Strategies for Annotating Portfolios: Mapping Designs for New Domains

Alma Leora Culén
University of Oslo
Oslo, Norway
almira@ifi.uio.no

Jorun Børsting
University of Oslo
Oslo, Norway
jorubo@ifi.uio.no

William Gaver
Goldsmiths, University of London
London, United Kingdom
W.Gaver@gold.ac.uk

ABSTRACT
In this paper, we extend the concept of annotated portfolios to include designs for new domains. Although annotated portfolios were intentionally left open to interpretation and appropriation, most of the published research that uses this method to articulate intermediate knowledge focuses on annotation strategies that abstract new knowledge about the qualities of *interaction* and about the design *domain*. We suggest that annotations can do more than pull towards concerns regarding abstraction and show that several not so very theoretical, but relevant findings can be achieved using other strategies. Two additional strategies are brought forward to illustrate this: a chronological design *trajectory* that shows the historical account of new domain explorations, and a design *ecosystem* strategy that aims to show how artefacts can work together. We apply all four strategies mentioned above and discuss how they contribute to revealing features of the design space for people with Myalgic Encephalomyelitis.

Author Keywords
Annotated portfolios; design practice; intermediate knowledge; research through design; annotation strategies

ACM Classification Keywords
• Human-centered computing~ HCI theory, concepts and models

INTRODUCTION
With recent advances of designerly ways of working in HCI, such as Research through Design (RtD), the relationship between research and design has been widely discussed, e.g., [9,17,20,24,29,40,42,53]. Typically, RtD researchers engage in design practice to make artefacts or systems that can be explored in their use contexts and reflect on new domain and design perspectives unveiled through the practice, artefacts, or their use. Increasingly, insights gained include reflections on methods and theoretical and conceptual framings of the work. Relying on designer's judgments, RtD allows for departure from the user-centered design perspective in HCI. At present, there is a large body of work that discusses and showcases how new knowledge emerges through design practice [2,26]. As design practice does yield knowledge of a particular kind, the questions concerning the nature, rigor, and relevance of such knowledge for the community, as well as its relation to scientific research, have come to the forefront [21].

A number of proposals have been made on how to bridge the gap between the knowledge gained through the design of a particular artefact or a group of artefacts and expectations of the research to yield more abstract and theory-oriented knowledge. Some of these proposals have discussed various forms of intermediate knowledge, e.g., annotated portfolios, strong concepts, design programs, manifestos, concept-driven design, and bridging concepts [4,10,15,22,27,42,46], to name a few. Others have demonstrated how concepts drawn from theory can inform design practice (e.g. [25]). Still others have focused on how design practitioners actually work in the everyday context of real-world design, to inform design research so that its outcomes better support design practice [45].

Despite evident progress in framing the knowledge and finding better ways to communicate design research in HCI, further understandings regarding how design practice may lead to new knowledge is needed. As the community embraces more complex design domains, including design for social innovation [14,33] and increased opportunities for personal fabrication of digital artefacts to have large social impact, it becomes crucial to explore strategies for understanding digital artefacts made for such purposes and the design domains that they populate [3,12,32,36,44,52]. This is particularly relevant when design aims to open new application areas through design practice, as is the case in this paper, where we discuss designs for people with Myalgic Encephalomyelitis (ME), also referred to as the Chronic Fatigue Syndrome, a debilitating, multisystem illness involving significant reduction in physical and cognitive functioning among those affected [13].

The everyday life of people with ME is a novel design domain, and presents a series of design challenges due to the nature of the illness and ability of those affected by it to engage with technology. The domain is starting to be populated by social innovation artefacts, such as AV1, the

Author Accepted Manuscript

To appear in *DIS '20, July 6–10, 2020, Eindhoven, Netherlands*

robot described later in this paper that was intended to reduce isolation among adolescents diagnosed with long-term illnesses, including ME [14]. Although we could find some previous work addressing the needs of people with ME specifically, that work did not start from design considerations, or opportunities for innovation by design. Instead, the research built on new (at the time), or emerging technologies to find ways to support people with ME, such as the Second Life ME Center described in [5], or the use of iPads for children with ME to attend school and take part in classroom activities from home [43].

Our approach was different. After working with AV1 and adolescents with ME, we gained insights into the design domain and decided to explore it further through design practice, resulting in several new artefacts. We then studied their use in everyday lives of people with ME. To reason about our designs, experiences with them, and possibly uncover more about the design domain, we used annotated portfolios [10,22,35] and considered a variety of annotation strategies that offered distinct perspectives on designs and led to insights from each artefact individually, and from ways in which multiple artefacts related to one another.

In this paper, we discuss four strategies to annotate a portfolio of four designs. The first two strategies were applied to elucidate new knowledge regarding *interaction* and *domain*, following the now established practice of creating annotated portfolios. The two novel strategies, *trajectory* and *ecosystem*, focus on how a chronological narrative of successive designs helps to reveal a progressively larger design space and future opportunities, and how the artefacts complement each other and work within the ecosystem that they create. Jointly, the four strategies contributed to revealing a rich set of features of the design space for people with ME. We suggest that the quality of knowledge gained in this way revealed more of the design domain without the need for a lot of abstraction.

To appreciate the difference, we discuss intermediate knowledge forms first, including annotated portfolios, before presenting the designs for ME and annotation strategies used.

INTERMEDIATE KNOWLEDGE IN DESIGN RESEARCH

Positioning design practice and its outcomes as research requires demonstrating the production of new knowledge. Design artefacts are rarely considered sufficient in themselves. Instead, the community tends to expect, or demand, some degree of abstraction, usually in textual form in which *"general rules and concepts are derived from the usage and classification of specific examples"* [57].

Given that artefacts are situated, specific and complex, the possibility of using them to form general and analytically 'pure' theory reliably is questionable. Moreover, the very abstraction away from situatedness, specificity and complexity seems to lose the compelling qualities that designs can offer. To what extent then can research outcomes and more abstract forms of knowledge guide design choices?

In [22], it is argued that design choices are most of the time underdetermined by theoretical reflections in that a given idea or theoretical concept can lead to many different kinds of design artefacts (and vice versa: theory is equally underdetermined by practice). Therefore, to bridge abstract knowledge to concrete and situated outcomes, a number of intermediate knowledge forms, explaining more than a set of designs but not aiming at producing general theories, have been suggested as ways to develop theoretical and abstract perspectives without completely effacing their origins in, and the qualities of, design practice.

In [35], Löwgren discusses intermediate knowledge forms, starting from a deeply familiar one – design tools and methods, which can be considered as representations of meta-knowledge that address how to design rather than what to design. Design guidelines served as the operationalization of general theories, making the theories more useful for design practice. Design patterns are another form of intermediate knowledge concerned with key ideas regarding a family of designs. In a similar vein, Löwgren [34] suggested experiential qualities as an intermediate knowledge form, similar to patterns, but pertaining to the experiences of artefacts as a whole rather than their elements in themselves.

Furthermore, as Stolterman and Wiberg [46] point out, some concepts are intermediate-level knowledge in design research and are much discussed in relation to theoretical reflections. This makes a virtue of the fact that a single concept can generate many different ideas resulting in distinct designs. Recently, strong concepts [27] have been suggested to distinguish generative design ideas with potential for inspiring subsequent design, possibly within multiple domains.

Gaver and Bowers's annotated portfolios [22] is another approach to articulating new knowledge gained from design research, close to designers' existing practices. The notion of annotated portfolios was originally represented by selecting a collection of artefacts, finding appropriate representations of artefacts and combining these representations with (typically) brief textual annotations that point out their salient qualities or the issues they address. Gaver and Bowers propose this approach as a methodology for communicating design research. As Löwgren argues [35], annotations can be interpreted as growing in abstraction as they are used to describe multiple artefacts in a portfolio – for instance, 'influencing autonomous drift' from one of the original annotated portfolios could easily be rewritten as a strong concept, pattern, or perhaps experiential quality.

What we explore in this paper are different sorts of knowledge that annotation strategies for our portfolio produced. For instance, while most intermediate knowledge forms focus on aspects of interaction itself and new domain knowledge, we argue that the two additional strategies have led to other kinds of knowledge that might not involve a

significant degree of abstraction at all, but instead elucidate other ways that designs can relate to one another.

We next present the designs for ME that comprise the portfolio. Subsequently, we explore several strategies for annotating the portfolio before considering the relations between the artefacts and implications for the portfolio and communication of new knowledge from design practice.

THE PORTFOLIO

ME is an illness of growing concern both scientifically and socially [18] with, at present, no available diagnostic tools or a curative treatment [50]. The initial domain sense-making included review of medical and other related literature, such as [11,13,19,28,39]. We found the illness described in terms of the following four categories: very severe (completely bedridden), severe (mostly bedridden), moderate (mostly house-bound) and mild (reduced in function by at least 50% over at least six months) [13:3]. The symptoms vary from day to day and can include hypersensitivity to external sensory input (touch, visual and auditory), impaired concentration and short-term memory, sleep disturbance, muscular pain, stomachaches, nausea, fatigue, headaches, and immune dysfunction. The symptoms are often triggered by either physical or mental exertion, and the upswing in symptoms after over-exertion ranges from moderate to disabling for a period of time, varying from hours to days, sometimes even weeks. As the cause of ME is disputed within the scientific community, and the illness rather invisible to others, those affected are often stigmatized [49], also by medical professionals [48].

The most commonly applied 'solution' is self-management of the illness, where the most effective way of handling the illness in day-to-day living builds on the concept of *energy balancing* [30] or *pacing* [23,39] – that is, keeping track of and limiting energy expenditure. This is difficult to accomplish with accuracy, as one does not know how much energy ordinary activities could take on any given day.

To understand more precisely what living with ME entails and assess if, and how, the technology might support every day living, we organized several workshops, described in [7,16], with medical professionals and organizations that help people with ME, and their kin, to cope with the illness.

After this initial sense-making, we engaged in research and design of digital artefacts that aimed to support everyday living with ME. We describe four such artefacts: a small, networked robot-like avatar called AV1 intended to reduce isolation of chronically ill children and youth (our research focus was on adolescents with ME), a bracelet RelaxMe that gives a subtle warning when the heart rate increases, indicating a need for repose, a pillow for guided meditation SlowBreath, and a networked lamp ShareME that indicates the bodily condition of the person with ME, for themselves and for others. The first three artefacts were used as research products [38], implying the level of finish to the extent that we could give them to study participants with ME for an extended period of time, allowing us to gain insight into real experiences with artefacts and understand the ways in which they fit in participants' everyday lives. Nine adolescents with ME used AV1, and their use of the robot was observed for approximately a year. RelaxMe and SlowBreath engaged, respectively, four and six participants for one to two weeks. In contrast, ShareME was not fully implemented and Wizard of Oz technique was used to enable six participants with ME to envision its use and reflect on how ShareME might fit into their lives.

AV1

The work with AV1 was done in collaboration with the social entrepreneurship startup No Isolation [55]. We were fortunate to be able to join this innovation project in its initial stages. AV1 was intended to help reduce isolation among long-term ill children and youth, who spend a lot of time alone due to their illness. We collaborated with No Isolation from the initial conceptualization of AV1, through design and development into a research product, and until the launch of AV1 as a commercial product, see [8,14].

AV1 (Figure 1) is a rather simple networked object, transmitting one-way video and audio over the 4G mobile network. The adolescents with ME controlled the avatar remotely, using an app on a touch device (a phone or a tablet). AV1 could perform a full body rotation and a head-lift, controlled by horizontal or vertical swipes. In addition, the light on top of AV1's head could be turned on/off, signaling active/passive participation. AV1 could not store any data, reducing some of the concerns regarding privacy.

Figure 1. A study participant learning to use AV1.

The use observations included homes and schools of the study participants [6,14], as those were the most important social arenas. While our research focused on how AV1 does – or does not – mediate relatedness and lessens the sense of isolation, other domain related insights were gained.

RelaxMe bracelet

RelaxMe (Figure 2) was designed in the context of our research, resulting in a master thesis [16]. The thesis work was supervised by the second author and started already at the time of the above-mentioned sense-making workshops.

Figure 2. RelaxMe bracelet vibrates when the heart rate gets high and alerts the risk for overexertion. Photo from [16:90].

The design was inspired by phenomenology [1,37,47]. The design process was loosely guided by concepts of *shrinkage* (the sense that the world around a person shrinks with the onset of illness and reduced capabilities), the *phenomenon of being ill*, and *body schema* (the kinesthetic awareness of the body in relation to the environment). The *incorporated object* (an object that becomes integrated with one's body) was also conceptually important. Shrinkage, through its relation to the lack of energy and the need for energy balancing, became especially interesting as a design concept for people with ME.

Many variables related to shrinkage and energy balancing, such as the length of sleep, the intensity of activities, diet, and lactic acid production, were considered as possible basis for design. A single variable – pulse – became the key variable to explore, as it provided a direct link to a need for energy balancing. The theoretical concerns then took the secondary position, and design practice central, following a common approach of looking into existing designs for inspiration. Finally, a watch-like design was chosen, in part guided by conceptual reversal of a fitness watch – not to encourage activity, but rest. Also, like the fitness watches for active people, if worn regularly, RelaxMe could become an incorporated object, always ready to remind when the rest may be needed. It had a simple 3-D printed housing for a heart-rate sensor, vibrator and a micro-controller. The only interaction with the devices happened when the pulse passed the anaerobic threshold – three repetitions of a slight vibration could be felt.

SlowBreath pillow

The design of the SlowBreath pillow (Figure 3) was guided by the sensory exploration of its computational and material components, where pleasure and relaxation were sought after experiential qualities. Explorations focused on sensory experiences of fabrics, the intensity of heat, the weight of the pillow, the quality of vibrations, and the length of the breath to invoke meditative states. A first-person research approach, see [25], was used by the second author, working with our own bodily sensations and responses to stimuli to make design decisions as to what could be soothing and relaxing for highly sensitive bodies of those with ME. The SlowBreath research product used in the study was the next iteration of the small, round cushion shown in Figure 3.

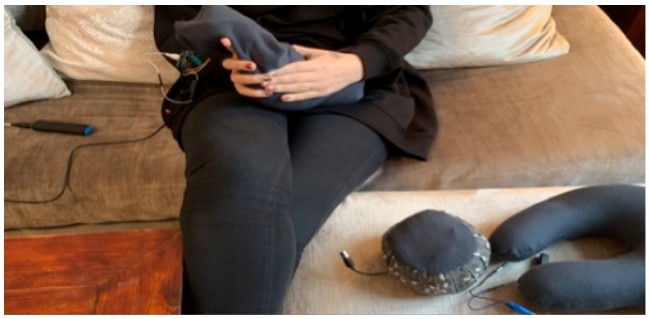

Figure 3. A user assessing her experiences with computational and material properties of pillows during the design process.

The interaction was based on the repetitive, rhythmic and pleasant (low intensity) vibration combined with warmth, which encouraged users to take long, deep breaths helping to relax. Vibrations as a design material for people with sensory challenges were difficult to work with. Many were simply not particularly soothing. Thus, finding vibrations that could facilitate experiences of meditative relaxation for most participants was crucial. The design also needed to fit easily and well in users' homes, including easy accessibility and an appropriate aesthetic expression.

ShareME lamp

ShareME was a networked lamp (Figure 4), connected to a fitness watch and an app on the smartphone. Its primary intent is to communicate the feedback from the fitness watch to the lamp, representing the 'quantified' state of the body through different colors of light. Importantly, others in the household could also see the color of the lamp. They could then, as appropriate, reduce noise, adjust brightness in the room, or strike a conversation.

Figure 4. The ShareME networked lamp used a 3-D printed 'Moon' lamp, available off the shelf, e.g., from Amazon.

The participants could choose for themselves the colors that 'interpret' the quantified data visually. Once the interpretations were learned, the need for explaining how they feel would be reduced – an important feature of ShareME, as talking about how they feel is frequently experienced as challenging. As the health data (pulse, sleep, or exercise) is stored on the participant's smartphone, it was possible to make designs that aggregate data in creative ways, such as creating color maps of their condition over

time using the same color schema as displayed by the lamp. This solution was inspired by our older project, Kulu, that implemented color mapping for tracking moods [51,54,56].

ANNOTATION STRATEGIES

To elucidate new knowledge gained from design practice and research with these four articles over almost four years, we chose and assembled their representations into a portfolio. We started with annotations that were inspired by mapping techniques, and had no particular perspective or strategy. Rather, they were intended as an unordered and unfiltered record, a map of sorts, based on insights gained through design, the observation of use, interviews, and even literature, showing the most important concerns regarding designs, technology, or the application area. Figure 5 shows an example of this kind of annotation for RelaxMe. The intent was to use these maps of concerns as reminders, and for new inspiration, conjoint with other annotations.

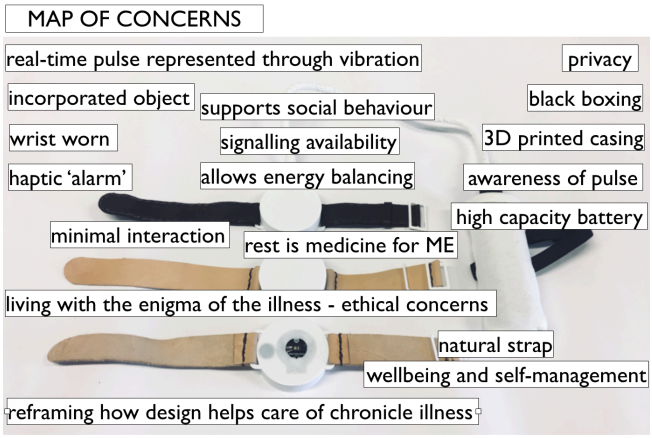

Figure 5. A range of concerns regarding RelaxME.

For example, a selection of the material for straps was important in design of RelaxMe – natural materials and non-toxic colors were desired. Even though attention was paid to materials, some participants were still too sensitive, calling for further material explorations. Another example – all artefacts had a label related to the ethical concerns. The most obvious ones were related to privacy, but there is a range of other concerns, such as stigmatization, that could potentially inspire future designs and research.

These annotations were not strategic, but like our domain inquiry before design, also pointed to minimal interactivity and energy balancing as crucial concerns for the domain. In the next step, therefore, we applied strategies aiming for some level of abstraction concerning interaction qualities and domain knowledge (see Figures 6 – 7 and 9 –10).

Elucidating interaction qualities and domain knowledge

AV1

AV1 (Figure 6) was intended as a commercial solution to mitigate the social issue of isolation among children and youth. It was made to support collaborative, but minimal interactions. Logging on automatically enabled the audio exchange and video streaming from the remote location. A user could only control the movements of AV1 and signal their active/passive participation at the remote location. However, for AV1 users with ME, prolonged and frequent use of AV1 could lead to overexertion. Therefore, it was essential for the participants to find appropriate strategies of energy balancing for safe use.

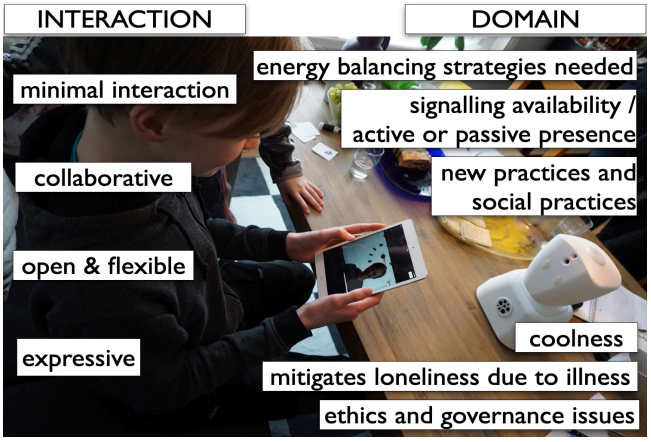

Figure 6. Annotations concerning interaction qualities and domain issues with AV1.

Furthermore, AV1 indeed provided for greater experience of relatedness, and mitigated the sense of loneliness [14]. It was also experienced as *cool*, confirming the role of coolness in design for teens [41]. However, in this domain, coolness might have new design implications. Development of new practices around taking the avatar places that the adolescent with ME wanted or needed to go was important for the sustainment of use, e.g., delivering AV1 to school or home of a good friend on a regular basis. Also, good *social practices* had to be created, e.g., using AV1 at school, but outside of the classroom. The importance of *ethical issues*, such as privacy and inclusion, came to the forefront through use, sometimes in unexpected ways. Also regulatory work allowing *governance* of novel technology like AV1 was not in place, neither in schools nor governmental bodies, as AV1 that was the first 'robot' to attend the school classes as an avatar for sick children in Norway.

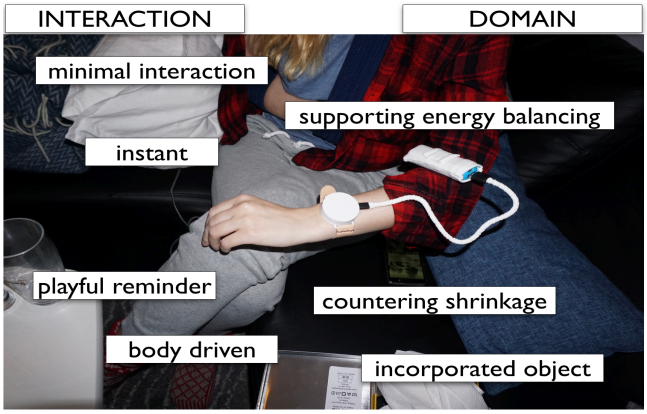

Figure 7. Annotations concerning interaction qualities and domain issues with RelaxMe.

RelaxMe

The artefact (Figure 7) had a simple and *instant* message to convey – your heart rate is over a given threshold. Awareness that the stress level is increasing was intended to scaffold *energy balancing* and self-management efforts. In the light of the fact that much about ME is still unknown, and that, at the very best, the participants in the study had reduced capacity by at least 50%, they have all experienced a substantial *shrinkage*, and had a need to find more about their bodies and symptoms triggers. For example, Figure 8 shows notes that one of the participants in the study kept, trying to find patterns in activities and bodily responses to them, as health professionals could not give them adequate feedback. RelaxMe was intended to support these practices in realtime. The interaction with RelaxMe was minimal and body driven, i.e., bodily data determined when the interaction happened. The repetitiveness of vibration was intended to be *playful* and *open*, in the sense that it did not lead to any pre-determined action. When worn all the time, RelaxMe became an *incorporated object* – it became a part of the body that could accesses the information about another part – the heart – and tell when the heart rate is too high.

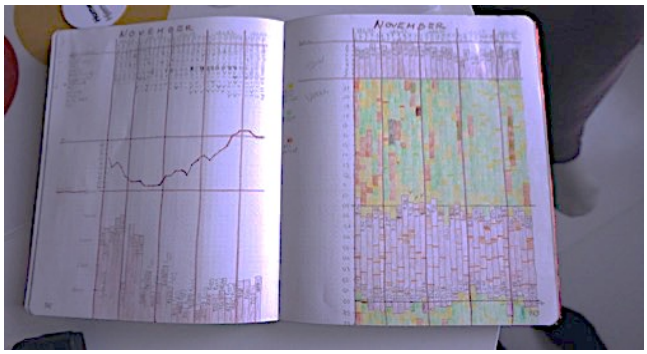

Figure 8. Notes taken by one of the RelaxMe study participants to make sense of their symptom patterns.

SlowBreath

The SlowBreath pillow (9) helped people reach a state of relaxation through *guided breathing* (by very gentle and pleasant vibration) and warmth. The interaction with the pillow was otherwise *minimal* (of and on), with possibility for users to adjust *heating and vibration intensity* of the heat and the intensity and quality of vibrations.

Placed at the sofa at home, SlowBreath was *always ready* for moments when some warmth and relaxation were needed. Participants have found that the size, shape, and relatively neutral, soft fabrics allowed the pillow to *blend in with their home interiors*, despite different personal preferences in styles.

The participants have used the pillow with great *flexibility* and variation. They had different ways to use the pillow on their bodies – for example, held against the chest laying down, or between the palms of the hands while sitting up. These placements gave different bodily sensations.

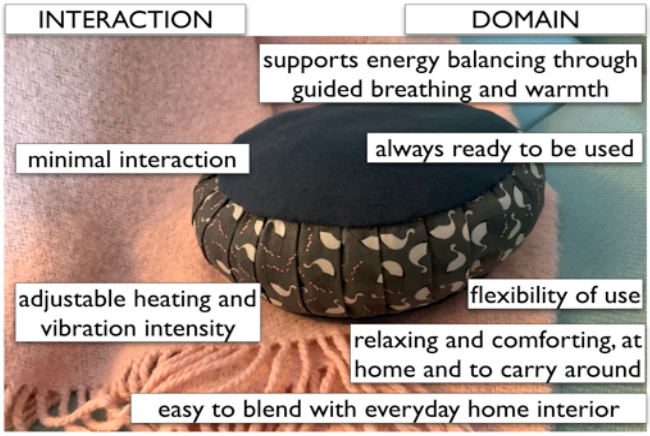

Figure 9. Annotations concerning interaction qualities and domain issues with SlowBreath.

Surprisingly, SlowBreath was found by some participants to provide relaxation in more dynamic situations than lying down on a sofa, e.g., touching the pillow with the palm of one hand when getting tired outside of the home was found to be both relaxing and comforting. However, the size of the pillow was not ideal for this kind of use.

ShareME

The light color of the ShareME (Figure 10) gives a *real time visual clue* concerning the physical condition of a participant, *driven by body data* measured by the fitness watch. Since the lamp's colors drift autonomously, the interaction is *minimal*, yet *expressive* The expressivity is brought about by the autonomous change of colors, making the lamp seem alive and alert. The visual feedback is *instantly shared with the family*.

The body states data is communicated to the smart device and aggregated into a color. Since the phone stores long-term data, a color map representing the condition over time can be *shared* with other people with ME, or with health workers, opening for collaboration and socialization, if desired.

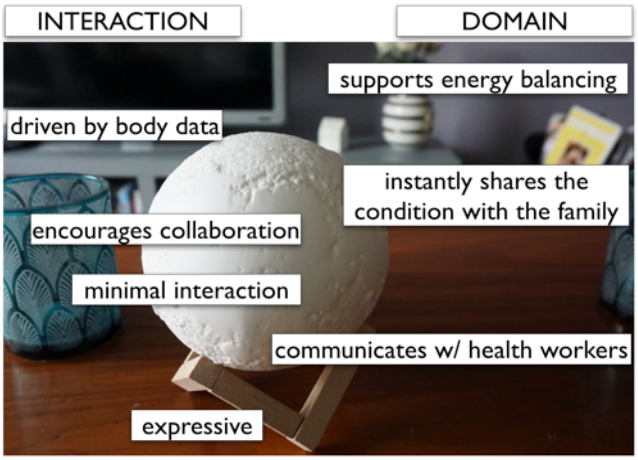

Figure 10. Annotations concerning interaction qualities and domain issues ShareME.

The most appreciated feature was that parents, or partners, who live in the same household could perceive without asking the ME patient's health situation in an ongoing manner. The participants commented that this would make it easier for people to be social with them if they saw that they are okay, rather than being constantly worried that they are taking too much of their energy. Also, the idea that the color maps could make compelling arguments about their condition over time was seen as really appealing.

Trajectory strategy – the chronology of designs

While Figures 6,7,9 and 10 show that minimal interactions and energy balancing are common traits for all designs, we felt that there is more to infer from looking at these designs jointly and from a different perspective. For instance, we found that the way they chronologically followed one after another was interesting.

Figure 11. Starting from the AV1, with each subsequent design, the design space was progressively revealed

Figure 11 captures this notion of designs *trajectory* in time, with annotations helping to unveil the design space by pointing to, for each design, the motivation for working with the next one. The annotations in red text – social access, awareness, support, and sharing, indicate areas of design space revealed so far by the artefacts made.

Even though we learned, prior to engaging in research through design and design practice, that energy balancing was an important concern for the domain, it was not until we did the study with AV1 as a research product at homes of adolescents with ME that we gained insight into what energy balancing really means for their everyday lives. Since AV1 was not designed for people with ME only, design did not explicitly support energy balancing and the study participants all needed to develop their own strategies to lower the risk of overexertion. Many chose to use the light to signal that they were switching to passive use when feeling tired. Some chose to not use AV1 for a while, and others to make rules and schedules on use. In contrast, the departure point for making RelaxMe was for the device to be designed specifically for people with ME and to support energy balancing explicitly. However, while RelaxMe provided awareness that the heart rate is increasing, it did not provide the way of resolving the problem. SlowBreath aimed to do that work through breathing relaxation. In turn, visualization of the results of SlowBreath's use, as well as the effect of other daily activities and sharing this data with others became the motivation leading to next design, the ShareME prototype.

What is interesting about this way of annotating the portfolio is that it integrates both time and 'space', simultaneously capturing the progression of designs and concerns that motivate them. This way of annotating opens a progressively larger space of issues and possibilities – a space that might lead to new designs, either within the space already established, or at its boundaries.

For instance, other devices might use physical monitoring, similar to RelaxMe, to automatically initiate comforting stimuli similar to SlowBreath – say, a scarf that warms when galvanic skin response becomes high. Alternatively, they might extend the space to consider, e.g. two-way communication of physical/emotional states between people with ME and their peers elsewhere. Used in this way, the annotation strategy not only captures a trajectory of creating a design space, but also suggests ways it might be extended or further populated.

Ecosystem strategy – relatedness of designs

Considering the nature of the design domain, it is highly relevant to consider devices used in this domain as an ecosystem [31] and ways in which they might jointly support better life quality for people with ME. Species in every ecosystem are interdependent, here too, different devices relate to one another in multiple ways, e.g., by complementing or continuing each other's role, presenting alternatives, etc.

Figure 12 illustrates ecosystem strategy of annotating portfolios. It visually highlights possible complementing relations among designs: if AV1 over-stimulates senses, and heart rate goes up, RelaxMe provides the awareness clue. The overstimulation then can be resolved using SlowBreath, while ShareME can communicate information on the state of overstimulation and create a context to determine the further course of action, including the possibility to reengage in social behavior through AV1.

In a sense, it is not surprising that the designs complement one another in this way, given that they were designed sequentially with each addressing issues highlighted by the preceding ones as described previously. This annotation strategy does not rely on these design dependencies,

however, but takes an atemporal approach to highlighting relationships that might be surprising or accidental – for instance, SlowBreath can be seen as helping to prepare people with ME for the social access offered by AV1, though it wasn't designed with this in mind.

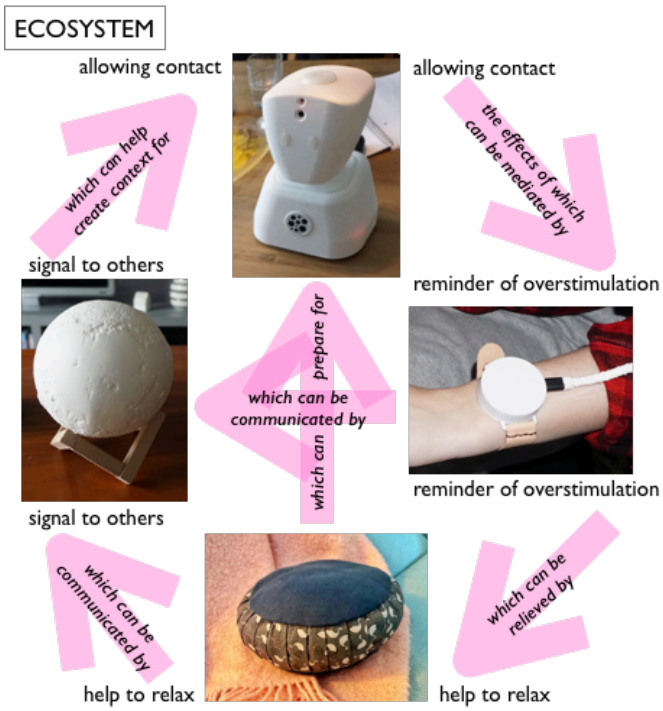

Figure 12. Links between designs, this time bringing forth ways in which they could work together for a user.

The strategy links artefacts in a portfolio together, not by their common qualities or concerns, but by the ways they work together in principle, and thus might also be useful in discussing artefacts that were not designed or produced together and which could appear quite distinct otherwise.

DISCUSSION

As we have demonstrated, annotated portfolios can be developed with several distinct annotation strategies. Each of these may produce different sorts of knowledge from design practice:

1) Annotations of *interaction* can capture stylistic similarities across designs (e.g. 'minimal interaction', 'easy fit'), similar to strong concepts, or experiential qualities.
2) Annotations pertinent to the *domain* can show how design practice highlight knowledge about a domain, in this case, design for people with ME, through the ways those artefacts explicitly or implicitly address the constraints presented by the illness, e.g., balancing energy expenditure.
3) *Trajectory* annotation strategy emphasizes the way new designs progressively reveal the domain space. They trace a chronological path of development and how each next design was informed by the previous one(s).
4) *Ecosystem* annotation strategy indicates how the artefacts complement one another to, jointly, support a range of the needs of people with ME. This annotation could be productive in suggesting new designs for the space or, alternatively, suggest opportunities for designs that do a better job of addressing issues than the ones already in the portfolio.

While the first two strategies have been widely used after the publication of [10,22,35] and other work discussing annotated portfolios, the choice of trajectory and ecosystem annotation strategies is novel. The four annotation strategies presented in this paper, in line with portfolios previously discussed in the literature, emphasize the conceptual and designerly concerns and intents behind designs both individually and collectively. Viewed individually, each design in the portfolio, together with annotations and narrative text next to it created a particular read of the work, as Figures 6 – 7, 9 – 10 show. Next, we consider gains from viewing designs collectively.

Gains from viewing designs collectively

Annotating the assemblage of designs from the perspective of re-thinking the main concerns within design space for ME (based on the first two annotation strategies) is shown in Figure 13. The indexical annotations point to important discussion themes when designing for people with ME.

Some of these themes are the same as in designs for other domains, but the concepts bear a particular set of implications with respect to domain for ME. For example, flexibility could be viewed as related to enabling options in response to the bodily condition, such as deciding to take active or passive part in a class lecture with AV1 or how to use SlowBreath for relaxation.

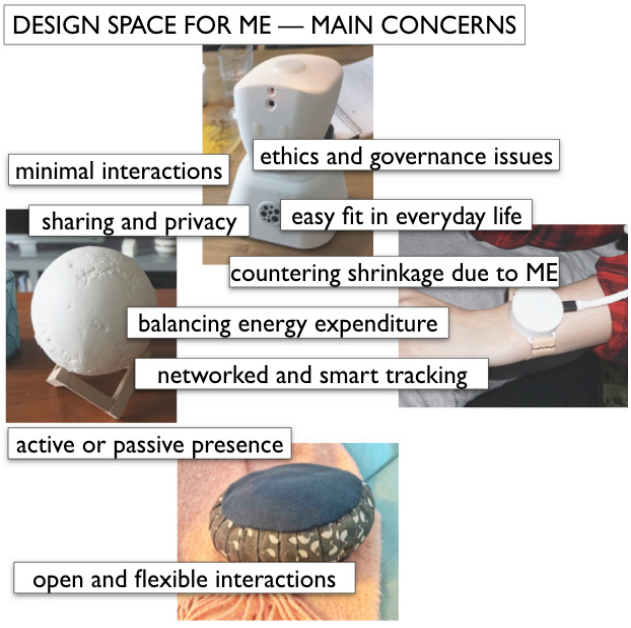

Figure 13. Juxtaposing the artefacts and annotations based on the most important domain and interaction issues

In addition to necessity for minimal interactions and energy balancing, the concept of shrinkage is an interesting one to explore in this context. All four designs are concerned with mitigating shrinkage, although each on its own premises. Shrinkage is a concept that can be further explored in the context of a design space for ME.

Openness and flexibility of interactions are also very important in this domain, because the body condition changes easily and for this user group, it is very important to make interactive devices, especially when they involve other people like AV1 does, to allow for flexibility in use without shame or stigma.

Sharing with others, either in the social context or in the context of expanding knowledge on ME, is also a very important part of the design domain. For example, ShareMe acts on site by giving visual cues regarding the condition of the person using it. It can also share, on occasion, by sending a color map analysis to health workers. Future re-design opportunities are also plentiful. Even if ShareMe could just record the personal data appropriately, our participants told us, it would be a relief for them. They are encouraged to make records of actions and their bodies' responses by the medical establishment, but when symptoms increase, recording is usually one of the first things that they give up on. Even when they persist, like the person whose notes are shown in Figure 8, there is little to do with those records – doctors do not have the capacity to look through them. Thus, if the future design looked into, e.g., AI to aggregate, analyze, and share short reports on illness patterns with health workers, it could add credibility and objectivity, perhaps even advancing knowledge on ME.

Furthermore, sharing social moments with others, for example, through AV1, has been shown to have great benefits, but brings about concerns with governance, ethical and privacy issues. SlowBreath, although personal, also has a potential sharing dimension – other household members liked to share this one. Some of the medical professionals at one of the largest hospitals, who attended a seminar on ME and had a chance to see and experience SlowBreath, said that they would love to have it in their own room for breaks, and use at times of heightened stress.

The last two annotation strategies are of particular interest for this paper. What kind of knowledge can they lead to?

Gains with using the trajectory strategy

After the study with AV1, many directions for further research and design were open. For example, there were opportunities for supporting sharing of AV1 by several children who cannot attend school. However, for the application area that we were interested in, tackling energy balancing, an essential part of self-management for those with ME, was more germane. Energy balancing was very domain specific and novel. No other design that we had done before was considering such a challenge. In addition, working with and for people with ME as primary users was central. Thus the next design was to be more personal, on the body and countering shrinkage. Of course, as stated when describing the initial stages of design of RelaxMe, many other variables and designs were considered, as well as more basic questions such as how to frame the way design looks into a chronic illness (such as ME), Figure 5. The point here is that the move from AV1 to RelaxMe represents a step from design for social relatedness to the design for a body, an intimate, personal and private space.

Staying in that space, but this time seeking a good way to calm and relax both the body and the mind, provided an opportunity to look for inspiration through the lens of somaesthetic, and design for the body [25], and get inspired.

SlowBreath was one example of a design that focused on relaxation. Many others would have been possible, but SlowBreath was appreciated for its simplicity and non-pretentiousness, ability to fit into the living spaces without taking much of them, being always available and effortless to use, and importantly, not giving any indication that it is an assistive technology.

After the period of use, both participants working with RelaxMe and SlowBreath reflected on the need to make their surroundings aware of their condition. Making close ones aware of the condition would eliminate some of the daily difficult conversations. Sharing long-term data with a health professional could, potentially, help to make sense of their efforts to record diverse symptom/activity patterns, such as those shown in the notes in Figure 8. Besides, many participants had a desire to fight the notion of ME being a psychosomatic illness and stigmatization that comes with it.

This could, again, lead to a number of new designs, and ShareME suggested addressing two areas at once – the close family and the medical professionals.

This chronological tour through the portfolio does not generalize much at all, but the new knowledge it generates has to do with opening of domain specific rooms for design explorations for people with ME: 1) technology for *social access*, 2) *awareness* of the body metrics 3) designs that directly provide *support* with ME, and 4) *communicating* about illness. As already discussed in the section describing the strategy, it opens an increasingly larger space of issues and possibilities towards new designs, either within the space already established, or by extending its boundaries.

Gains from the ecosystem strategy

The last, ecosystem strategy, addresses extent to which designs work together to support everyday lives of people with ME. While we did not deploy all four designs together to explore how well they work in concert in real life, we could annotate our portfolio to reflect on possible relations between the designs and discuss their role in the ecosystem.

As Figure 12 indicates, the four designs can be viewed as complementary, implying that a person with ME could use all four designs. For example, an adolescent could use AV1

to attend a school lecture. If the lecture is long and difficult, stress might start to build up. RelaxMe alerts about this and the adolescent turns off AV1, picks up SlowBreath and starts to relax, taking long breaths and feeling the warmth of the pillow. As the stress levels were increasing, ShareME started to glow orange. The family notices. Dad reduces the volume on TV, and mom draws the curtains. Soon, ShareME changes the hue to a warm white light – it is getting better.

Figure 12 offers a visualization and reasoning regarding the complementarity of artefacts in the ecosystem. Similar visualizations and reflections are possible for other kinds of relations among artefacts. For example, RelaxMe and ShareME both provide awareness clues regarding the state of the body. Prioritizing specific values over the others, such as privacy or connectedness might be a deciding factor in making a choice to use only one of them (RelaxMe is entirely private, while ShareME is not). Moreover, while AV1 and ShareME are both connected objects, AV1 is designed to protect the privacy of its users, while the purpose of ShareME is the opposite - it shares personal data for the benefit of its users, their immediate families, distant friends and, potentially, the benefit of the society at large. The latter is based on the opportunity (through a future alternative design and development of 'smart' ShareME-like artefacts) for social innovation that could generate new insights into the illness, as we tried to outline when describing ShareME.

Although we did not have the opportunity to explore all four designs simultaneously with people with ME to see how well they would work together in a real-life context to support their everyday lives, it is clear that ecosystems thinking is beneficial in rethinking the design of multiple devices and their use [31]. However, our purpose here is to suggest that trajectory and ecosystems annotations of a portfolio are reflective tools for designers that might lead to insights that help guide and plan future designs in a more responsible way [3]. We believe that they communicate in a succinct manner [22], highlighting the important relations, motivations, and intents with designs.

Precisely because the trajectory and ecosystem annotations are not intended to elucidate abstract knowledge but remain focused on the practice and the domain, the insights are simple and easy to communicate not only to others within our community but also those outside of it – something that might offer new opportunities to increase the impact of HCI outside of the academia. For example, we believe that communicating this kind of knowledge might be useful to those with ME (when the design domain becomes more densely populated, and they have to make choices about devices), as well as those in medical professions, associations working with ME or other governance bodies that make recommendations and decisions on how innovative designs reach the society (as was the case with AV1 [8]).

In [35:1], Löwgren suggests that *"The essence of research is to produce knowledge, and the essence of design is to produce artifacts"*, stating further that whatever the purpose of the research is in terms of its benefits, such as curing an illness or changing the society, its primary aim is to produce knowledge. Design practice, on the other hand, is directly changing the world by populating it with its constructs. Since matters of social innovation are of growing importance within HCI, research through design should not merely continue to populate the world with designs, especially when designs aim to resolve social concerns, without systemic reflections on the context. In such situations, it is essential to combine mindful design with research on the use, the fit of designs in people's lives, and their impact on the situated context.

We believe that this justifies seeking to extend annotated portfolios to include strategies focusing on trajectories and ecosystems. Such strategies are productive in allowing further differentiation and development within a design space. In our case, the design space is linked to concerns of a vulnerable social group – people with ME. From this point of view, annotating our design space is a way of giving supportive care to its future development. For the HCI community, extending annotated portfolios to include trajectories and ecosystems offers a possibility for reflection over how this kind of knowledge contributes to the discussion on knowledge production in HCI.

CONCLUSION

In this paper, we have introduced two novel strategies for annotating portfolios of designs for a novel design domain. Annotated portfolios, as an intermediate knowledge form, have sought to communicate how research through design can elucidate new knowledge and help designers to gain some level of abstraction when reasoning about their practices. In contrast, the new strategies focus on temporal and relational aspects among designs. The trajectory strategy highlights the historical/motivational development of artefacts in time, to progressively explore the new domain. The ecosystem strategy highlights how designs can work together or how they could offer alternatives to one another. Both strategies are useful for suggesting new design possibilities but also for reasoning about designs at a level of their possible impact, use, etc., supporting a deeper understanding of a particular domain, but without much generalization. Taken together, the designs and all four types of annotations map out a design space, or ecology of designs, interlinking deeper and specific domain insights with somewhat higher levels of abstractions allowed by the first two, more commonly applied strategies. Although the annotation strategies differ in both intent and kind of knowledge that they produce, we suggest that they work well together to articulate the range of new knowledge produced by design practice.

REFERENCES

[1] James Aho and Kevin Aho. 2008. *Body matters: A phenomenology of sickness, disease, and illness*. Lexington Books.

[2] Jeffrey Bardzell, Shaowen Bardzell, Peter Dalsgaard, Shad Gross, and Kim Halskov. 2016. Documenting the research through design process. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, 96–107. https://doi.org/10.1145/2901790.2901859

[3] Oliver Bates, Kathy New, Samantha Mitchell-Finnigan, Matthew Louis Mauriello, Christian Remy, Roy Bendor, Samuel Mann, Simran Chopra, Adrian K. Clear, and Chris Preist. 2019. Towards a Innovation Agenda for HCI. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (CHI EA '19), W24:1–W24:8. https://doi.org/10.1145/3290607.3299017

[4] Jordan Beck and Hamid R. Ekbia. 2018. The theory-practice gap as generative metaphor. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18), 620:1–11. https://doi.org/10.1145/3173574.3174194.

[5] Kirsty Best and Stephanie Butler. 2013. Second life avatars as extensions of social and physical bodies in people with Myalgic Encephalomyelitis/Chronic Fatigue Syndrome. *Continuum* 27, 6: 837–849.

[6] Jorun Børsting and Alma L. Culén. 2017. Experiences with a Research Product: A Robot Avatar for Chronically Ill Adolescents. *Smart Technology Applications in Business Environments*, 159–183. https://doi.org/10.4018/978-1-5225-2492-2.ch008

[7] Jorun Børsting and Alma L. Culén. 2018. Youth with ME/CFS: Untangling Complexities in Technology Design to Support Everyday Living. *International Journal On Advances in Intelligent Systems* 11, 1 & 2: 1–12.

[8] Jorun Børsting, Alma L. Culén, and William Odom. 2019. AV1, Media and Socio-technological Imaginaries: Implications for HCI Research. In *Proceedings of ICT, Society and Human Beings*, 28–36. https://doi.org/10.33965/ict2019_201908L004

[9] Andrew Boucher and William Gaver. 2006. Developing the Drift Table. *interactions* 13, 1: 24–27. https://doi.org/10.1145/1109069.1109087

[10] John Bowers. 2012. The Logic of Annotated Portfolios: Communicating the Value of "Research Through Design." In *Proceedings of the Designing Interactive Systems Conference* (DIS '12), 68–77. https://doi.org/10.1145/2317956.2317968

[11] Gunn J. Bringsli, Anette Gilje, and Bjørn K. Getz Wold. 2014. The Norwegian ME Association National Survey Abridged English Version. Retrieved April 22, 2020 from http://me-foreningen.com/meforeningen/innhold/div/2014/05/ME-Nat-Norwegian-Survey-Abr-Eng-Ver.pdf

[12] Tim Brown and Jocelyn Wyatt. 2010. Design Thinking for Social Innovation (SSIR). *Stanford Social Innovation Review*. Retrieved April 22, 2020 from http://www.ssireview.org/articles/entry/design_thinking_for_social_innovation/

[13] Bruce M. Carruthers, Marjorie. I. van de Sande, Kenny et al. 2011. Myalgic encephalomyelitis: International Consensus Criteria. *Journal of Internal Medicine* 270, 4: 327–338. https://doi.org/10.1111/j.1365-2796.2011.02428.x

[14] Alma L. Culén, Jorun Børsting, and William Odom. 2019. Mediating Relatedness for Adolescents with ME: Reducing Isolation Through Minimal Interactions with a Robot Avatar. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (DIS '19), 359–371. https://doi.org/10.1145/3322276.3322319

[15] Peter Dalsgaard and Christian Dindler. 2014. Between Theory and Practice: Bridging Concepts in HCI Research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '14), 1635–1644. https://doi.org/10.1145/2556288.2557342

[16] Oda Sofie Dahl Eide. 2018. Research Through Design for Myalgic Encephalomyelitis. Master Thesis. University of Oslo. Retrieved April 22, 2020 from https://www.duo.uio.no/handle/10852/62816

[17] Daniel Fallman. 2007. Why research-oriented design isn't design-oriented research: On the tensions between design and research in an implicit design discipline. *Knowledge, Technology & Policy* 20, 3: 193–200. https://doi.org/10.1007/s12130-007-9022-8

[18] Anne Farmer, Tom Fowler, Jane Scourfield, and Anita Thapar. 2004. Prevalence of chronic disabling fatigue in children and adolescents. *The British Journal of Psychiatry* 184, 6: 477–481.

[19] Scott J. Fatt, Erin Cvejic, Andrew R. Lloyd, Ute Vollmer-Conna, and Jessica Elise Beilharz. 2019. The Invisible Burden of Chronic Fatigue in the Community: a Narrative Review. *Current Rheumatology Reports* 21, 2: 5.

[20] William Gaver. 2012. What Should We Expect from Research Through Design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 937–946. https://doi.org/10.1145/2207676.2208538

[21] William Gaver. 2014. Science and Design: The Implications of Different Forms of Accountability. In *Ways of Knowing in HCI*, Judith S. Olson and Wendy A. Kellogg (eds.). Springer New York, New York, NY, 143–165. https://doi.org/10.1007/978-1-4939-0378-8_7

[22] William Gaver and John Bowers. 2012. Annotated portfolios. *interactions* 19, 4: 40–49. https://doi.org/10.1145/2212877.2212889

[23] Ellen M. Goudsmit, Jo Nijs, Leonard A. Jason, and Karen E. Wallman. 2012. Pacing as a strategy to improve energy management in myalgic encephalomyelitis/chronic fatigue syndrome: a consensus document. *Disability and rehabilitation* 34, 13: 1140–1147.

[24] Sabrina Hauser, Ron Wakkary, William Odom, Peter-Paul Verbeek, Audrey Desjardins, Henry Lin, Matthew Dalton, Markus Schilling, and Gijs De Boer. 2018. Deployments of the table-non-table: A Reflection on the Relation Between Theory and Things in the Practice of Design Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 201:1–13. https://doi.org/10.1145/3173574.3173775

[25] Kristina Höök. 2018. *Designing with the Body: Somaesthetic Interaction Design*. The MIT Press.

[26] Kristina Höök, Jeffrey Bardzell, Simon Bowen, Peter Dalsgaard, Stuart Reeves, and Annika Waern. 2015. Framing IxD knowledge. *interactions* 22, 6: 32–36. https://doi.org/10.1145/2824892

[27] Kristina Höök and Jonas Löwgren. 2012. Strong Concepts: Intermediate-level Knowledge in Interaction Design Research. *ACM Trans. Comput.-Hum. Interact.* 19, 3: 23:1–23:18. https://doi.org/10.1145/2362364.2362371

[28] Leonard A. Jason, Abigail Brown, Erin Clyne, Lindsey Bartgis, Meredyth Evans, and Molly Brown. 2012. Contrasting case definitions for chronic fatigue syndrome, Myalgic Encephalomyelitis/chronic fatigue syndrome and myalgic encephalomyelitis. *Evaluation & the Health Professions* 35, 3: 280–304. https://doi.org/10.1177/0163278711424281

[29] Laewoo Leo Kang and Steven Jackson. 2018. Collaborative art practice as HCI research. *Introducing ACM Transactions,* 25(2): 78–81. https://doi.org/10.1145/3177816

[30] Tamara E. Lacourt, Elisabeth G. Vichaya, Gabriel S. Chiu, Robert Dantzer, and Cobi J. Heijnen. 2018. The High Costs of Low-Grade Inflammation: Persistent Fatigue as a Consequence of Reduced Cellular-Energy Availability and Non-adaptive Energy Expenditure. *Frontiers in Behavioral Neuroscience* 12. https://doi.org/10.3389/fnbeh.2018.00078

[31] Michal Levin. 2014. *Designing multi-device experiences: An ecosystem approach to user experiences across devices*. O'Reilly Media, Inc.

[32] Ann Light. 2019. Design and Social Innovation at the Margins: Finding and Making Cultures of Plurality. *Design and Culture* 11, 1: 13–35. https://doi.org/10.1080/17547075.2019.1567985

[33] Silvia Lindtner, Garnet D. Hertz, and Paul Dourish. 2014. Emerging Sites of HCI Innovation: Hackerspaces, Hardware Startups & Incubators. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '14), 439–448. https://doi.org/10.1145/2556288.2557132

[34] Jonas Löwgren. 2009. Toward an articulation of interaction esthetics. *New Review of Hypermedia and Multimedia* 15, 2: 129–146. https://doi.org/10.1080/13614560903117822

[35] Jonas Löwgren. 2013. Annotated portfolios and other forms of intermediate-level knowledge. *Interactions* 20, 1: 30–34. https://doi.org/10.1145/2405716.2405725

[36] Ezio Manzini. 2015. *Design, when everybody designs: An introduction to design for social innovation*. MIT press.

[37] Maurice Merleau-Ponty. 2013. *Phenomenology of perception*. Routledge.

[38] William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. 2016. From Research Prototype to Research Product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16), 2549–2561. https://doi.org/10.1145/2858036.2858447

[39] Peter White, Kimberly Goldsmith, Anthony Johnson, et al. 2011. Comparison of adaptive pacing therapy, cognitive behaviour therapy, graded exercise therapy, and specialist medical care for chronic fatigue syndrome (PACE): a randomised trial. *The Lancet* 377, 9768: 823–836. https://doi.org/10.1016/S0140-6736(11)60096-2

[40] James Pierce. 2014. On the Presentation and Production of Design Research Artifacts in HCI. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (DIS '14), 735–744. https://doi.org/10.1145/2598510.2598525

[41] Janet Read, Daniel Fitton, Benjamin Cowan, Russell Beale, Yukang Guo, and Matthew Horton. 2011. Understanding and designing cool technologies for teenagers. In *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems* (CHI EA '11), 1567–1572. https://doi.org/10.1145/1979742.1979809

[42] Johan Redström. 2017. *Making Design Theory*. The MIT Press, Cambridge, Massachusetts.

[43] Anna Katherine Sheridan, Lesley Scott, Nancy MacDonald, Lorraine Murray, Samantha Holt, and Allen Kat. 2013. Exploring E-learning provision for Children with ME in Scotland. *Other Education* 2, 1: 78–80.

[44] Adrian Smith. 2017. *Social Innovation, Democracy and Makerspaces*. Social Science Research Network, Rochester, NY. Retrieved December 5, 2019 from https://papers.ssrn.com/abstract=2986245

[45] Erik Stolterman. 2008. The nature of design practice and implications for interaction design research. *International Journal of Design* 2, 1: 55–65.

[46] Erik Stolterman and Mikael Wiberg. 2010. Concept-Driven Interaction Design Research. *Human–Computer Interaction* 25, 2: 95–118. https://doi.org/10.1080/07370020903586696

[47] Dag Svanæs. 2013. Interaction design for and with the lived body: some implications of Merleau-Ponty's phenomenology. *ACM Transactions on Computer-Human Interaction (TOCHI)* 20, 8: 1–30. https://doi.org/10.1145/2442106.2442114

[48] Julia Terman, Joseph Cotler, and Leonard A. Jason. 2019. How psychiatric referrals influence stigmatization in patients with myalgic encephalomyelitis and chronic fatigue syndrome: An examination of American and British models. *Community Psychology in Global Perspective* 5, 2: 19–29. https://doi.org/10.1285/i24212113v5i2p19

[49] Julia M. Terman, Jessica M. Awsumb, Joseph Cotler, and Leonard A. Jason. 2018. Confirmatory factor analysis of a myalgic encephalomyelitis and chronic fatigue syndrome stigma scale. *Journal of Health Psychology*: 1359105318796906. https://doi.org/10.1177/1359105318796906

[50] Frank Twisk. 2018. Dutch Health Council Advisory Report on Myalgic Encephalomyelitis and Chronic Fatigue Syndrome: Taking the Wrong Turn. *Diagnostics* 8(2), 34.

[51] Maja van der Velden, Margaret Machniak Sommervold, and Alma L. Culén. 2015. Patient-Initiated Personalisation: Privacy, Moods and Colours. In *Proceedings of the International Conference on e-Health 2015*, 95–103.

[52] Vasillis Vlachokyriakos, Clara Crivellaro, Pete Wright, and Patrick Olivier. 2018. Infrastructuring the Solidarity Economy: Unpacking Strategies and Tactics in Designing Social Innovation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (CHI '18), 481:1–481:12. https://doi.org/10.1145/3173574.3174055

[53] John Zimmerman and Jodi Forlizzi. 2014. Research Through Design in HCI. In *Ways of Knowing in HCI*, Judith S. Olson and Wendy A. Kellogg (eds.). Springer New York, 167–189.

[54] KULU. 2014. Cool technology for youth with long-term health challenges. Retrieved April 22, 2020 from http://www.kulu.no/english.php

[55] No Isolation. 2015. Retrieved April 20, 2020 from http://www.noisolation.com/uk/

[56] KOOLO. 2015. Retrieved April 20, 2020 from http://www.kulu.no/koolo.php?lang=en

[57] Abstraction. *Wikipedia*. Retrieved April 22, 2020 from https://en.wikipedia.org/wiki/Abstraction