5]."

E.4 Empathy-In Glasses/Empathy-Out Gloves, by Trudy. Transcribed from notes.

- (2) Timmy had glasses to see the colour of people's moods, and gloves for people to understand him [O2, O4]. By wearing these things, other people felt more connected to Timmy and he to them [O5].
- (4) It all went wrong when some bullies broke the glasses.
- (1) Timmy was different, and they didn't understand him.
- (4) Timmy was heartbroken because he could no longer connect with others.
- (5) However, the bullies had learned an unexpected lesson. Through the remains of Timmy's broken glasses, they saw that his emotions were blue and grey with sadness. The bullies could not unsee what they had seen, nor un-feel the emotions they saw in Timmy because of their actions. And so they returned Timmy's glasses.

E.5 Jacinda Dragonfly and Mr. X, by Ursula. Verbatim from author's text.

- (1) The year is 2070 - Jacinda Dragonfly, adventuress, travels across the galaxy to discover exciting and unusual artefacts of historical and cultural importance on behalf of the **Earth World Institute**.

- (3) I say "discover", but sometimes the environments in which she finds herself can be challenging to say the least! High speed rocket chases evading mercenaries around Io, misunderstandings with the elite traders of Hyperion Z, to say nothing of making small talk at the museum's annual gala dinner.

- (2) Jacinda lives for adventure and the thrill of discovery... [O5] fortunately her trusty AI Mr. X has a clearer head [O5] and is able to assist and guide with information both tactical and historical. Together they make a formidable pair documenting lost civilizations across the known universe... Mr. X has been woven into the very fibres of Jacinda's clothing [O4]. Her long jacket, which looks at first glance like a cross between a 1940s detective's overcoat and a traditional kimono, occasionally seems to shimmer as the pattern changes and a small rabbit or sometimes a koi carp, Mr. X's preferred avatars, can be seen moving across the hem. Mr. X was originally programmed by the Troll Underbridge Collective to be her rocket ship's onboard AI guidance system... [O3] although Jacinda did most of his training herself, she was both surprised and pleased when Mr. X started to develop his own characteristics and interests, it was wonderful to have an interesting companion [O2, O5] on her adventures whose skills complemented her own... and also someone to talk to on the long lonely flights across the galaxy.

- (2) Mr. X repeatedly expressed a desire to experience the adventures off-ship too so Jacinda designed a portable mainframe for him. The coat was woven by the spider seamstresses of Luna 6, and cost a small fortune in their preferred currency, littlecakes. Conversation between Jacinda and Mr. X continues freely through the hood of the coat as the garment itself is the housing of the AI, visual information swirls across the sleeves - maps, documents, decorative symbols appropriate to the culture in which the pair find themselves... and if Jacinda pulls the hood down further, she can see right through the fabric, with the digital information given by Mr. X superimposed on the world around her... Sometimes of course it would have been nice to have a little peace and quiet... But Mr. X complained dreadfully now if he was left behind...

- (3) Jacinda looked at the shards of pottery before her. Through the hood Mr. X was already digitally re-assembling the pieces to show an elegant vase with tentacled handles swirling around the impossible geometrical stem. She shuddered and snapped the suitcase closed. Mr. X's voice said clearly in her ear, "Yes as I thought - it's been missing for eight years - stolen from the palace." Jacinda looked up: "I'm sure Miss Wyles at the Keropian Embassy will be very interested to know how one of their iconic artefacts of Kero Pia 8 came to be in your possession Mr. - er - Smith."

- (4) "Now look here!" the Martian bounty hunter began... but Jacinda continued... "contrary to what you may have been told, this establishment is not in the habit of receiving stolen goods, to say nothing of the fact this item is dangerous, if reassembled it could summon one of the elder gods from the dark reaches... They eat planets you know, and I'm sure we don't want that..."

- (4) "Martian Guards on their way, ETA 4 minutes" the voice of Mr. X continued in her ear.

- (5) After a brief tussle, during which the thief attempted to escape, Mr. X caused a distraction by appearing across the coat as a fire breathing dragon, Jacinda broke a nail and the Martian guard arrived. Miss Wyles, Curator of Keropian Artefacts, was contacted, thrilled to have recovered the lost treasure, and promptly invited them for cocktails at the embassy...

E.6 Wearable Life Support, by Viola. Transcribed from notes.

- (1) Viola works in international development. She imagined a dystopia caused by water shortage. Water will be a limiting resource in the world because we are contaminating it so rapidly. Water is a limiting factor for all humanitarian projects [O5]. So Viola is anticipating solutions like those in *Dune* [120].
- (1) There is always a level of organicness about it. If we had a way to recycle, to get more water out of it.
- (1) Badlands: Viola can see the writing on the wall with the droughts. Physiological regulation: what could I achievably contribute?
- (2) So Viola's idea is a mask to collect our water as we breathe. Filamentous nets that would go out and keep the condensation down to a pooling area.
- (2) Another idea is inspired by *Avatar* [44] - the tree would be symbiotic/sentient. Simple and achievable, mass producible: recycle respired air. Collect urine in little packets worn round our body. More futuristic technologies - repurpose it.
- (2) Bodysuits to create kinetic energy, addressing the obesity problem, even with pets. If you don't move, your phone or laptop will not work, so you would have to generate your own power for your secondary needs. If you had a secondary need you would have to work for it.
- (2) Extending human faculties/sensory range to match that of certain animals. Tune in to hear ultrasonic or subsonic channels. Make max use of environmental resources.

E.7 Gallery Jacket, by Warren. Verbatim from author's text.

Part 1: Warren cannot read

- (1) A long time ago, Warren was at school. The school was a highly academic traditional school, where the majority of pupils left the school at 18 to go onto university. While Warren was intelligent to be at the school, he showed a passion beyond the academic life of the classroom, to the art room. By GCSE he had completed a full art portfolio, of both vibrant and exquisite pieces, in 2D and 3D.

Exploring all sorts of other media too, photography was a key supporting part, many of those resulting in unique pieces on film cameras. The GCSE showed something that had kept him going, throughout the school there was something social where he had never quite fitted in, creativity was frowned upon in an intellectual environment, often jealousy. The majority of the pupils at the school were academics, Warren was awarded the Art Scholarship at school!

- (1) Unfortunately, at the time, art was not deemed a successful career path and therefore was frowned upon. Weighing up the options, engineering was the next creative route where art could, perhaps, be integrated. University applications were a demanding time. At the time Warren had a tutor who was writing his references to support his university applications. The tutor was an old man, with grey curly hair. The tutor had an outstanding feature, where he had a lazy eye, so no one knew which direction he was looking! With regards to the interview for the references, simple questions were easy, choose an engineering degree and some universities that were realistic to apply to. The next part of the references weren't as straightforward.
- **Tutor:** "What books do you read?"
- **Warren:** "I don't read, I prefer to draw a picture"
- **Tutor:** "You can't get into university without reading, how about newspapers?"
- **Warren:** "I don't read those either, I don't find the news enjoyable"
- **Tutor:** "What about journals and magazines?"
- **Warren:** "Well I do look at the pictures in Photography monthly..."
- The tutor at this point looks in a shocked manner, the tutor assumes that Photography Monthly must be some sort of dirty photographic magazine.
- **Tutor:** "Well you don't seem to read, so you can't read then!"
- (1) Warren didn't bother to respond to this, as having known this tutor it was easier to not respond to avoid trouble, ever since then "I can't read" has been the normal reply to people following this incident.
- (1) Perhaps the moral of the story at this time isn't about intellectuals, but about where life will take us. With 5 out of 6 offers for university and no rejections, completing a Masters in Mechatronic engineering do we really need to read to be creative, after all, a picture is worth 1000 words.

Part 2: Anti-social-media and the disappointment of expectations

- (1) University, some say it is the best days of our lives. It is meant to be an opportunity to define ourselves, or is that an empty, vacuous tale we forge to encourage as many people to attend as possible? The films out there give a false impression, a false reality. While Warren was at school, life was unhappy, he neither fitted into the high intellectual (grade churner), nor was he in the category for sport - there weren't really any other gracious categories at school and artist certainly wasn't one of them, nor was having the Art Scholarship in the sixth form. School days were miserable, but then life was meant to be better at university.

- (1) University was completely the opposite, it was nothing to what it was made out to be, once there Warren was the high academic flyer, studying hard at engineering, trying to utilise art and development in the course. Night life was a miserable town, the lowest of low lives, fizzy gas lager, loud noises and a few hundred people shouting over a speaker set. Clubs and societies were the same, if you didn't go to the social at the night club then you were no longer a member of the club or society! By the second year, Facebook had been introduced, so life ended up worse, not better, people no longer knocked on their flatmates doors, where instead they could just write insults on the electronic walls, and lock people out of their lives as quickly as they let them in.

- (1) The fact was that you could lead a false shallow life on social media, people who wanted to live a normal life like Warren suddenly became even more lost. Almost like a needle in a haystack. Not only becoming lost in the large bodies of the night clubs but now banished to a mere existence in social media too.

- (1) One evening there was a power cut... well social media was no good without the internet, Warren set out with his new Digital SLR camera, out into a cold misty evening, with just a small torch on his phone for light. Walking down the road to a remote spot he realised that the best people weren't those at university, but those that could be seen in the sky, the stars. By locking the camera for anywhere from 15 minutes up to an hour, relaxation and a real getaway from the hustle of university could be found and so could new photographic concepts.

- (1) The only real problem at this point was that all of the images ended up shut away on a computer, even when posted on Facebook they were ignored and often covered by a few hundred other photos of people going to the night clubs drinking bright blue poison, that will eventually eat their livers alive.

- (1) Everyday there was more passion, back to the start for this creative outlet. Building cars, making the films for them as supporting material, and flying machines were all part of the Engineering Degree.

- (1) So Engineering was the career path, chosen, not by choice.

Part 3: Is society a place of integration?

- (1) Rejection is a common ritual for large companies on applications, not only that but the time and the poor communication really is a reality of the 21st century. Warren eventually got a job, apparently it was meant to be a dream job?

- (1) Well the job was a lie, promises were broken by the employer, numerous staff problems started to occur. Bullying in the work place became common place. Events such as being shaken by a 6ft7 ex rugby player, HR response - could be seen as an office joke.

- (1) Well, things got serious and health and safety fell apart. Eventually he became ill, too ill to work, vertigo, spinning every day, depression and anxiety.

- (1) Who are we to stand in the way of large corporate businesses?

- (1) Along with vertigo came something far worse. The morning of the vertigo starting, also the high pitch hearing disappeared, no longer hearing the birds tweeting in the morning. Instead just a muffled life. At this point hearing aids had to be fitted.
- (1) Unless you have hearing aids, you can never really understand the social, or rather anti-social side to society. What we learnt from earlier was that Warren was the person who was hidden in society without trying. At this point life could only get worse.
- (1) Social interaction was made far more difficult. With hearing aids, in the middle of a crowd, hearing is almost impossible, there is too much noise and voices cannot be distinguished. So it is easier to stand on the edge of a crowded room. Unfortunately society doesn't see kindly on this, any hearing aid user is seen as anti-social, and why, well for a proper conversation you need to be on the edge, the fact is that you are considered to be anti-social for having the body language of the person on the edge. There is a yearning inside, for humans are social creatures, but reject things they don't want to understand.
- (1) To be seen or heard, how will this work?
- (1) Even as a teacher, and at teacher training the social rejection was unbearable, who are teachers, they are meant to be inclusive of all people, even disabled?

Part 4: To be seen, is to be heard, a picture is worth 1000 words and a conversation?

- (1) A few older people had seen Warren work and had been encouraging him to get his work out there, in the market place and out on the streets. This was a lot of hard work, not only that but talking to people and social interaction were creating depression and anxiety making it harder, even in the right places.
- (1) Until one day.
- (1) To be seen is heard? - at university it was always the outgoing, with some distinguishing feature, height or an icon that grabbed attention. One day someone saw Warren in the shadows of a local bar. They had seen his photography, and wanted to see it further.
- (2) Discussions one day came and suddenly someone found a strange jacket [O4]. Like an electronic frame, where the images could be loaded to the memory of the jacket, suddenly they would shimmer on the back, showing the stars and the beauty of nature that could be captured from the camera.
- (3) All of a sudden people would go over to talk about the images. Life was perhaps much better with this, but what was important was that the jacket was a one-off.
- (2) In fact, a moving gallery was setup where people could wear the jackets and become a living gallery.

Part 5: Aspergers and Social Communication

- (1) With regards to the social communication aspect, conversations had never been an easy progression, and making friends/relationships was awkward. Always the one who was reserved and in the back ground, never one to be spoken to either. In social situations is was as though there was a strange black cloud hanging over but there was no understanding why.
- (5) One day, visiting the Disability Centre, the adviser picked up on something odd, that eye contact and body language were perhaps something that had almost gone. Being sent to the assessment centre for Aspergers and the initial traits explored.
- (3) Where people require something they have for people to talk to them, making life easier, the equivalent to a confidence booster, something to engage others, and start that initial friendship. The realisation behind the traits was just as important, understanding personal strengths and weaknesses. The fact that high intelligence was preferred to small talk that seems irrelevant.
- (5) How to engage? Therefore a tool, item that was always available to cross this boundary.

Appendix F

Iteration of Design Fictions

F.1 Wooden Horse, by Grace

F.1.1 Version 1. Verbatim from author's text.

MY STORY inspired by Philip Pullman's *"The Amber Spyglass"* [218] and by *Blade Runner* film 2 [271].

1. This is the story of John. John is a boy of 7 years. He is very timid and scared & quiet because he is bullied at school and has low self-esteem. In the school there are many long corridors where John can hide. It's a dark, old place. He has few friends. He's been wearing a hearing aid for a long time. Everyone thinks John is deaf. But this is no ordinary hearing aid - this is a special tool that is disguised as a hearing aid [Figures K.1 and K.2] [O1].

2. It's in the shape of a jumping horse and is bright red with a white spotty saddle on a dark brown leather saddle. He feels comfortable and happier wearing this device because inside is a computer chip/a voice that is always talking to him. The voice is like one of Philip Pullman's Daemons [218] - a special friend programmed to fit the personality of the wearer - in this case John aged seven.

3. When a bully approaches John's little voice might talk to him - tell him where to walk and how to avoid the other child. It also gives him phrases as a retort to bounce back at the bully. The voice is only heard by John so it sounds like the words he says are John's words. An example of a phrase might be "at least I know how to write", "if you are so strong/clever why don't you try it yourself", "I dare **you** to do it!".

4. One day John didn't manage to avoid his worst bully, who was called James. James took the children's things and hid them in John's bag. Then he told the teacher that John had stolen some things and showed her John's bag. But John had his hearing aid voice which told him to say "Miss, James isn't telling the truth. He's been playing tricks on me so that I look like a thief. He's done the same thing to some of the other children. Ask them, they will say the truth."

5. The wearable is manufactured to fit neatly & comfortably over the ear of both child or adult. This is something that can help with autism or adults with learning difficulties or anyone who suffers from stress, anxiety and depression. **The voice helps to make decisions that keep the wearer safe: such as if a woman is walking home at night, it says not through the park, walk around that way, left at the lamp post - it's lighter if you walk by the A13 route. The voice speaks kindly and with empathy and understands how you feel. The voice tells you what to say to strangers.** The voice can tell when the wearer's heartbeat is raised or has a flight/fight response: **It advises according to the stress levels detected.** The device can be switched on and off manually.

F.1.2 Final version. Verbatim from author's text.

- (1) Long ago, and in a parallel universe, there lived a small boy called John. In this world there are no living trees and no wooden products. They were all burnt in a huge fire that engulfed the planet and the seeds were unable to grow again (although other plants could). If there was anything left made of wood then it was extremely rare.

- (1) John was an orphan living in a home for orphaned boys and he was very miserable. The ladies that looked after the children were supremely cruel and the children were not nurtured or well fed. In fact John had nothing but the rags hanging off the frame of his thin, poor body. There was no magic in the land but there was a legend that if a piece of wood survived the blast (when the planet was destroyed so many years ago), then it had magical properties and was very special.

- (1) The day that John found the "wooden trinket" was when he had been hiding from some boys that had been bullying him. He scrambled into the chimney of the municipal kitchens and managed to climb up its sooty walls by using loose bricks as stepping stones. The wooden horse was on a ledge in the kitchen's fireplace and it fitted snugly into John's fist. He slipped it in to a fold in his right sleeve where the material had worn through and there was a natural pocket perfect for hiding treasure [O1].

- (1) It wasn't until later that John realized that the horse was magic and could speak to him telepathically. It became his only friend and confidant.

- (2) When John put the little horse near his right ear it would jump into his ear and it morphed into a hearing aid. When it rode in his sleeve (now safely sewn in with stolen cotton), it had the ability to communicate telepathically and felt warm to the touch. It could fly and never slept, and therefore could be summoned day or night. It also had the strength to move John out of the way of flying objects like the frying pan the cook would regularly throw at John when he came to steal food. It could be carried in these two positions.

- (3) John felt more confident when he had the little horse close to him. It warned him when another nasty boy was coming close and John was able to run and hide. It also told him how to defend himself and how to speak words that would act as a retort. The other children didn't know about the horse because it was so well hidden

and because it spoke to the wearer telepathically. It was also too quick for them to see. It flew around at high speed - faster than the speed of light and noiselessly.

- (4) One day John was approached by a nasty boy called James. He told the chief Nurse 1 at the home that John had stolen some things from the kitchens. This time it hadn't been John who had stolen the stuff. The wooden horse got hot, flew to his ear and told John what to say to Nurse 1. The voice suggested John say:

- (4) "He's not telling the truth and I can provide the evidence. He's lied to you before and the other children know this. They will tell the truth." Then it quickly lifted him clear of James' punch without James or Nurse 1 even noticing.

- (5) The wearable is manufactured 218 years later. It is made of magic wood and can be worn both in the ear and in the sleeve of a specially designed hoodie. Those that benefit are the elderly, vulnerable women, sick children and people with learning difficulties. The wooden horse's voice helps to make decisions that keep the wearer safe such as if a lone woman is walking home late at night it will direct her the lightest and safest route. The voice speaks kindly and with empathy and understands how you feel. It gets hot when there is danger, when the wearer is stressed and/or if it senses danger. It helps people to avoid conflict by pushing them out of harm's way and keeping them from striking back when attacked. It never sleeps or switches off.

F.2 Amelia and the 8 Inventions, by Hunter. Verbatim from author's text.

- (1) Once upon a time there was a girl called Amelia. She loved inventing things. She wasn't like the other children, she lived on the wrong side of the tracks and her father was ill, so she spent most of her time looking after him, and she didn't have many friends.

- (1) She spent most of her time in her bedroom, using her imagination to invent something new every day. Amelia wanted to invent something that would make people feel better. All she wanted was to make other people happy.

- (2) She invented many different things, but none of them seemed right. First, Amelia invented the Anxiety Anklet - an ankle bracelet that would sense when the wearer was feeling anxious and would help to lower their heart rate and calm them down [O4, O5].

- (2) Then she invented the Watch of Wisdom - it could tell how the wearer was feeling and cheer them up if they were sad, or it could impart sage advice: if the person wearing it felt awkward it could tell them what to say to feel included [O4, O5].

- (2) Her third invention was the Breathing Bracelet - it knew if you were scared or worried and it helped to calm you down by reminding you to breathe in and out slowly [O4, O5]. But it wasn't good enough.

- (2) Amelia knew everybody had secret fears or worries, so she made the Scarf of Secrets: a scarf you can whisper your darkest thoughts or wildest dreams into and it would help you to feel listened to, so that you had somebody to talk to who would understand anything you wanted to say [O4, O5].

- (3) Sometimes the teacher pointed at Amelia to answer a question in school, but then she would panic and be unable to think of the answer. The other pupils often teased her as though she was stupid.

- (2) It was very embarrassing, so to solve this she designed her invention number five: The Mask of Mystery! The mask could scramble your face into a jumble of pixellated squares so that nobody would know who you were if you said something wrong in class - but if you got the answer right it would reveal your face so everyone would know you did actually have a brain after all [O1, O4, O5].

- (2) Then Amelia realised that as she spent most of her time in her room, what would be really good to have was something to cheer up her room - so she created the Creativity Curtains - curtains that allowed her to colour in a small section of the design and then it would fill the entire fabric with whatever pattern she created.

- (2) But the curtains weren't enough, she was still anxious and lonely. So she had her seventh idea: the Huggable Hoodie! It was a jumper which gave the wearer hugs whenever they needed one, and it had Serotonin Sleeves to give the wearer a boost if they felt low [O2, O5]. It even came with free Gloves of Glamour that would change colour to match exactly what you were wearing, and make you feel fabulous on the outside, even if you were feeling not so great on the inside [O4, O5].

- (4) After making all seven inventions, Amelia decided to pluck up the courage to show other people. She took her inventions to the school science fair - where, of course, they went down like a lead balloon with all the popular kids, who teased her for wasting her time making things that weren't "cool".

- (4) Luckily, there was one teacher at school who seemed to understand her. He looked at all her inventions, and then said. "Why don't you combine them all, and make something everyone will want to wear?" So Amelia went home, and spent hours sketching, designing and building her eighth invention.

- (2) It was the Positivity Patch. Small enough to be worn on the move, it monitors your serotonin level and can boost it with a miniature SAD lamp. It can even sense when the wearer was anxious or sad and come up with positive slogans and images that could cheer you up or calm you down. She even came up with a catchy slogan: "The Badge that Boosts your mood!" [O4, O5].

- (5) In time, her invention became used all over the world, and people called it the "Amelia-8". Amelia is now a successful entrepreneur, she has found her tribe of friends who understand her and she still tries to make people happy when she can. And when she can't, she just sits with them and listens, and gives them a Positivity Patch so they can continue the rollercoaster ride of life, one step at a time, moving forwards towards a happier future.

F.3 Hat-of-All-Assistance, by Rachel. Transcribed from notes.

- (1) The only place she really feels well now is in the forest.
- (1) Her name is Millie [? Meep ?] She ran and danced, skipped and sang, read books, travelled to faraway places, jumped out of planes, always took chances. She led negotiations. She broke bad news, comforted people, formulated arguments.
- (1) She felt ill. She relocated, busted down her job. Gave up every activity in an attempt to recover.
- (1) Her skin itched and burned all over, every day. The merest touch made her flinch. Humidity and warmth made her desperate for escape. Every day she woke up feeling worse than when she'd gone to bed. She began to envy the goldfish for its memory. The computer became her social life, and she began to find people around the world who had a similar kind of life.
- (1) Nobody can be that ill, surely? You look perfectly fine to us.
- (1) One day, someone shouted out "scrounger". Millie went out less often.
- (1) Millie went out to the forest with bottles of water, soft cloth that she could drape over her skin to stop it burning.
- (1) She noticed the little things that made life better for a moment: a soft breeze...
- (1) She loved to lie down and watch tiny creatures climbing up blades of grass, inspired by their determination.
- (2) She fell into a deep sleep... woke up, felt completely refreshed and wide awake! She felt better than she had in years! She didn't know what had happened, but something had.
- (2) A beautiful scent filled the air... she noticed a small patch of a mosslike plant where her head had been. The most exquisite tiny starlight white flowers hidden in the little cushion. They seemed to be twinkling back at her! Surely it was a trick of the light!
- (2) As she watched mesmerised, that patch of magic moss began to pulsate, it floated right off into her hand. At once her whole body relaxed, warmed and seemed to breathe out. The knots unknotted, the muscles smoothed, and all the pain flowed out like a river. She had a desire to run and run and run.
- (2) She put the moss under her hat and she ran off into the forest to explore it with all the excitement and joy of a little child. It fitted perfectly inside the brim, the hat itself seemed to have taken on the special qualities of the magic moss.
- (3) Every night she sat the hat carefully on an east facing windowsill where it would be struck by the beams of the rising sun. She breathed in its mystical scent, absorbed its healing properties through her skin. Each new day saw her awake with increasing energy and vigour, her aches and pains became a distant memory, and her thinking was clear as a bell.

- (3) She cleaned her house from top to bottom until it shone. She painted the skirting boards, polished the furniture. She started piano lessons, singing lessons. Bought a spaniel and a parrot, bought a camper van. She went to a music festival where she played the guitar, danced round the campfire all night. Did whatever she wanted, everywhere she went she met new friends and fellow travellers.

- (3) She lent the hat only to those who would not ask too many questions [O1]. Then she searched for the hidden ones, the ones who'd faded from life.

- (4) She looked for a job, things had changed, norms had changed. "How do you account for this long gap in your employment record, miss?" "How do we know you won't fall ill again?" and "Why do you always wear that hat?" They didn't believe she was properly well again and they didn't believe in taking chances.

- (4) Some people started to eye her hat suspiciously. It was a terrible shame, not to mention rather shortsighted that nobody was willing to take a chance on employing her. She was not prepared to explain to people about her boundless energy or reveal the secret of the magic moss. Big Pharma might plunder the forest and destroy the moss's magic in the process.

- (5) So she wrote a book, founded a donkey sanctuary with the proceeds, and lived happily ever after.

F.4 Mood Bracelet, by Serena. Verbatim from author's text.

- (1) Margherita Banks was known as Rita to her friends. She would have preferred Daisy, the Anglicized version of her name but she wasn't sure her disposition was sunny enough for such a cheery name. Sometimes she wondered if in fact Rita was short for irRITAble as that's how she often felt; not all the time but often enough to get her down.

- (1) Her husband was great, very understanding about the Jekyll and Hyde character she often was... buoyant with enthusiasm and affection one week, only to be short-tempered and pessimistic the next. She had always suffered from the occasional bouts of depression and anxiety but coupled with a monthly swing from rational and calm to weepy and cross it was getting hard to bear.

- (2) One day, whilst browsing her local junk shop, she found an unusual bracelet [O4]. She tried it on and it started glowing with a gentle white light, which gradually changed to a serene green. She was entranced. Checking the price tag she realised it wasn't too expensive and headed straight to the counter to pay the shop's owner.

- (2) "Are you sure love?" said the woman, "I'm not sure green goes with that dress." Rita felt a stab of irritation and the bracelet turned red.

- (2) Looking in her capacious bag she struggled to locate her purse. Had she forgotten it? What a useless mess she was, what an IDIOT not even able to keep track of her purse, what would she do if it wasn't in her bag? It MUST be here somewhere!

- (2) She felt a wave of embarrassment and noticed her heart quickening with anxiety. The bracelet glowed a pale blue. She found her purse, paid the woman and headed home as quickly as possible.

- (3) She loved her new bracelet, the way it emitted a soft light every time she put it on, the way it changed colour, seemingly at random. She wore it every day. Mainly it was green but sometimes it turned red or blue, or shone bright yellow or vivid purple. It reminded her of a mood ring she'd owned as a child which changed colour with body heat and supposedly showed how you felt at the time. Suddenly it struck her, the bracelet DID change with her moods. How did it know? Was it reading her mind or electrical signals? She had no idea, she just knew it was alarmingly accurate.

- (3) Her husband was sceptical to say the least but even he had to admit she was right when it turned blue when she was anxious the evening before starting a new job or red when everything seemed designed to annoy her and she was close to losing her temper.

- (4) He learned to read the colours for what mood Rita was in. He began to just leave her alone when she was angry. He stopped suggesting they go out and see friends when he thought her anxiety levels were high. This made Rita miserable.

- (4) On a whim he booked a table at a local restaurant as a surprise for Rita, to celebrate her new job but when she got in from work he was dismayed to see the bracelet glowing red and blue alternately. He said nothing but immediately called the restaurant to cancel, thinking she certainly wouldn't want to go out feeling sad and angry. Rita heard the call and asked what was happening. He explained and she burst into tears.

- (4) "How could you?" she wailed. "I would have LOVED to go out, it would have really cheered me up, I've had SUCH a rough day!" The bracelet glowed ever brighter and as she watched it she felt more angry and upset than she had thought possible. Here were her emotions made solid and real, a physical reminder of how bad she was at controlling them or herself.

- (4) Her husband felt terrible. Maybe anticipating her feelings based on the mood bracelet wasn't as straightforward as she had thought. He promised to always talk it through with her in the future.

- (5) Gradually they learnt to see the bracelet as a barometer of emotion, not something to start living your life around. Rita found it useful as it acted as an early warning system when she began to feel low or anxious or hormonal. She would see it start to change and check in with herself, recognising that maybe that day wasn't the day to take any big decisions. It helped her to see when she needed to take a break from the overthinking and go for a walk or meditate.

- (5) The bracelet's colours became a gentle reminder that she should stop, breathe and check in with herself. Over time she learned to be a little kinder to herself which in turn made everyone else a little happier [O5].

F.5 Jacinda Dragonfly and Mr. X, by Ursula. Verbatim from author's text.

- (1) **Introduce character and build world:** The year is 2070 - Jacinda Dragonfly, adventuress travels across the galaxy to discover exciting and unusual artefacts of historical and cultural importance on behalf of the EWI - "Earth World Institute".

- (2) **Wearable technology - what does it do?:** The AI "Mr. X" has been woven into the very fibres of Jacinda's clothing [O4]. Her long jacket, which looks at first glance like a cross between a 1940's detective's overcoat and a traditional kimono occasionally seems to shimmer as the pattern changes and a small rabbit or sometimes a koi carp, Mr. X's preferred avatars, can be seen moving across the hem. Mr. X was originally programmed by the Troll Underbridge Collective to be her rocket ship's onboard AI guidance system... [O3] although Jacinda did most of his training herself, she was both surprised and pleased when Mr. X started to develop his own characteristics and interests.

- (2) Conversation between Jacinda and Mr. X continues freely through the hood of the coat as the garment itself is the housing of the AI, visual information swirls across the sleeves - maps, documents, decorative symbols appropriate to the culture in which the pair find themselves... And if Jacinda pulls the hood down further, she can see right through the fabric, with the digital information given by Mr. X superimposed on the world around her... [O2]

- (3) **Day in the life using the tech:** It was wonderful to have an interesting companion on her adventures whose skills complemented her own... and also someone to talk to on the long lonely flights across the galaxy. The environments in which Jacinda often finds herself can be challenging to say the least! High speed rocket chases evading mercenaries around Io, misunderstandings with the elite traders of Hyperion Z, to say nothing of making small talk in the evening at the museum's gala dinner.

- (3) Jacinda lives for adventure and the thrill of discovery... fortunately Mr. X has a clearer head and is able to assist and guide with information both tactical and historical [O5]. Together they make a formidable pair documenting lost civilizations across the known universe...

- (4) **Drama! Conflict!** One day the inevitable happened and the AI coat was stolen by the Lunarian Mafia who were determined to hold it to ransom and force Mr. X to work for their evil corporation. Jacinda had to work alone to rescue the coat and its resident AI from the Lunarians.

- (5) **resolution/success/sequel:** It was difficult for Jacinda having relied on Mr. X for so long to now be on her own, but she managed to formulate a plan and successfully discovered and broke into the villains' hideout. Mr. X caused a distraction by appearing across the coat as a fire breathing dragon and the two of them made their escape via a life pod which the AI successfully hacked.

Appendix G

Final Story Updates

G.1 Addendum to Gallery Jacket, by Warren. Verbatim from author's text.

G.1.1 Alternate ending 1: Utopia?

What happens when there is a happy ending?

Suddenly new galleries opened in the high street, niche creators were being recognised in shops. QR codes, no longer forced people to online shops, but instead to apps that directed people to shops of local interest. Scan the shirt QR code and get directions to the café, or location of the nearest piece [O2, O3, O4].

Mental health and recovery rates were much higher allowing individuals to no longer feel crushed but to express emotion through art [O5].

Then again, the next question is, is there a happy ending?

G.1.2 Alternate ending 2: Breakdown of Society

So what do you believe?

The violation of society and recent outbursts including the election showed that individuals had no control.

What had become an object of desire and positive mental and social benefits to the lesser unheard individuals, was now being abused. Propaganda was not only going out on television, Facebook and Twitter, but now false news was everywhere, walking down the streets.

Being used and abused and not for the intended purpose of the design. Knock off foreign designs in other cultures were stealing the data [O1] as people up loaded it from their computers and smart phones and were maximising profits and illegally stealing copyright without permission.

Society turned back to where it was before, the individuals in the corner being ignored again, events sabotaged and sacrificed for conglomerate greed.

Images no longer had meaning and due to lack of censorship there was no happy ending, instead as sad as it started [O5].

G.2 Amelia and the 8 Inventions, v2, by Hunter. Verbatim from author's text.

Once upon a time there was a girl called Amelia. She loved inventing things. She wasn't like the other children, she lived on the wrong side of the tracks and her father was ill after chemicals from the factory near their house leaked into the water supply, so she spent most of her time looking after him, and she didn't have many friends. The country was at war. Half of the country had voted to make the wealthy have more wealth, the other half had voted to make the poor less poor. A state of emergency had been declared, with a curfew after dark, to try to prevent the nightly attacks from each faction towards the other. Half the country was poor and depressed, the other half wealthy but depressed because their extra wealth had not made them extra happy, a fact which surprised them.

Amelia spent every evening in her bedroom trying to invent something that would make people feel better. All she wanted was to make other people happy. Rich or poor. She invented many different things, but none of them seemed right.

First, Amelia invented the Anxiety Anklet - an ankle bracelet that would sense when the wearer was feeling anxious about the war and would help to lower their heart rate and calm them down [O4, O5].

Then she invented the Watch of Wisdom - it could tell how the wearer was feeling and cheer them up if they were sad, or it could impart sage advice: if the person wearing it felt awkward it could tell them what to say to feel less awkward around people who were rich or poor [O4, O5].

Her third invention was the Breathing Bracelet - it knew if you were scared or worried and it helped to calm you down by reminding you to breathe in and out slowly [O4, O5]. But it wasn't good enough. The attacks were getting worse. Rich people were setting light to money in front of homeless people, and laughing about it.

Amelia knew everybody had secret fears or worries, so she made the Scarf of Secrets: a scarf you can whisper your darkest thoughts or wildest dreams into and it would help you to feel listened to, so that you had somebody to talk to who would understand anything you wanted to say [O4, O5]. But that made the rich people more powerful, instead of ashamed.

Sometimes the teacher pointed at Amelia to answer a question in school, but then she would panic and be unable to think of the answer. The rich pupils often teased her as though she was stupid simply because she was poor. It was very embarrassing, so to solve this she designed her invention number five: The Mask of Mystery! The mask could scramble your face into a jumble of pixellated squares so that nobody would know who you were if you said something wrong in class - but if you got the answer right it would reveal your face so everyone would know that poor people did actually have brains after all [O1, O4, O5].

Then Amelia realised that as she spent most of her time in her room, what would be really good to have was something to cheer up her room - so she created the Creativity Curtains - curtains that allowed her to colour in a small section of the design and then it would fill the entire fabric with whatever pattern she created. But when she opened the curtains each morning and saw the new devastation outside, it didn't help.

The curtains weren't enough, she was still anxious and lonely. So she had her seventh idea: the Huggable Hoodie! It was a jumper which gave the wearer hugs whenever they needed one, and it had Serotonin Sleeves to give the wearer a boost if they felt low [O2, O4, O5]. It even came with free Gloves of Glamour that would change colour to match exactly what you were wearing, and make you feel fabulous on the outside, even if you were feeling not so great on the inside [O4, O5].

After making all seven inventions, Amelia decided to pluck up the courage to show other people. She took her inventions to the school science fair - where, of course, they went down like a lead balloon with all the rich kids, who teased her for wasting her time making things that weren't "cool".

Luckily, there was one teacher at school who seemed to understand her. He looked at all her inventions, and then said, "Why don't you combine them all, and make something everyone will want to wear?" So Amelia went home, and spent hours sketching, designing and building her eighth invention.

It was the Positivity Patch [O4, O5]. Small enough to be worn on the move, it monitors your serotonin level and can boost it with a miniature SAD lamp. It can even sense when the wearer was anxious or sad and come up with positive slogans and images that could cheer you up or calm you down. It had an algorithm to prevent fake news and horrible political messages from appearing. It only allowed things that would improve your mood. She even came up with a catchy slogan: "The Badge that Boosts your Mood!"

In time, her invention became used all over the country, amongst the rich tribes and the poor, and people called it the "Amelia-8". It helped people of all factions to feel their voices were being heard. It helped people forget their differences and come together.

Amelia is now a successful entrepreneur, she has found her tribe of friends who understand her and she still tries to make people happy when she can. And when she can't, she just sits with them and listens, and gives them a Positivity Patch so they can continue the rollercoaster ride of life, one step at a time, moving forwards towards a happier future.

Appendix H

Pilot Studies

This appendix describes four pilot experiments conducted in October 2017 in order to sanity-check the workshop format and recruit volunteers.

The experiments took the form of two pairs of participatory storytelling workshops. The first pair were public engagement events for the Cambridge Festival of Ideas 2017 [1] (CFI2017), in partnership with Makespace, on Saturday 21 and 28 October 2017. The second pair was attended by students and hosted by the Design Informatics Programme at the University of Edinburgh, on Monday 30 and Tuesday 31 October 2017, thanks to the hospitality of Dr. Maria Wolters.

H.1 Background

The pilot studies were practice runs to recruit longitudinal study participants. The target was six participants (plus up to 12 reserves) for two years, renewing consent at each phase.

During this first year, the six participants would be asked to attend up to five workshops lasting two-and-a-half to six hours each.

H.2 Purpose

The study would follow a design process beginning with storytelling workshops (O5). The first risk was failure to elicit stories from participants. The second risk was that they might not enjoy the process enough to stay involved.

The first question for the pilot studies: **Do the workshop participants tell stories about wearable devices, or not?**

The second question: **Do the participants find the storytelling process at least somewhat enjoyable, or not?**

If the answer at any of the workshops was "no", the next question was: How must the workshop be changed so that participants a) can tell stories about wearable devices, and b) enjoy doing so?

[1] *University of Cambridge,* 16 October 2017: **Cambridge Festival of Ideas 2017 Begins** https://www.cam.ac.uk/news/cambridge-festival-of-ideas-2017-begins

H.3 Format of the experiment

Each workshop was planned to last two and a half hours. Participants in the first workshop of each pair were not asked to do any preparation, and received the Participant Information Sheets and Consent Forms 24 hours ahead. The Participant Information Sheets included the workshop schedule, an explanation of the workshop activities, and a description of the research study.

The schedule for the first workshops was as follows:

1. Example Story: five minutes.
2. Q&A: five minutes.
3. Group into teams of up to six people.
4. Teams compose a story and nominate a storyteller: 30 minutes.
5. Storytelling: five minutes each.
6. Paper prototyping: 30 minutes.
7. Presenting prototypes: five minutes each.
8. Vote for the winner.

Participants in the second workshop received the Participant Information Sheets and Consent Forms plus preparatory exercises (Appendix H.3.1), up to four days ahead. The schedule for the second workshops was as follows:

1. Group into teams of up to six people and nominate a storyteller.
2. Storytelling: five minutes each.
3. Paper prototyping: 60 minutes.
4. Presenting prototypes: five minutes each.
5. Vote for the winner.

It was not possible to create the controlled conditions necessary for an AB test, nor would that kind of testing be suitable for a creative public engagement event. The plans were a basis for improvisation, not a rigid process.

Although the paired workshops were not AB tests, if the prepared groups had a noticeably better experience than the unprepared groups, or vice versa, that would show how much advance preparation was necessary (O5).

H.3.1 Preparatory exercises for CFI2

The following is the text of the preparatory exercise worksheet:

OUTLINE

Your character has something that they wear every day, or regularly. It does something useful for them.

If you can, imagine this wearable thing as something you would really, really love to have in your life, if only it were possible. Something that you would put on, if your fairy godmother offered it to you. Something you would love to wear every day. Something you dream of having.

If you can only think of silly stories, that's great too. I use some examples later in the exercises that are pretty silly. But if you can imagine a wearable that you would really wish for, if you were granted a wish? That's even better.

In your story, you will tell us about a day in your character's life, wearing this wearable thing. Maybe they've had the wearable thing all their lives, or maybe this is the story of how they got it.

Your character could be you, or an original character that you've created, or a character from a book or TV show. This wearable thing could be your own invention, or it could be something from a book or TV show, like Wonder Woman's bracelets or Get Smart's shoe phone.

Your story should take up to 5 minutes to tell.

MY EXAMPLE STORY

My story is inspired by a children's book by James Thurber, called "Many Moons". Published in 1943, it was read to me as a schoolchild.

1. Introduce Your Character and Build Their World

"Many Moons" is the story of a little princess named Lenore, who falls ill and cannot be healed. She is inconsolable because she wants the moon, and will not be well again until she gets it.

The King sends experts, astronomers, and scholars from all the land to explain to Lenore why she can't have the moon. They explain the size of the moon, its distance from the Earth, its effect on the tides. Nothing helps.

Finally, the court jester visits Lenore and asks her: how big do you think the moon is? And she replies, just as big as my thumbnail. As proof, she holds up her thumb, to show that her thumbnail covers the moon.

The jester asks Lenore, how do you think we will replace the moon after we give it to you? And Lenore replies that it grows back every night - just like a fingernail, or a daisy.

The King makes a necklace for Lenore, a little gold disc about the size of her thumbnail. Now Lenore has the moon, she can get well again.

Well, my story is what you might call "Lenore II - The Revenge". Lenore's back, and she's all grown up now - and she's suffering the effects of parents who just couldn't say no to her, all through her childhood.

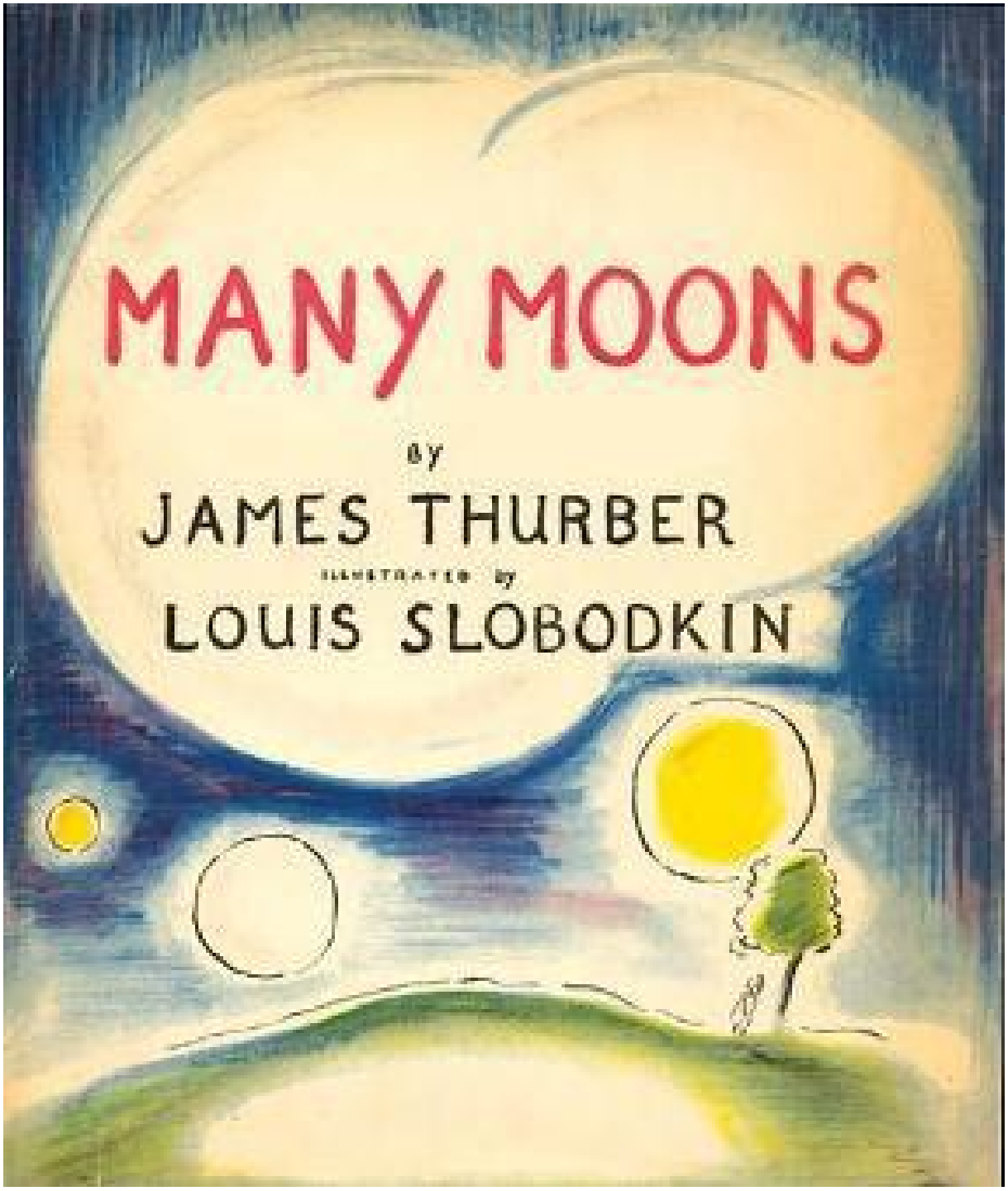

Figure H.1: *James Thurber, Many Moons. Cover illustration by Louis Slobodkin. Harcourt, Brace & Company, 1943.*

2. The Wondrous Wearable

A necklace isn't enough any more... Now Lenore wants a magic dress, to sing a spellbinding song when the moon is full...

You see, Lenore's friends are putting on an opera. Lenore tried out for the opera, but when she opened her mouth and sang, birds fell dead from the trees. If only Lenore could sing, she could join her friends and be popular!

Lenore visits every magician in the land until someone agrees to make the dress she desires.

The dress is made of water and shows the moon's reflection, at every changing phase.

3. A Day in the Life

When the moon is full, Lenore sings. She sings with the voice of a goddess. No words can express the entrancing sound that poured from Lenore's mouth like moonlight. Every living thing that could hear Lenore was spellbound.

4. Drama! Conflict!

In the span of six weeks, Lenore loses 20 iPhones to water damage.

Lenore wins a reality show, and scandal ensues over the legitimacy of her use of voice augmentation.

Mass production of knockoff dresses results in both better and worse quality product, but more importantly extends the lunar phase window in which the wearer's voice is enhanced. This leads to mass immobilization events throughout the land.

Singing loses its status as a special talent.

More seriously, scientists sound the alarm amidst mounting evidence that drawing down the moon so frequently is pulling down the sky, and causing stars to fall at an increased rate.

5. Resolution!

The dresses are manufactured without pockets, or with plastic-lined pockets, reducing incidents of phone damage.

To assert the value of their skill, the Mermaids' Union votes unanimously to go unplugged. This decreases the distance range of their voices, with the unexpected effect that sailor fatalities are dramatically reduced.

Lenore joins *I'm A Celeb* [2] for a redemption arc and to salvage her popularity, and she...

No, wait. That's not how it goes. Is that really how we want it to end? I don't think so. Instead...

Instead, Lenore realizes that this all started with her longing to be in the opera so her friends would accept her. And she realizes that she was looking to her friends to give her something that she really needed to give to herself - and, more importantly, to others.

So Lenore organizes a huge festival and invites everyone in the land to paint the sky with stars. Together, they pin the sky back up where it belongs, and restore the stars to their rightful place in the heavens.

[2] *Wikipedia:* **I'm a Celebrity... Get Me Out Of Here! (British TV Series)** https://tinyurl.com/y73nq6j9

NOW FOR YOUR STORY!

For each minute of storytelling, one step:

1. Introduce Your Character and Build Their World

Tell us who your character is, how old they are, and the time period and place that they live in. Are they a child, an adult? A human? A superhero? An animal? A supernatural creature?

Do they live in the past, the present, the future? Is their world real or imaginary? Is it this planet or another world?

What do they do - are they an ancient Greek god? A sales assistant at Carphone Warehouse? An eccentric Victorian professor?

2. The Wondrous Wearable

Now tell us about the wearable thing.

What does it look like?

What does it do?

Note that I didn't specify the mechanism of action of Lenore's water dress. You can explain how it works if you want to, but I don't require it.

3. A Day in the Life

What is it like for your character to put on their wearable and wear it for a day?

What is it like for the other people to be around your character and their wearable?

What works better with the wearable? What becomes more inconvenient? For your character? For other people?

4. Drama! Conflict!

Something happens!

- **Example:** Lois Lane [3] unwittingly wears an X-Kryptonite [4] necklace, giving her superhuman powers but causing Clark Kent debilitating symptoms!
- **Example:** Snakes on a Bus [5] - the snakes have no difficulty finding the correct change, thanks to their amazing Snake-O-Vests With Hands-Free Pockets! They board the bus without incident, and another sequel is panned by the critics.
- Something else!

5. Resolution!

How does your character use their wearable to resolve their conflict?

- **Example:** The X-Kryptonite necklace is replaced with the Kryptonite-X necklace that Lois actually ordered, which restores Superman's powers. Clark recovers, and Lois receives a refund for the difference.

[3] *Wikipedia:* **Superman** https://tinyurl.com/7uarav5
[4] *Wikipedia:* **Kryptonite** https://tinyurl.com/ycz7taop
[5] *Wikipedia:* **Snakes on a Plane** https://tinyurl.com/y7yc86xr

- **Example:** Vinny the Viper catches the bus on time and makes it to his "surprise" birthday party, salvaging his relationship with Renée Rattlesnake.

How does the wearable solve problems in your character's world?

- **Example:** Thanks to Lois' investigative journalism, stricter regulations are introduced on hazardous materials in the jewellery manufacturing process.
- **Example:** Access to public transit is the main obstacle to snakes' social mobility. The vests enable them to participate fully in public life.

The Sequel: Does the wearable cause any new problems in your character's world?

- **Example:** Thanks to an incomplete product recall, a few X-Kryptonite necklaces are still out there. What if they fall into the wrong hands?
- **Example:** Public support for snake integration is not universal and there are calls for a ban on the sale of Snake-O-Vests to rattlesnakes.

You might want to draw your character with their wearable device.

- What is the wearable made of? What does it do?
- How did your character acquire the wearable?
- Why is your character wearing it in this picture?

The Last Word

You can tell your story in any format you like: reading from a script, improvisational slapstick, interpretive dance, puppeteering, you name it.

If you want to tell your story with a PowerPoint presentation, you can bring it on a USB stick, or bring your laptop.

You can bring props to help you tell your story, and feel free to turn up in partial or full costume. We will have a dressing-up box available during the workshop, but if you have something specific in mind, go for it!

All we ask is that your presentation stays respectful of your fellow storytellers, and doesn't pose a hazard to yourself or anyone else (so maybe keep The Politically Sensitive Adventures of Ethel the Human Torch for another occasion). If you're unsure about the suitability of your act, you can check with me by emailing [email] beforehand.

H.4 Recruitment

H.4.1 Cambridge Festival of Ideas 2017

The workshops were publicized with the following event listing:

CAMBRIDGE FESTIVAL OF IDEAS

TITLE: Design Fiction Jam: Wondrous Wearables

DISABLED FACILITIES: Step-free access, Accessible toilet

EVENT FORMAT: Workshop

RECOMMENDED AGE: Adults

TIMING: Arrive on time

SHORT DESCRIPTION: The Wearable Tech Fairy grants you a wish! Anything you can dream of, with any amazing powers you can imagine - as long as it's wearable. And in return? You have to tell her a story.

DESCRIPTION: What do you wish for? Would you swap your Fitbit for Wonder Woman's bracelets? How about a Garrote-Proof Collar for your Victorian whodunit? Ever coveted Get Smart's shoe phone or Hermione's handbag? Or have you thought of something even better, that nobody's thought of before?

Dare to dream. Join us for an afternoon of storytelling and paper prototyping at the Cambridge Makespace. 18+.

COST OF THE EVENT: Free

CAPACITY OF THE EVENT: 36

=====

TIME AND DATE

Start time: 14:00

End time: 16:30

Date: 21 October 2017, 28 October 2017

Breakdown and purpose of the listing

The listing was worded to communicate the most important aspects of the event:

1. That the subject matter is wearable technology.
2. That the imaginary wearable does not have to be realistic.
3. That the imaginary wearable may be realistic.
4. That participants would be expected to tell a story during the workshop.
5. That participants would be expected to think of an imaginary item of wearable technology.

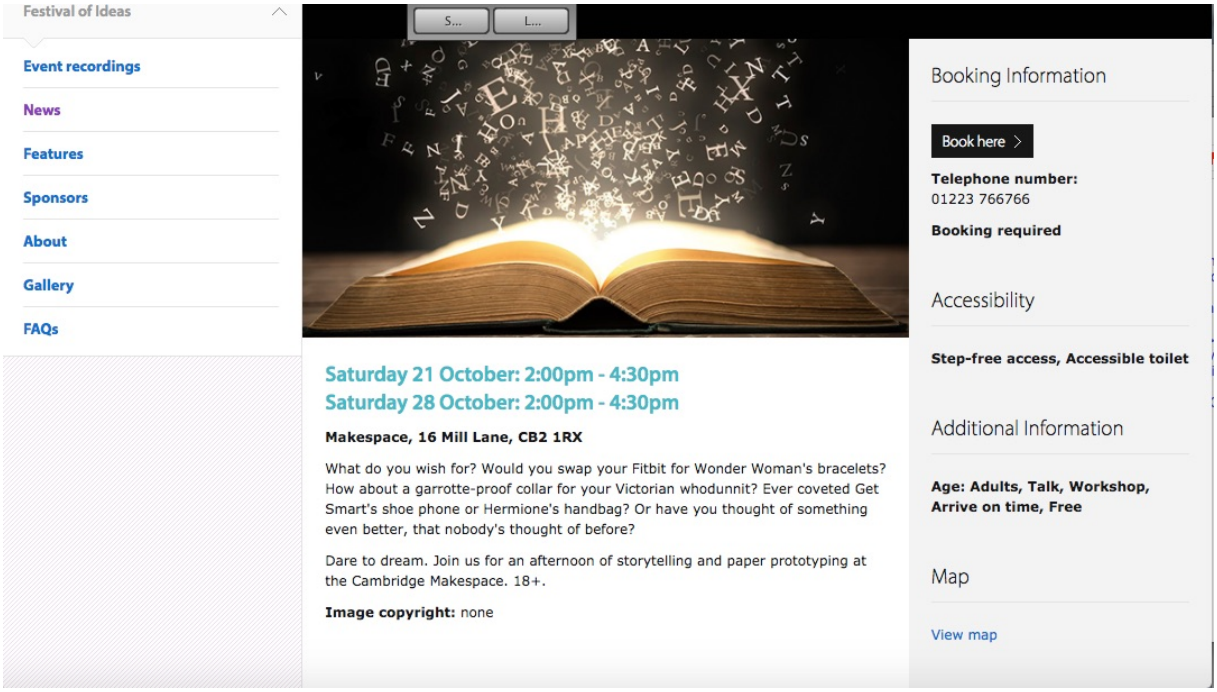

Figure H.2: *Listing on the CFI2017 webpage.*

6. That the imaginary wearable could be inspired by existing media.
7. That the imaginary wearable could be the participant's original idea.
8. That the stories could be set in any time period, including the past.
9. That the stories could be set in any time period, including the present.
10. That the imaginary wearable could be supernatural.
11. That the imaginary wearable could be technological.
12. That the workshop would involve paper prototyping.
13. That the workshop was for adults.

Publicity

The official listings comprised the A5 printed brochure and the the CFI2017 webpage with the Description (Figure H.2) leading to the Eventbrite booking page with the Short Description (Figure H.3). Not everyone saw both pages, so not everyone saw the full text of the advertisement before booking. One attendee described the Eventbrite booking page as "cryptic", having expected the workshop to be more results-oriented.

To make sure advertisements were circulated with all the information in one place, I submitted listings to multiple local listing sites, local and national STEM networks, and personal and professional contacts.

I printed A3 posters and put them up in the most popular areas in Cambridge town centre, as well as in several fashion boutiques and second-hand shops. A well-connected contact with public relations expertise kindly created and circulated a press release.

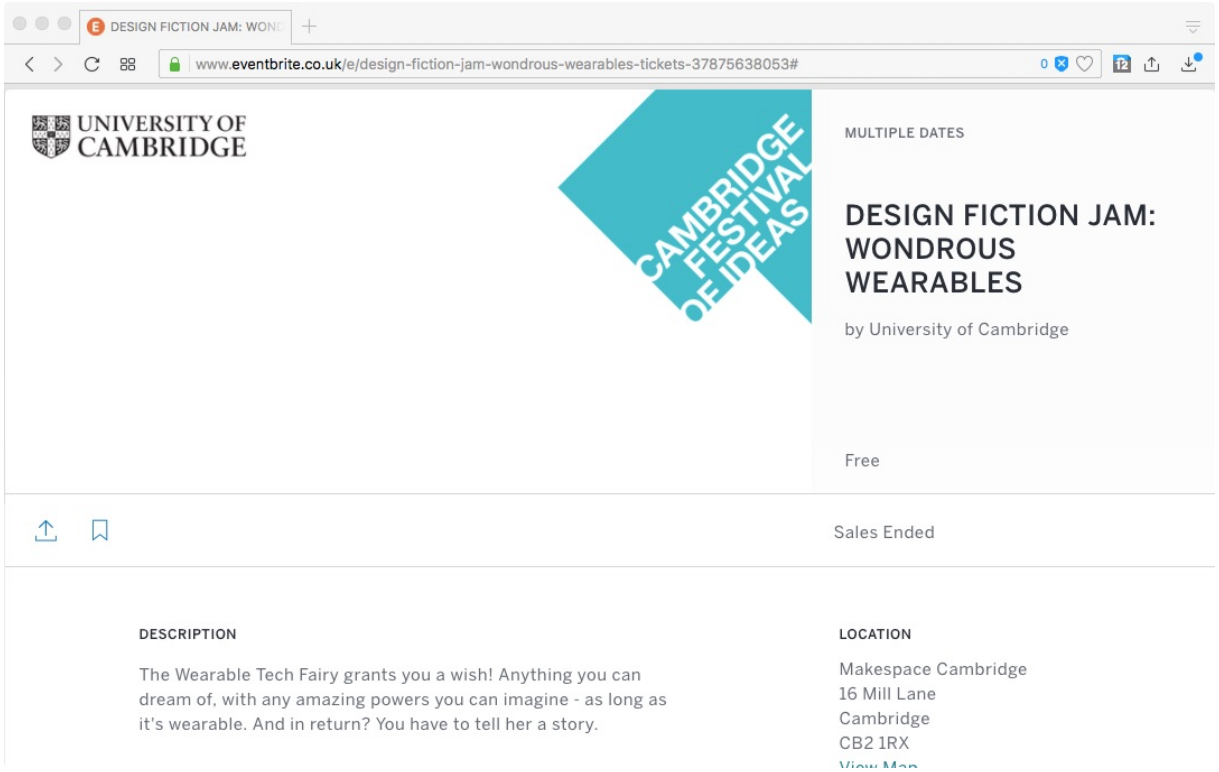

Figure H.3: *Eventbrite booking page.*

H.5 Creative toolkits

The creative toolkits (O5) consisted of three parts: the craft materials, the dressing-up box and the story prompts.

H.5.1 Craft materials

The craft materials consisted of **basic supplies** including rulers, glue sticks, scissors, pencils, paper, tape and paint (Figure H.4); and **embellishments** such as alphabet stickers, pearl stickers, blank bottle caps, crochet hearts, blank masks, craft ribbons and many more (Figure H.5).

H.5.2 Dressing-up box

The dressing-up box included items of **fancy dress** including toy items such as a crown, a monster suit and a sceptre (Figure H.6); as well as 18 items of **character clothing** (Figure H.7) in feminine and gender-neutral styles. Second-hand clothing is harder to find in larger sizes, and only two of 13 sized items were larger than a UK 14, not as size-inclusive as I wanted.

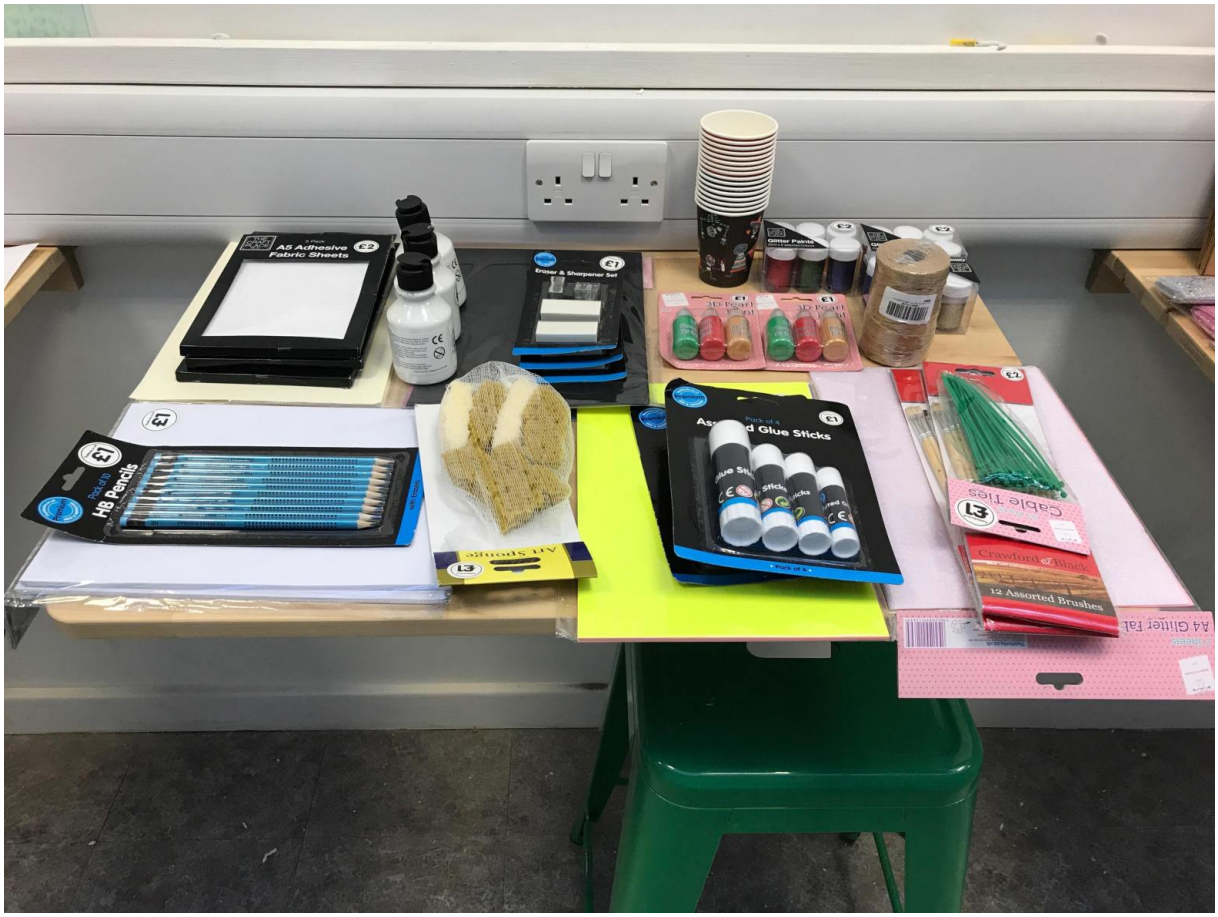

Figure H.4: *Table of craft supplies at CFI1.*

Table H.1: Adaptation of Johnson's "Five Steps"

Original	**Adapted**
1. Pick Your Science and Build Your World	Minute 1: Introduce Your Character and Build Their World
2. The Scientific Inflection Point	Minute 2: The Wondrous Wearable
3. Ramifications of the Science on People	Minute 3: A Day in the Life
4. The Human Inflection Point	Minute 4: Drama! Conflict!
5. What Did We Learn?	Minute 5: Resolution! Sequel?

H.5.3 Story prompts

Example story

I presented the example story (Appendix H.3.1) at the start of each workshop, showing how to structure the story over five minutes and assigning each minute to one of Johnson's "Five Steps" [135, p25]. Johnson's original Five Steps, and my adaptation, are compared in Table H.1.

Figure H.5: *Table of craft embellishments at CFI1.*

H.6 CFI1

H.6.1 Attendance

The event capacity was 36 and up to seven no-shows were allowed for. 27 tickets were booked out of a possible 43. Three people cancelled and four people attended, making 20 no-shows. The attendance rate was only 15%. There may have been too much competition on a Saturday afternoon, or perhaps the content or amount of documentation was off-putting. It is tedious to read a multi-page document that must be signed as a condition of attendance, and perhaps those who did read it simply did not care for it.

The four people who did attend were fully engaged with the process. For an exercise of this kind, enthusiastic participation from a few is better than a full house with half-hearted participation (O5).

No-shows and publicity

I listed the event at a number of online venues.

For a general audience:

- Makespace's Meetup channel;

Figure H.6: *Table of costume items at CFI1.*

- wereallneighbours.co.uk;
- chooseyourevent.co.uk;
- localsecrets.com;
- Personal contacts in my professional and social groups.

For a technical audience:

- Cambridge Ring, the graduate association of the Department of Computer Science and Technology [6];
- Cambridge Network, for STEM professionals [7];
- The BCSWomen special interest group of the British Computer Society [8];
- The Women in Technology unlisted group on LinkedIn;
- Alumni of the UK Space Design Competition [9].

[6] *The Ring:* https://www.cst.cam.ac.uk/ring
[7] *Cambridge Network:* cambridgenetwork.co.uk
[8] *BCSWomen:* https://bcswomen.bcs.org
[9] *UKSDC:* https://uksdc.org

Figure H.7: *Table of character clothing at CFI1.*

Twitter and LinkedIn were the only social media accounts I used for recruitment. I posted on my Twitter account which had 291 followers, to target strangers and loose connections. 14 tweets were published before CFI1, between 2 and 20 October 2017. Four tweets were published after CFI1 and before CFI2, between 22 and 27 October.

The rate of engagement on Twitter (measurable interactions with tweets, divided by number of followers) is very low [10], averaging 0.05% even for large companies with large followings. As an obscure user, my mean engagement rate was 0.03%.

Twitter proved more fruitful with loose connections than the general public. Direct messages to STEM professional followers I have not met, went unanswered. Through a local fandom group that had some connections in my network, and by reaching out to several individuals directly, I recruited one attendee. Only one, but the contribution of this one turned out to be essential to the success of CFI2.

As demographic information for Twitter is publicly available, it is informative to take a closer look at the size and composition of this audience of potential volunteers.

As of June 2018, Twitter in the UK had 18.6 million users split 59% male and 41% female [11]. These users have some computer literacy by definition (except for those whose

[10] *Rival IQ,* 4 April 2017: **2017 Social Media Industry Benchmark Report** https://www.rivaliq.com/blog/2017-social-media-industry-benchmark-report/

[11] *Hootsuite,* 26 June 2018: **Top Twitter Demographics That Matter to Social Media Marketers** https://blog.hootsuite.com/twitter-demographics/

accounts are managed by professionals).

Differences between Short Description and Description: The Short Description (Appendix H.4.1) contained all the essential facts about the workshop, except that it was for over-18s, which was stated elsewhere in the listing. The Description fleshed out the Short Description with examples.

After CFI1, I sought the advice of the CFI2017 organizers about the high percentage of no-shows.

They suggested Twitter and poster campaigns. I explained that I had already put up posters around the city and listed it at a number of online venues. The organizers said it sounded like I had done a substantial amount of promotion, and that they would retweet any tweets that mentioned them. In fact, of the 14 tweets published before CFI1, six @ mentioned CFI2017, the #CFI2017 hashtag was included in 11 tweets, but the CFI2017 organizers only retweeted one of them.

Many of the events of CFI2017 were publicized and promoted in articles and on social media by CFI2017's organizers, but the Design Fiction Jam was not among them, possibly because ticket sales were not high enough to attract their attention. After the Festival, I sought (but did not receive) feedback about what an event organizer should do to merit more promotion from CFI2017.

H.6.2 Participants

The four participants at CFI1 were:

1. "Aaron": white/British, engineer, over 35, English mother tongue (EMT)
2. "Beate": white/European, scientist, over 35, English as a second language (ESL)
3. "Ciaran": white/British, STEM researcher, under 35, EMT
4. "Dominic": Asian, engineer, over 35, ESL

H.6.3 Start of discussion

After the example story, I sat at the laptop table on the right-hand wall, several feet away from the group discussion, to take notes using designVUE. At first, the discussion was led by Aaron, a drop-in from Makespace who did not receive the Participant Information Sheet. Without this information, he was talking in terms of practical reality: what solutions are suitable for the market? What do people want in a wearable? What wearables are available today and what solutions are available for extending their range? From this point of departure, the discussion led quickly to wearables for m-health, for managing epilepsy and other diseases.

It seemed better to let them continue than interrupt their flow. After about 15 minutes I suggested it was time to think about further-future solutions. The participants opted to brainstorm together rather than each producing individual stories.

Participants began by considering existing real-world wearables (intelligent shirt with Velcro add-ons, baseball cap with sensors and an airbag), for use in safety-critical situations

(epilepsy assistance) with current feasibility (temperature-sensing shirt which turns red to warn bystanders that a seizure is coming, and deploys an airbag to protect the patient from impact during the seizure) as well as further-future applications ("if you were epileptic it would be nice if you could drive a car") (O4).

Still in analytical mode, the participants thought of a list of functions they might want their wearables to provide or affect: heat, colour, strength, shape, dirt, emotion, movement (O4, O5).

Considering the further future, the participants thought about what clothes are not already available, and drew inspiration from the abilities of nonhuman animals (an eagle spotting a mouse from a mile away, biomechanics of insects and snakes for sensing the environment) and considered ways of using wearables to put on and take off other animals' abilities. The topic of invisibility came up, as well as the ability to see/sense outside the human-visible spectrum (O4, O5).

H.6.4 IronWoman, by Aaron, Beate, Ciaran and Dominic

Selecting a character, the group created IronWoman [154]. The story, fitted to the Five Steps [135, p25], is in Appendix A.1.

IronWoman paper prototypes

Because an amorphous/polymorphous and polypotent suit (O2, O4) is a difficult concept to express in physical form, the participants chose to symbolize it with a waxed paper cup sealed across the top with a disc of white adhesive fabric (Figure H.8). In effect, it is a Schroedinger's cup, with the suit it contains only existent if IronWoman opens it, which can only be done using her biodata (O1).

Reflection

As Beate needed to leave 30 minutes early, it was soon time to wrap up the discussion and finalize the story. IronWoman is not a perfectly structured story and does not perfectly fit the Five Steps, nor was there much emotional investment from the storytellers (O5). However, it is a story, and thus the goal of CFI1 was met.

Aaron helped by launching an energetic discussion, but by taking an analytical rather than a narrative approach, it set the tone more for brainstorming than storytelling. The brainstorming was rich and divergent, but the participants did not end up converging on an actionable design concept.

H.6.5 Feedback

I distributed CFI's feedback forms at the end of the workshop. Table H.2 shows the feedback.

All of the feedback is consistent with the participants' apparent experience during the workshop (O5). Ciaran did not seem comfortable, despite contributing insightfully throughout.

Figure H.8: *Paper prototype of IronWoman's polymorphous multifunctional suit.*

Table H.2: CFI1 Feedback Form

Participant	Rating out of 5	Did you learn anything new?	Who did you attend with?	Any comments?
Aaron	5	8	Alone	Interesting - Thought provoking would like to see where this goes
Beate	4	10	Alone	Storytelling for scientists - good idea!
Ciaran	4	1	Alone	I don't think story telling and in front of strangers is very natural
Dominic	4	9	Alone	Useful introductory to wearables story

All four participants added their names to the signup sheet, but only Aaron had any further contact. Aaron later expressed willingness to be a reserve if anyone dropped out.

H.7 CFI2

CFI2 took place from 14:00 to 16:30 on Saturday 28 October 2017.

H.7.1 Preparatory exercises

As well as the Participant Information Sheet and Consent Form, a set of preparatory exercises (Appendix H.3.1) was emailed to all participants on or after the Wednesday before the workshop.

H.7.2 Attendance

This time, 14 tickets had been booked. After two cancellations, 12 attendees were expected and four people attended. Fortunately, participation was high quality and the participants showed high commitment (O5). Though mass appeal was unattainable, niche appeal was enough.

One of the attendees tweeted very enthusiastically about looking forward to the event and urging others to join in, with all the right hashtags and @-mentions. This was the participant who had been recruited through a local fan group. The feedback was very encouraging in itself. The tweet was retweeted by CFI2017 and the researcher, liked by CFI2017 and Makespace, and also liked by three individuals with common interests plus one seemingly random individual. However, none of this directly led to any more ticket bookings.

H.7.3 Participants

The participants at CFI2 were:

1. "Erica": white/British, arts and humanities, over 35, EMT
2. "Francine": Asian, engineer, over 35, ESL
3. "Grace": white/British, artist, over 35, EMT
4. "Hunter": white/British, artist, over 35, EMT

A fifth attendee was a white/European male, over 35, ESL. He had not received any of the documentation and was reading it for the first time at the event. He said the event was "not what he was expecting", with no explanation of what he was expecting, and left before the workshop began.

H.7.4 The Hermit and the Shepherd Boy, by Erica

After the example story, the participants' stories began auspiciously with 1000 words penned by Erica. This technology stops at the bronze age. The technology in question is buttons, and the main character has a cloak with interior pockets that have button closures (O4).

The full text of the story, mapped to the Five Steps, is in Appendix B.1.

Source material

Technically, the story is a derivative work. The two main characters are neolithic versions of characters from existing media [98] (O5). This was not apparent from the text as presented, so the story also counts as an original work.

H.7.5 True Story: Fertility Ring, by Francine

Francine had a true story to tell: the story of the Fertility Ring she was developing for a friend (O4). The full text of the story, mapped to the Five Steps, is in Appendix B.2.

In the discussion, various solutions were considered, weighing conspicuousness against privacy. If the ring were mass produced, everyone would know what it was - would one want to be seen checking it (O1)? What if the ring were used to control women's reproduction? Erica pointed out that some communities are keen on enhancing fertility and bespoke versions could be made for communities that wanted to either hide or show off the functionality of the ring.

A unisex solution was suggested, a bandana that both men and women could wear.

Options for keeping the technology out of sight were considered. Instead of lighting up, the sensor might vibrate, and might be placed inside clothing, e.g. on the inside front of jeans, so that only the wearer would see it in the privacy of the bathroom. Other

ideas included a patch, a bra clip, or a component fixed to the back of an Apple watch. Some form factors have more positive associations than others, for example, a belt quickly evokes a chastity belt.

A swappable form factor, "like a USB stick", was suggested.

H.7.6 Wooden Horse, by Grace

Due to an error on my part, Grace only saw the preparatory exercises on the morning of the workshop. Grace devised her story on the way to the workshop.

Wooden Horse is partly inspired by the film *Blade Runner 2049* [271].

The story, fitted to the Five Steps, is in Appendix B.3.

Source material

Besides *Blade Runner 2049* [271], which Grace cited, the horse reminds of the doll in the Russian fairy tale *Vasilisa the Beautiful* [214] and also of the wooden horse in the story of Kaspar Hauser [122] (O5).

H.7.7 Leaf Me Alone, by Hunter.

Hunter also did not read the preinstructions in time, for the same reasons as Grace. Fortunately this was no deterrent, as Hunter shared a true story from her own experience.

The story, fitted to the Five Steps, is in Appendix B.4.

Source material

Leaf Me Alone is Hunter's original work, not derived from any existing media besides some inspiration from GI Joe.

Invisibility cloaks (O1) have an ancient history in folklore [12] despite Hunter's ruling out her first two implementations as "ridiculous".

H.7.8 *The Hermit and the Shepherd Boy* paper prototype

CFI2 participants took to the paper prototyping more readily than those at CFI1. It may have helped that three of the participants were artists.

Erica used the ribbons and miniature glass jars to make "Wish Spell Bottles" (Figures H.9, H.10 and H.11) (O4). The iridescent shell sequins went into one bottle to represent insect wings. Erica said that if she had "lots of little natural things" she would use those. A dog charm was added to represent the Shepherd Boy's dog (the equivalent character in the source material is known for an affinity with dogs).

The Wish Spell Bottle is a charm for the Shepherd Boy, for whenever he is in a difficult situation (usually aggression in the family). He has to take one wing out and hold it in his hand, and let it go when he makes the wish (O5).

[12] *Wikipedia:* **Cloak of Invisibility** https://tinyurl.com/gu8vafd

Figure H.9: *Paper prototype of the Shepherd Boy's Wish Spell Bottle, which works by sympathetic magic.*

Figure H.10: *The Wish Spell Bottle has a dog charm attached.*

H.7.9 *Fertility Ring* paper prototype

Francine used ribbons and gem stickers to embellish some jump rings. Jingle bells make the alert mechanism. The ribbon attaches the device like a key ring (Figure H.12) (O4).

H.7.10 *Wooden Horse* paper prototype

The hidden compartment for carrying the horse is a concealed zip along the cuff of a sleeve (O1, O4). The cuff has a stirrup to go over the thumb, to stop it from riding up.

Grace was the first participant to use any of the costume items. She used the cobalt blouse because it had a vent in the cuff which she placed over her thumb to show where the hidden pocket would fit (Figure H.13).

Grace made an alternative carrying pouch from a craft bag and a tie-dye shoelace (Figure H.14).

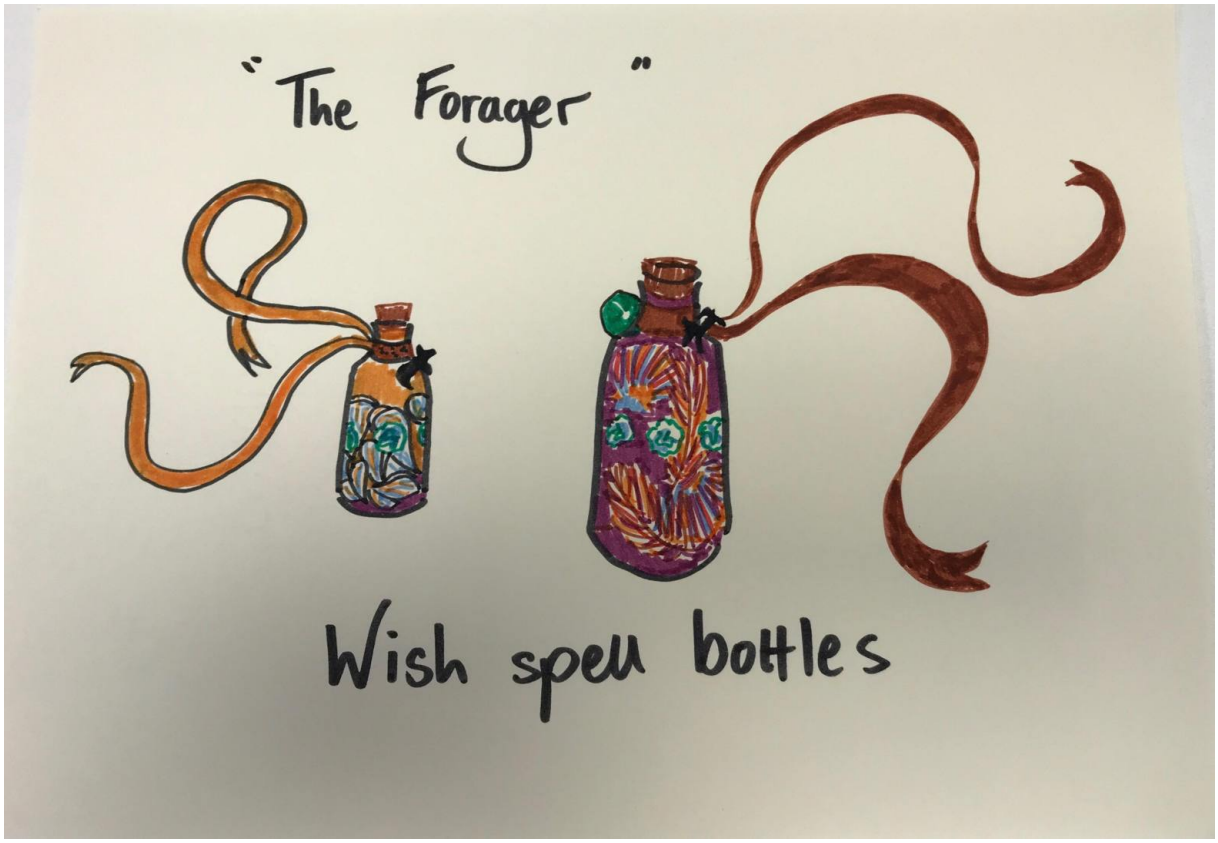

Figure H.11: *Illustration by Erica of the Wish Spell Bottles from The Hermit and the Shepherd Boy. Captioned "The Forager" and "Wish spell bottles"*

H.7.11 *Leaf Me Alone* paper prototype

Hunter used the white adhesive fabric with some markers and paint to represent a patch from her "Leaf Me Alone" camouflage (O1, O4, O5) (Figure H.15).

H.7.12 Reflection

At CFI2 everyone brought a story idea, and all four stories suggest at least one concept. In a sense, the participants began by converging on their stories, and then diverged into discussion during the workshop. Compared to the more nebulous concepts generated by the brainstorming at CFI1, CFI2 came closer to the outcome I was hoping for.

Francine was one of two participants to bring a true story. The Fertility Ring describes a real device designed to meet an individual's real-world need (O4, O5). The other three stories were about protection from harm (O5). Invisibility came up again with Hunter's camouflage idea.

H.7.13 Feedback

All the CFI2 participants added their names to the signup sheet. Feedback is laid out in Table H.3 (O5).

The CFI2017 organizers later returned the following feedback:

Figure H.12: *Francine's Fertility Ring.*

Figure H.13: *Paper prototype of the Wooden Horse showing how it is carried.*

Figure H.14: *Alternative carrying pouch for the Wooden Horse.*

Figure H.15: *Paper prototype of Leaf Me Alone camouflage.*

Table H.3: CFI2 Feedback Form

Participant	Rating out of 5	Did you learn anything new?	Who did you attend with?	Any comments?
Erica	5	10	Alone	I loved it and found it utterly motivating
Francine	5	9	Alone	
Grace	5	10	Alone	Very unusual and enlightening. Thanks!
Hunter	5	9	Alone	

"I loved it. I came from [out of town] especially once I heard about it!"

In response to my thank-you email, Grace replied:

"We seemed to be all artists of sorts which helped - in the sense that we were able to look outside the box in a more conceptual way. In a larger group this would have been diluted and I may have been more nervous... so you were lucky in some ways, that no one else turned up!"

H.8 CFI2017 creative toolkits

Put together, the CFI2017 groups used a mix of art materials and craft embellishments, but only one item from the dressing-up box.

H.9 Edinburgh workshops

Two more workshops were held on 30 and 31 October 2017, this time with students of Design Informatics and HCI at the University of Edinburgh, hosted by Dr. Maria Wolters.

There were 16 attendees signed up for the first workshop, nine for the second.

H.10 Edinburgh Group 1

H.10.1 Preparation

For logistical reasons, documentation could not be circulated beforehand, so the students read the Participant Information Sheets for the first time at the start of the workshop.

H.10.2 Attendance

Nine of the expected 16 attendees arrived, a 56% attendance rate.

The attendees were:

1. "Iris", under 35, Chinese, ESL
2. "Jameson", under 35, Chinese, ESL
3. "Katrina", under 35, Chinese, ESL
4. "Leo", under 35, Chinese, ESL
5. "Millie", under 35, white/North American, EMT
6. "Noah", under 35, Chinese, ESL
7. "Opal", under 35, Chinese, ESL
8. "Priscilla", under 35, Chinese, ESL
9. "Quinn", under 35, Chinese, ESL

One of the men participated in two stories, which escaped my notice at the time, so the mysterious double is marked "M4".

H.10.3 Timing

The workshop was scheduled for 16:00. An hour and a half was allocated, 60 minutes less than at CFI2017. The workshop immediately followed a class in the same space, and setting up took 30 minutes from the planned start time. The students were visibly excited by the creative toolkits, and dug in as fast as I could put them out.

After the example story, the students had 30 minutes to create their own. To save time, they made the paper prototypes as they went along.

H.10.4 Flower, by Iris, Katrina and Millie

Iris, Katrina and Millie told the story of Flower and her time-travelling crown (Figure H.16) (O4).

The story, fitted to the Five Steps, is in Appendix C.1.

None of the Edinburgh storytellers cited their sources of inspiration, so I may have missed allusions to existing media. *Flower's* premise is similar to *Bill & Ted's Excellent Adventure* [121], and fits the trope Field Trip to the Past as described on the TV Tropes wiki [13] (O5).

[13] *TV Tropes:* **Field Trip to the Past** http://tvtropes.org/pmwiki/pmwiki.php/Main/FieldTripToThePast

Figure H.16: *Flower's time-travelling crown.*

H.10.5 Agent X, by Jameson and Opal

Jameson and Opal told the story of Agent X using a blank papier-maché mask and a child's red costume cape (not pictured).

The story, fitted to the Five Steps, is in Appendix C.2.

In *Agent X*, the Invisibility Cloak (O1) makes another (non-)appearance (O4). Realistically, its electronics malfunction when wet. It is layered over a more basic invisibility suit (O4).

It is combined (O2, O4) with an inflatable-dinghy-style Bulletproof Vest [14] which, realistically, is not stab-resistant.

The Mask of Power (O4) is a popular trope [15], but polymorphous masks that can dynamically resemble any face are not so common in media that I know of.

H.10.6 Little Strawberry, by Leo, Priscilla and Quinn

Leo, Priscilla and Quinn told the story of Little Strawberry using pink glitter mesh and some gem stickers (Figure H.17).

[14] *TV Tropes:* **Bulletproof Vest** http://tvtropes.org/pmwiki/pmwiki.php/Main/BulletProofVest
[15] *TV Tropes:* **Mask of Power** http://tvtropes.org/pmwiki/pmwiki.php/Main/MaskOfPower

Figure H.17: *Little Strawberry's transforming all-purpose bra.*

The story, fitted to the Five Steps, is in Appendix C.3.

The washing/transforming machine is like a Star Trek replicator. [16]

H.10.7 GodSon, by Noah

Noah told the story of GodSon, who has a mask of omniscience (Figure H.18) (O4). It is a blank papier-maché mask decorated with felt-tip markings of binary numbers. A red gem is positioned just below the corner of each eye. Along the chin is the caption "I know you" (O1).

The story, fitted to the Five Steps, is in Appendix C.4.

This is another Mask of Power.

H.10.8 Green, by M4

The fifth and final story was told by the mysterious double, "M4".

M4 told the story of Green. The story, fitted to the Five Steps, is in Appendix C.5.

[16] *Star Trek Database:* **Replicator** https://tinyurl.com/yaj8vtbk

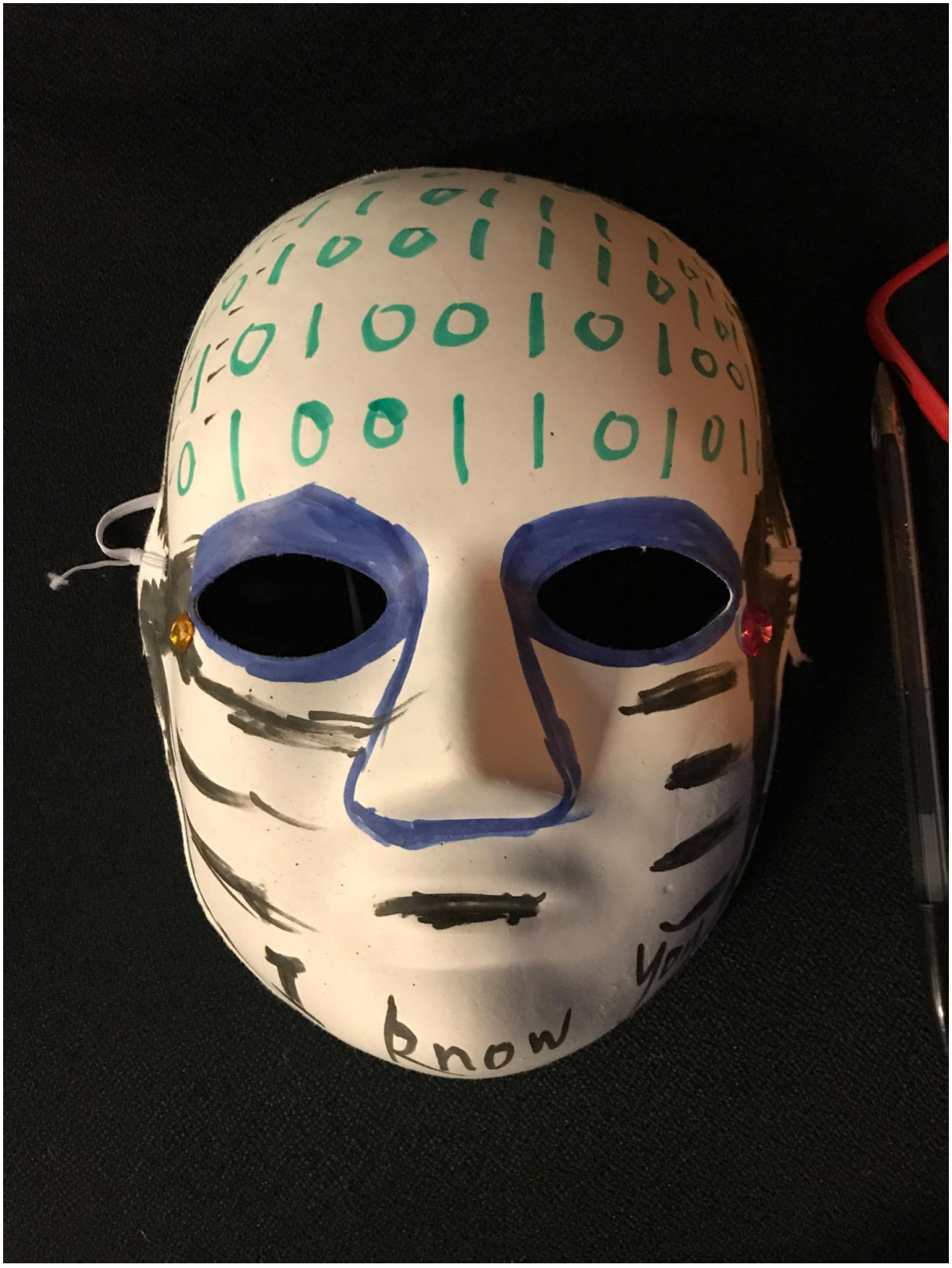

Figure H.18: *GodSon's mask of omniscience.*

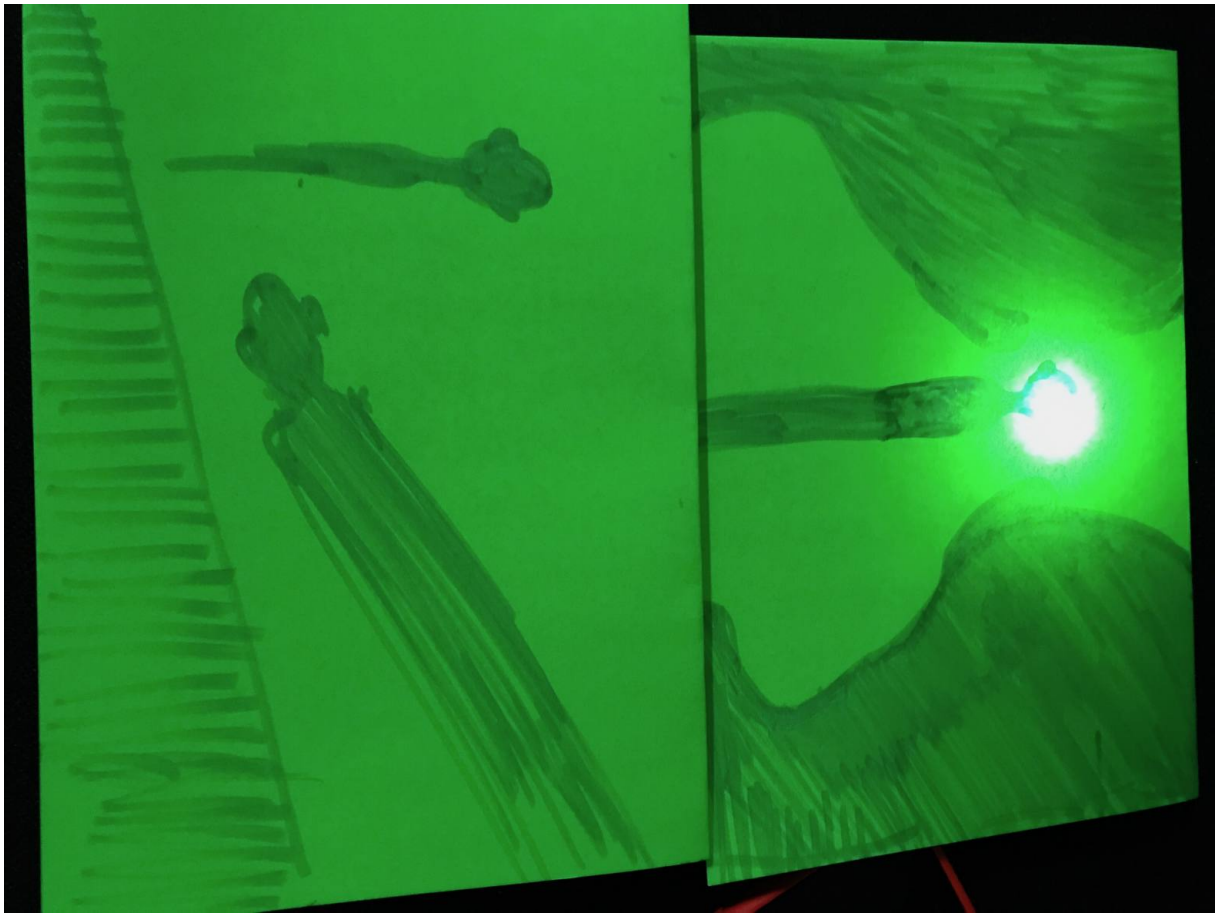

Figure H.19: *Green.*

Green conforms to the Sentient Cosmic Force trope [17], a type of Anthropomorphic Personification [18].

The paper prototype (Figure H.19) indicates that Green has, or can assume, a human form and/or cast a human-shaped shadow, but he also seems to be amorphous, polymorphous, and/or omnipresent (O2, O4).

The only other sentient colour I know of is the Hooloovoo, a "superintelligent shade of the colour blue" in *The Hitchhiker's Guide to the Galaxy* [1, p38].

H.10.9 Prizegiving

Edinburgh Group 1 was the first group to vote on a winner. The clear winner was *Little Strawberry* (O4) with seven votes.

H.10.10 Reflection

In the span of one hour, and having received no information about the activity ahead of time, a group of nine students told five stories that exactly fit the Five Steps. This broke

[17] *TV Tropes:* **Sentient Cosmic Force** http://tvtropes.org/pmwiki/pmwiki.php/Main/SentientCosmicForce
[18] *TV Tropes:* **Anthropomorphic Personification** http://tvtropes.org/pmwiki/pmwiki.php/Main/AnthropomorphicPersonification

my assumption that less advance preparation would mean more inhibition in storytelling.

Flower The first story which is resolved by destroying the wearable item which has become too dangerous, but not before enjoying its benefits (O4, O5). The crisis comes when the technology falls into the hands of an incompetent user, Flower's younger sister.

Agent X raises the theme of invisibility, and control of how the wearer is seen (O1), for the third time in as many workshops (see *Ironwoman* and *Leaf Me Alone*). The layered outfit affords self-protection, a theme which appears for the fifth time (*Ironwoman, The Hermit and the Shepherd Boy, Wooden Horse, Leaf Me Alone*) (O5).

This time, Agent X's vulnerability is flipped into heroism - but he is wearing three different protective devices: two for invisibility, one to change his face, one for self-protection (O2, O4). Agent X's self-protection is all in service of other-protection (saving the world), the threat becomes an action plot, and the hero survives until the next episode (O5).

Little Strawberry The polymorphous bra (O4) is simple wish fulfilment to address a common conundrum of women's lingerie. It is the most realistic of the fanciful stories so far, the fictitious counterpart to the real-world Fertility Ring.

Little Strawberry anticipates and handles boredom with the one "perfect" solution (O5), and remembers that wearable items must be cleaned.

GodSon GodSon's mask is the second mask of the day (O4). It is the second story to be resolved by the destruction of the wearable object (see *Flower*), but the first to conclude that the wearable provided no benefit whatsoever, only suffering (O5). The suffering comes from loss of privacy - not the wearer's, but everyone else's (O1).

Green Green (O2) is the only character who does not *have* a wearable, but *is* wearable because he is a colour (O4?).

There are no descriptions of Green being worn by humans, who seem beneath the notice of the implied author. Green can read and/or influence human minds, but unlike *GodSon* he is untroubled by this.

Green was the only story in which nothing changes. Green begins the story in a state of equanimity and ends the story in a state of equanimity (O5).

H.11 Edinburgh Group 2

The workshop was scheduled for 09:30 on 31 October 2017. 90 minutes were allocated, the same as Group 1, and 60 minutes shorter than expected.

H.11.1 Preparation

Group 2 received their Participant Information Sheets, Consent Forms and preparatory exercises 23 hours ahead of time. They were asked not to disclose any information to Group 1 and Dr. Wolters confirmed that there were no leaks.

H.11.2 Attendance

Nine participants were expected in Group 2. One participant cancelled due to illness but asked to be kept informed about the research.

Three attendees arrived, a no-show rate of 62%, possibly because of the early start.

The attendees were "Xenia", "Yolanda" and "Zara", all under 35, Chinese and ESL.

H.11.3 MirrorMask, by Xenia, Yolanda and Zara

Xenia, Yolanda and Zara had not prepared stories in advance and opted to work together.

They told the story of the MirrorMask (O4). The story, fitted to the Five Steps, is in Appendix D.1.

Source material

MirrorMask seems to be a genderflip of *Beauty and the Beast* [19].

The mask can be seen as a reification of the Stepford Smiler trope [20]. Perhaps there is no magic and it is simply a mirror; either way it has all the tradeoffs of a mirror (glare in sunlight, loss of facial reflection at night) (Figure H.20).

When the girl meets someone who is willing to see her real face, the mask transforms itself (O2) into a Friendship Trinket [21], a necklace with her image on it (Figure H.21) (O5).

Reflection

The MirrorMask is a solution to a societal problem, set in an alternate universe with attitudes to appearance similar to ours. For the fourth time in as many workshops, we see the theme of controlling how the wearer is seen, but this time it is subverted. When the girl finds true intimacy the mask transforms to a much smaller necklace showing her true likeness (O2), symbolizing that her appearance has been put in its proper perspective (O5).

H.12 Edinburgh: creative toolkits

The Edinburgh groups used a mix of basic and representational craft materials. The character clothing was excluded because of luggage limits, but they used a toy tiara and a child's cape from the dressing-up box.

[19] *Wikipedia:* **Beauty and the Beast** https://tinyurl.com/mmatlad
[20] *TV Tropes:* **Stepford Smiler** http://tvtropes.org/pmwiki/pmwiki.php/Main/StepfordSmiler
[21] *TV Tropes:* **Friendship Trinket** http://tvtropes.org/pmwiki/pmwiki.php/FriendshipTrinket

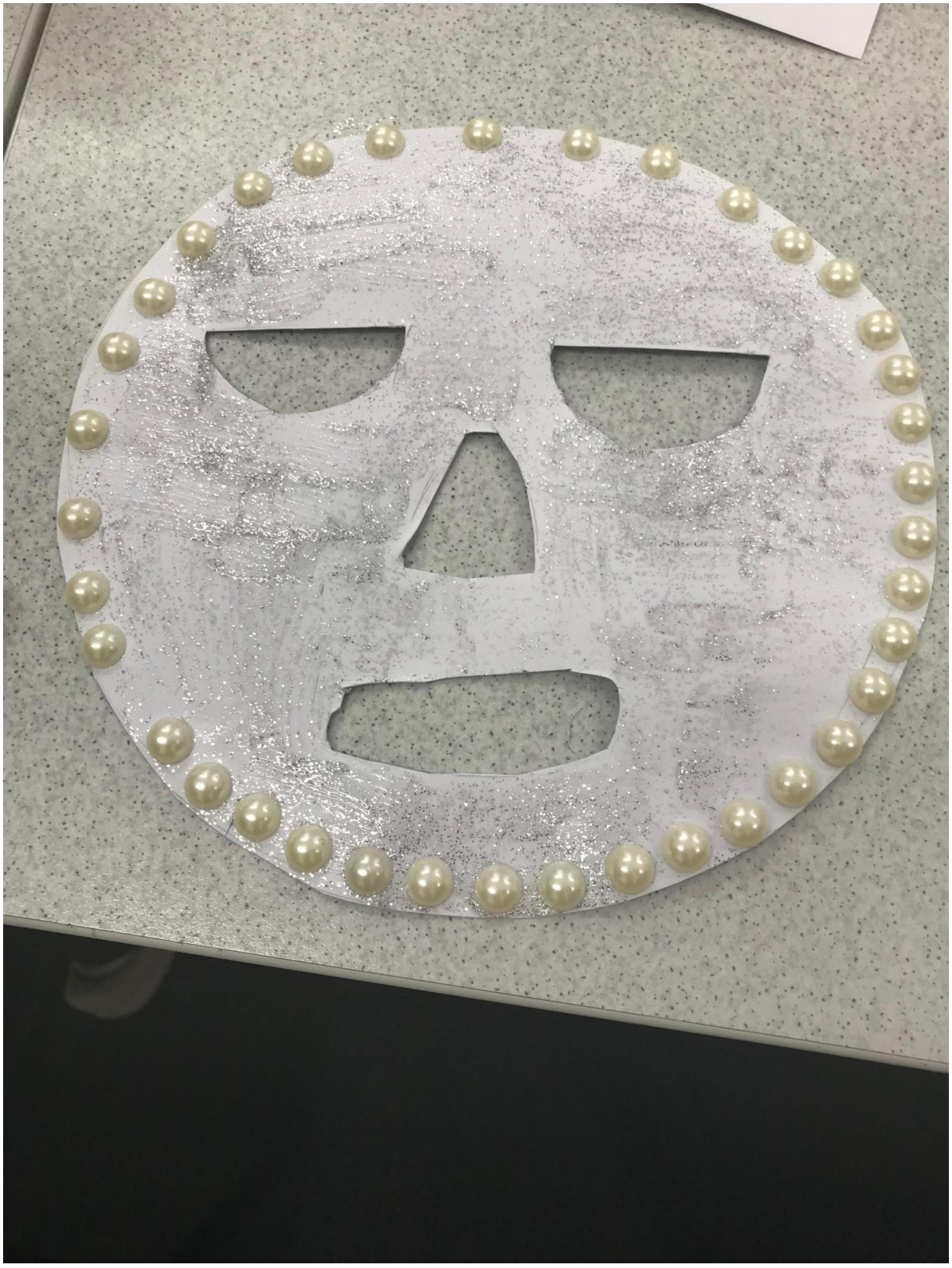

Figure H.20: *The MirrorMask.*

Figure H.21: *The MirrorMask, transformed.*

H.13 Discussion of pilot studies

H.13.1 Storytelling

Success/failure criteria

There were no workshops in which participants did not tell stories. Over the course of four workshops, 11 stories were told by a total of 20 participants.

Unprepared vs. prepared groups

Opportunity to prepare made no obvious difference to the quality of storytelling. The CFI1 participants were the least comfortable, but so was I on the début of a high-stakes occasion.

CFI2017 vs. Edinburgh (or, public vs. students)

Edinburgh Group 1 was the most compliant: in go the instructions, out come the Five Step stories. The CFI2017 groups' stories were more freeform and there was more time for discussion than at Edinburgh. The true values and desires of the CFI2017 groups shone through, but the Edinburgh students were surrounded by an audience of classmates and were there to learn, not to self-disclose. It is not clear how much the Edinburgh participants were emotionally invested in their stories, if at all (O5).

Little Strawberry, the winner of Edinburgh Group 1, described a pragmatic invention that the storytellers and probably everyone would want. Sadly, it is probably impossible to build. [22]

H.13.2 Creative toolkits

The creative toolkits seemed well suited to their purpose, with plenty of consumable supplies used and plenty left. Both of the blank masks were used, so future toolkits will stock more.

Future toolkits should allow for more sensory outputs, such as sound (e.g. jingle bells) and touch (e.g. textured surfaces). Might future mobile technologies use taste (wrapped sweets) or smell (prescented cards)?

Most costume clothing was ignored, except the child's costume cape and the tiara. Instead of clothing, lengths of cloth such as saris or curtains might be more versatile.

H.14 Summary

This appendix described four pilot experiments conducted in October 2017 in order to sanity-check the workshop format and recruit volunteers.

The pilot studies unfolded as I hoped they would: participants told stories and most of them enjoyed doing so. I could use the workshop format and creative toolkits in the longitudinal study with no changes.

[22] Unless self-fitting intelligent clothing comes to fruition. *Business Weekly,* 14 February 2020: **Put Your Shirt On Intelligent Clothing That Really Does Wash** https://www.businessweekly.co.uk/news/hi-tech/put-your-shirt-intelligent-clothing-really-does-wash

Appendix I

Inaugural Workshop of the Longitudinal Study

This appendix describes the inaugural workshop, for the purpose of introduction to and recruitment for the longitudinal study, which was held at Makespace on 29th January 2018 from 18:30 to 22:00.

I.1 Attendance

I advertised only through Meetup and Twitter.

I circulated the preparatory exercises one week in advance, and also linked in a comment on the Meetup event listing:

"Hi everyone, thanks for signing up! I am so looking forward to meeting you! To get your story ready, here are some preparatory exercises: [link] Please let me know if you have any dietary needs. See you next week!"

Just over a day in advance, an information sheet and consent form for the Inaugural Workshop were circulated to all participants. A combined information sheet and consent form for the longitudinal study was also provided. All three documents were also linked in an explanatory comment on the Meetup event listing:

"Hi everyone, In this folder is an info sheet and a consent form for the Inaugural Workshop: [link] Please take a look at it before Monday, and when you arrive I will have a print version ready for you to sign. This consent form is ONLY for the Inaugural Workshop and doesn't entail any commitment to the long-term study.

"However, if you want to look ahead to what volunteering for the long-term study will involve, the docs are here: [link] I'll bring printouts for those too, anticipating the inevitable mad rush to join in.

"And remember, please let me know by SUNDAY if you have any dietary needs, or accessibility needs and so on. See you on Monday evening! Warm regards, Helen"

Despite advertising on Makespace's channels, it turned out that only two attendees were members, joining one workshop each.

Places were booked by 12 women, five men, and two people of unknown gender.

Four attendees cancelled. One of these ("Rachel") explained that a chronic illness was keeping her at home, and asked about remote attendance. We arranged for her to Skype in. She wrote (O5):

"Musing - this kind of project would be therapeutic for people like me who are isolated by illness or other reasons and unable to find an outlet for our creative leanings. It would help us find our voice and gain some control over our situation, to be involved in something potentially life-enhancing (the final products as well as the process). I've taken part in virtual get-togethers for 'housebound' people (on the Blue Jeans platform, if that's the right word) and even played hide-and-seek with children over Skype, so I think there's potential for creative workshops done online, with a little imagination!"

Six people attended. These were:

1. Hunter from CFI2
2. "Rachel", over 35, EMT. Maker, nontechnical, interested in assistive devices for disability, via Makespace.
3. "Serena", over 35, EMT. Costume designer & wearable tech enthusiast, via Meetup.
4. "Trudy", under 35, EMT. Freelance fashion tech designer, via Twitter.
5. "Ursula", over 35, EMT. Author & costume designer, via Meetup.
6. "Viola", over 35, EMT. Wearable tech maker, via Makespace.
7. "Warren", engineer, under 35, EMT. Via Meetup, registered interest since 2015.

I.2 Note-taking

Because of the last-minute Skype setup, I could not use the laptop to map notes in designVUE (section 2.7), so I resorted to handwritten notes, with concomitant loss of detail.

I.3 Storytelling and paper prototyping

I.3.1 Hunter

Wearable Plant, by Hunter

Hunter's story, fitted to the Five Steps, is in Appendix E.1.

Hunter's paper prototype

Shown in Figures I.1, I.2, I.3 and I.4.

Figure I.1: *Hunter's paper prototype of her sun sensor badge, in coloured card, felt, and gold mesh with a gemstone sticker.*

Figure I.2: *Hunter's paper prototype for her emotion recognition badge: a frame with a drawing of a smiling face, captioned "HAPPY"*

Figure I.3: *A cocktail umbrella adds a component to Hunter's sun-sensing badge system.*

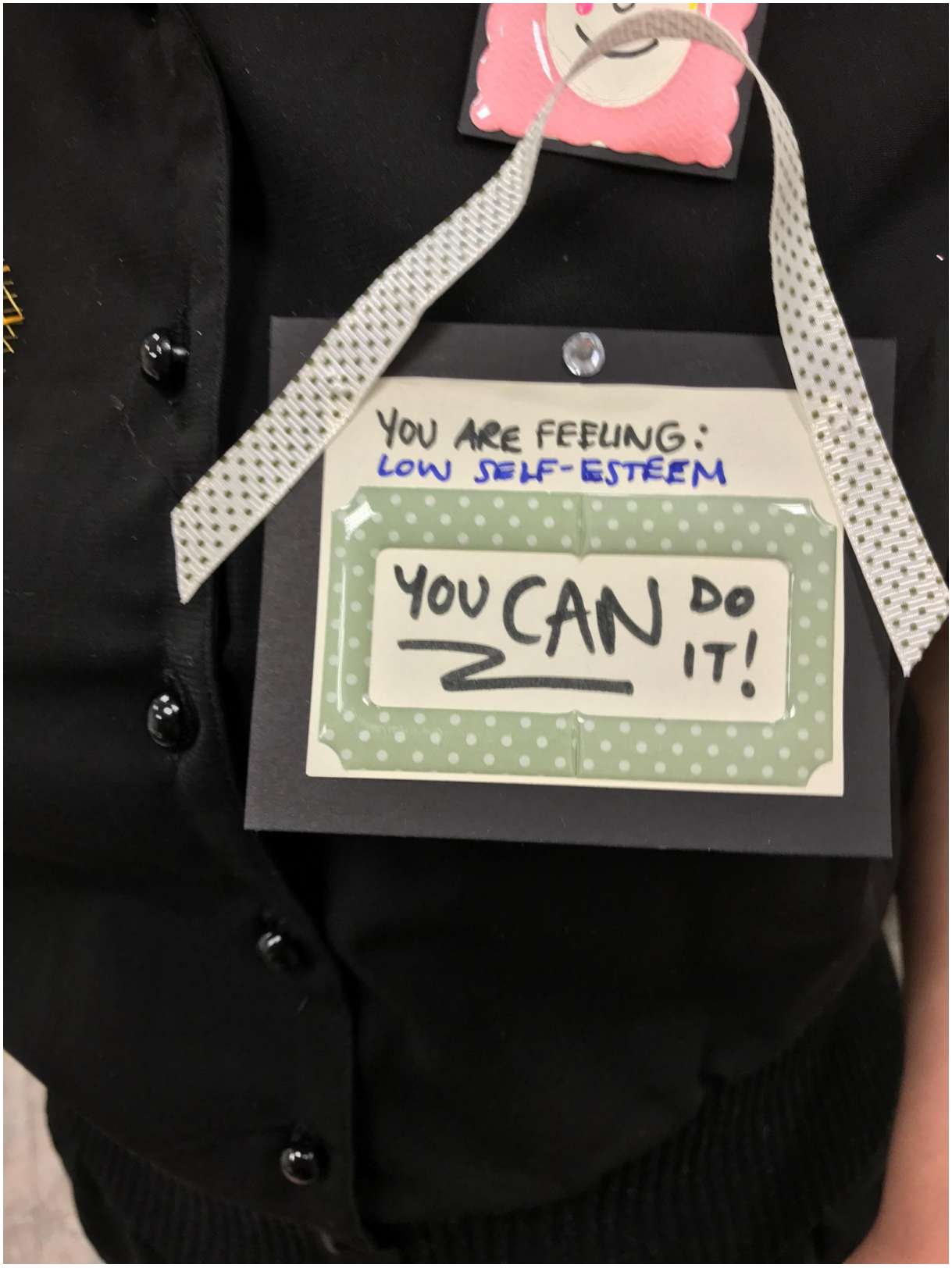

Figure I.4: *Hunter's paper prototype for her badge. Inside a frame is the slogan: "YOU **CAN** DO IT!'. Above the frame is the label "YOU ARE FEELING: LOW SELF-ESTEEM".*

Figure I.5: *Serena's colour-changing mood hat.*

I.3.2 Rachel

Freedom Hat, by Rachel [O2]

Rachel's story, fitted to the Five Steps, is in Appendix E.2.

I.3.3 Serena

Mood Shirt, by Serena

Serena's story, fitted to the Five Steps, is in Appendix E.3.

Serena's paper prototype

Inspired by the HAT personal data store, Serena constructed a colour-changing mood hat (O4) with black card, pink felt, silver glitter paper, felt flower stickers, green paint and silver glitter paint (Figure I.5).

I.3.4 Trudy

Empathy-In Glasses/Empathy-Out Gloves, by Trudy

Trudy's story was partly inspired by the novel *Extremely Loud and Incredibly Close* [230], and by her little brother Timmy who is on the autistic spectrum.

Trudy's story, fitted to the Five Steps, is in Appendix E.4.

I.3.5 Ursula

Jacinda Dragonfly and Mr. X, by Ursula

Ursula arrived with an original fiction featuring characters from her own published work.

The full text of Ursula's story, fitted to the Five Steps, is in Appendix E.5. "Jacinda Dragonfly" and "Mr. X" are pseudonyms for characters in Ursula's books.

Ursula also supplied a hard copy of a moodboard (Figure I.6). The middle left image is a black-and-white screenshot of Harrison Ford as Rick Deckard in *Blade Runner* [238].

Ursula's paper prototype

Ursula used white card and felt markers to construct and illustrate the kimono which embodies Mr. X. (O2, O4) and makes him portable (Figures I.7 and I.8). The illustrations represent animated figures that appear and disappear as they move across the fabric.

I.3.6 Viola

Wearable Life Support, by Viola [O2, O4]

Viola attended for only part of the evening, being hard at work on a wearables project of her own.

Viola's story, fitted to the Five Steps, is in Appendix E.6.

I.3.7 Warren

Gallery Jacket, by Warren

The full text of Warren's story, fitted to the Five Steps, is in Appendix E.7.

To illustrate his point, Warren brought a t-shirt that he had painted himself with thermochromic paints.The t-shirt elicited much admiration and discussion from the group.

Warren's paper prototype

Warren extended the idea of the communicative display shirt in his paper prototype, which features screens on the front, back, and breast pocket for showing the wearer's photography and artwork (Figures I.9, I.10, I.11, I.12 and I.13).

Figure I.6: *Ursula's moodboard for* Jacinda Dragonfly and Mr. X.

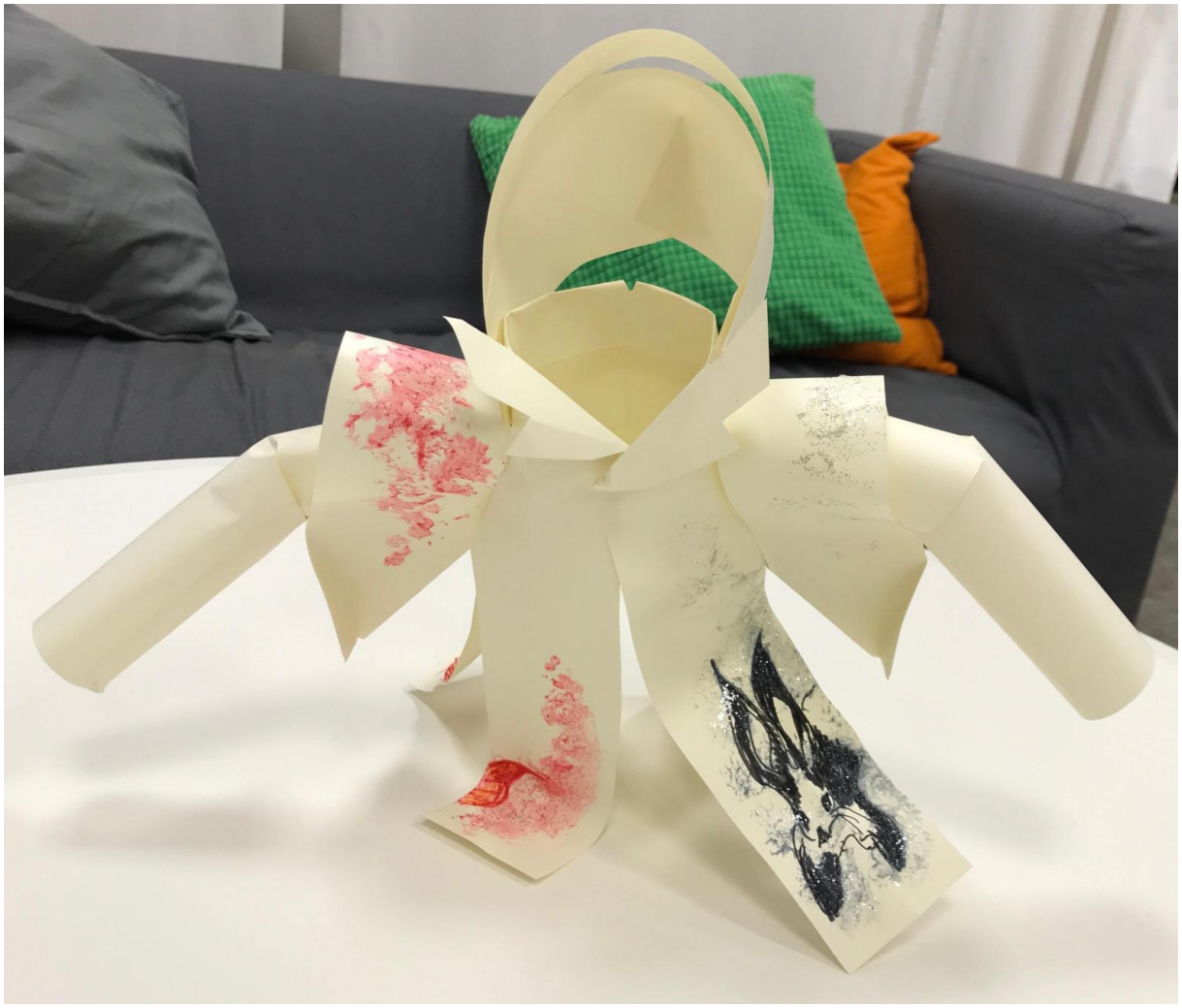

Figure I.7: *Front view of the kimono in which Mr. X. is embodied and made portable outside the ship. Figures appear and disappear on the fabric: on the right, a rabbit; on the left, a butterfly wing.*

I.4 Recruitment outcome

In total, recruitment efforts exceeded expectations with eight signed volunteers: Erica, Grace, Hunter, Rachel, Serena, Trudy, Warren and Ursula.

I later received very enthusiastic feedback from Hunter, Serena, Ursula and Warren (O5).

I.5 Summary

This appendix described the inaugural workshop, conducted for the purposes of recruitment for and introduction to the longitudinal study.

The storytelling process was very successful, with many actionable design concepts already discernible in the stories. Eight participants signed up, exceeding the goal to recruit six participants for the longitudinal study.

Figure I.8: *Back view of the kimono inhabited by Mr. X. On the right, a koi carp moves across the fabric; on the left, a raven's wing.*

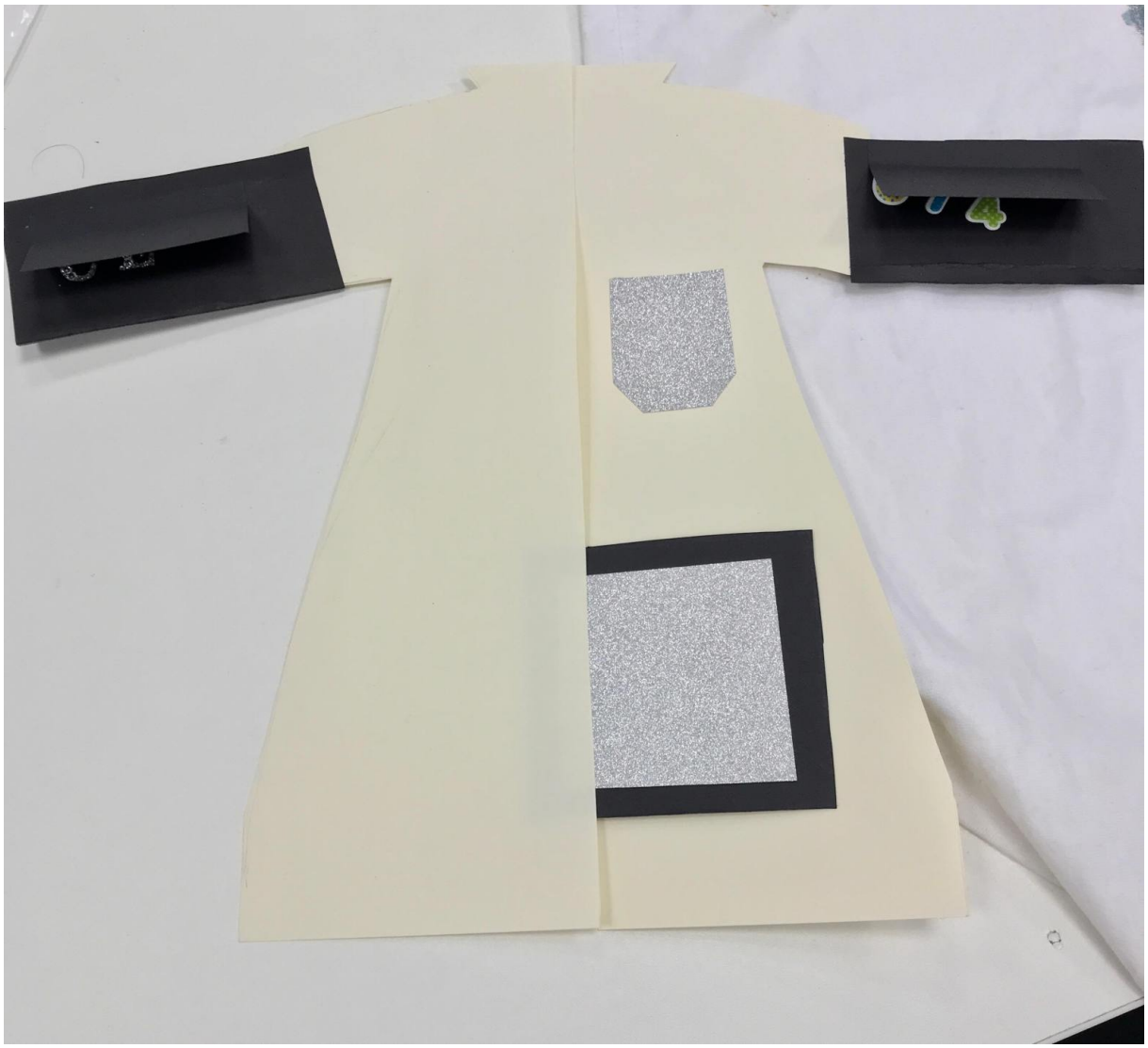

Figure I.9: *Paper prototype of the Gallery Jacket, with screens to show the wearer's artwork. Made from card and glitter paper.*

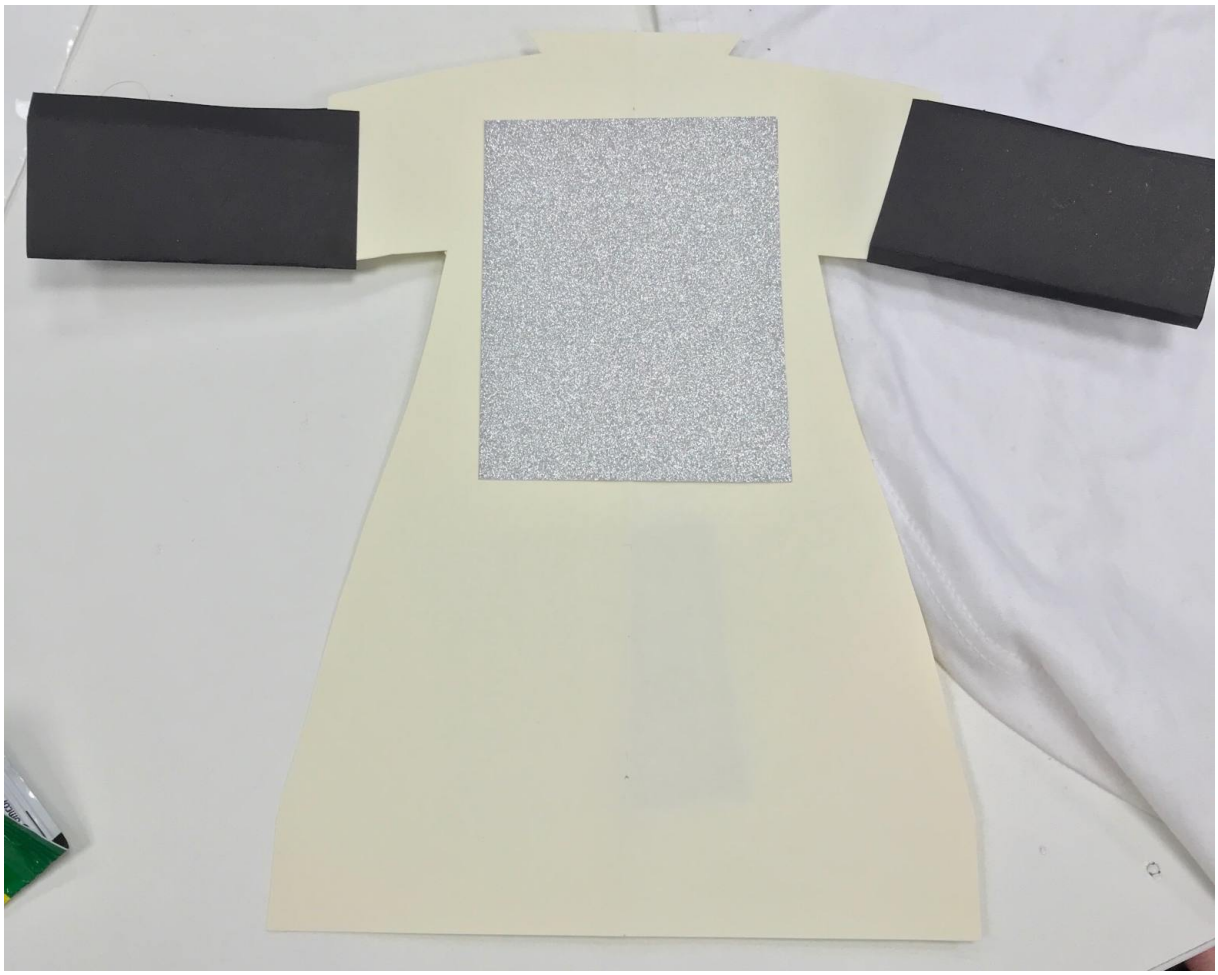

Figure I.10: *Back view of the Gallery Jacket.*

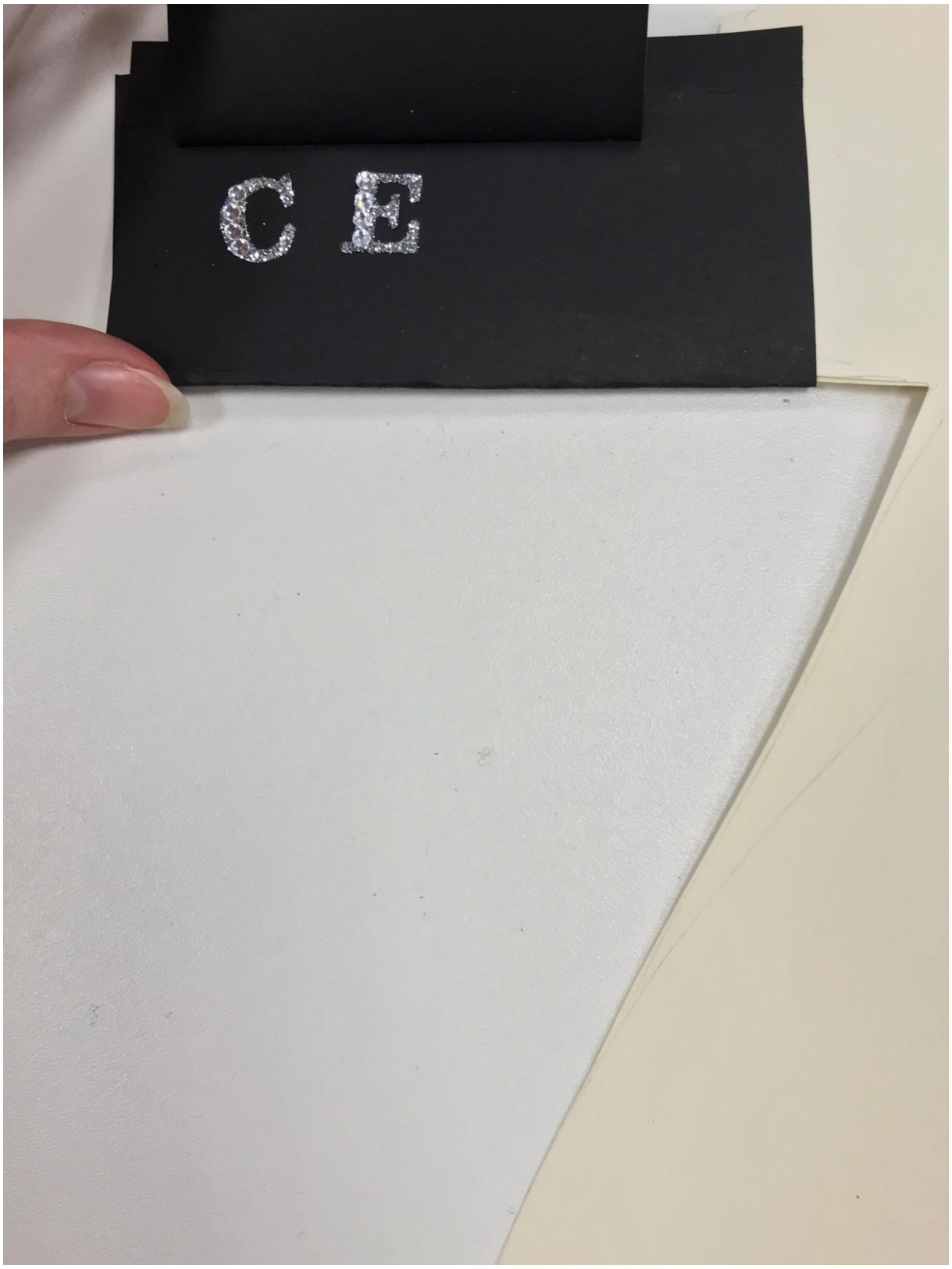

Figure I.11: *Left sleeve of the Gallery Jacket with open-close dynamic display, made from card and holographic letter stickers.*

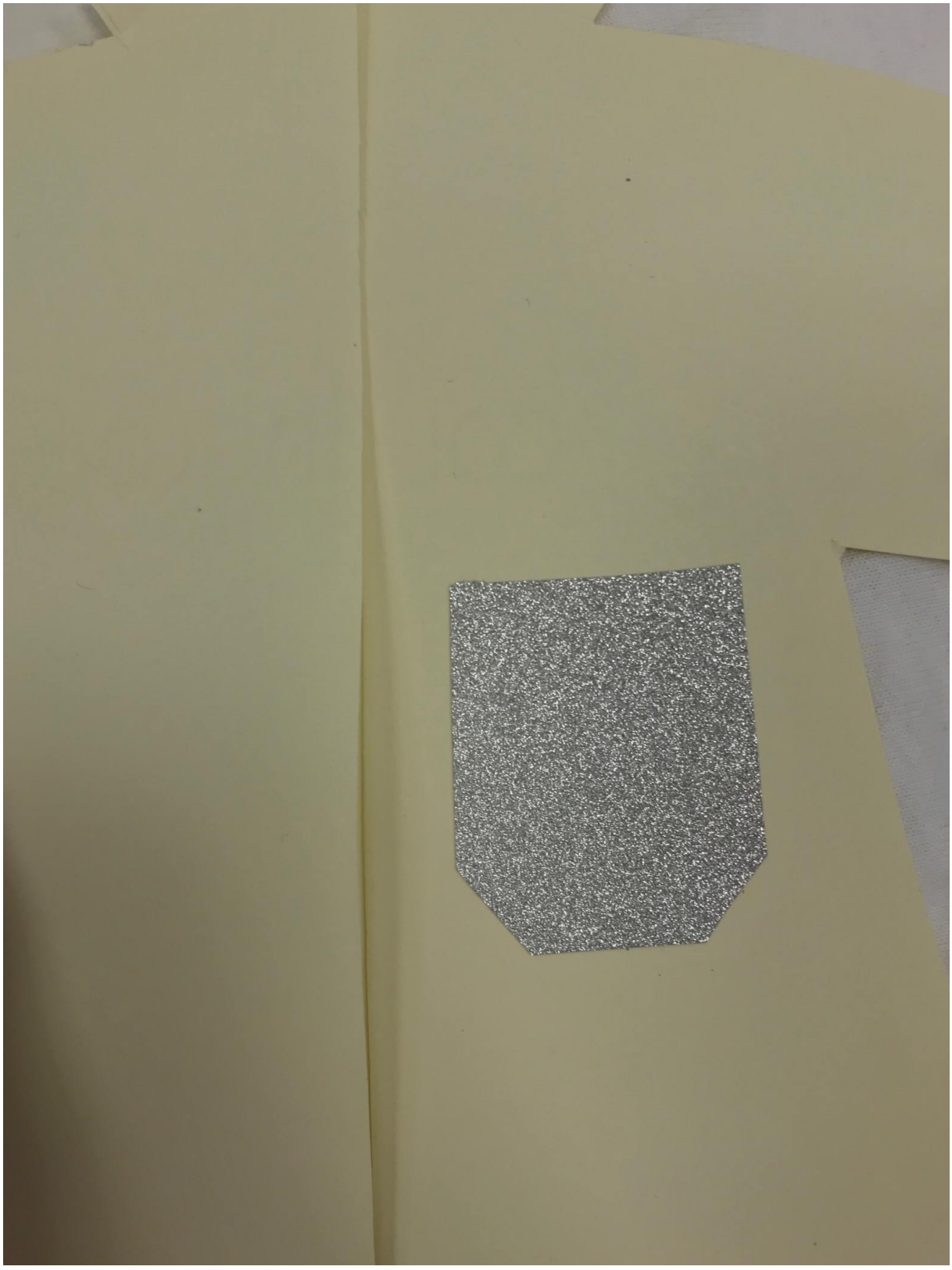

Figure I.12: *Pocket of the Gallery Jacket with screen, made from card and glitter paper.*

Figure I.13: *Right sleeve of the Gallery Jacket with open-close dynamic display, made from card and puffy coloured numeral stickers.*

Appendix J

Analysis of Design Fictions in the Pilot Workshops

This appendix analyzes the themes emerging from the PDFis created during the pilot studies.

The PDFis can be found in Appendices A through D. A description of the pilot studies can be found in Appendix H.

J.1 Technologies

Table J.1 lists the technologies in the pilot stories (Appendix H).

J.2 Forms, functions and numbers of technologies

The technologies had the following form factors (O4):

- **Clothing:** Ironwoman, Leaf Me Alone, Agent X
- **Jewellery:** The Hermit and the Shepherd Boy, Fertility Ring, MirrorMask
- **Mask:** Agent X, GodSon, MirrorMask
- **Pocket(s):** The Hermit and the Shepherd Boy, Wooden Horse
- **Fastening:** The Hermit and the Shepherd Boy
- **Carried Object:** Wooden Horse
- **Headwear:** Flower
- **Armour:** Agent X
- **Underwear:** Little Strawberry
- **Colour:** Green

Table J.1: Pilot Stories: Technology

Story	**Technology**
IronWoman	Polymorphous multifunctional suit (O1, O2, O4)
The Hermit and the Shepherd Boy	Buttons (O4)
	Wish spell bottle (O4)
Fertility Ring	Body temperature sensing ring with light-up alert (O4)
Wooden Horse	Intuition doll in wrist pocket (O4)
Leaf Me Alone	Nature camouflage clothing (O1, O4)
Flower	Time-travelling crown (O4)
Agent X	Polymorphous mask (O1, O4)
	Invisibility suit with bulletproof tent function (O1, O2, O4)
	Backup invisibility suit (O1, O4)
Little Strawberry	Polymorphous all-purpose bra (O4)
	Cleaning & transformation machine
GodSon	Mask of omniscience (O4)
Green	Sapient, omnipresent, omniscient colour with powers of influence and polymorphism (O2, O4)
MirrorMask	Mirrored Echo mask & keepsake necklace with image of wearer's face (O1, O2, O4)

The most popular form factors, appearing in three stories each, were clothing, jewellery and masks.

The pocket appeared in two stories: in *Wooden Horse*, the pocket was the means of carrying the technology. In *The Hermit and the Shepherd Boy*, the fastening of the pocket was the technology.

These form factors cover almost every body area and clothing type, from head but not to toe. There were no stories featuring footwear or hosiery.

Some of the technology was polymorphous and some was in a fixed form; some of the technology was multifunctional and some had a single function; some of the stories included multiple devices and others just one device. These are compared in Tables J.2, J.3 and J.4.

There was an almost-even split between fixed-form and polymorphous devices (Table J.2).

Eight stories included single-function devices, three included multifunctional devices (Table J.3) (O2).

Most of the stories (eight) included only one device, three included multiple devices (Table J.4). MirrorMask is unusual for including a single device which changes form and function (O2), but the transformation is not under the wearer's control. Little Strawberry is unusual for including two devices, one wearable and one accessory to maintain it.

Table J.2: Pilot Stories: Forms

Story	Polymorphous	Fixed Form
IronWoman	X	
The Hermit and the Shepherd Boy		X
Fertility Ring		X
Wooden Horse		X
Leaf Me Alone		X
Flower		X
Agent X	X	X
Little Strawberry	X	
GodSon		X
Green	X	
MirrorMask	X	

Table J.3: Pilot Stories: Functions

Story	Multifunctional	Single Function
IronWoman	X	
The Hermit and the Shepherd Boy		X
Fertility Ring		X
Wooden Horse		X
Leaf Me Alone		X
Flower		X
Agent X		X
Little Strawberry		X
GodSon		X
Green	X	
MirrorMask	X	

Table J.4: Pilot Stories: Numbers of Technologies

Story	Multiple Devices	Single Device
IronWoman		X
The Hermit and the Shepherd Boy	X	
Fertility Ring		X
Wooden Horse		X
Leaf Me Alone		X
Flower		X
Agent X	X	
Little Strawberry	X	
GodSon		X
Green		X
MirrorMask		X

Table J.5: Pilot Stories: Anonymity

Story	Invisibility	Disguise
IronWoman	X	
The Hermit and the Shepherd Boy		
Fertility Ring		
Wooden Horse		
Leaf Me Alone	X	
Flower		
Agent X	X	X
Little Strawberry		
GodSon		
Green		
MirrorMask		X

Table J.6: Pilot Stories: Care

Story	Comfort Object	Love Token	Personal Health
IronWoman			
The Hermit and the Shepherd Boy	X		
Fertility Ring		X	X
Wooden Horse	X		
Leaf Me Alone			
Flower			
Agent X			
Little Strawberry			
GodSon			
Green			
MirrorMask		X	

J.3 Powers of the technologies

The different powers of the technologies are compared in Tables J.5-J.9. These can be grouped into themes (O5):

- Invisibility/Disguise: **anonymity** (Table J.5) (O1)
- Comfort Object/Love Token/Personal Health: **care** (Table J.6)
- Self-Protection/Other-Protection: **protection** (Table J.7)
- Intuition/Influence/Omniscience: **mind** (Table J.8)
- Time Travel/Omnipresence/Portability: **movement in spacetime** (Table J.9)

Fertility Ring, the real design case, is the only device for personal health, one of the most common real-world applications of wearable technology.

Table J.7: Pilot Stories: Protection

Story	Self Protection	Other Protection
IronWoman	X	
The Hermit and the Shepherd Boy	X	X
Fertility Ring		
Wooden Horse	X	
Leaf Me Alone	X	
Flower		
Agent X	X	X
Little Strawberry		
GodSon		
Green		
MirrorMask	X	

Table J.8: Pilot Stories: Mind

Story	Intuition	Influence	Omniscience
IronWoman			
The Hermit and the Shepherd Boy		X	
Fertility Ring			
Wooden Horse	X	X	
Leaf Me Alone		X	
Flower			
Agent X			
Little Strawberry			
GodSon			X
Green		X	X
MirrorMask			

Table J.9: Pilot Stories: Movement In Spacetime

Story	Time Travel	Omnipresence	Portability
IronWoman			
The Hermit and the Shepherd Boy			X
Fertility Ring			
Wooden Horse			X
Leaf Me Alone			
Flower	X		
Agent X			
Little Strawberry			
GodSon			
Green		X	
MirrorMask			

- The most popular power was **self-protection**, which appears in six of 11 stories. **Other-protection** appears in only two stories. It makes sense that wearables would be protective of the wearer rather than anyone else - though Agent X's mission to save the world requires him to protect himself from The Company.
- The second most popular power was **influence**, which appears in four of 11 stories. In three out of the four stories featuring influence, it was a means of **self-protection**.
- **Invisibility** appears in three of 11 stories (O1). In all three stories, the invisibility contributed to the **self-protection**.
- **Disguises** appeared in two stories (O1). In one of them, the purpose of the disguise is, yet again, **self-protection**.
- **Omniscience** appeared in two stories. Green was perfectly happy in his omniscient state; GodSon was unhappy and renounced his power (O1).
- Also appearing in two stories were **comfort objects**. In both stories, the comfort objects contributed to the ever-popular theme of **self-protection**.
- **Love tokens** appeared in two stories. These were *not* self-protective. In *Mirror-Mask*, the love token manifested when the girl no longer needed to protect herself.
- **Portability** was provided by two devices: the buttons in *The Hermit and the Shepherd Boy* enabled the Hermit to secure the supplies he carries. The cuff pocket in *Wooden Horse* was a secure place to carry the comfort object.
- *Fertility Ring* featured the only **personal health** application.
- *Flower* was the only story about **time travel**.
- *Green* was the only story involving **omnipresence**.
- *Wooden Horse* was the only story about **intuition**.

Self-protection was the dominant theme, and devices made for other purposes often functioned wholly or partly as means to a self-protective end. Conversely, there are no stories featuring self-protection that do not also include other powers.

J.4 Realism, time period and genre

The stories told of devices that conferred superpowers, increased the wearer's self-mastery, or simply increased convenience. The devices might work by magic or by technology. Tables J.10 and J.11 compare these (O5).

Although the Shepherd Boy's Wish Spell Bottle works by sympathetic magic, we do not know if magic works in that story world, so it is not counted as providing superpowers.

The stories can be classified by these profiles as follows:

- **Superpowers by Technology:** Ironwoman, Agent X, GodSon

Table J.10: Pilot Stories: Types of Power

Story	Super Powers	Self Mastery	Convenience
IronWoman	X		
The Hermit and the Shepherd Boy		X	X
Fertility Ring			X
Wooden Horse		X	
Leaf Me Alone		X	
Flower	X		
Agent X	X		
Little Strawberry			X
GodSon	X		
Green	X	X	
MirrorMask		X	

Table J.11: Pilot Stories: Sources of Power

Story	Magic	Technology
IronWoman		X
The Hermit and the Shepherd Boy	X	X
Fertility Ring		X
Wooden Horse	X	
Leaf Me Alone		X
Flower	X	
Agent X		X
Little Strawberry		X
GodSon		X
Green	X	
MirrorMask	X	

- **Superpowers by Magic:** Flower
- **Superpowers AND Self-Mastery by Magic:** Green
- **Self-Mastery by Magic:** Wooden Horse, MirrorMask
- **Self-Mastery by Technology:** Leaf Me Alone
- **Convenience by Technology:** Fertility Ring, Little Strawberry
- **Self-Mastery by Magic AND Convenience by Technology:** The Hermit and the Shepherd Boy

There were stories set in the past, present and future; stories set in the current universe and stories set in alternate universes. Tables J.12 and J.13 compare these.

The stories were works of SF, historical fiction and fantasy. There were both original and derivative works. Tables J.14 and J.15 compare these.

Table J.12: Pilot Stories: Time Period

Story	Past	Present	Future
IronWoman		X	
The Hermit and the Shepherd Boy	X		
Fertility Ring		X	
Wooden Horse			X
Leaf Me Alone		X	
Flower		X	
Agent X			X
Little Strawberry		X	
GodSon		X	
Green		X	
MirrorMask		X	

Table J.13: Pilot Stories: Worlds

Story	Current Universe	Alternate Universe
IronWoman		X
The Hermit and the Shepherd Boy		X
Fertility Ring	X	
Wooden Horse		X
Leaf Me Alone	X	
Flower		X
Agent X	X	
Little Strawberry	X	
GodSon		X
Green		X
MirrorMask		X

Table J.14: Pilot Stories: Genre

Story	Science Fiction	Historical Fiction	Fantasy
IronWoman			X
The Hermit and the Shepherd Boy		X	
Fertility Ring			
Wooden Horse	X		
Leaf Me Alone	X		
Flower			X
Agent X	X		
Little Strawberry	X		
GodSon	X		
Green			X
MirrorMask			X

Table J.15: Pilot Stories: Derivation

Story	True Story	Derivative Work	Original Work
IronWoman		X	
The Hermit and the Shepherd Boy		X	X
Fertility Ring	X		
Wooden Horse		X	
Leaf Me Alone			X
Flower		X	
Agent X			X
Little Strawberry			X
GodSon			X
Green			X
MirrorMask			X

Derivative works are inspired by existing media. *The Hermit and the Shepherd Boy* counts as both an original and a derivative work (section 2.3; Appendix H.4.1). I counted four derivative works; there may be more, as I may have missed some allusions to existing media.

J.5 Accepted and rejected devices

In five stories the wearables were already accepted at the beginning. In two stories the wearables are rejected. Flower enjoyed the benefits of her time-travelling crown until it posed a danger to her sister - and the solution was to duplicate the crown and keep using it, then destroy both when they were no longer needed. At that point, Flower reverted to natural methods of study as the moral of the story.

GodSon's mask of omniscience brought him no benefits, only unhappiness. Resolution comes when he destroys the mask, choosing privacy over too much information (O1). There is no prospect of modifying the mask to make it more acceptable.

In two stories, the wearables need some modification before acceptance. Little Strawberry has trouble cleaning her all-purpose bra, and is also bored wearing the same thing every day. The cleaning and restyling device (sold separately) solves these problems. The girl with the MirrorMask wears it out of grim necessity, but when her life changes, it transforms into something completely different; the girl is not going to try to replace her MirrorMask, not unless there is a sequel where her life changes for the worse.

Two of the technologies - Fertility Ring and Leaf Me Alone - were neither accepted nor rejected, but are works-in-progress (Table J.16).

J.6 Utility and feasibility

Some of the wearables served a practical purpose, and some were more fanciful: Flower's crown had the practical excuse of an educational use case, but time travel is not necessary

Table J.16: Pilot Stories: Technology Acceptance

Story	Accepted	Accepted with Modifications	Rejected
IronWoman	X		
The Hermit and the Shepherd Boy	X		
Fertility Ring			
Wooden Horse	X		
Leaf Me Alone			
Flower			X
Agent X	X		
Little Strawberry		X	
GodSon			X
Green	X		
MirrorMask		X	

Table J.17: Pilot Stories: Utility

Story	Practical	Fanciful
IronWoman	X	
The Hermit and the Shepherd Boy	X	
Fertility Ring	X	
Wooden Horse	X	
Leaf Me Alone	X	
Flower		X
Agent X	X	
Little Strawberry	X	
GodSon	X	
Green		X
MirrorMask	X	

to pass a history test. Some of the wearables are feasible now or in the near future, others less so. These are compared in Tables J.17 and J.18.

In terms of utility and feasibility, the stories can be grouped by the similarity of their profiles:

- **Practical and Feasible:** The Hermit and the Shepherd Boy, Fertility Ring
- **Practical and Unfeasible:** Ironwoman, The Hermit and the Shepherd Boy, Wooden Horse, Leaf Me Alone, Agent X, Little Strawberry, GodSon, MirrorMask
- **Fanciful and Unfeasible:** Flower, Green

None of the wearables were both fanciful and feasible - indeed, the categories seem mutually exclusive.

Table J.18: Pilot Stories: Feasibility

Story	Feasible as Described	Unfeasible as Described
IronWoman		X
The Hermit and the Shepherd Boy	X	X
Fertility Ring	X	
Wooden Horse		X
Leaf Me Alone		X
Flower		X
Agent X		X
Little Strawberry		X
GodSon		X
Green		X
MirrorMask		X

Table J.19: Pilot Stories: Enchantment 1

Story	Omniscience	Telepathy	Safekeeping
IronWoman		X	X
The Hermit and the Shepherd Boy			X
Fertility Ring			
Wooden Horse		X	X
Leaf Me Alone			X
Flower	X		
Agent X			X
Little Strawberry			
GodSon	X	X	
Green	X	X	
MirrorMask		X	

J.7 Enchantment

Finally, let us see how the stories express the six human desires that Rose [226, Pt2] believes enchanted objects (O4) can satisfy (O5). These six desires are: omniscience (desire to know everything), telepathy (desire to connect and communicate), safekeeping (protection), immortality (good health and longevity), teleportation (effortless movement through space) and expression (creativity).

IronWoman's invisibility cloak seems to provide her with **safekeeping**, but she connects with George Clooney (**telepathy**) in spite of the cloak, not because of it.

In this framing, an artificial intuition device like the Wooden Horse provides **safekeeping** through literal **telepathy**: anticipating the actions and reactions of others. Flower is not **omniscient**, but her crown gives her access to knowledge that others do not have. And GodSon does not desire his literal **omniscience**, because it ends relationships before they begin. What he wants is connection with others, **telepathy** in the strictly figurative sense, like the girl in *MirrorMask*. Green has literal **omniscience** and literal **telepathy**

Table J.20: Pilot Stories: Enchantment 2

Story	Immortality	Teleportation	Expression
IronWoman			
The Hermit and the Shepherd Boy			
Fertility Ring	X		
Wooden Horse			
Leaf Me Alone			
Flower		X	
Agent X			
Little Strawberry			X
GodSon			
Green		X	
MirrorMask			

and is happy about it.

The desire for **immortality** is provided for by personal health devices like the Fertility Ring, figuratively speaking. Flower moves effortlessly through space *and* time because of her **teleportation**-enabled crown. And Little Strawberry's magic bra makes changes of **expression** effortless for her.

J.8 Summary

In this appendix I have analyzed the themes emerging from the PDFis in the pilot study.

I emphasized to participants that derivative works were allowed, and the pilot stories included several derivative works (and possibly some I did not recognize). The most interesting finding is how many devices were dedicated to self-protection, and how frequently the theme of invisibility (or controlling how the wearer is seen) recurred in the service of self-protection. I initially thought of wearables as a means of enhancing personal style (Chapter 1). In one of the most popular stories, *Little Strawberry*, they are. In many other stories appearances are defensive.

Appendix K

Iteration of Design Fictions

This appendix describes the participants' iteration of their PDFis into their final versions, during a second workshop which was followed by 1-1 unstructured interviews with six participants.

K.1 Second workshop and 1-1 interviews

The second workshop of the longitudinal study was held on 30 March 2018 from 16:00-22:00 at Cambridge Makespace.

Present were Grace, Hunter, Rachel remotely, Serena, Ursula and Warren. Erica sent apologies and Trudy cancelled last-minute due to workload. Erica subsequently moved cross-country, ending her active participation.

Afterwards I conducted unstructured 1-1 interviews with Grace, Hunter, Serena, Trudy, Ursula and Warren. After her 1-1 interview, Trudy faded from the group.

K.2 Grace

Grace kept the same story and expanded it into a full text. This time she put more emphasis on the horse's role as an advisor than a companion (O5), and did not mention that it is made of wood or explain the importance of wood in this world. The horse has become an earpiece disguised as a hearing aid, instead of being hidden inside the cuff pocket (O1, O4).

K.2.1 Wooden Horse, by Grace

The full text of Grace's story is in Appendix F.1.1.

K.2.2 Grace's 1-1 interview

I conducted a 1-1 interview with Grace via Skype for 30 minutes on 18 May 2018.

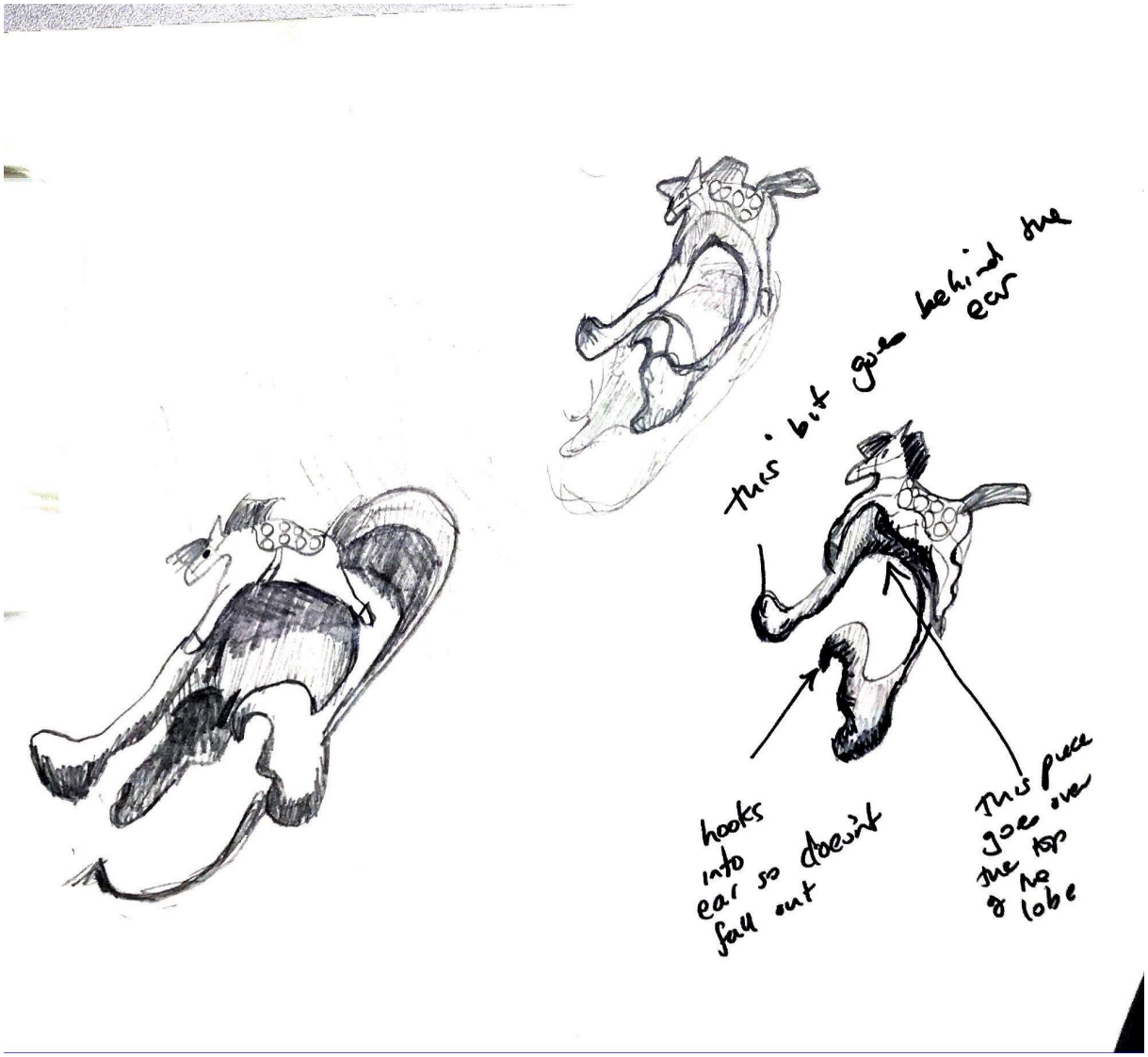

Figure K.1: *Illustration of the Wooden Horse. The rightmost figure is labelled "This bit goes behind the ear" (top), "hooks into ear so doesn't fall out" (bottom left), "This piece goes over the top of the lobe" (bottom right).*

Before the interview Grace sent an updated version of her story. She expressed frustration that the previous version had been too grounded in realism - disguising the horse as a hearing aid, when it could just be invisible; thinking about moving the horse from sleeve pocket to ear when, being magical, it could just move itself. Grace emphasized how important it was that the device should be made of wood, and not from any other material.

Another source of inspiration was a Disney film she had seen as a child: "There was a ghost of the dead girl and the ghost needs the boy to find out the mystery of how she died. He eventually finds her doll in the well or something... and solves the mystery." The film was "Child of Glass" [86].

This version puts the emotion back into the story, re-emphasizes the importance of wood, and makes John someone who has lost not only his family, but his entire planet. Finding the wooden horse is now scaled up to legendary proportions, like pulling the sword from

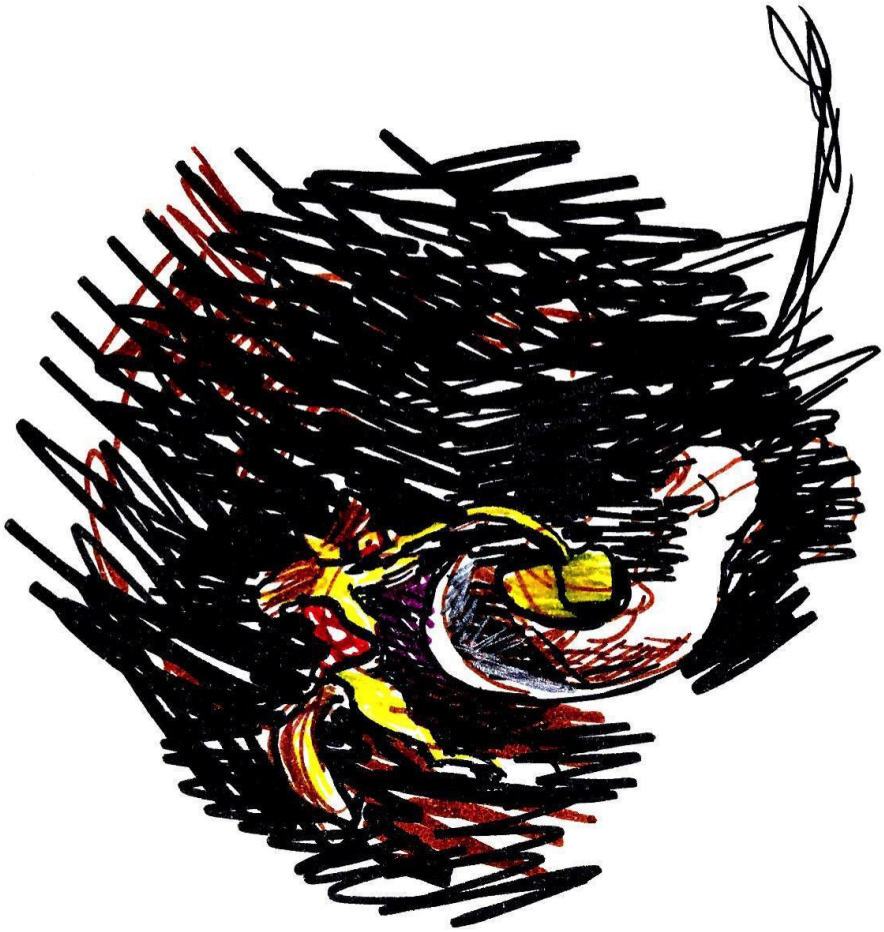

Figure K.2: *Illustration of the Wooden Horse.*

the stone. John again has a sleeve pocket to hide the horse, and the horse's powers are greater than ever: it can not only switch forms, fly, and move faster than the eye can see; it can even physically move its wearer out of harm's way. Much later, the wooden horse is manufactured on a large enough scale to help many vulnerable people.

K.2.3 Wooden Horse, by Grace: final version

The full text of Grace's updated story is in Appendix F.1.2.

K.3 Hunter

Once again, Hunter (or her character) discards multiple ideas before settling on one. Again, the character is without the expected support - in this case, parental and emotional

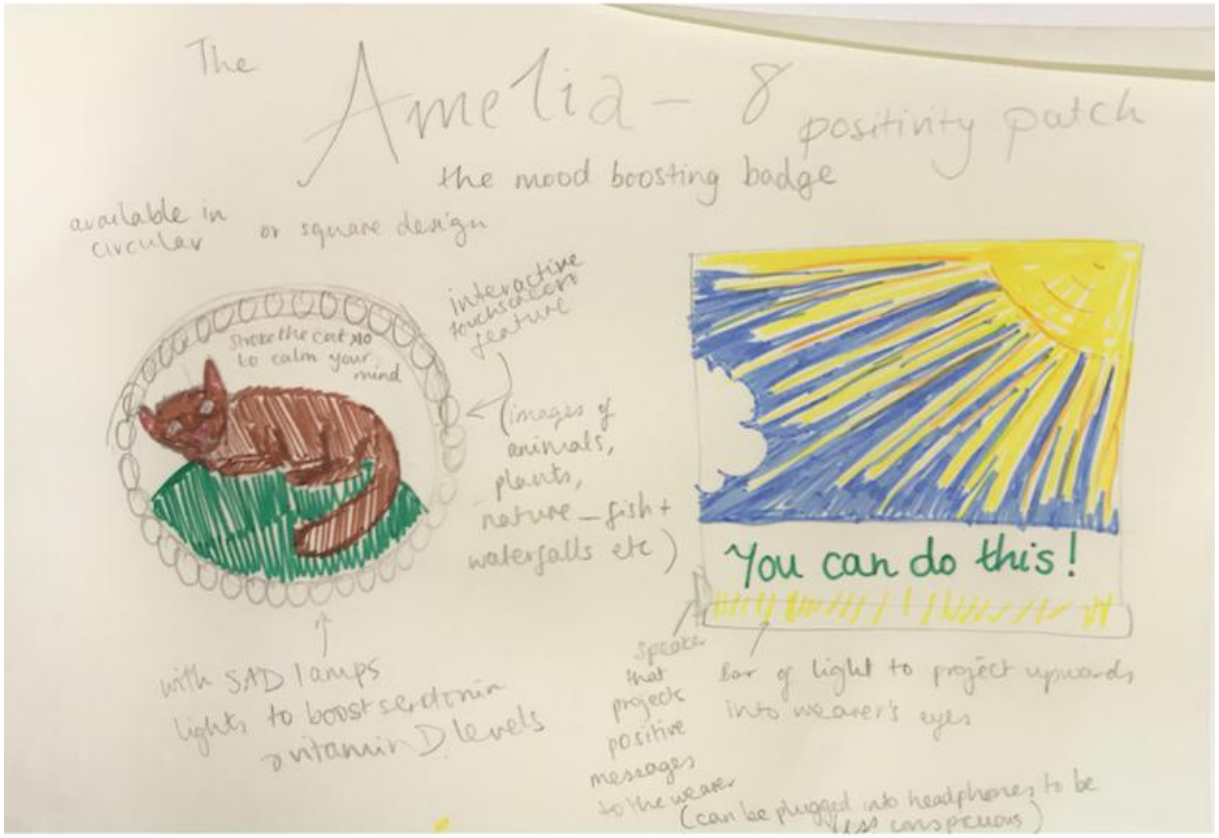

Figure K.3: *Hunter's illustration for* Amelia-8.

support (if Amelia has a mother, she is not mentioned) - and has to be self-reliant. The process of invention, and progression towards success and connection with others through creativity, is as important to the happy ending as the wearable itself (O5).

K.3.1 Amelia and the 8 Inventions, by Hunter

The full text of Hunter's story is in Appendix F.2.

K.3.2 Hunter's illustration

The illustration (Figure K.3) is captioned "'Amelia-8', available in circular or square design", respectively "the mood boosting badge" and the "positivity patch" (O4, O5).

The annotations in Figure K.3 read:

- Stroke the cat [on the mood boosting badge] to calm your mind
- With SAD lamps/lights to boost serotonin and vitamin D levels
- Interactive touchscreen feature
- (images of animals, plants, nature - fish & waterfalls etc)

- Speaker that projects positive messages to the wearer (can be plugged into headphones to be less conspicuous)
- Bar of light to project upwards into wearer's eyes

K.3.3 Hunter's 1-1 interview

On 5 June 2018 I conducted a 30-minute telephone interview with Hunter.

Hunter explained why stress relief was so important to her, recounting an experience of institutional failure culminating in an inquest. Over a long period, professionals who should have protected Hunter had, instead, delegated unreasonable responsibilities to her in a dangerous situation in which she was merely a bystander. Combined with the other experiences recounted by Hunter at workshops, it was easy to understand her focus on private solutions to systemic threats, and her pessimism about solutions at a societal level.

Hunter talked about all the things that had helped her keep her spirits up during dark times. For the Positivity Patch, Hunter was trying to think of all the different ideas for a person who was isolated or depressed or anxious and wanted to improve life, and what they could do to cheer up themselves or others.

Possibilities included a weighted vest and other things popular with those on the autistic spectrum or with tactile sensitivity. She was enthusiastic about the "Buddy Box" monthly subscription box from Blurt [1], a social enterprise for depression support. The box contains surprise items such as "believe in yourself" cards, a " self-care champion" badge, or a "one step at a time" snail patch.

About the Positivity Patch (O4, O5), we wondered whether you would want to advertise it if you were feeling low self-esteem. Hunter was more focussed on the SAD lamp and the images: "if you see really nice images of food or nature it boosts your mood and your serotonin". Or, instead of serotonin, an ultra-violet (UV)-detecting shirt.

Hunter also wanted gloves that change your skin, and spoke of a friend with a burnt hand who had a tattoo sleeve.

K.4 Rachel

Rachel took her ideas from the inaugural workshop and fictionalized them (O4, O5). Notice that news of the healing moss is shared clandestinely, through private networks. Industry in the form of "Big Pharma" is not trusted to do anything other than destroy the healing moss. Nothing good is expected of mainstream society, and the solution to Millie's problems is not only private, it is underground.

K.4.1 Hat-of-All-Assistance, by Rachel

The text of Rachel's story is in Appendix F.3.

[1] *Blurt:* **About Blurt** https://www.blurtitout.org/about/

K.5 Serena

K.5.1 Mood Bracelet, by Serena

The full text of Serena's story is in Appendix F.4.

K.5.2 Serena's illustration

Serena's illustration of her mood bracelet (and matching ring) is in Figure K.4.

K.5.3 Serena's 1-1 interview

I conducted a 30-minute 1-1 telephone interview with Serena on 25 May 2018.

Serena talked about "hormone levels an indicator other than just feeling". To her, the Mood Bracelet was a story about mindfulness, and naming your feelings: "if you can avoid being caught up in your feelings you can avoid being affected by them". This thinking was influenced by ideas from Cognitive-Behavioural Therapy (CBT) [2]. "Now I feel angry or sad without going too deeply into the reasons why [...] you feel things because you have the thoughts. Your brain rationalizes your feelings for you [...] this bracelet tells you that's what you're feeling, so you can check in on yourself." Serena gave an example of becoming upset when the work she was doing was not going as fast as it should: "If I'd had an indicator that I was getting wound up I could've handled it".

The flip side is ceding all your wisdom to an external device: "The absolute ideal bit of tech would be something that would actually be something that was somehow knowing what I was thinking." (O1, O4, O5) This would help at a time of very bad anxiety: "stuff going over and over and over in my head, 'you'll always fail"' - so the most perfect technology would be one that hears those thoughts.

Why a bracelet? I asked. Serena said it was the one thing she was most likely to wear regularly. You have Fitbits to do more steps, her phone might not be on her (O4); what other bits of clothing would you always want to wear?

Another potential problem is that "wearing your heart on your sleeve" requires you to count on others' benevolence. A secret code might help with this, so that only chosen people would know what it meant, so the bracelet would be showing cues to yourself or your nearest and dearest.

The idea that the bracelet would give her access to her own wisdom was very close to the feel of what Serena wanted.

K.6 Trudy

K.6.1 Trudy's 1-1 interview

I conducted a 1-1 telephone interview with Trudy for 30 minutes on 16 June 2018.

[2] *Wikipedia:* **Cognitive behavioral Therapy** https://tinyurl.com/7fbcra4

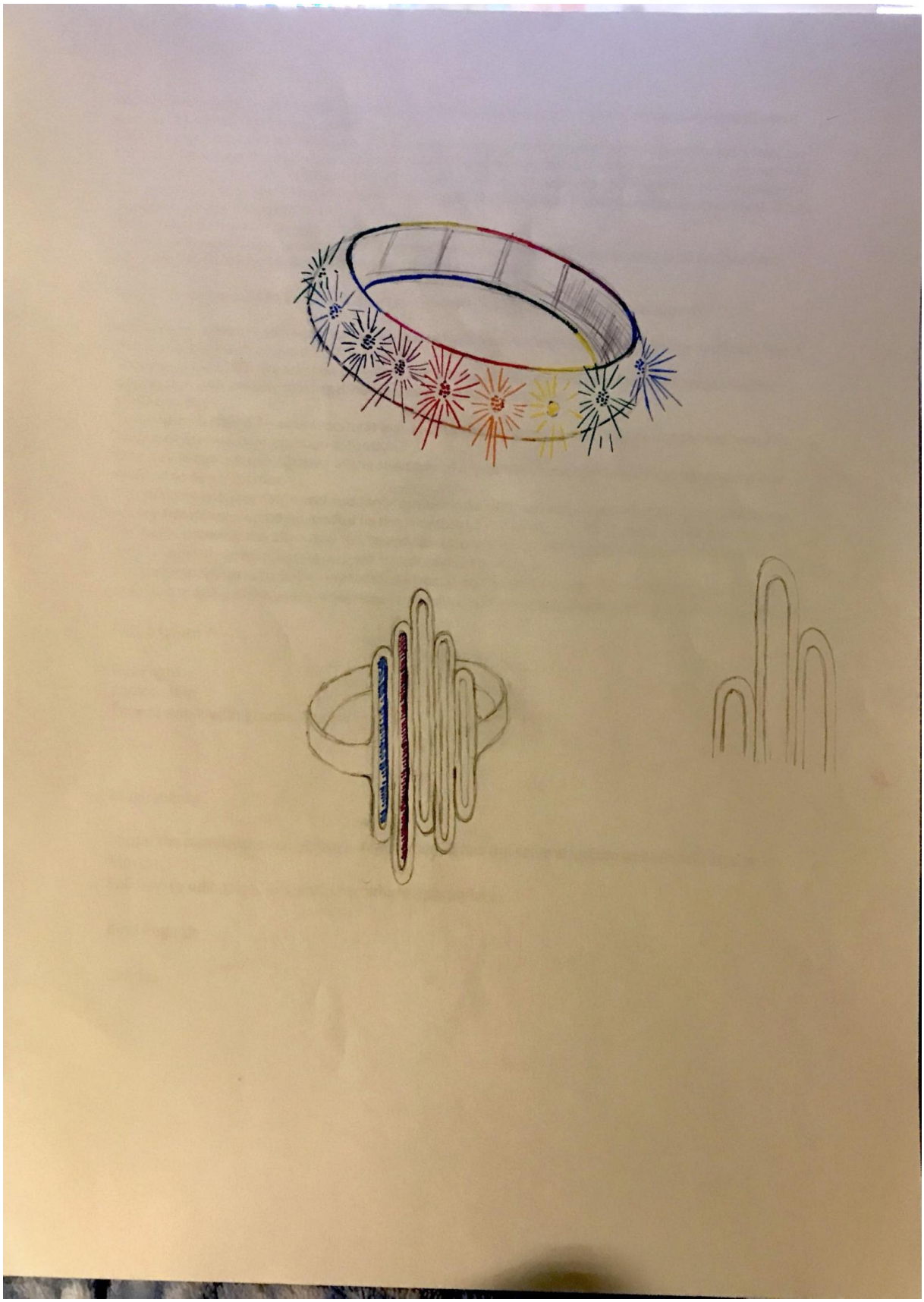

Figure K.4: *Illustration of the Mood Bracelet, with a matching ring.*

Trudy added the following details to her story (Appendix E.4): the colour transitions should be fuzzy and use shades between colours. Black for angry, yellow for happy. Otherwise she preferred to keep it to seven colours for seven emotions: short and simple (O5). Possible ways to implement it could be with thermochromatic dye, and measuring pulse rate (O4).

K.7 Ursula

K.7.1 Jacinda Dragonfly and Mr. X, by Ursula

Ursula rewrote her story to finalize it and to fit it to the Five Steps. The second version feels more forced into the structure and has lost some freshness compared to the original, which underlines the importance of emphasizing that the Five Steps are a basis for improvisation, not a template.

The full text of Ursula's story is in Appendix F.5.

K.7.2 Ursula's illustration

Figure K.5 shows Ursula's drawing of Jacinda Dragonfly wearing Mr. X (O4).

K.7.3 Ursula's 1-1 interview

On 22 May 2018, I conducted a 30-minute interview with Ursula over Skype.

Ursula talked about Jacinda Dragonfly as an alter ego, a confident double who can move freely through the world and face down adversaries without fear. This echoes the discussions with Grace and Hunter at CFI2, with Jacinda Dragonfly as a character who has mastered all social anxieties and systematic threats (with the help of Mr. X (O4, O5)).

K.8 Warren

K.8.1 Warren's story

Warren kept *Gallery Jacket* (Appendix E.7) unchanged from the inaugural workshop (O4, O5). He also talked about a "coat of many colours" with small armbands that could help the wearer and guide them in social interaction (O4).

K.8.2 Warren's illustration

Warren drew three illustrations (Figures K.6, K.7 and K.8) that show his problem and its solutions: Warren with his hearing aid, Warren with his communicative display jacket, the display jacket in action.

Figure K.5: *Illustration of Jacinda Dragonfly wearing Mr. X.*

Figure K.6: *Warren's illustration for* Gallery Jacket.

K.8.3 Warren's 1-1 interview

I conducted a 30-minute 1-1 Skype interview with Warren on 25 May 2018. Warren's story, paper prototypes and illustrations were a thorough exposition of his thinking, so the interview reaffirmed his ideas as expressed so far.

K.9 Summary

This appendix described the participants' iteration of their PDFis into their final versions, during a second workshop which was followed by 1-1 unstructured interviews with four participants.

After the 1-1 interviews were completed, I began work on the user-centred design of the technology probe based on one of the PDFis (Chapter 4).

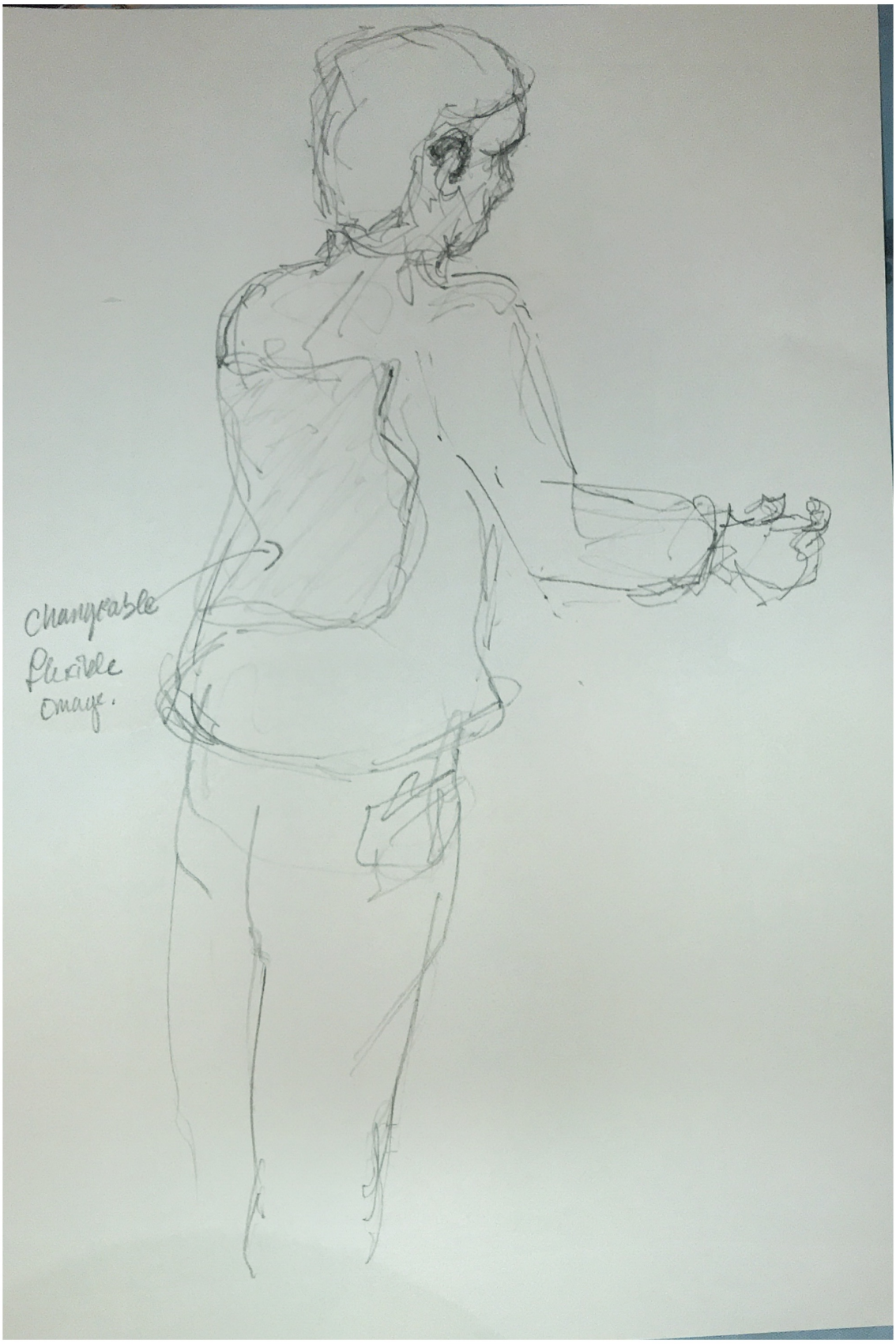

Figure K.7: *The annotation reads "changeable flexible image"*

Figure K.8: *Warren's illustration for the* Gallery Jacket. *The left annotation reads "Too loud, sound distorted due to multiple considerations". The right annotations read, from top to bottom: "Hearing aid user/Aspergers" "avoids crowds/noise" "prefers individual one to one conversation and a talking point." "sleeve with subject/talking point - attracts social conversations"*

Appendix L

Analysis of Final Design Fictions

In this appendix I analyze the themes emerging from the final PDFis.

After two workshops and four 1-1 interviews (Appendix K), the final set comprised eight PDFis. Unlike the pilot stories, these were written with the possibility of realization. Did that mean the final stories were more realistic than the pilot stories?

L.1 Technologies

Table L.1 lists the technologies in each story.

L.2 Forms, functions and numbers of technologies

The form factors of the technologies were as follows (O4):

- **Clothing:** Amelia-8, Jacinda Dragonfly and Mr. X, Gallery Jacket
- **Jewellery:** The Hermit and the Shepherd Boy, Amelia-8, Mood Bracelet
- **Mask:** Amelia-8
- **Pocket(s):** The Hermit and the Shepherd Boy, Wooden Horse
- **Fastening:** The Hermit and the Shepherd Boy
- **Carried Object:** Wooden Horse
- **Headwear:** Hat-of-All-Assistance
- **Smartwatch:** Amelia-8
- **Scarf/Shawl:** Amelia-8
- **Gloves:** Amelia-8; Empathy-In Glasses/Empathy-Out Gloves
- **Non-wearable textile:** Amelia-8

Table L.1: Final Stories: Technology

Story	Technology
The Hermit and the Shepherd Boy	Buttons (O4)
	Wish Spell Bottle (O4)
Wooden Horse	Intuition doll in wrist pocket (O4)
Amelia-8	Calming cardiovascular ankle bracelet (O4)
	Comfort/advice smartwatch (O4)
	Calming breath-control bracelet (O4)
	Speech-recognition confidante scarf (O4)
	Face-saving identity obfuscation mask (O4)
	Auto-redrawable creativity curtains
	Emotion-sensing auto-hug hoodie with serotonin-boosting sleeves (O2) plus chameleonic gloves (O3, O4)
	Badge with SAD lamp and context-aware encouraging words and pictures (O4)
Hat-of-All-Assistance	Healing hat (O4)
Mood Bracelet	Emotion-sensing feedback bracelet (O4)
Empathy-In Glasses/Empathy-Out Gloves	Other-emotion detecting glasses
	Self-emotion displaying gloves (O2, O4)
Jacinda Dragonfly and Mr. X	AI companion kimono (O2) with just-in-time information retrieval (O4)
Gallery Jacket	Jacket with dynamic artwork display to assist social integration (O4)

- **Eyewear:** Empathy-In Glasses/Empathy-Out Gloves

In the pilot stories, the technologies included armour, underwear and colour (as a form rather than a function). None of these appear in the final stories. Underwear is personal; armour is not everyday wear. Colour, in the real world, is a function, not a form.

New form factors in the final stories were:

- smartwatch
- scarf/shawl
- gloves
- non-wearable textile
- eyewear

Clothing and jewellery held their popularity. Masks were popular in the pilot but had not yet become everyday wear in the UK. Gloves join pockets in second place.

There were still no stories featuring footwear or hosiery.

Table L.2: Final Stories: Forms

Story	Polymorphous	Fixed Form
The Hermit and the Shepherd Boy		X
Wooden Horse	X	
Amelia-8		X
Hat-of-All-Assistance		X
Mood Bracelet		X
Empathy-In Glasses/Empathy-Out Gloves		X
Jacinda Dragonfly and Mr. X	X	
Gallery Jacket		X

Table L.3: Final Stories: Functions

Story	Multifunctional	Single Function
The Hermit and the Shepherd Boy		X
Wooden Horse		X
Amelia-8		X
Hat-of-All-Assistance		X
Mood Bracelet		X
Empathy-In Glasses/Empathy-Out Gloves		X
Jacinda Dragonfly and Mr. X	X	
Gallery Jacket		X

This time, most of the devices are fixed-form (Table L.2), except the Wooden Horse which self-converts to a hearable; and Mr. X, who has a desktop version (O3).

Most of the devices had a single function (Table L.3), making them more plausible candidates for immediate realization. Mr. X. has two functions: self-aware companion, and information provider (O2).

Three of eight stories described multiple devices (Table L.4). The *Empathy-In Glasses/Empathy-Out Gloves* were a set to be worn by the same person at the same time (O3), as were *Amelia-8's* Gloves of Glamour and Huggable Hoodie (O3).

Table L.4: Final Stories: Numbers of Technologies

Story	Multiple Devices	Single Device
The Hermit and the Shepherd Boy	X	
Wooden Horse		X
Amelia-8	X	
Hat-of-All-Assistance		X
Mood Bracelet		X
Empathy-In Glasses/Empathy-Out Gloves	X	
Jacinda Dragonfly and Mr. X		X
Gallery Jacket		X

Table L.5: Final Stories: Anonymity

Story	Invisibility	Disguise	Self-Expression
The Hermit and the Shepherd Boy			
Wooden Horse	X		
Amelia-8		X	X
Hat-of-All-Assistance			
Mood Bracelet			
Empathy-In Glasses/Empathy-Out Gloves			
Jacinda Dragonfly and Mr. X			
Gallery Jacket			X

Table L.6: Final Stories: Care

Story	Comfort Object	Personal Health
The Hermit and the Shepherd Boy	X	
Wooden Horse	X	
Amelia-8	X	
Hat-of-All-Assistance		X
Mood Bracelet	X	
Empathy-In Glasses/Empathy-Out Gloves		
Jacinda Dragonfly and Mr. X	X	
Gallery Jacket		

L.3 Purposes of the technologies

The different powers granted by the technologies are compared in Tables L.5-L.9 (O5). Invisibility and disguise (O1) are fading, but the anonymity theme has added an opposing dimension: **self-expression**.

The **comfort object** is the most popular of all, with ten devices appearing in five stories. (See Appendix K.7.3 for why Mr. X is counted as a comfort object.) There is one personal health device, the healing Hat-of-All-Assistance. None of the wearables are Love Tokens.

Protection now takes a backseat to care, with no new stories featuring self- or other-protection. Communication is a new dimension to the theme of mind.

- Invisibility/Disguise/Self-Expression: **anonymity** (Table L.5)
- Comfort Object/Personal Health: **care** (Table L.6)
- Self-Protection/Other-Protection: **protection** (Table L.7)
- Intuition/Influence/Knowledge/Communication: **mind** (Table L.8)
- Space Travel/Portability: **movement in spacetime** (Table L.9)

Table L.7: Final Stories: Protection

Story	Self Protection	Other Protection
The Hermit and the Shepherd Boy	X	X
Wooden Horse	X	
Amelia-8		
Hat-of-All-Assistance		
Mood Bracelet		
Empathy-In Glasses/Empathy-Out Gloves		
Jacinda Dragonfly and Mr. X		
Gallery Jacket		

Table L.8: Final Stories: Mind

Story	Intuition	Influence	Knowledge	Communication
The Hermit and the Shepherd Boy		X X		
Wooden Horse	X	X		
Amelia-8	X			
Hat-of-All-Assistance				
Mood Bracelet				
Empathy-In Glasses/ Empathy-Out Gloves				X X
Jacinda Dragonfly and Mr. X			X X	
Gallery Jacket		X		X

Table L.9: Final Stories: Movement In Spacetime

Story	Space Travel	Portability
The Hermit and the Shepherd Boy		X
Wooden Horse		X
Amelia-8		
Hat-of-All-Assistance		
Mood Bracelet		
Empathy-In Glasses/Empathy-Out Gloves		
Jacinda Dragonfly and Mr. X	X	
Gallery Jacket		

Table L.10: Final Stories: Types of Power

Story	Super Powers	Self Mastery	Convenience
The Hermit and the Shepherd Boy		X	X
Wooden Horse		X	
Amelia-8		X	
Hat-of-All-Assistance		X	
Mood Bracelet		X	
Empathy-In Glasses/Empathy-Out Gloves		X	
Jacinda Dragonfly and Mr. X		X	X
Gallery Jacket		X	

Table L.11: Final Stories: Sources of Power

Story	Magic	Technology
The Hermit and the Shepherd Boy	X	X
Wooden Horse	X	
Amelia-8		X
Hat-of-All-Assistance	X	
Mood Bracelet	X	
Empathy-In Glasses/Empathy-Out Gloves		X
Jacinda Dragonfly and Mr. X		X
Gallery Jacket		X

L.4 Realism, time period and genre

Whereas a number of pilot stories involved superpowers (Table L.10), none of the final stories does. The Hermit's buttoned cloak pockets are now the only device offering mere convenience.

Self-mastery is a goal in *every* story, while *no* stories feature superpowers.

The final stories can be classified by these profiles as follows:

- **Self-Mastery by Magic (Table L.11):** Wooden Horse, Hat-of-All-Assistance, Mood Bracelet
- **Self-Mastery by Technology:** Amelia-8; Empathy-In Glasses/Empathy-Out Gloves; Gallery Jacket
- **Self-Mastery AND Convenience by Technology:** Jacinda Dragonfly and Mr. X
- **Self-Mastery by Magic AND Convenience by Technology:** The Hermit and the Shepherd Boy

As before, most of the final stories were set in the present (Table L.12) and in the current universe (Table L.13).

Table L.12: Final Stories: Time Period

Story	Past	Present	Future
The Hermit and the Shepherd Boy	X		
Wooden Horse			X
Amelia-8		X	
Hat-of-All-Assistance		X	
Mood Bracelet		X	
Empathy-In Glasses/Empathy-Out Gloves		X	
Jacinda Dragonfly and Mr. X			X
Gallery Jacket		X	

Table L.13: Final Stories: Worlds

Story	Current Universe	Alternate Universe
The Hermit and the Shepherd Boy		X
Wooden Horse		X
Amelia-8	X	
Hat-of-All-Assistance	X	
Mood Bracelet	X	
Empathy-In Glasses/Empathy-Out Gloves	X	
Jacinda Dragonfly and Mr. X		X
Gallery Jacket	X	

The stories covered many different genres, and included both original and derivative works. Tables L.14 and L.15 compare these.

Why is *Gallery Jacket* fantasy and not SF? Versions of dynamic display t-shirts, usually using ePaper, have existed for well over a decade, though they have yet to catch on. The fantasy element is in the unexplained appearance of the Gallery Jacket: it simply materializes, bestowed by an unseen benevolent force.

Gallery Jacket is more design memoir [70] than DF, but the important thing is that Warren was trying to *write his own ending.*

Table L.14: Final Stories: Genre

Story	Science Fiction	Historical Fiction	Fantasy
The Hermit and the Shepherd Boy		X	
Wooden Horse	X		
Amelia-8	X		
Hat-of-All-Assistance			X
Mood Bracelet	X		
Empathy-In Glasses/Empathy-Out Gloves	X		
Jacinda Dragonfly and Mr. X	X		
Gallery Jacket			X

Table L.15: Final Stories: Derivation

Story	True Story	Derivative Work	Original Work
The Hermit and the Shepherd Boy		X	X
Wooden Horse		X	
Amelia-8			X
Hat-of-All-Assistance			X
Mood Bracelet			X
Empathy-In Glasses/Empathy-Out Gloves			X
Jacinda Dragonfly and Mr. X			X
Gallery Jacket	X		X

Table L.16: Final Stories: Technology Acceptance

Story	Accepted	Accepted with Modifications	Rejected
The Hermit and the Shepherd Boy	X		
Wooden Horse	X		
Amelia-8	X		X
Hat-of-All-Assistance	X		
Mood Bracelet	X		
Empathy-In Glasses/Empathy-Out Gloves	X		
Jacinda Dragonfly and Mr. X	X		
Gallery Jacket	X		

L.5 Accepted and rejected devices

Not surprisingly since all the final stories were candidates for development, only one story included rejected devices (Table L.16), and those were phases in Amelia's progress until she found her killer app.

L.6 Utility and feasibility

All of the wearables in the final stories served a practical purpose (Table L.17). Mr. X is practical in Jacinda Dragonfly's world, but he supports an adventurous lifestyle, so falls into both categories.

The Mood Bracelet and Amelia-8's Positivity Patch are plausible (Table L.18). A Wooden Horse might not be able to jump to your ear, but a hearable with an intelligent agent is realisable with enough resources. Smart glasses could be developed to read facial expressions, motion sensing and biodata and could work in gloves. A disappointing version of Mr. X could be made in the present. A Hat-of-All-Assistance is unrealizable, but an assistive hat is feasible.

Table L.17: Final Stories: Utility

Story	Practical	Fanciful
The Hermit and the Shepherd Boy	X	
Wooden Horse	X	
Amelia-8	X	
Hat-of-All-Assistance	X	
Mood Bracelet	X	
Empathy-In Glasses/Empathy-Out Gloves	X	
Jacinda Dragonfly and Mr. X	X	X
Gallery Jacket	X	

Table L.18: Final Stories: Feasibility

Story	Feasible as Described	Unfeasible as Described	Day after Tomorrow
The Hermit and the Shepherd Boy	X	X	
Wooden Horse		X	X
Amelia-8	X	X	X
Hat-of-All-Assistance		X	
Mood Bracelet	X		
Empathy-In Glasses/Empathy-Out Gloves			X
Jacinda Dragonfly and Mr. X		X	
Gallery Jacket	X		

L.7 Enchantment

How do the devices in the final stories meet the six human desires that Rose [226, Pt2] said enchanted objects (O4) could provide for (O5)?

L.7.1 The seventh desire

Technically, the devices in *Amelia-8* and *Mood Bracelet* meet the **immortality** desire because they use biodata to take care of (emotional) health. The **comfort objects** do

Table L.19: Final Stories: Enchantment 1

Story	Omniscience	Telepathy	Safekeeping
The Hermit and the Shepherd Boy			X
Wooden Horse		X	X
Amelia-8			
Hat-of-All-Assistance			
Mood Bracelet			
Empathy-In Glasses/Empathy-Out Gloves		X	
Jacinda Dragonfly and Mr. X	X	X	X
Gallery Jacket		X	

Table L.20: Final Stories: Enchantment 2

Story	Immortality	Teleportation	Expression
The Hermit and the Shepherd Boy			
Wooden Horse		X	
Amelia-8	X		
Hat-of-All-Assistance	X		
Mood Bracelet	X		
Empathy-In Glasses/Empathy-Out Gloves			
Jacinda Dragonfly and Mr. X			
Gallery Jacket			X

not quite fit the **immortality** desire (Table L.20) to live a long and healthy life; nor any of the other desires defined by Rose [226, Pt2], despite being the most popular type of device in the final stories (Appendix L.3). Even if they are personified like the Wooden Horse, they do not fit the **telepathy** desire (Table L.19) by providing a means or a substitute for connecting with others - even Margherita Banks, who has a caring husband, uses her bracelet to improve the way she relates to herself. The comfort objects are more like an intuition doll [214]: they encourage and soothe and console and enlighten. We have discovered the mythical Seventh Desire: ***heart*** (O5).

L.8 Summary

In this appendix I have analyzed the themes emerging from the final PDFis.

These stories were written with the possibility of realization, and differences are apparent from the pilot stories (Appendix J), when the prospect of realization was more distant. Most of the devices this time are fixed-form and have a single function. None of the new stories feature superpowers, and there are no new stories where the wearable offers mere convenience, even though all the devices in the final stories served practical purposes. All of the new stories have self-mastery as a goal. Only one story featured rejected devices, and those were part of Amelia's progress towards her killer app.

We also discovered a **seventh desire** that Rose's [226, Pt2] framework of enchantment forgot: ***heart***.

Appendix M

The Participants' Stories as Design Fiction

In this appendix I analyze the complete set of PDFis as examples of the DF genre, first by showing how it fits into the typology of Knutz and Markussen [147] (Appendix M.1), then by classifying them according to the patterns identified by Blythe and Encinas [32] (Appendix M.2).

From October 2017 to December 2019, 19 DFs were created by 26 volunteers, of whom 18 were one-off participants and eight contributed to the longitudinal study.

To recap, the stories were:

1. IronWoman (Appendix A.1)
2. The Hermit and the Shepherd Boy (Appendix B.1)
3. Fertility Ring (Appendix B.2)
4. Wooden Horse (Appendices B.3 and F.1)
5. Leaf Me Alone (Appendix B.4)
6. Flower (Appendix C.1)
7. Agent X (Appendix C.2)
8. Little Strawberry (Appendix C.3)
9. GodSon (Appendix C.4)
10. Green (Appendix C.5)
11. MirrorMask (Appendix D.1)
12. Wearable Plant (Appendix E.1)
13. Freedom Hat (Appendix E.2)/Hat-of-All-Assistance (Appendix F.3)
14. Mood Shirt (Appendix E.3)/Mood Bracelet (Appendix F.4)

15. Empathy-In Glasses/Empathy-Out Gloves (Appendix E.4)
16. Jacinda Dragonfly and Mr. X (Appendices E.5 and F.5)
17. Wearable Life Support (Appendix E.6)
18. Gallery Jacket (Appendices E.7 and G.1)
19. Amelia and the 8 Inventions (Appendices F.2 and G.2)

M.1 Classifications of design fiction

As stated in section 1.4.2, there is no canonical definition of DF. Section 3.7.3 notes that much of the literature on design fiction struggles with the boundaries of the genre. Sturdee et al. [255] described DF as "pre-paradigmatic" and differentiated it from SCD by its characteristic worldbuilding. There have been efforts, some tentative [113] and others substantive [147], to review DF as a genre.

If works outside of HCI can be classed as DFs [252], reviewing is an infinite task. I believe a wiki (section 1.8.2), for DF and all other subgenres of imaginary design, would lighten the workload by distributing it amongst the research community, disseminate lesser-known works, facilitate review of genres and subgenres, and make space for a plurality of opinions.

Knutz and Markussen [147, p8.11] proposed a typology that categorizes fiction's role in design experiments by five criteria. The method of PDFi in this study fits that typology:

1. **Basic Rule of Fiction (What-if scenario?)** - fits steps 1, 2 and 3 of the Five Steps (Table H.1) [135, p25].
2. **The manifestation of critique (How is it critical?)** - steps 4 and 5.
3. **Design aims (What are the possible consequences?)** - steps 3, 4 and 5.
4. **Materialization & form (How is it visualized?)** paper prototypes, illustrations, a wearable IoT device.
5. **Aesthetic of DF** - ours is "grassroot-movement" [147, p8.11].

M.2 Categorization of the participatory design fictions

Blythe and Encinas' [32] analysis is insightful and actionable. They classify DFs into four main categories:

1. **Extrapolative and scientistic:** as in *Star Trek*. Typified by popular SF, through which most fictionally-inspired inventions enter the real world. Corporate videos and research papers describing fictional systems are examples.

2. **Critique and irony:** A category manifesting in abundance as concepts, not products, of DF and SCD. The work of Dunne and Raby [82] and the Near Future Laboratory [29] are examples.

3. **Alternatives and ambiguity:** alternative worlds, like Superstudio's Continuous Monument, which portrays the whole world under one roof. [1]

4. **Magic and wonder tales:** "The wonder tale articulates, perhaps better than any other, our deepest desires and fears. [O5]" Rebaudengo's self-reallocating networked toaster [2] is an example of magical realism.

Most of the examples in [32] have two common characteristics: first, they were pure fiction (with exceptions, such as Project Glass); second, they were produced by professionals, not end users. How will my volunteers' PDFis compare?

M.2.1 Extrapolative and scientistic

- IronWoman (Appendix A.1)
- Fertility Ring (Appendix B.2)
- Leaf Me Alone (Appendix B.4)
- Agent X (Appendix C.2)
- Little Strawberry (Appendix C.3)
- Wearable Plant (Appendix E.1)
- Freedom Hat v1 (Appendix E.2)
- Mood Shirt v1 (Appendix E.3)
- Empathy-In Glasses/Empathy-Out Gloves (Appendix E.4)
- Jacinda Dragonfly and Mr. X (Appendices E.5 and F.5)
- Wearable Life Support (Appendix E.6)
- Gallery Jacket (Appendices E.7 and G.1)
- Amelia and the 8 Inventions (Appendices F.2 and G.2)

The most popular category, which makes sense given the nature of the brief. *Little Strawberry* (O4) was the one most of us would want in real life; it conforms to type and is not a personal expression of deep desires and fears (O5), which are supposedly the preserve of the magic and wonder tale.

[1] *MoMA:* Superstudio, Cristiano Toraldo di Francia, Gian Piero Frassinelli, Alessandro Magris, Roberto Magris, Adolfo Natalini **The Continuous Monument: On the River, project (Perspective)** http://www.moma.org/collection/works/934

[2] *Simone Rebaudengo:* **Addicted Products** http://www.simonerebaudengo.com/addictedproducts

It was at CFI2 that stories began to show personal significance. At CFI2, Grace and Hunter were forthcoming about their own emotional investment in *Wooden Horse* (Appendices B.3 and F.1) and *Leaf Me Alone*. These stories focussed on self-protection, confidence and vulnerability. This contrasts with the one-off action hero *Agent X*. *The Hermit and the Shepherd Boy, Wooden Horse, Leaf Me Alone* and *Amelia and the 8 Inventions* portray characters who have little or no protection from society and must be their own heroes.

The characters' vulnerability raises questions about solutionism. While the *Fertility Ring* appears to be in a class of its own as a non-safety-critical personal health solution, digital health technologies have been criticized as a potential vehicle for shifting societal responsibilities onto the individual in an age of austerity [166, p178]. The most ominous story of all is Viola's *Wearable Life Support*, which describes the ultimate individual solution to institutional failure on a planetary scale: a closed-loop water recycling system which compensates for the unavailability of drinking water.

M.2.2 Critical and ironic

- IronWoman (Appendix A.1)
- Flower (Appendix C.1)
- GodSon (Appendix C.4)

The absurdity of IronWoman's invisibility suit's (O1, O2, O4) being widely adopted, and worn in mundane situations, nearly derails the story's romantic subplot. Although [32] suggests that deep desires and fears are the territory of magic and wonder tales, in our case that level of expressiveness seems to be spread around every category (O5).

M.2.3 Alternatives and ambiguity

- The Hermit and the Shepherd Boy (Appendix B.1)
- Mood Bracelet v2 (Appendix F.4)
- MirrorMask (Appendix D.1)

In *The Hermit and the Shepherd Boy*, we see how Hannibal Lecter [98] would operate in neolithic times. The *Mood Bracelet* appears as if by magic but could be mundane. *MirrorMask* (O2) is a wonder tale set in an alternative world, based on the real-world pressure of stereotypical beauty standards exacerbated by social media [41] (O5).

M.2.4 Magic and wonder tales

- Wooden Horse (Appendices B.3 and F.1)
- Flower (Appendix C.1)
- Green (Appendix C.5)

- MirrorMask (Appendix D.1)
- Hat-of-All-Assistance (Appendix F.3)

The Wooden Horse is an intuition doll, which is a magical item, but its functionality is similar to Amelia's (Appendices F.2 and G.2) Positivity Patch and, partly, Mr. X (Appendices E.5 and F.5) (O5).

M.3 There is no Santa Claus, no Easter Bunny and no Electric Monk

A great deal of ink has been spilled on efforts to define and categorize DF [256] [113] [147] [159] [162] [163] [32] [258] but as I argue in section 3.7.3, the value of this pursuit of precision has its limits. Just as there is no Electric Monk that will automate the work of believing things for you [3, p4], there is no substitute for actually reading a text (section 2.5).

The most useful suggestion so far has been to categorize DFs by their purpose [20] and the purpose of the PDFis in this thesis is "User Studies" according to that system. Classifying the PDFis into existing taxonomies does not do much to help me to understand my users.

Lee [155, pp. 1-2], in an article on narrative in futures research, complains of an overemphasis on schematization of narratives in that discipline: "Images of the human imagination are surely not discoverable and empirically determinable in such a manner and the idea that they could be indicates a profound misunderstanding of how fictional texts are created and how they become meaningful as part of cultures." What would be the point of getting dozens of individuals to tell their story if all I am going to do is categorize them instead of listening?

M.3.1 Stories from CFI

IronWoman

IronWoman (Appendix A.1) is one of the unfinished narratives, and is essentially the result of brainstorming (section 3.7.3). The guest appearance by George Clooney, and the location at a very ordinary coffee chain, are an allusion to a series of commercials the actor was starring in at the time, which were themselves very bathetic. Advertising is a genre that essentially prepares its audience to be disappointed, and sure enough, the coffee commercials' bathos carries over into the PDFi as the characters experience the mundane reality of technology so fantastical the authors have not even narrowed down its limits yet.

IronWoman (an avatar for Beate) has an invisibility cloak, but so has everyone else, so the invisibility becomes something they have to work around. The invisibility cloak forces people to detect each other in negative space, outlined by the steam from the coffee. It is unclear why so many people want or need to be invisible; George Clooney has to take additional measures to avoid being recognized, including a voice distorter.

However, IronWoman seems to have one advantage that is not yet available to everyone else: she can see thought waves, which is how she recognizes her quarry. Presumably this is a commercial technology which everyone will have sooner or later, requiring yet more workarounds.

Other than the thought wave visualizer, the one benefit IronWoman seems to get from her polymorphous superpower suit is minor temperature regulation, which could also have been provided by a cardigan.

The story of *IronWoman* contrasts the exciting romantic possibilities of new technology with the mundane reality of its widespread adoption. *IronWoman* is a story of "technology's greatest triumph to date over both itself and plain common sense". [4, p51]

IronWoman does not tell us much about what its authors really want. The discussion preceding the storytelling speculated about extending the range of human senses to imitate the powers of animals. IronWoman's polymorphous multifunctional suit encapsulates infinite potential with only a few functions expressed in the story.

M.3.2 Stories first read at CFI2

The Hermit and the Shepherd Boy

The Hermit and the Shepherd Boy (Appendix B.1) is a story that appears to be about care, specifically, the first aid and hospitality that the Hermit provides to the Shepherd Boy. It is actually a fan fiction, and the Hermit is a neolithic version of Hannibal Lecter [98], whose concept of care is functionally indistinguishable from harm. However, that discovery is still under the surface in this first chapter.

It is not obvious from the text what the wearable technology even is - the author told us that it is the buttons that fasten the pockets inside the Hermit's cloak, where he carries the flask and meat that he offers to the injured Shepherd Boy. These buttons are not mentioned in the text, nor are the pockets. Perhaps the wearable technology is an ex post facto insertion into a prewritten text, but this story, written by an archaeologist, is a reminder that all things wearable are technology. Ihde [128, pp. 13-17] makes this point when he argues that human society is inseparable from technology use; even the Tasaday, a technologically minimal society, wear figleaf-type loincloths. Buttons are still in use today because they are a perfect design which cannot be improved upon. Protocols for networked objects change continually, and it is difficult to imagine a wearable IoT component that would not become junk at best, a compatibility problem at worst within a short timespan. The passive nature of RFID tags makes them appropriate for the sustainable IoT that Sterling [252, pp. 85-91] proposes, but the perfect design for a machine-readable tag has yet to be imagined.

The other wearable item in *The Hermit and the Shepherd Boy* was the Wish Spell Bottle (Appendix H.7.8) belonging to the Shepherd Boy. Like the buttons, the Wish Spell Bottle is not mentioned in the text, but it is depicted in Erica's paper prototype and illustration. The bottle functions by sympathetic magic, as discussed in section 4.1.1. Wish spells are one of the services the Hermit sells; he sells the means of making your wish come true, as does his 21st century descendant, a Luciferian figure to his patients and colleagues.

The author said the buttons were an innovation in the storyworld. The history of buttons is beyond my expertise, but according to Milisauskas and Kruk [183, pp. 303-304], the

presence of the earliest discovered bone and antler buttons and needles is evidence of the use of sheep for wool production at around 2800 BC in Switzerland. Earlier than that, in the middle and late neolithic period, amber buttons were extremely popular in certain forest Baltic cultures, and were produced on "a mass scale" (p. 231) in a region that includes Lithuania, birthplace of Hannibal Lecter. One would not put it past the Hermit to migrate across the Alps (the logistics of travel are conspicuously unaccounted for on the television series) and take his innovative buttons with him to the Shepherd Boy's home territory.

The Hermit's buttons closed the pockets on the inside of his clothing, where they would not be seen, otherwise one would assume they were decorative. Modern Hannibal is a flamboyant dresser, but he is also well equipped to provide hospitality. The cloak buttons in the Hermit's cloak are the equivalent of the high-design carafe and tumblers [3] in which modern Hannibal brings breakfast to Will Graham (the modern Shepherd Boy) in his motel room on the first morning of a murder investigation. The breakfast is an omelette that contains what you think it contains, and serving it, especially to the agent investigating the murder of its key ingredient, is an example of harm disguised as care. The uninitiated reader of Erica's story suspects nothing and awaits Chapter Two.

The modern-day equivalent component for a DF would be an RFID tag, to honour Sterling's concept of Spimes [252, pp. 76-84]. Unfortunately, my experience with RFID tags (section 4.1.2) indicates that they would be too difficult to work with in the use case suggested by the PDFi, which was automatic inventory of the contents of a bag or pockets (section 4.1.2).

Fertility Ring

Fertility Ring (Appendix B.2) was a real use case, rather than a story, of a woman trying to make a ring to monitor her friend's fertility by temperature. The designer's problem was how to make the ring beautiful.

Before I discuss the Fertility Ring I will introduce another smart ring that monitors temperature. The Oura Ring (https://ouraring.com/blog/innovative-fertility-research/) has been in the news during the COVID-19 pandemic. It is a commercial smart ring which the National Basketball Association (NBA) in the USA issued to players to monitor their health. It claimed to predict COVID symptoms up to three days in advance [4].

The idea that using the Oura Ring to detect signs of fever was a good idea for controlling the spread of a novel pandemic disease - that it was a good solution in disaster - is an example of a private company responding to a global public health problem, which by definition it cannot solve, and may create a market for prolonging. Gilmore [106, p388] identified two lines of inquiry from the technocultural implications of the solutionism of the Oura Ring.

The first line of inquiry was about "legitimation and authority". Outside of a pandemic, I believe biofeedback wearables can be benign if used "for recreational purposes only",

[3] *Wear the Rude:* **Royal VKB Iso Carafe and Tumblers** https://weartherude.tumblr.com/post/112445511894/royal-vkb-iso-carafe-and-tumblers-as-owned-by

[4] *The Intelligencer,* 28 May 2021: **WVU Rockefeller Neuroscience Institute says it can predict COVID-19 related symptoms up to three days in advance** https://www.theintelligencer.net/news/top-headlines/2020/05/wvu-rockefeller-neuroscience-institute-says-it-can-predict-covid-19-related-symptoms-up-to-three-days-in-advance/ cited by [106, p386]

that is, as long as the wearer accepts its limitations and never puts faith in it for anything safety-critical. A technology does not have to solve everything to be helpful. Inside of a pandemic, anyone promoting a biofeedback ring *to compensate for the unavailability of infectious disease testing, when testing exists but the institutions for providing it have failed* might as well be casting runes and hawking horoscopes. As Gilmore points out, claims that the Oura Ring could predict COVID symptoms were not validated as of January 2021, after it had already begun to be promoted for this purpose; nor was its temperature monitoring validated as being meaningful for individuals.

The second line of inquiry was "a vacuum of authority and expertise" [106, p388] in which "datafication has reached something close to social authority". *Leaf Me Alone* (Appendix B.4) is a perfect example of a systematically oppressed individual groping for private solutions after institutions have repeatedly failed to protect her. If Hunter believes she has to fend for herself, without even the protection of the law, she has evidence for that belief. If a private company believes that selling individuals the means of constantly monitoring their own biodata is a solution rather than an exploitation, they may easily cross the line into becoming part of the problem. Even if its technology functioned perfectly, "Oura acts as a proxy for long-term planning, preparation, and public mindedness." Dystopia comes gradually, then suddenly.

By contrast, the Fertility Ring is a gift of intimate friendship, given by a husband to a wife as a token of the marriage and its potential to create life. The engineer-designer was confident that the ring she had made could monitor temperature adequately in comparison to conventional methods, which is a more modest claim than that made by the Oura Ring. The ring is not just a means of fitting technology onto a body in this case, but a gift of a friend's creation, symbolizing the marriage bond. By disguising the sensor within a beautiful setting, the function of the ring is concealed and the intimacy of its purpose is preserved [131]. Both the Oura Ring and the Fertility Ring are personal health technologies but the context and relation to the wearer are qualitatively different.

Wooden Horse

Wooden Horse (Appendices B.3 and F.1) and *Leaf Me Alone* (Appendix B.4) are both tales of characters who have been completely abandoned. Both find private solutions when institutions have failed them.

However, *Wooden Horse* is also a story about the value of loneliness. Baba Yaga, a character in a closely related story, wrote:

> *The life of every being has , some vast emptiness in it. Unspeakable, grievous. ;There is a field in the middle of my wood where no one goes. It is the heart of my loneliness. I go there to dance & be quiet. & I love the intensity of its silence. If I were human I would wish to take another there. You must know every contour of yr emptiness before you can know who you wish to invite in.* [5]

There are no significant characters in *Wooden Horse* other than the orphan boy. The horse never displays any signs of autonomous personality, because it is an externalization of the boy's intuition.

[5] *The Hairpin*, 5 March 2014: **Ask Baba Yaga** https://www.thehairpin.com/2014/03/ask-baba-yaga-how-do-i-keep-from-dwelling-on-the-love-i-havent-had/

The Wooden Horse is partly inspired by a plot point in *Blade Runner 2049* [271] in which a replicant, K, recovers a childhood memory of owning such a toy in an orphanage, leading him to believe in his own humanity and sending him on a quest. In fact K is a replicant and the memory is not his own, but he now refuses the subhuman status that society tries to impose upon the beings it has created.

The other source of inspiration for the Wooden Horse is the daemons in *The Amber Spyglass* [218], in which human souls are externalized from their bodies in the form of sentient animals. In the PDFi, the orphan's Wooden Horse is an intuition doll like Vasilisa's [214, p77], bequeathed to her by her mother on her deathbed. Like Vasilisa, the orphan boy uses his intuition doll to attain wisdom. [214]

In the version told by [214, p83] there are nine tasks which Vasilisa must complete with the help of the doll, the first of which is to let go of the overprotective mother figure. There are no mothers in the world of *Wooden Horse*, an absence symbolized by the forest without trees (Appendix F.1.2). The Wooden Horse is the organic artefact of a once-living thing, as Vasilisa's doll is the legacy of her mother's care. The horse helps the wearer "let die what must die": the fears that make you too shy to go to a party are conquered by the horse's prompts for things to say (Appendix B.3).

The second task is to confront "the underdeveloped but provocatively cruel elements of the psyche" [214, p88] which appear to Vasilisa as her stepmother and stepsisters, and to the orphan - who is given the name "John" as the versions progress - as school bullies like James and cruel caretakers like Nurse 1.

The third task is "navigating in the dark" [214, p91]; as the doll guides Vasilisa through the forest, the horse guides the wearer away from bullies and towards safer routes. It tells the wearer what they cannot see for themselves: "Being bound to one's intuition promotes a confident reliance on it, no matter what." (p. 93)

Vasilisa's fourth task, as described by [214, p91] is meeting Baba Yaga, the "Wild Mother", who never appears in John's story directly. The fifth task is to wash the witch's clothes and clean her house, tasks representing cleansing of the persona and the psyche. John never does this either.

But the central task of connecting with one's own self by oneself is the work that the Wooden Horse helps John to do. The sixth task is to learn discernment. The Wooden Horse "never sleeps or switches off" (Appendix F.1.2), like the doll that sorts the mildewed corn from the good corn while Vasilisa sleeps. If you sleep on a problem and let your intuition guide you, then "perhaps the two-million-year-old woman will come visit you from the night land. Perhaps she will be bearing the solution, or will show you that the answer is under your bed, or in your pocket, in a book, or behind your ear." The Wooden Horse might be behind John's ear, or in his special sleeve pocket; on a ledge in the kitchen's fireplace, or flying to John's aid faster than the eye can see.

Vasilisa's seventh task [214, p106] is to ask Baba Yaga about the men on horseback that rode into her hut. John's wooden horse is red (Appendix F.1.1) The man on the red horse is Baba Yaga's "Rising Sun" (p. 81). Red is the colour of anger and violence, but also the colour of the life force. "It is a color that is considered strong medicine for psychic malaise, a color which rouses appetite." (p. 107)

The eighth task [214, p109] is "Taking on immense power to see and affect others [...] Looking at one's life situations in this new light". John never uses the horse to protect

others in the story, but keeps it with him all his life as Vasilisa keeps her doll; and centuries after his life is over, the horse is manufactured as a product that helps other vulnerable people (Appendix F.1.2).

The ninth task [214, p113] is to "recognize and react to one's own psyche and/or negative aspects of persons and events in the outer world". Vasilisa burns her stepfamily to ashes with the flaming skull Baba Yaga gave her; the horse gives John the words and the courage to stands up for himself to Nurse 1 (Appendix F.1.2.).

The Wooden Horse provides companionship and support in specific ways. It:

- provides verbal scripts for responding to social situations;
- provides direction for nonverbal responses;
- speaks comforting words;
- differentiates well-lit from dark routes;
- detects other hazards, including human aggression, and directs the wearer towards safer routes;
- provides context-aware emotional support;
- physically moves the wearer away from hazards;
- hides its presence and functionality from bystanders.

Computationally, the Wooden Horse is an artificial intuition device. At first glance this seems like a paradox: humans have better intuition (of the kind described in the PDFi) than a machine will be able to provide for the foreseeable future. Johanssen and Wang [134] analyze journalistic imaginaries of artificial intuition and critique the assumption that intuition is a technicality that can be implemented in code; and more generally, the bias and ethical hazards that result from taking claims about artificial intuition at face value.

However, what the Wooden Horse is actually doing in the PDFi is not substituting or surpassing human intuition, but helping an orphaned (deprived of the expected sources of human guidance and emotional support) boy to develop *his own* abilities. In the immediate term, a version of the Wooden Horse could be added to the set of tools we use to help us to think: John Cage and Merce Cunningham [91] used chance procedures such as I Ching to make decisions about composition and choreography; Brian Eno created the *Oblique Strategies* card deck for musicians, and so on. A more immediately realizable version of this concept is the Positivity Patch (Appendix F.2).

The Wooden Horse also augments human senses by "seeing round corners" on the wearer's behalf, to detect hazards such as bullies or unlit street lamps in real time: a cross between and end-user version of *Minority Report* [29, pp. 35-63] and a pedestrian version of the *Waze* app which used to crowdsource traffic information to warn drivers in traffic jams that they had just joined a traffic jam. I will leave that can of ethical and safety-critical worms unopened for now.

The desire expressed in *Wooden Horse* is for a comfort object that will help the wearer to communicate with themselves better.

Leaf Me Alone

I wrote above, regarding the Oura Ring, about the inadequacy of private solutions to systemic problems. *Leaf Me Alone* (Appendix B.4) includes two instances of authority figures failing to protect Hunter despite their responsibilities to do so. In Appendix K.3.3 she described a more recent cascade of institutional failure, during which she was both endangered and tasked with safety-critical responsibilities that were not her rightful duty. Hunter acknowledged in passing that what she really wanted was societal measures to improve safety, but because of her experiences had no expectation of making that happen.

Wissinger [280, p9] wrote: "Wearables aimed at keeping women safe in public, for instance (via purse clipped or jewelry encased body alarms or geolocation trackers that automatically dial emergency services when the wearer pushes a distress button), hide a subtext that assumes women alone in public spaces are automatically victims-in-the-making." But, Hunter is not a company pushing commercial technological solutionism, she is a citizen trying to survive without support from anyone but herself. As mentioned regarding the Fertility Ring (Appendix B.2), a technology does not have to solve everything to be helpful, but Hunter was trying to find a way to make invisibility helpful in practice (see also *IronWoman* (Appendix A.1)) and could not make it work. *Leaf Me Alone* is a metonym for a problem that cannot be solved within this paradigm.

M.3.3 Stories from Edinburgh Group 1

Flower

In *Flower* (Appendix C.1), the diegetic prototype is only a plot device to enable time travel, and was probably chosen because there was a toy crown in the creative toolkit. However, in the days before passports, a crown was probably good enough proof of royal identity to admit the wearer to state occasions of crucial educational importance, from which commoners would normally be excluded.

This PDFi, like all the Edinburgh contributions, is perfectly structured according to the instructions of the assignment. *Flower's* contribution was not so much about insight into wearables as raising the energy in the room to start off a session of live storytelling, which can be critical to the success of the occasion.

Agent X

Agent X (Appendix C.2) shows off the latest in military and security wearables as he tries to get control of a virus that The Company has rather self-defeatingly released worldwide.

The first obstacle he has to contend with is facial recognition, which he defeats with his polymorphous mask. A generic, realistic disguise prosthetic was previously available from URME Surveillance (http://www.urmesurveillance.com/) at cost price. What the authors failed to anticipate was that a benefit of a global pandemic would be only having to disguise the top part of the face.

Having gained access to The Company building, Agent X dons an invisibility cloak, but he got blood on it during a fight, and because the cloak is not waterproof - which is the kind of limitation that always happens in reality - the invisibility functions fail and he is

discovered. Anticipating this eventuality, the designers of the cloak added a bulletproof tent option. But unfortunately, just as in real life, bulletproof material is not stabproof, so now Agent X is visible *and* full of holes.

Fortunately Agent X has anticipated this scenario by layering a basic invisibility suit underneath, and is able to escape. *Agent X* is a story about the tradeoffs that are an inevitable part of design.

Agent X is a well thought out use case for a field espionage ensemble, but is it a DF or a scenario? Most of what it tells us is task-oriented. Pressure of time at the event, and my own condensed note-taking, make for a more focussed story, but *Agent X* is trying to convey excitement and drama in ways a scenario would not.

Little Strawberry

Little Strawberry (Appendix C.3) is perfectly thought out, anticipating the boredom of getting exactly what you want. It is the one story that definitely reads like a scenario rather than a DF (section 3.7.3) despite conforming to the prompt; it includes no details that are not task-oriented, although I may have left some out of the compressed transcript.

GodSon

GodSon (Appendix C.4) describes the disadvantages of living in an information society, through the eyes of a character who knows too much. Symbolizing his omnipotence through the mask implies that others cannot read GodSon's thoughts the way he can read theirs.

Palen and Dourish say [210, p130] "Although Big Brother actions may threaten life and liberty, it is interpersonal privacy matters that figure primarily in decisions about technology use on an everyday basis." This story is about how GodSon's personal relationships are ruined by the mask.

I infer that the others do not know GodSon has knowledge of them that they do not control. In the real world, that might translate into hacking, but you can also learn more about someone than you want to know through social media "stalking" in the colloquial rather than criminal sense: potentially unhealthy but not law- or rule-breaking attentiveness to a target's online activity, where the target knows they have published this information but is unaware that particular individuals are paying this much attention to it.

Green

Green (Appendix C.5) is a vignette that evokes tranquility and oneness with nature. The special thing about *Green*, like its main character, is its quiddity. In my opinion, it is the most perfect of all the PDFis.

M.3.4 Stories from Edinburgh Group 2

MirrorMask

MirrorMask (Appendix D.1) evokes anxieties about appearances and the presentation of self in ways that feel characteristic of the social media era. Women in this age group could have told a story like this before social media, but since social media the concept of presenting a permanently masked and disguised self to a world unaware of the disguise has become a real possibility. Previously, young women were warned that anyone can hide their real identity behind text on the Internet. Nowadays we have the bandwidth for images and video, and the tools to disguise ourselves have not been far behind.

In 2021 a Japanese motorbike influencer with the online identity and appearance of a young woman, "Soya no Sohi", turned out to be a 50-year-old man named Yasuo Nakajima. [6] Nakajima reportedly retained and even increased his audience after his real identity was discovered, because his overall content is authentic and only his appearance is altered.

Nippert-Eng [198, p23] wrote that "the central claim to privacy in the U.S. is the desire to control identity". The 7 News article describes Nakajima as a "divorced father of three" which implies that his children do not live with him, which would reduce opportunities for anyone in his offline life to connect his online and offline personas. But he got the idea to use FaceTune from his children.

The character in *MirrorMask* has to hide *everything* about herself, which in the real world can be experienced as the chilling effect of an increasingly aggressive online culture.

These problems were not created by the Internet; they were and are typical of adolescence and young adulthood, when fitting in is necessary, and beauty feels both necessary and unattainable. It is as it has always been, but more so, as every human tendency is amplified by technology.

M.3.5 Stories first read at the inaugural workshop

Wearable Plant

Leaf Me Alone (Appendix B.4) tries to blend its wearer in with nature, which is probably meant to contribute to emotion regulation. *Wearable Plant* (Appendix E.1) focuses on nature's role in mental well-being.

I have seen a tiny spherical terrarium with a living succulent inside, worn as a pendant, so Hunter's idea is not only plausible but real. Itoh et al. [130] created a networked dress for interacting with a forest's soundscape in real time from a distance.

Freedom Hat/Hat-of-All-Assistance

Rachel brainstormed the *Freedom Hat* (Appendix E.2) at the inaugural workshop and finalized it as *Hat-of-All-Assistance* (Appendix F.3).

[6] *7 News,* 12 May 2021: **Why fans love beautiful female motorbike influencer who was exposed as a middle aged man** https://7news.com.au/lifestyle/why-fans-love-beautiful-female-motorbike-influencer-who-was-exposed-as-a-middle-aged-man-c-2821620

Rachel imagined a *Freedom Hat* (Appendix E.2) with extra powers because she needed to wear a hat with a brim in real life anyway. She was also using a Polar smartwatch to monitor her vital signs so she would know when she needed to do things like sitting down. An eInk display inside the brim of the hat would have saved her the vigilance of constantly checking the watch.

Rachel was not treating the watch like a medical monitor; she knew it was not going to have that level of accuracy, but she still found it helpful. The smartwatch was not a cure, and it could not campaign on her behalf for more research into fatigue disorders and better treatments and social support for patients. Her smartwatch was an example of a device that was helpful even though it could not solve everything (see *Fertility Ring* (Appendix M.3.2)). And it was her own interest in assistive technology that had drawn Rachel to the workshop. The *Freedom Hat* is what tech solutionism is *not*.

Millie enters *Hat-of-All-Assistance* (Appendix F.3) as a person who does things: "She ran and danced, skipped and sang, read books, travelled to faraway places, jumped out of planes, always took chances. She led negotiations. She broke bad news, comforted people, formulated arguments." She then becomes someone who is ill. Then she finds the moss and puts it into the hat that restores her to her former identity, and more.

The moss can heal her, but it cannot restore her to industry standard. She still, like all people with any disability of any kind, must get permission from a normative gatekeeper to participate in normative society, and provide a list of what she has done and not done, and when. She tries to regain employment as a person who does things, but gatekeepers read the list and see what she has not done: she is not allowed to control her own identity [198, p23]. She cannot take the conventional route out of her sick identity and into a healthy one.

When Millie shares her discovery of the moss that cures her illness, she does so through underground networks of fellow secret-keepers who never relinquish control over the agent of their liberation.

Millie continues to do things. She reclaims her right to earn a living by telling and selling her story (the narrative of her identity), and uses what she earns to give sanctuary to abandoned beasts of burden (donkeys). She still must search to find the spaces in society within which she is permitted and able to live.

Hat-of-All-Assistance is a story of a wearable material that only partially solves Millie's problems by changing her, while society remains unchanged.

Mood Shirt/Mood Bracelet

Maragiannis and Ashford [173, p208] wrote: "when discussing aesthetics it is not only the exterior of the object which is to be considered but also, how the information is displayed to the consumer." Not everyone wants their data display to be readable to bystanders, which was part of the discussion around *Mood Shirt* (Appendix E.3) as well as *Fertility Ring* (Appendix B.2).

Mood Bracelet (Appendix F.4) is not just about the bracelet's effect on Rita, the wearer, but on Rita's relationship with her husband (section 3.7.3). The story depicts the technology as amplifying the negative in human behaviour, but expresses more balance and optimism than mainstream imaginaries such as *Black Mirror* [38] about human resilience,

self-awareness and perspective-taking. Unlike *GodSon* (Appendix C.4) who destroys his technology, Rita keeps her bracelet as an aesthetic item of jewellery, and she and her husband learn not to overreact to its feedback. This is similar to how the oppressiveness of the *MirrorMask* (Appendix D.1) is reduced to its appropriate proportions because of the wearer's intimate relationship with another.

In the real world, Serena wanted to add the practical, scientific function of air quality monitoring to her Gallery device (Chapter 5) and did not believe a machine could usefully contribute to the regulation of human emotion (sections 5.1.4 and 5.5.2).

Empathy-In Glasses/Empathy-Out Gloves

As stated in section 1.9.1, Trudy's PDFi (Appendix E.4) would read differently if she were expecting it to inspire a wearable to give to her brother (the character) rather than for herself; and if the boy in the story were the only one who needed the technology. It would read like a *typical* mainstream perspective on assistive and accessible technology.

Williams and Gilbert [278, p2] critique an example of the mainstream perspective, from the accessible technology field, which "objectifies the disabled person as a site of employment for an able-bodied carer rather than as an autonomous user of technology."

Trudy's description of the bullies' stealing the glasses only to learn to see themselves and Timmy as they actually are, is a subversion of typical mainstream narratives of "social prosthesis and normative violence", of which Williams and Gilbert [278, p4] also supply an example: "assaulting a disabled child is expected behavior, and the disabled child is the deviant in need of intervention."

Empathy-In Glasses/Empathy-Out Gloves is an example of the value that PDFi can offer to researchers in wearable technology who are seeking to leverage "situated knowledges" [278, p2].

Jacinda Dragonfly and Mr. X

Jacinda Dragonfly (Appendices E.5 and F.5) is the embodiment of technological optimism. She is Ursula's avatar for self-confidence and her dress sense is one more outward expression of her adventurous spirit.

As a steampunk character, the optimism of Jacinda Dragonfly recalls that of the Victorian era. Tanenbaum and Wakkary [256] argued for steampunk as a design strategy for HCI and contended that DF is an intrinsic practice in the subculture, together with DIY and appropriation.

As DF, steampunk involves "the creation of fiction that better engages with the issues of an imagined or desired future" [256]. There is a strong culture of making in steampunk, and Jacinda's history as a published character in Ursula's DIY jewellery manuals supports this argument by Tanenbaum and Wakkary, who also extol steampunk's appropriation techniques as "alternatives to modularity and top-down design with respect to customization".

When Ursula describes her fictional AI companions as extensions of their owners' personalities (section 6.4), saying "there are no bad dogs, only bad owners" she expresses optimism about the future of bias in AI. This is a place where the participatory culture of

steampunk, and researchers of AI in general and AI for wearable computing in particular, could meet in working together towards a desired future.

Wearable Life Support

Viola's experience in international development has led her to believe a wearable life support system (Appendix E.6) that recycles exhaled, evaporated and excreted moisture in a body-worn closed loop, is a solution she could "achievably contribute" to alleviate the limiting factor of water shortages.

This is how the closed-loop systems on the International Space Station work, and sewage water is recycled in many countries. I am not quite clear from Viola's proposal how a body-worn solution is meant to contribute to international development work. If such systems are intended for everyday use by the general population, that would seem to be an abandonment of hope for the earth's future as a habitable planet.

I meant to look into forecasting and proposed solutions for global water shortages in the near-and medium-term, but I needed to go out and get a pint of milk, so I had to stop and update my literature review on the minimum standard of face mask appropriate for a fully vaccinated female in my age group, factor in my caring responsibilities, and check the estimates of local COVID case levels, so I could decide what to wear.

Masks are most effective when everyone wears them, of course, and I am quite shocked at how inconsistently the personnel in the 2011 documentary *Contagion* [246] seem to know about them. Viola's idea for a mask to collect condensation would have to take the airborne nature of COVID into account, or would the water filtration components be enough?

I know I should be watching the new *Dune* [272] to keep up with current and near-future events, but my motivation is lacking for some reason and I cannot follow a train of thought. Viola's scientistic PDFi was not meant to evoke a strong emotional response. I need a Huggable Hoodie (Appendix F.2). My family are still living. Inhale. Exhale.

Gallery Jacket

As described in section 3.6.2, the Gallery Jacket (Appendices E.7 and G.1) is conceptually different from mainstream wearables because of its role in an *alterity* relation with the wearer, rather than the embodied or heuristic relation so typical of earbuds and wristband monitors.

Furthermore, the Gallery Necklace (Chapter 4) is not primarily a computer-that-is-wearable; its main function is not computational, but relational, a tool for the wearer to relate to the world through self-expression. That mainstream wearables have minimized self-expression is attributable both to cost (section 3.5.2) and the functional anti-fashion aesthetic of hacker culture (section 3.6.3).

Serena's suggestion to add an air quality monitor to her Gallery device and change it to a bracelet form factor might cause it to be mistaken for a failed smartwatch with only one function. As explained in section 3.4.1, it would still primarily function as a gallery, and the eInk screen would function as the aesthetic focus of the device for bystanders as well as the wearer.

As explained in section 1.9.1, the Gallery Necklace is not an assistive device. It does, however, leverage the situated knowledge of a disabled participant [278, p2] who was looking for ways to live his best life. His dystopia is an extremely online one, where creators lose control of their content by unstoppable large companies which drain their livelihood, subject their aesthetics to enforced disappearance, and misappropriate visual communication to spread propaganda. Unfortunately, it is also a present reality. The utopia he imagines is a modest one: independent creators thriving in small shops and galleries, apps directing people there to enjoy local art in person. I have stated in section 3.7.2 how I think this might be achievable.

The Gallery Jacket-become-Necklace-to-be-Badge is not a social wearable in the sense of connecting humans through electronic networks; it works face-to-face and its success depends on the actions and interactions of its wearers outside of the networked system. Of course, functionality can be added to track in-person interactions or automate social media connections, but the base case does not require it. In theory, the wearer could do all these things just as well without it, and almost certainly does; but Warren is an artist, so his goal is not necessarily to reduce every process to maximum efficiency - some things are to be enjoyed for their own sake, as he explained in section 5.5.4. As stated in section 1.9.1: "This thesis is about wearables that users want to wear, even when they don't have to (O5)."

M.3.6 Stories first read at the second workshop of the inaugural study

Amelia and the 8 Inventions

Like *Gallery Jacket* (Appendices E.7 and G.1), *Amelia and the 8 Inventions* (Appendices F.2 and G.2) is a story about finding ways to end loneliness.

It is also a story about the creative process itself as a way to work through feelings of isolation. Amelia is a child who has caring responsibilities for her father, as many children do. Like John in *Wooden Horse* (Appendices B.3 and F.1), Amelia in some ways has to bring herself up. Like Warren, Amelia finds that her creative endeavours are an obstacle to making friends with other children, but instead of making herself a MirrorMask (Appendix D.1) she perseveres. Some of her inventions are artificial companions: a scarf as a confidante, a hoodie to hug yourself without the remote pairing typically required by a hug-from-a-distance system. When the emotions get too much, Amelia builds self-regulation anklets and bracelets. These descriptions only invoke more loneliness and, unsurprisingly, leave Amelia dissatisfied.

Amelia lives within an oppressive system, but is convinced that she can invent something to make the people around her happy. The stakes are even higher in the divided and embittered society of the updated version (Appendix G.1). Is this tech solutionism, or is it a belief that art and creativity have real power?

The thing about a badge form factor is that it is easier for bystanders to see than it is for the wearer. Whether Hunter intended it or not, this display makes the Positivity Patch an alterity-relational device in the same way as the Gallery Jacket (Appendices E.7 and G.1), even though its main intended function is as a comfort object to improve the wearer's relationship with the self, it will inevitably be seen by others. As such, a

Positivity Patch/Gallery Badge hybrid is a natural iteration (section 5.4). In Appendix G.1, this improved self-regulation is a necessary step in improving relationships between individuals, with beneficial effects for society.

Amelia's happy ending consists of success as a social entrepreneur, and friendship with a group of like-minded people. Hunter describes finding great comfort from images and slogans for depression support (Appendix K.3.3); the Positivity Patch is not a MacGuffin [7] for her. But *Amelia and the 8 Inventions* is a story about the journey as well as the destination; it is a story about the process, not only the outcome.

M.4 Summary

In this appendix I have analyzed the complete set of PDFis as examples of the DF genre, first by showing how it fits into the typology of Knutz and Markussen [147] (Appendix M.1), then by classifying them according to the patterns identified by Blythe and Encinas [32] (Appendix M.2).

Unsurprisingly given that the goal was to produce a real piece of technology, extrapolative and scientistic stories are the most frequent type. Though Blythe and Encinas [32] thought that "deep desires and fears" would be found in the magic and wonder tales, evidence of participants' emotional investment was spread around every type of story.

However, PDFis created by volunteers in a user study are most usefully understood by reading [155] (section 2.5), not by reducing them to schemas for classification (Appendix M.3). The former helps to understand the users, which is the purpose of PDFis in a user study [20]; the latter does not.

[7] *TV Tropes:* **MacGuffin** https://tvtropes.org/pmwiki/pmwiki.php/Main/MacGuffin