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ENCOURAGING SOCIAL CONNECTION WITH WEARABLE TECHNOLOGY DESIGN

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Abstract

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Toward innovating ways to help people develop interdependent, more connected ways of relating, I took research through design (RtD) [61] approach to explore how ubiquitous and embodied technology design could encourage connection and draw people's attention to each other. Focused on wearable technology, I built on my background in fashion design, psychology, and interactive storytelling. I identified and explored the design space of *social wearables*, i.e., wearable technology that augments co-located interaction. This dissertation contributes: (1) practice-based knowledge through three case studies of social wearables design prototypes, (2) conceptual contributions through a design framework for social wearables, the strong concept of synergistic social technology, and the experiential quality of vulnerability, and (3) translational contributions that bridge theoretical framing with practice in the form of instructional materials, to teach and practice social wearable design. The prototypes described in the case studies serve as design exemplars for the design space. I made copies of each final wearable design to test with people in social situations. These studies resulted in surfacing intermediate-level knowledge, thus contributing to theoretical framing. Finally, the instructional materials are starting points for educators and designers to teach and develop social wearables.

To my grandmother Savta Hella

and my grandfather Saba Yermiyahu,

for inspiring me to “learn, learn, and learn.”

And to my children– Leonie and Adam,

who make everything I do worthwhile.

Acknowledgments

I am deeply grateful to Professor Katherine Isbister for advising me on my Ph.D. research. Katherine– your mentorship and kind support propelled and encouraged me to follow my curiosity. You inspired me to be true to my values and joyfully and creatively explore human-computer interaction research. Working with you and learning from you is a great privilege.

This dissertation is a synthesis of collaborative research projects. I am grateful to have worked alongside talented and inspiring individuals– Elena, Ferran, James, Miguel, Peter, Robb, Katherine, and research assistants. While I am often the first author of the published articles, when I write "I" or "my," I mean "we" or "our".

I also want to acknowledge Despina's wearable technology design class at New York University Tisch's Interactive Telecommunications program. Taking this class was my first hands-on engagement with wearable tech. I began bridging my fashion design background with embodied and interactive designs there. Also, thank you, Nancy, Dan, Benedetta, and Katherine, for supporting my research journey.

I want to express my gratitude to the many people who have supported and inspired me throughout this journey, including my friends and family: Shai– my love, Leonie, Adam, Imma, Abba, Tali, Ori, Amir, Dorit, Amram, Hagit, Roy, Tamar, Noga, Gilli, Ilay, Lia, Ellie, Nivie, Aviva, Moshe, all my cousins, and aunts; thank you Nati, Yael, Noa, Kineret, Yasmin, Pearl, Elizabeth, Suz, Logan, Brooke, Liz, Stephanie, Lars, Ella, Gal, Viniyata, Shelly, Galia, Katie, Margherita, and Julie.

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Chapter 1

Introduction

In this dissertation research, I have explored the potential of embodied technology interventions to support co-located social connections. Specifically, I have researched the design space of social wearables, namely wearable technology designed to augment co-located social interaction [105]. This research puts the human values of *social connection* and *play* at its core. These values shaped the design, research, and conceptual thinking processes described in this work.

The contribution of this dissertation consist of research projects that were published, or presented at top tier human-computer interaction academic venues. All these projects are the result of working with collaborators in interdisciplinary teams. These teams included other researchers, engineers and designers.

This dissertation research provides three levels of knowledge contributions [149, 150, 61, 100, 73]:

- **Practice-focused contributions.** These contributions can inspire and motivate by identifying opportunities for new technology directions [149]. Such contributions may also bridge theory and specific problem spaces by evaluating the use of design artifacts with people in co-located settings.

- **Conceptual contributions.** These are theoretical findings that provide intermediate-level knowledge contributions. For example, an annotated portfolio [58, 100], an experiential quality [100], and a strong concept for design [73].

- **Translational contributions.** These are contributions that translate theory to make it applicable– "to facilitate the adoption, implementation, and institutionalization of theoretical [human-computer interaction] findings into design practice" [23]. In the case of this dissertation, these are the instructional materials I developed to inform educators.

In this Chapter, I share my research approach, including the research questions, the methodologies I applied, and the background for this work. As part of this background, I introduce the research topic and related work that motivated my dissertation research. Part of this motivation stems from my professional experience before pursuing this work. The dissertation chapters proceed as follows:

Chapter 2 | Design Framework for Social Wearables (conceptual contribution I): I present the design framework, which is based on an annotated portfolio of others' work [58, 9, 100] as well as my design practice in creating social wearables. I developed this framework with my collaborators to map out the-state-of-the-art in this area and identify design opportunities.

The framework was published as a full paper in DIS 2019 [36]. Specifically, my roles in this work included initiating the research, leading it by surveying over fifty wearable design across research and aesthetic work, creating an annotated portfolio, reaching out to collaborators, hosting discussions to identify value areas in the design space, and articulating guiding questions. In the paper, I wrote the following sections: background and related work, research approach, areas of value for social wearables, and the guiding questions. I also led the design and research of the two social wearable designs that were presented as case studies in the section titled “using the framework to evaluate designs.” Later I updated the framework with additional design exemplars and included it in the book *Playful Weararbles: Understanding the Design Space of Wearables for Games and Related Experiences* [15] in the chapter on social wearables.

Chapter 3 | Social Wearables Case studies (practice-based contribution): I present three case studies: True Colors, Lågom, and the Robo-Shoe-Flies. The three case studies were the result of working with interdisciplinary teams. In all cases, I engaged in the iterative design, the theoretical framing and the user testing (when applicable), and analysis as part of the research through design approach [61]. Two of the case studies (True Colors and Lågom) were both informed by the design framework introduced in Chapter 2 and also informed the framework’s development. With these case studies, I show how I arrived at mid-level theories explained in the following Chapter.

My roles in each of these case studies are as follows: **True Colors:** This case study was published as a full paper at CHI 2019 [34]. I initiated and led this project.

I researched local larp (live action roleplaying games)[1] events and then reached out to the larp designers for collaboration. I designed the first iteration of the prototype, including hardware integration and organized the bodystorming[2] sessions, on site and at our lab. I iterated the design after the co-design workshops, including its interactive functionalities and its crafting materials. I ordered the hardware components based on discussions with Miguel Flores, the Engineer on our team. I created three copies of the design and planned a playtesting session during a graduate student class that included a short form of roleplaying. I worked closely with Miguel to update the code based on the feedback we received, regarding main states, and events in the interaction. I developed templates to follow to create multiple copies of the design and then crafted the prototypes with a team of assistants. This included many aspects of hardware integration, such as connection conductive fabric to wire, and buttons on soft material and more. I wrote the IRB[3], and developed the study plan, including creating a qualitative questionnaire, and semi-structured interview guide. I attend the larp event to observe the interaction with the designs, which lasted four days. I created the consent forms. Before the game officially began, the larp participants could sign the form, and I collected the signed copies. I also hosted a short session to guide the participants, demoing the use of the design, and providing them with a flyer I created that summarized all the interactive

[1]Larps are physical games inspired by participatory theater, featuring rich interactive narratives played through performance and engagement in the physical world.

[2]Bodystorming is a technique that assists designers in generating ideas for interactive systems. It involves physically engaging in a co-design play-based activity with peers. During this process, designers explore the design space, considering both digital and non-digital artifacts, arranging contextual elements in physical space, to understand underlying physical core mechanics [106].

[3]The Institutional Review Board (IRB) is an administrative body established to protect the rights and welfare of human research subjects

functionalities. Dressed in a research lab coat I also participated in the larp a non-player character. I took notes, pictures, and videos of the event while in-character. In the last day, and not in-character, I conducted half of the interviews, and deployed and collected the questionnaires. Next I transcribed all the interview recordings. I individually analyzed the data thematically, and then met with two other researchers in the lab to discuss and adjust the themes. I synthesized our discussion and met with the rest of the research team to identify the high level themes. In the paper, I wrote the following sections: the design process, final design, design iterations, user study, and results. Collaboratively, I wrote the following sections with my co-authors: background, methodology, supported experiential qualities, designing for vulnerability. I also illustrated the design, and created a figure that highlights all its functionalities.

Lågom case study was presented as a work in progress at CHI 2018 [38]. In this work, I collaboratively designed the prototypes' functionalities, made the aesthetic decisions, and worked on integrating the microphone into the design. I created the copies of the design, wrote the IRB, developed the study plan, wrote the interview and questionnaire questions, led the pilot study, conducted the interviews, transcribed them, thematically analyzed and wrote the extended abstract.

The Robo-Shoe-Flies case study was presented as a work in progress at CHI 2020 [31]. I initiated and led this work. I applied the framework questions (from Chapter 2 when hosting a bodystorming workshop to ideate design opportunities. I collaboratively designed the prototypes functionalities. I made aesthetic decisions, developed a template to create multiple copies of the final design, and then created seven copies. I wrote the IRB, developed the study plan, wrote the interview and questionnaire questions, recruited participants, led the preliminary study with three groups, conducted the interviews, transcribed them, thematically analyzed and wrote the extended abstract.

Chapter 4 | Encouraging Social Connection Through Wearable Technology Design (conceptual contribution II): I present the strong concept of Synergistic Social Technology and the experiential quality of Vulnerability that were derived from the case studies presented in Chapter 3.

The Synergisitc Social Technology strong concept was published as full paper [33] at DIS 2021. This work was based on the Robo-Shoe-Flies case study, which I initiated and led. I conducted a literature review to ground the concept in related human-computer interaction (HCI) theory and design exemplars. I conducted another round of thematic analysis based on the findings from the Robo-Shoe-Flies preliminary study. I reflected on the design process, and developed the core principles of the concept by mapping the design dimensions I found in the study to design implications. I wrote all the sections of the paper except for the introduction, and created the illustrative figures.

The experiential quality of **Vulnerability** was identified as a result of the True Colors case study (that was published as a full paper [34] at CHI 2019) which I initiated and led. My contribution to this work is highlighted above. My role in identifying vulnerability as an experiential quality was a result of the research through design process, participating in the larp as an observer, conducting the study, and thematically analyzing participants' responses and researching for related work.

Chapter 5 | From Theory Generation to Developing Instructional Materials (translational contribution): I share the process from developing and applying the design framework in my practice, all the way to creating embodied design exercises to teach others how to design social wearables. This instructional material was used within edu-larp[4] camps for youth.

In this chapter, I mention a bodystorming design exercise that I created to guide social wearables design (published in the book on playful weararbles [15]). I developed this exercise based on my design and experience hosting an embodied design workshop in the Robo-Shoe-Flies case study.

I also mention a full paper that was published in DIS 2022 that summarized the first deployment of the edu-larp camp design [49]. My role in this project was creating two online embodied co-design workshop, facilitating them, and synthesizing findings to develop the bodystorming design class that was used in the edu-larp camp. In this research, I participated in the data collection, including developing the interview guide, conducting interviews, transcribing them, and thematically synthesizing data (from logs, notes, interviews, and questionnaires). In the paper, I contributed writing to the results section. I also reviewed all the photos and videos data from the camp and created the illustrative image collages.

Chapter 6 | I conclude by recapping how I set out to explore the design space of social wearables using a research-through-design approach, summarize the major outcomes of my dissertation, and discuss how this can inform design work beyond wearable

[4]edu-larp is a structured, live action roleplay experience that teaches through social enactment and reflection [10].

technology and impact future work.

Finally, I include my complete list of research output in Appendix A to provide a broader lens on my Ph.D. work as a student.

1.1 Research Methods

Here I discuss my methodological approach. I introduce the research questions that guided my inquiry and include a research approach related to the design process, theory development, and the evaluative methods I implemented.

1.1.1 Research Questions

In this dissertation work, my broad research goal was to address the questions: *How can we design to encourage co-located social connection?* and *How can we use design qualities and strategies to enhance co-located social connection?* To narrow the scope of this inquiry, I focused on wearable technology and asked:

- **RQ1** What design opportunities for wearable technology exist to support and encourage co-located social connection?
- **RQ2** What concepts and theoretical frames could designers and researchers use to explore the design space of social wearables?

1.1.2 Research through Design Approach

This dissertation work follows the *research through design* (RtD) approach in HCI [149, 150, 62]. I describe the methodologies I used to generate several intermediate-level knowledge contributions [100].

The term research through design [51] developed from Christopher Frayling's concept "where design researchers focus on making the right thing; artifacts intended to transform the world from the current state to a preferred state" [149]. Before the term was adopted, HCI researchers using design methods and interaction designers did not have a formulated and well-defined method to call their own [149].

Zimmerman, Forlizzi, and Evenson [149] explored and advanced a model of RtD methods to make design research contributions better integrated into HCI practice communities. They wanted to help lead extensible knowledge transfer for other researchers that could support inquiry into wicked problems [5].

RtD methods are supposed to contribute to the HCI research community in three ways [149]: First is by providing **inspiration and motivation**: Identifying opportunities to advance current technology to impact the world significantly, and by **bridging general aspects of a theory with a specific problem space**, channeling HCI research to the practice community (i.e., "In evaluating the performance and effect

[5] Wicked problems were initially identified in 1973 in a conference on public policy issues at UC Berkeley [129]. A good description of what they are comes from Interaction Design Foundation: "Wicked problems are problems with many interdependent factors making them seem impossible to solve. Because the factors are often incomplete, in flux, and difficult to define, solving wicked problems requires a deep understanding of the stakeholders involved and an innovative approach provided by design thinking. Complex issues such as healthcare and education are examples of wicked problems." (https://www.interaction-design.org/literature/topics/wicked-problems)

of the artifact situated in the world, design researchers can both discover unanticipated effects" [149]); second by creating "artifacts that provide concrete embodiments of theory and technical opportunities" [149]; and third, by promoting **holistic research contribution**: Achieved by framing issues of importance and across conflicting perspectives.

Zimmerman, Forlizzi, and Evenson also suggested a set of four critical lenses for researchers following this model so that they could evaluate what constitutes a good design research contribution:

1. **Process**: The rigor applied to the methods used and the selection of methods rationale. The documentation of the process should provide sufficient detail so it would be possible to reproduce it. However, there are no expectations that following the same process would yield the same results.

2. **Invention**: The contribution should reflect a significant invention and include a novel integration of various subject matters (i.e., "The intent going into the research is to produce knowledge for the research and practice communities, not to make a commercially viable product [...] and [t]he contributions should be novel integration of theory, technology, user need, and context; not just refinements of products that already exist in the research literature or commercial markets" [149]).

3. **Relevance**: Instead of the concept of validity standard in scientific research, they suggest *relevance* as a shift from what is true to what is real. Further, there is a need to articulate the preferred state for the design attempts and explain why this would be so for the community [149].

4. **Extensibility**: The community should be able to leverage the knowledge derived from the design research work, as it is thoroughly described and documented [149].

Later, Zimmerman, Stolterman, and Forlizzi raised concerns regarding the need to standardize the processes of RtD to ensure higher quality and nascent theory instead of intermediate-level theory. Further, they suggested that researchers practicing RtD methods should use theory to lead their process [150]. Gaver [61] responded to these arguments by warning the design community of "impulses towards convergence and standardisation" [61] and addressed the lack of falsifiability of the design process. Gaver mentioned that researchers who engage in RtD share many paradigms and are closer to comprising a research program than is acknowledged.

Gaver extended the model of RtD by pointing out that "it is a generative discipline, able to create multiple new worlds rather than describing a single existing one. Its practitioners may share many assumptions on how to pursue it, but equally, they may build as many incompatible worlds as they wish to live in" [61]. Gaver argued that "a designer artifact is a 'theory nexus': the choices made by designers reveal both the issues they think are important and their beliefs about the right way to address those issues" [61]. Also, he explains that implicit theories are embodied in objects that reflect philosophical, function, social and aesthetic perspectives and proposes the notion of annotated portfolios as a research contribution.

Annotated portfolios are one form of conceptual contribution that RtD can produce. They are considered intermediate-level knowledge contributions– theoretical contributions that reside at a level of abstraction between theory and practice [100].

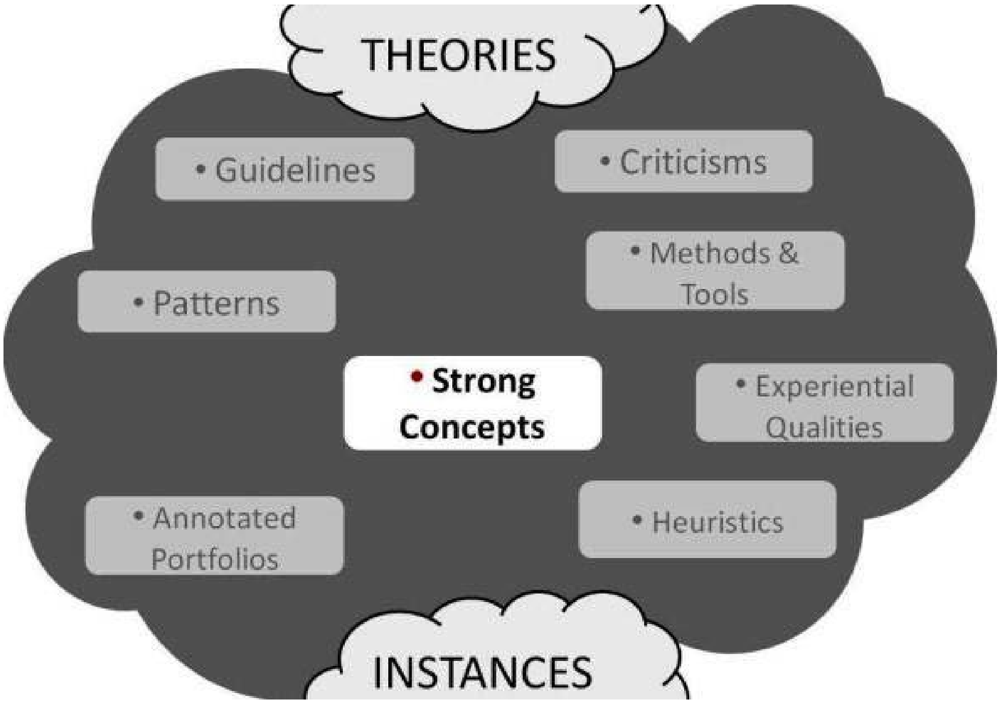


Figure 1.1: Intermediate-level-knowledge contribution by [94], adapted from [73].

Annotated portfolios "maintain the particularity of individual examples, while articulating the ideas and issues that join and differentiate them" [61]. The logic behind them is that each design artifact represents the myriad of choices that went into creating it, occupying "a point in [the] design space" [59]. Then, when designs get discussed as a collection, their features are abstracted, and they can establish an area in that space– where researchers can also articulate what future design should be. The design choices reflect a wide range of concerns that may include: the design's functionality ("What should it do?"), its aesthetics ("What form and appearance should the artifact take?"), the people who will use it ("What will our users make of this? How can we best design for them?"); the motivation for making it ("Why are we doing this?"); and more [59]).

Finally, another form of intermediate-level knowledge contribution relevant to this dissertation is "strong concepts" [73]. Strong concepts can abstract design elements beyond particular instances. This abstraction lets designers and researchers appropriate them in their practice: extending their repertoires and enabling new concept instantiations. Strong concepts need to be grounded horizontally in the context of related HCI theory and vertically in design instances that can exemplify it [73] (see Figure 1.1).

1.1.2.1 Design with Values

A design process is an act that requires making many decisions that eventually inform an artifact of sorts which ends up in our world. The designers' values inform this process, whether consciously or not. In my dissertation work, I was inspired by Value Sensitive Design (VSD) [54], a theoretically grounded approach designed to account for

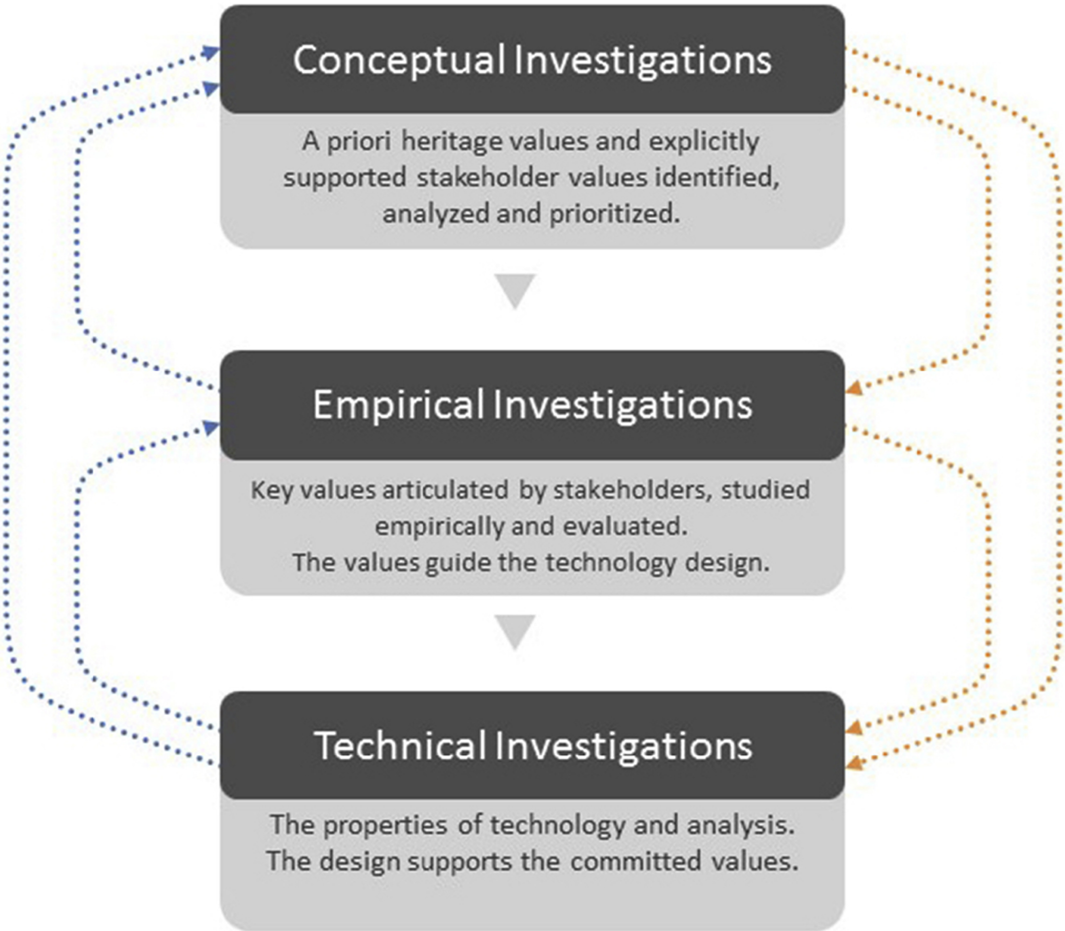


Figure 1.2: VSD's three investigation methods, called the tripartite methodology, involve a conceptual, empirical, and technical investigation. Figure from [109]

human values throughout the design process.

The definition of *value* within this framing refers to "what is important to people in their lives, with a focus on ethics and morality" [53]. Moreover, it suggests taking into account the context of how people live their lives, emphasizing the complexity of social life. The VSD approach encourages using an iterative methodology that integrates conceptual, empirical, and technical investigations (see Figure 1.2). VSD promotes "progress and not perfection" in all aspects, "reminding designers that achieving progress is a worthy goal even though perfection remains ever elusive" [53]. It also encourages designers to consider how their technological designs might impact direct and indirect stakeholders thoughtfully.

A closely related approach is 'values' in design [90]. This approach emphasizes values in the earlier stages of technology design. In my dissertation projects, I took value driven RtD approach to conceptual development. The values that started my research inquiry were *social connection* (i.e., encouraging positive interaction between people), *playfulness* (i.e., designing interactions that delight and foster a sense of ease and joy), and *wellbeing* (i.e., interaction design that promotes socio-emotional, and physical health).

1.1.3 Qualitative Evaluation

To gain insight into social wearable design and generate new knowledge, I implemented RtD frameworks and was inspired by VSD. In my projects, I took multiple approaches while applying traditional qualitative evaluation methods. First, I surveyed existing state-of-the-art designs and qualitatively analyzed them. Then, in three case studies, I created design prototypes. To evaluate these designs, I developed multiple copies of them (see Figure 1.3), enabling deployment in related social environments, which allowed me to study how multiple people interact with them. Finally, I took insights from these projects to create instructional materials for a middle school girls' summer camp that focused on the creation of social wearables within the context of an

Figure 1.3: In my research projects, I make multiple prototypes as part of my RtD process to test the designs with people in a social context.

edu-larp.

To collect data, I used several methods. I designed and conducted semi-structured interviews; I created and deployed questionnaires; and when possible, I observed research participants interacting with the design prototypes while socializing (at times, I documented the interaction using video capture). In some cases, I designed educational programs that had resulting design artifacts. To study these, I collected these artifacts as well.

Depending on the project hypothesis, I performed deductive and/or inductive thematic analysis [64, 140]. I triangulated data to form insight for design and learn about the potential impact of the design prototypes.

1.2 Background

1.2.1 Personal Statement

My broader research goal is to guide technology design that helps people develop interdependent, more connected ways of relating. In my Masters from the Interactive Telecommunications Program (ITP) at the Tisch School of The Arts at New York University[6], my thesis topic was an interactive, fully functioning embodied design installation exploring the notions of intimate relationships and means of sharing memories with others through tangible artifacts infused with digital content[7].

As a fashion and costume designer[8] I worked for several years in various market categories and art performances. This familiarity with working with the body and aesthetics inspired my interest in wearable technology as a social mediator.

In my undergraduate education, I was drawn to people's stories, so I studied Psychology[9] and Film[10] at Tel Aviv University.

My previous educational and professional experience served as the background to this dissertation work– I was eager to explore the design space of *social wearables* (i.e., wearable technology designed to augment co-located social interaction [105]) and integrate my 'designer' mind with my intellectual curiosity and interest in people. In my

[6]ITP is a two-year graduate program whose mission is to explore the imaginative use of communications technologies: https://tisch.nyu.edu/itp

[7]I wrote an extended abstract paper about this work presented at the TEI 2018 conference [28]

[8]I studied Fashion Design at Istituto Marangoni, where the study methods in visual design are rigorously oriented towards industry demands and 'real-world' project experiences: https://www.istitutomarangoni.com/en/schools/london-school-of-fashion-and-design

[9]The School of Psychological Sciences Faculty of Social Sciences Tel Aviv University: https://en-social-sciences.tau.ac.il/psy

[10]The Steve Tisch School of Film and Television The David and Yolanda Katz Faculty of the Arts Tel Aviv University: https://en-arts.tau.ac.il/filmTV

dissertation research, I was inspired by the *value sensitive design* (VSD) approach [54] to technology development to account for human values throughout the design process. In addition, I share similar values to those reflected in the Positive Computing framework [16] and in the design agenda of Slow Technology [66], which also consider studies that emphasize improvements to human wellbeing as a whole.

Toward research goal, I found that engaging in research through design (RtD) [61, 149, 150] process offered a way to integrate my past experiences and draw from my multidisciplinary background: I combined values-driven design practice with technical development and user studies to explore the potential of interactive experiences to enhance co-located social interaction.

1.2.2 Co-Located Interaction and Technology

Humans are social by nature. Erickson and Kellogg state, "As humans, we are fundamentally social creatures" [45]. Establishing good communication and social interactions has helped us thrive as a species [113]. Quality co-located interaction has clear health benefits [18, 147], is an essential indicator for enhanced productivity in business settings [20, 119], and also contributes to our happiness [8]. Prosocial behaviors such as communicating emotions, authenticity, reciprocity, cooperation, or compassion are also highly valuable in the personal domain [12]. Nowadays, more than ever, people engage with various screens many hours a day. There are still limited opportunities to use new technology for co-located social interactions in a way that does not include passively watching a shared screen.

Regarding co-located practices, Reitmaier, Benz and Marsden [127] assert that the spatial and social are interwoven. The spatial perspective in co-located interactions is often described and analyzed using two notable lenses (see Figure 1.5). First, Hall's proxemics lens focuses on the distances maintained in the social encounters by highlighting four proxemic zones: public, social, personal, and intimate [65]. Second, Kendon's F-formations lens observes "how people organize themselves spatially in relation to their interactional projects" [87]. It adds to Hall's framework by showing that people also employ space, bodily orientation, and positioning to organize their attention in social encounters.

In their research on designing mobile experiences for co-located interaction, Lundgren, Fischer, Reeves, and Torgersson [103] developed a framework to support the design process, which demonstrates the interplay between the social, technological, temporal, and spatial perspectives (see Figure 1.4). Integrating the impact of spatial experience into broader technology design, Hornecker, and Buur developed a framework for physical space and social interaction (see Figure 1.6). This framework focuses on the connection between the material/physical and social aspects of interaction design using four themes (which are not mutually exclusive): (1) Tangible Manipulation: which refers to material representations; (2) Spatial Interaction: which refers to the movement in space needed for tangible interaction; (3) Embodied Facilitation: refers to the impact of the configuration of material objects and space on emerging group behavior, and (4) Expressive Representation: refers to expressiveness and legibility of the material and digital representations of tangible interaction [75]. This framework contributes to the larger research agenda of Embodied Interaction [146], making an insightful connection between embodied and social interaction.

In regards to designing embodied interaction, *embodied storming* [130] was developed to let designers "take advantage of the collective's unique ability to distribute cognitive facility in the tangible, physical performance of activity" [130]. It helps in transforming tacit knowledge to generate ideas, to rapidly communicate envisioned stories and scenarios. Embodied storming often works as a pre-brainstorming activity. It involves participants engaging in simulations of envisioned scenarios and collaboratively sustaining it through enactment. This process allows those who engage in it to personally experience and gain insights into the situation they are designing for .

Embodied sketching [106] is one kind of embodied storming. It supports the ideation phase rather than evaluation, and involves "the inclusion of bodily experiences early in the design process," to "spur creativity by harnessing play and playfulness" [106]. Embodied sketching is distinguished from other embodied ideation methods through five guiding principles: First, it adopts an activity-centred approach to ideation, placing emphasis on engaging in hands-on processes to generate ideas; second, it leverages the complete setting as a valuable resource for design, acknowledging that the environment itself can serve as a source of inspiration and guidance; third, it encourages designers to physically and actively participate in unscripted activities, fostering a tactile and experiential connection to the design process; fourth, it incorporates movement and play both as methods and goals, recognizing their power to stimulate creativity and exploration; lastly, it establishes a sensitizing and design-conducive space which can nurture heightened awareness and receptivity to innovative ideas.

Three distinct scenarios illustrate the application of embodied sketching. The first scenario, *bodystorming*, involves designers physically engaging in co-design play-based activities to generate movement-based interactive system ideas. The second scenario, *participatory embodied sketching*, democratizes design by involving end users in exploring, modifying, and creating game or activity design structures. Lastly, practice-driven *sensitizing for designers*, helps to cultivate somaesthetic appreciation[11], enabling designers to access and articulate specific embodied phenomena they want to design for.

Other scholars proposed to consider *the social* as a material for embodied design as well. Gaver, in an article from 1996 on affordances for interaction said that "social meanings are based on facts of the physical world." Therefore, "the more we can understand social behavior in terms of its material context, the better can design efforts focused on relevant attributes" [63]. Gaver argued for taking an ecological approach to social behavior as a way to guide "the design of things that meant to support interaction" [63]. In turn, Gaver articulated the notion that the "design itself can serve as a methodology for better understanding social behavior and its underlying affordances" [63].

Along this line, Reitmaier, Benz, and Marsden recognized the need to consider the "social ecology" and not only design around "device ecology" when articulating the

[11]"Somaesthetic design focuses on making people more aware of their felt bodily experiences."[74]. Somaesthetic is an interdisciplinary field which emphasizes the significance of the body, considering it not only as an object of aesthetic representation but also as a subjectivity for aesthetic appreciation. It incorporates theories and practices that revolve around bodily perception, performance, and presentation [106].

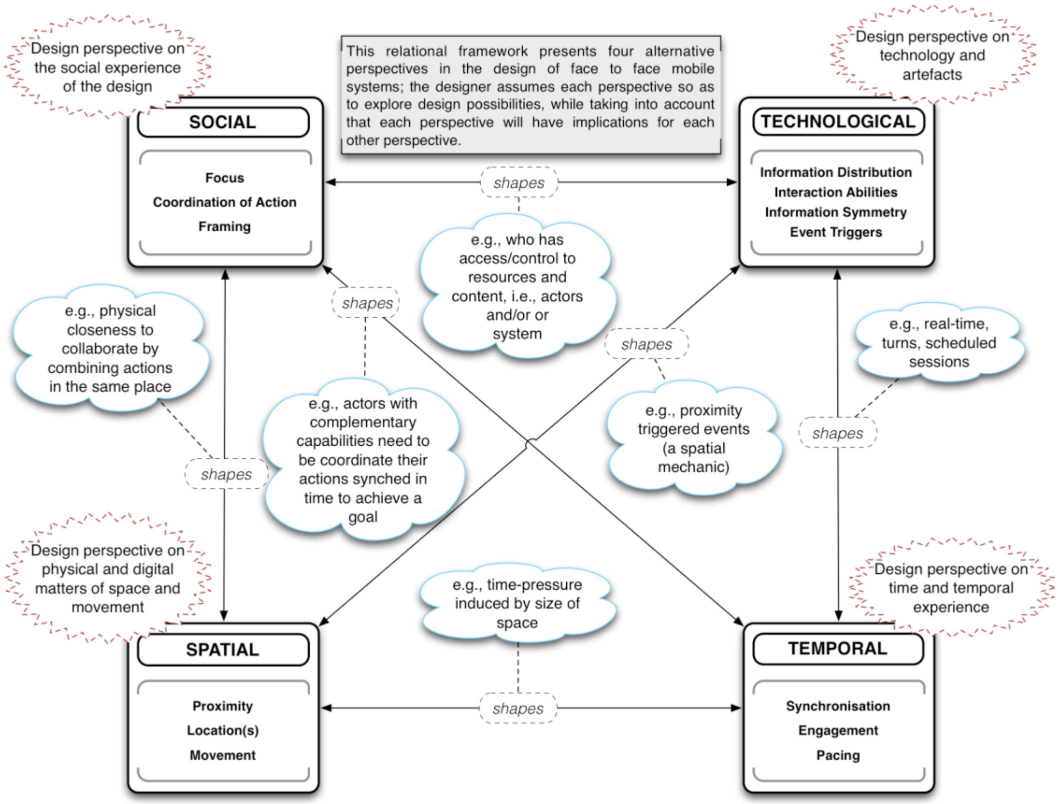


Figure 1.4: Framework for designing mobile experiences for collocated interaction (diagrammatic representation) [103].

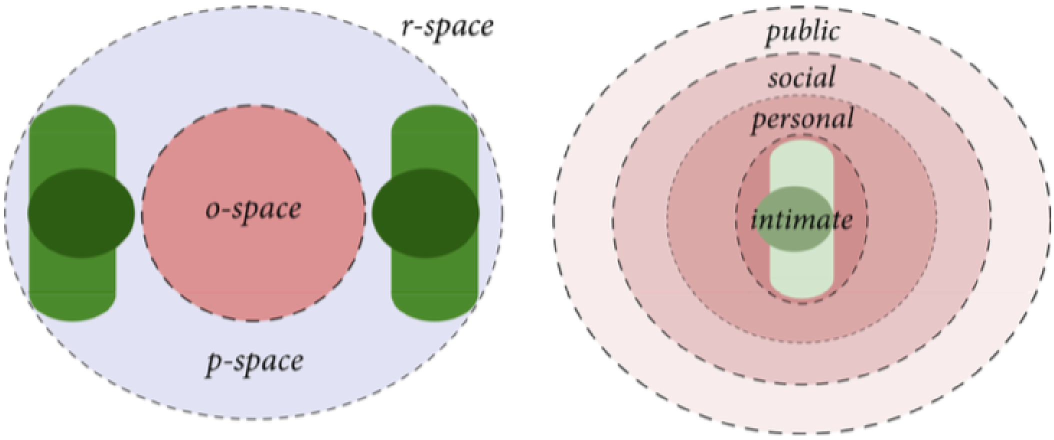


Figure 1.5: Kendon's F-formations and Hall's proxemic zones [127].

design space of co-located interactions [127]. They argued that discussions, as well as "interpretations of theory in relation to co-located interactions, probes, and technology experiments surrounding the probes" [127] are necessary for this process.

In 2019, Olsson et al. [115] surveyed literature revolving around technology design for co-located interaction to identify state-of-the-art. They articulated in this article the need for better technologies that work to enhance co-located social interaction. They identified the lack of clear design guidelines for developing technology for co-located interaction. This lack leads to a low conceptual and methodological understanding of how to design technology that improves social interactions. They emphasize that by "improving" they mean enabling social interaction and "taking an active role in deliberately attempting to improve its quality, value or extent" [115].

As humans are social beings, technology design is embedded in our social environment. Therefore, every technology could impact psychological wellbeing positively by design. However, there could be more thought in the design process towards this end [16]. As described in section 1.1.2.1, I took a value-driven approach to design that included values in my RtD process. Supporting and encouraging social connection is one of the design values driving my work.

In regards to co-located interaction, intermediate-level knowledge contributions as *experiential qualities* [100], *social affordances* (e.g., shaping of proxemics [81], spectator sensitivity [105]), and *strong Concepts* [73] (e.g., interdependent wearable design [79]) have been identified by HCI researchers to help guide technology design to enhance co-located interaction as they provide a fruitful level of abstraction and concreteness [34].

However, there are still gaps in the literature on the potential of design to influence co-located interaction. This motivated me to research how embodied technology design could enhance co-located social interactions– tending to our socio-emotional and psychological wellbeing. Designing for humans as "social creatures" should focus on the role and potential of technology, products, and systems to support the social experience [45]. In my dissertation work, I explored the use of wearable technology to influence and support co-located social interaction, to encourage social connection.

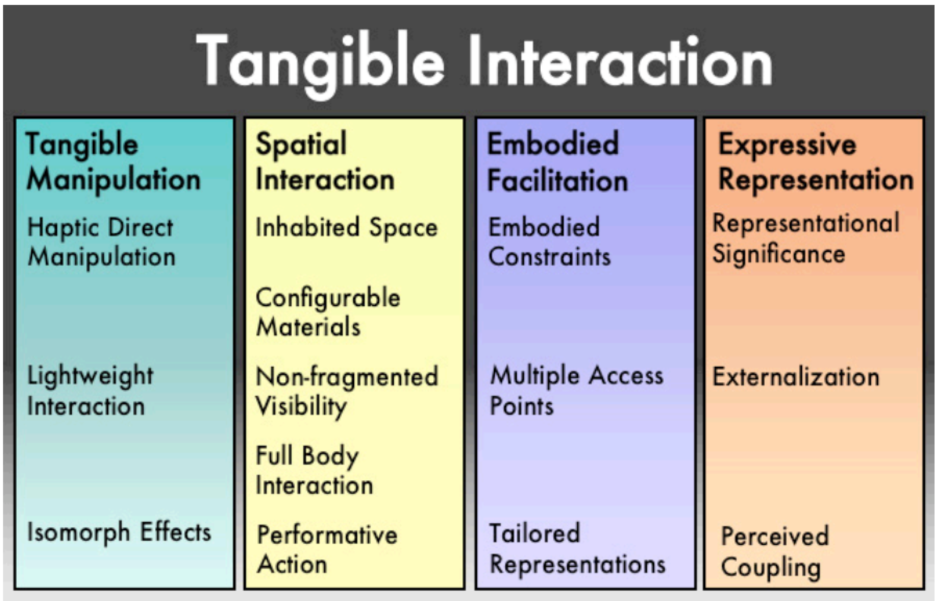


Figure 1.6: Tangible Interaction Framework with themes and concepts [75].

1.2.3 Towards Co-located Social Interaction Using Wearable Technology

Wearable technologies (i.e., technologies integrated into our clothes and other accessories that people wear fueled by advances in sensors and connected technologies [70]) have been in the limelight for over a decade [123]. Many consulting agencies project rapid progress in connected devices due to advances in miniaturization, increased availability of electronic components, the ubiquitous use of smartphones, and "the development of personal and professional mobility" [118]. As the production techniques of wearables continue to advance [42, 104], "devices will become smaller and yet more powerful, enjoy greater connectivity and utilize more sophisticated input and output"

[57].

There are several academic and industry surveys and forecasts on the types of wearable application instances (e.g., [7, 19, 118, 1, 71, 118]). There is a vision for wearables to become "ubiquitous augmentative technology used by everyone" [57]. The term *wearables* is "a generic word encompassing a multitude of elements that can be worn, the very varied elements that we wear, or that we can wear on ourselves or in ourselves (for example, clothes, accessories, watches, shoes, pair of glasses, medical devices (heart, prostheses, implants, etc.), elements that have a role in the wellbeing of an individual, etc." [118].

Wearing anything on the body affects co-located social interaction on some level. Clothing and accessories have been part of the human experience for thousands of years. These items have been used for warmth and protection and to signal to others about one's identity as well as influence social interaction [27]. Don Norman notes that imbuing worn items with computation is an opportunity to augment the social experience. However, it could also wreak disconnection between co-located people [114]. As wearable technology designs are worn on our bodies, they accompany us when we are with others. Therefore they are already playing a social role [137], even without explicit technological features aimed at augmenting co-presence [27].

Some commercial experts say that the next phase of wearable technology will be "The Social Age" [25]. Thus far, there has been a relative increase in focus on prosocial experiences in wearables, but it is mainly targeted at supporting virtual social interaction (e.g., [98, 96]). As wearables become increasingly integrated into many aspects of our lives, we need further guidance to develop devices that genuinely consider their impact on co-located interactions.[12]

In this dissertation, I delve into the topic of social wearables to unpack design opportunities for wearable technology to enrich interactions and connect people in person. When designing technology for people to wear close to their bodies, in my view, the guiding design values should be strongly human-centered– they should first and foremost benefit the people who wear them and consider the wearable designs' impact on those around the wearers as well. Specifically, wearable designs can support people socially and emotionally by facilitating and encouraging prosocial behavior.

The underlying design values have accompanying ethical assumptions. These can profoundly impact how wearables affect social situations and dynamics by design. For example, considering the environment (context) of where interaction happens and how transparent the interplay between the way the wearable is sensing that environment and how it performs to the people involved (the wearer and those nearby) can affect design decisions and outcomes from the interaction. As with any other technology, design decisions are full of trade-offs. Therefore, with social wearables, every design decision should be considered from the wearer's perspective and that of others around them.

In the next Chapter, I present the published design framework for social wearables [36] I developed with colleagues based on surveying the state of the art of wearable

[12] This topic began to gain traction in the HCI and UbiComp/ISWC communities. In 2019 I participated in a workshop titled *Beyond individuals: exploring social experiences around wearables* that brought together researchers, designers, and practitioners who were interested "in designing wearable technology as social, communicative artifacts" to present and discuss their related work [83].

design and designing social wearables myself. Another version of this Chapter was published in the MIT Press book Playful Wearables [15].

Chapter 2

Conceptual Contribution I: Design Framework for Social Wearables

Here I explore the design space of social wearables–i.e., wearable technology designed to augment co-located social interaction [105]. I reflect on what "the social age of wearable tech" [25] could look like, taking the social wearables design space perspective and analyzing recent examples of such design. I demonstrate how wearable technologies are intertwined in social environments, including identity elements related to self-expression in a social context.

My colleagues and I initially defined the concept of social wearables in research on wearable technology in the context of a larp. Larps are physical games inspired by participatory theater, featuring rich interactive narratives played through performance and engagement in the physical world. In a larp, the game occurs in a physical space that simulates the larp world where players embody their characters and physically enact their actions [**?**].

The "social" in social wearables denotes using wearable technology for co-located interaction between people in the same physical space [105]. Therefore when people message through their wearable smartwatches or compare biometric activity remotely using wearables such as Fitbits[13] they are not using this type of 'social wearables' because their social engagement is *not* co-located. Social wearables facilitate two main perspectives: that of the wearer (personal) and that of other people around them (social). We should also consider the relationship between the wearer and others as they interact.

I started my investigation of the social wearables design space by asking: *How could wearable devices enhance co-located social interaction and create new forms of social experiences?*

Considering this question, I studied state-of-the-art social wearable technology by surveying over 50 wearable designs from research, industry, and the art world. I searched for designs that focus on the co-located social space. With my colleagues, I worked to create an annotated portfolio–where we outlined recurring themes that address co-located social interactions and abstracted design dimensions to help designers and researchers think about what happens when we introduce wearable technology into social experiences.

Toward creating a design framework, we discussed the value areas using concepts such as social affordances (e.g., [105]). We identified two main areas of value in

[13]Fitbit: https://www.fitbit.com/

the social wearables design space [36]: (i) Social wearables augment what people have already been doing from a social perspective with fashion, clothes, and costumes; adding computation to worn pieces and making them interactive adds to their novelty, appeal, and non-verbal social signs. (ii) Social wearables may create new opportunities for people to interact with each other in person by adding computation to worn pieces and making them interactive.

In the framework we reflected on the potential of social wearable scenarios and social needs as opportunity gaps for future designs, extending a series of guiding questions to consider when designing social wearables. These questions were grounded in prior work, as well as my design research, based on the two design practice projects with social wearables (described in the next Chapter: the Lågom [38], and 'True Colors' [34]). In these design projects, I used the guiding question identified in the framework and simultaneously used insights from the design practice to refine the questions.

The framework highlights the design space– it identifies the main value areas and proposes open questions to ponder when designing future social wearables. It leaves room for interpretation, so designers have flexibility in crafting solutions to particular needs and contexts. It can help designers in the ideation phase by raising valuable questions to begin their inquiry and evaluate their designs. The framework could help other wearables researchers and practitioners to adequately consider the nuances of supporting rich co-located social interaction with appropriate design decisions. More details can be found in the paper itself [36].

Next, I examined a collection of designs to articulate social wearables' two main value areas. I highlighted the need for further evaluation of social wearable designs with multiple people because we can only really understand the wearables' social value when they are actually used by people when they are socializing. After the discussion of social wearables value areas, I turned to ethical considerations that should ground future wearable design innovation. I listed the questions designers should consider when developing wearable technology if they want to support co-located, human-to-human interaction.

2.1 Area of value I: Augmenting Existing Social Signaling

Adding computation to worn items can help a person present themselves to others as both individuals and social beings. As we know, people are already signaling identity and self-presentation (e.g. who they are and their needs, desires, and preferences) through verbal and non-verbal cues such as clothing and other cosmetic choices. The question, then, is how computation can enhance existing social signaling cues from the wearer. Most commonly, computation adds dynamic visualization of social signs through visual effects (for example, light-animation color changes, kinetic movement), at times reinforced with sound effects. Wearables in performance arts (e.g. theater, dance, cosplay, and fashion) can characterize and present the wearer in a particular way to the audience, such as to impress, surprise, or delight them. Computation can add an extra layer of novelty, surprise, and sensual pleasure to worn items. It can be integrated into existing garments or used in others crafted from scratch, creating new affordances

Figure 2.1: Chalayan's wearable designs: Left: The Laser dress; Center: a dress featuring a digital screen; Right: a dress that can change its hem's length.

and infusing garments and accessories with dynamic qualities.

Some artful wearable designs include dramatic effects that could be used as social signaling, including behavioral cues that let others know what the wearer's intentions are (around social interaction) by augmenting the expressivity of nonverbal communication [105]. Works by renowned avant-garde fashion designer Hussein Chalayan [122] are good examples (see Figure 2.1). Chalayan has been experimenting with embedding computational technology in his runway pieces for two decades. Among his notable designs are the Laser Dress [110] or the creative use of motor systems and pulleys to change shape and style and even make clothes disappear [14]. These designs could be used as self-expression and communicate the wearer's desire. For example, when the hem of the dress is shortened, the wearer might want to signal to others they are ready for a dance party, while when the hem of the dress is long, they might want to signal their interest in a more serious interaction.

Other design studios have experimented with embedding computation into fash-

Figure 2.2: Studio XO designs: Volantis

ion to create spectacle and novelty. Studio XO designers, for example, created a very dramatic showpiece for Lady Gaga, called Volantis (see Figure 2.2). This wearable design is a flying dress controlled remotely by twelve battery-powered propellers [116]. Imagine the effect on real-life spectators when Lady Gaga suddenly began to fly! Such expressive, spectacular designs extend previous material forms designers could achieve with non-computational artifacts. This self-expression is made to impress others by communicating that previous boundaries can be broken.

Some wearable designs take expressiveness a step further by using computational means to sense the wearers' biosignals or the environment around the wearer, and

Figure 2.3: Design exploration of kinetic mechanical attachments by Kao et al.

then express those changes. The design of the Bubelle dress, for example, is a conceptual piece that changes colors based on sensing the wearer's mood. Others experiment with different forms of expression. Kao et al. introduced a robotic wearable system with kinetic mechanical attachments (see Figure 2.3). Its untethered, motoric moving pieces can be added as accessories to a garment, looking a bit as if your shirt has turned into a race track with miniature cars driving on it. This design explored the potential of kinetic wearables, letting people express their style fluidly by customizing the movement of the little accessories to represent different aspects of themselves [86].

The designs we discussed thus far were not yet tested or embedded in social settings. However, they are good examples of wearables' broad potential for enhancing how wearers can express themselves and communicate with others when designs are infused with computational capabilities. Another design that explores the concept of attaching mechanical moving pieces to clothes is far more ambitious: The Butterfly Dress incorporates many small robotic butterflies, triggered by proximity sensors, that

Figure 2.4: Left: The Butterfly Dress. Right: The Robotic Spider Dress

can flutter on and off the wearer (see Figure 2.4-Left). The behavior of the reactive wings can change depending on the presence and motion of people nearby, making the dress socially interactive and an obvious conversation piece; they can also fly away from and alight on the dress. For performance's sake, the butterflies can also be activated remotely via mobile phone [107].

Now let's consider a luxurious feminine dress that starts to shake when someone touches it (see Figure 2.5) [44], or a feather harness that senses the wearer's heartbeat and then signals the stress levels of the wearer to others by ruffling its feathers [11].

Figure 2.5: Shiver 1 and 2 were presented at ISWC 2010. These garments represent an exploration of subtle haptic and kinetic effects: “Each garment responds to touch by reacting with a visible and perceptible tactile vibration response. The flowers of Shiver 1 respond to being touched by ‘touching back’ – each flower startles when the stamens are bent. When the sleeve of Shiver 2 is stroked, a gentle quiver propagates diagonally through the feathers of the skirt” [44].

Figure 2.6: The Social Body Lab of OCAD University. Activated by muscle contractions, this design augments the wearer's body language cues [68]

Such reactive designs could help wearers, for example, signal when they want others to keep their distance if they prefer to avoid physical touch or are open to starting a conversation.

Wearable designs could also involve other dramatic kinetic movement effects in their social signaling. For example, Monarch (Figure 2.6) is a shoulder harness wearable made of textile forms; wearers can intentionally activate the harness, using their arm muscles, to make it expand or contract [68]. The Monarch is designed to extend expressive body language cues to help wearers better physically indicate their "enthusiasm, excitement, assertion or aggression, flirtation or mischievousness" [92]. Another

Figure 2.7: This hat design by Sang Li is part of a project exploring way that clothes may express "the wearer's attitude directly without the concern of adhering to social conventions"[97].

interesting example is a hat with small fans that can fold and unfold (Figure 2.7). The fans react to the wearer's environment, changing their form in response to loud noises, bright lights, or other people coming too close. The hat's movements were designed to resemble people's bodily gestures when feeling uncomfortable, such as covering one's ears or face in embarrassment [97].

Some designs include social signaling that simultaneously expresses the wearer's emotional state (as read by biosensors) and senses and responds to the environments around the wearer. For example, the Robotic Spider Dress is 3D printed with mechanical limbs resembling spider legs and built around the wearers' shoulders (Figure 2.4-Right).

It has embedded proximity sensors and wireless biosignal sensors measuring respiration; these connect to Intel's Edison processors, controlling the limbs' movement. That movement not only expresses the wearer's emotional states but also responds to changes around the wearer's personal space by lashing out: "The dress is intended to not only inspire ruminations on the mechanics of outward interaction but also on the wearer's internal reactions to social stimuli" [48]. Other designers explored signaling to others to keep appropriate physical distance by using other methods, such as a dress (Figure 2.8) that lets its wearer inflate it to extend it further out from the body [3] or a coat that plays barking-dogs sounds from its embedded speakers as a response to changes in its proximity sensors [142].

Such designs illustrate how wearables can augment social signaling. Taken together, these designs show how expressive, far-out, and imaginative wearables could take many different forms; they also open new avenues for interaction. The majority of these designs have been one-offs or artful explorations. Because we haven't yet had the opportunity to evaluate such designs in real situations, worn by real people, we don't yet know if what they aim to express is understood by others. In order to glean real insight into how and why these wearables can enhance co-located social interaction, the designs need to be tested in a related social context.

Figure 2.8: The Space Dress inflates to signal to others the wearer prefers more space around them. Space Dress by Teresa Almeida, photos by Kate Kunath.

2.2 Area of value II: Intervening in the Social Situation Proactively

Social wearables can also intervene proactively in the social situation when the designs facilitate, encourage, or create new opportunities for people to interact with one another. These interactions could help create new social connections or enhance existing ones. In such cases, wearers might need to come closer, verbally communicate, and connect with others to make use of their wearables. Such designs are often made for multiple people to wear simultaneously and include clear guides for social interaction. This section explores how wearable designs use technology to encourage people to interact in ways ranging from playful games to pragmatic tasks, creative collaborations, to simple hugs.

By design, some wearables encourage people to come close and touch each other. Designers have experimented with social touch by creating pairs of wearables that can activate only when specific parts of the two designs touch to close a circuit. For example, the Hug Jackets (Figure 2.9-Left) are a pair of jackets with conductive fabric applique on both front sides; when the wearers hug, the circuit they close turns on lights and sound [117]. The Co-dependent Gloves (Figure 2.9-Right) similarly use the closed-circuit technique; when two different wearers hold hands, the glove begins to warm up, symbolizing the warmth in human connection [17].

These examples demonstrate how wearables worn by different people can include interdependent qualities. When interdependency is included in the design, one

Figure 2.9: Closing a circuit to facilitate physical social connection. Left: Hug Jackets; Right: Co-dependent Gloves.

person's wearable device will need the wearable of another person (or just another person's action) to make use of its interactive features. Such interdependent interaction suggests how wearable design can entice or reward social interaction. Games and play are an important lens here, as we see in Hotaru's wearable designs, which create interdependencies between players built in through the core game mechanics (Figure 2.10). Two players each wear different Hotaru wearables. One player wears a "tank" on their back and a glove and the other player wears a glove and a gauntlet. The first player collects energy by making certain gestures [2]; that energy turns on lights in that player's tank. The goal of the game is to transfer the first player's energy to the second, who releases it through a specific action; the players must complete this mission as many times as possible in a limited time window. But how? The players transfer energy by holding their glove-wearing hands. The second player releases energy with a quick upward arm gesture with their gauntlet-wearing arm, and a sound effect signals success [2]. This cooperative game, in which one wearable or player alone is insufficient, demonstrates how we can create interdependencies between wearers/players.

Another wearable example of play and games is Massage Me, an alternative video game controller in the form of a wearable vest that works only when two people use it, a wearer and a player (Figure 2.11). The wearer wears a vest, which is the video game controller, and the player controls the game by pressing on specific parts of the wearer's back. As a result, the wearer receives a light or deep massage, depending on how the player plays the game [108]. This example demonstrates the breadth of ways physical social connection could be incorporated into wearable designs, in a way that

Figure 2.10: Hotaru's wearables facilitate interdependence between players, and require physical social contact.

Figure 2.11: Massage me wearable vest is used to control a video game by massaging the wearer.

Figure 2.12: An Illustration demonstrating how the Nudgeables can work in the social space

can encourage people to interact with each other.

Now let's consider another type of design, in which wearers share control: The Nudgeables Accessory Kit. It is a "modular hardware kit for creating paired sets of wireless wearables accessories" [93]. The idea is that when partners are in the company of a larger group of people, they sometimes secretly want to communicate among themselves. With the Nudgeables, they can send and receive nudges secretly (Figure 2.12). The flexible design lets its wearers customize how to send the nudge to their partner (for example: press a button or pull a string) and what will happen when they send the nudge (a small vibration, a blinking light). As it is an accessory kit, the wearers have a lot of room to customize these options. The Nudgeable technology can also be embedded into pre-made accessories like ties, scarfs, pendants, socks, and so on [93].

Some wearables could be activated remotely by people who are not wearing the device themselves. For example, Xylobands™are bright radio-controlled LED wristbands that can be worn by large audiences to create stunning collective light shows. These wearables flash changing color patterns with LEDs, programmed to create a vast array of visual effects. The Xylobands™was invented by Jason Regler for the band Coldplay. In an interview, Regler recalls, "In 2005, when Coldplay did the Glastonbury Festival [...] there was just such a feeling of it bringing everyone together, as well as the line 'lights will guide you home.' That's when the idea of a wristband came to mind" [22]. These wearables have been used at events ranging from small weddings to large stadium concerts (Figure 2.13). These wearables are worn by the audience, but operated by someone else who controls all of them; from the wearer's perspective, they light up automatically, as they have no control over the activation. When synced with music, these lights can greatly enhance the aesthetic experience, but they also create a shared social experience, as the audience collectively shares the spectacle through wearing the Xylobands™. As Regler reflected, "It's amazing to hear the roar the moment [the lights] kick in at the start of each show" [22]. The visual effect is spectacular, but more importantly, when everyone at the event wears the same design it creates a sense of being part of a group; everyone who wears the bands contributes to that effect equally.

Many of the examples discussed showcased two people interacting through wearables. The example of the Xylobands™clearly demonstrates there is no limit to the number of people who could experience social wearables at a given time. Evaluating social wearables Many of the designs I surveyed in the previous section were not evaluated while being worn by people in a social setting. More practitioners are beginning

Figure 2.13: An audience of people at a concert wearing Xylobands™

to explore social wearables strategically while also considering real-world applications; such practitioners have also begun evaluating these designs with multiple people in social settings.

2.3 Ethical Considerations: Un-Surveilling the Body, Choice, Consent, and Social Acceptability

The investigation of social wearables is grounded in value sensitive design approach [52]. In this section, I dive deeper into design considerations and questions to think about when designing social wearables. It is important to consider the underlying design values and their accompanying ethical assumptions, as these may have a profound impact on how wearables shape social situations and dynamics. For example, considering the environment where interaction happens (the context), and how the wearable performs to the wearer and those nearby can greatly affect design decisions. As with any other technology, design decisions are loaded with trade-offs.

With social wearables, every design decision therefore should be considered from both the wearer's perspective and that of others around them. The guiding design values should be strongly human-centered in that design goals should first and foremost be to benefit the wearers and consider the wearables' impact on others. Designs should support people socially and emotionally by facilitating and encouraging prosocial behavior. However, being mindful of how much (human) energy a design requires is also important; designers must consider how much time and attention people need to spend in order to use a design. Here I present a series of key guiding questions to tackle a few of the above-mentioned ethical considerations:

What are the personal and social commitments that the wearables require? In other words: What degree of focused attention is required from the wearer and others? This could be described as a spectrum where low commitment is represented by wearables that do not require intentional effort from the wearer to activate and use them, such as automatic tracking of biometrics, gestures, or environmental changes outside the wearer's control. Such wearables do not necessarily detract from engaging in other activities or interacting with others. A medium commitment represents wearables that require some degree of an intentional effort to activate, but do not completely hijack the wearer's and others' attention and energy. Interacting with these wearables could coexist with other activities. These typically use inputs that can be provided while engaged in those other activities. High-commitment wearables demand all the interactants' attention, orientation, and energy, likely preventing them from engaging in other activities. These typically require concrete and specific gestures. Devices that require high levels of commitment to activate or interact with them could unwantedly detract from the in-the-moment co-located social experience.

However, if high commitment such as focused attention is required by both the wearer and others, or by both wearers, the wearables might foster a joint activity that supports relating. For example, screen-based interaction, now common with mobile phones and smartwatches, requires a lot of attention. It is hard to hold a conversation while responding to a text message or while reading a notification that just popped up. The phenomenon of people spending time with others while they are drawn away into their own personal screens even received its own term: phubbing. Researchers found that people perceive excessive phubbing as related to poor communication quality and relationship satisfaction [21]. If two people need to hug or hold hands in order to activate their wearable, or do other gestures synchronously (instead of staring at their personal screens in parallel), this could make them feel more connected in the moment and support them in relating to one another. These two types of interaction should be compared empirically and evaluated with people to glean more insights. It is therefore important to be aware of the amount of investment (of time and attention) the wearables require from the wearer and others and design this strategically.

Wearable designs (like other computational products) may include forms of data collection from the wearer, from their environment, and from other co-located people; such data may include biometrics, voice recordings, footage/videos, location, social ties, etc. It is extremely important from an ethical point of view to make sure that data-collection mechanisms are transparent, modifiable by the wearers, and designed to benefit the wearers. From a social responsibility lens, we suggest designs that explicitly aim not to surveil the body of wearers but to make sure designers, companies, and other stakeholders will not take advantage of the fact that devices are worn on the body. Designers must also consider questions related to choice and consent, such as the wearers' ability to customize the design and retain agency over its objectives. Guiding questions we should ask are: Can the wearer customize the sensing and/or actuation methods? Can wearers opt out, or make the initial decisions of what biometric data is collected? Can wearers choose where and how long data is stored and who has access to it?

Jarusriboonchai and Häkkilä found that creating mechanisms that let wearers customize wearables to fit their values and needs is important not just ethically but also for user experience. Giving users control can support a sense of ownership and strengthen identity. It can transform the sense of technology into "my technology" [84]. Jarusriboonchai and Häkkilä identified four main customizable attributes that could "address diverse needs and preference of users" [84]: (1) functional features, (2) interaction techniques, (3) on-body location, and (4) appearance. Empowering the wearer to customize their wearable and adapt it to their social situation and needs may not only allow wearers to express themselves but also support prosocial behavior and increase the acceptability of wearer use, all areas that demand further study in context.

Considering wearables' on-body location also raises ethical questions: Can the wearers modify or adjust it based on their social needs? Does the chosen location work towards bringing people together? Designers must consider the social and emotional impact of interacting with devices worn in particular body areas. Researchers studied a selection of on-body locations for wearables from the lens of social acceptability [148]. They mapped on-body interactions with wearables and provided body maps to show how people feel about them. They advise in general "to avoid touch-based interactions and displays within regions of the body associated with sexual activity or elimination of body waste. An exception would be if the wearable device were specifically designed to aid in sexual stimulation" [148]. The opportunities for novel on-body locations have not yet been fully explored. If wearables are to support a social experience, designers should ask: What is the best on-body location for it to work to enhance the interaction between people? Answering this question is not straightforward; it depends heavily on the intended interaction and the embodied experience. Using socially acceptable body areas for wearables can bring people together without requiring too much intimate contact. Still, designers must also consider complex sociocultural contexts, such as the difference in acceptability for touching certain body parts based on gender and in different cultures. In the next section, we will discuss the case study of the True Colors social wearables, where we will dive deeper into this topic.

Other considerations relate to the social environment, such as an interaction's social context and whether wearing the devices is socially acceptable. Considering the context of wearing a device is important. Still, we also should consider how the wearable is activated and responds, which can significantly affect how comfortable (or not) people would feel in a particular social environment. Certain gestures and ways users touch to interact with wearable technology could also lead to uncomfortable social situations. In one on-body gestural input case study, researchers found that people wanted to avoid “social discomfort” [43]; they preferred performing natural gestures that could blend in the environment rather than making awkward gestures. As a result, the researchers suggested that on-body interactions could leverage existing interaction with clothing to design more discreet and acceptable wearables. These results should be taken into account. Still, we should also remember that part of what drives and encourages the adoption of new wearables are the “cool aspects of wearing the device, and the novelty of the interaction” [43].

These findings mean that trying new forms of interactions and new body locations is good and valuable, but we need to be thoughtful in our design endeavors. There is room to experiment with different on-body locations and gestures because people are adaptable creatures, but we should evaluate designs with people before the designs become commercial products. We know that some designs are made to be worn in particular situations; for example, Massage Me is designed for playing a video game. Other wearables might be designed to be worn all day; Nudgeables could be worn around the office. It is critical to remember that what people find acceptable in one setting might not work elsewhere. Also, what is and what is not appropriate changes over time. For example, before hands-free headsets, people who talked to themselves with no one nearby were perceived as potentially insane; nowadays, it would not raise any eyebrows [124].

When wearable designs pass the experimentation stage and are being prepared for broader real-world deployment, there are further ethical considerations in the design and evaluation stages, including making sure the designs are accessible and inclusive. Universal design (UD) principles [111], for example, urge designers to follow principles such as Equitable Use, which means that people with diverse abilities could use it, and Simple and Intuitive Use, which means designing to make use easy for anyone regardless of previous experience, knowledge, or language skills. Also, we argue it is always best to account for the UD principle of Tolerance for Error, which means the design would "minimize hazards and the adverse consequences of accidental or unintended actions" [136].

2.4 Conclusion

In this Chapter, I presented the design framework for social wearables, consisting of the two value areas for design and a series of guiding questions to consider in the design of social wearables designs. The two areas of value in the social wearables design space show that the design of these wearables can build on what people do with nonverbal cues or fashion choices and prompt all-new interactions. How wearables could affect co-located interaction is still an underexplored research space, with little published work evaluating social wearables in action with groups of people.

The framework is based on surveying design work and some of my design practice. To understand how wearables work between people (their social effects), we need to evaluate the designs with people in relevant social environments when people use wearables with others.

When we design the future of wearable technology for the real world, we want to ensure that the designs are not causing harm to people. That said, there are benefits to designing and creating future wearables as a critique or a provocation–those engaged in critical design may intentionally include demanding (hard to ignore) or disrespectful devices to draw attention to elements people usually take for granted or try to ignore.

As we evaluate social wearables, key questions include: How many wearables are there? What is the interplay between them? Are the wearables being triggered in a way that relies on other people in the wearer's environment? Can people nearby even notice it was being triggered? If so, who notices it, and what should they do in response? Is it the wearer, others, or maybe both?

In the next Chapter, I present the social wearables case studies I developed with this framework.

Chapter 3

Practice-based Contribution: Social Wearables Case Studies

As Gaver argued, the design artifact is in itself “a theory nexus” because it embodies all the design choices, reveals issues of importance, and the ways the designers believed are best to address those issues [61]. Here I present the artifacts that sum up my practice-based contributions: the three social wearables artifacts I designed, developed, and evaluated in a social context. Each design research project culminated in publications and/or presentations at HCI conferences.

3.1 True Colors

3.1.1 Description

In the True Colors project, I explored how wearable technology could enhance the social experience in a larp, concurrent to developing the design framework for so-

Figure 3.1: Augment players in New Gyr larp interacted with other player characters.

cial wearables (Chapter 2). I initiated and led this project by creating a collaboration between Event Horizon (EH), a larp production team, Isbister, and colleagues from the Social Emotional Technology Lab at the University of California Santa Cruz.

I engaged in a three-month co-creation process building on the expertise of EH designers. This process culminated in producing multiple copies of the True Colors social wearable prototype (see Figure 3.1 and 3.2), deploying it at an in person larp event (lasting four days), and studying the players who wore or interacted with it.

True Colors had many interactive features. It supported different social interactions, ranging from friendly to more confrontational. For example, wearers could use the device to 'stun' other players in the game. Still, at times their wearables 'over-loaded,' and other players could interact with the design to help (I will describe the different afforded interactions in more detail in the next section).

While the front interface was designed to be used by the wearer– empowering them to initiate action– the back was designed for others, divesting the wearer of complete control. In-game, this could have a positive or negative effect (see Figure 3.4).

The design of True Colors reflected and leveraged physical and social bodily practices, such as social touch for comfort and bonding [14].

The contributions of this work are twofold. First, the design artifact had novel interactive features designed for the wearers' use and for other people in the social environment. It is an exemplar of social wearable design. Second, the RtD process led to conceptual contributions: I used my practice during the RtD process to inform the design framework for social wearables, which I developed concurrently; and evaluating the True Colors in a relevant social environment resulted in identifying "vulnerability" as an experiential quality for design.

The True Colors project was published at CHI 2019 [34], and I demonstrated the design prototype at UBICOMP/ISWC 2019 [29].

3.1.2 Prototype Design

The prototype design process was iterative: I designed the True Colors social wearable for one of EH's larp events. This event was created around New Gyr, a sci-fi story that explores life in a fictional galaxy. The New Gyr event was based on an

[14] See the video here: https://www.youtube.com/watch?v=BBAlV4MCY04

Figure 3.2: I created 15 copies of our prototype so we could test it with multiple people simultaneously.

Integrated larp experience, a style of larp that draws elements from Nordic larps[15] –it is typically non-competitive and very character-driven. It balances "story, emotion, and mechanics while emphasizing collaboration and community building" [56]. In New Gyr, "some players go for a light-hearted and casual experience, while others dive into politics, drama, and life-altering situations" [55]. New Gyr's larp backstory included four main types of characters. These characters were referred to as "human variants" and included: (1) regular Humans, (2) Evos– humans with altered genomes, (3) Androids– who are artificial intelligent agents, and (4) Augments.

I extensively reviewed the documentation about New Gyr larp before creating the initial prototype. This prototype was worn around the upper chest area on its front side and lay on the shoulders and upper back (see Figure 3.3-Right). It was easily secured to the body by bending it to adjust its wire structure to fit flexibly onto various shoulder sizes.

Then, I held a bodystorming session (as described in Chapter 1.2.2) with the research team and one of EH's designers at the site where the larp event would be hosted. During that session, I used this prototype as an interactive boundary object [134, 95]. The session involved co-designing play-based activities with the EH designer, to generate movement-based play mechanics. The session also served as a sensitizing experience for us– it made us more aware of our felt bodily experiences, which helped our thinking about those who would use the design in the larp.

[15]"Nordic-style larp, or Nordic Larp, is a term used to describe a tradition of larp game design that emerged in the Nordic countries. Some aims and ideals typical for this unique gaming scene include immersion, collaboration and artistic vision" [144].

Figure 3.3: Left: visiting the site where the New Gyr larp event was planned to take place.; Right: We used the initial prototype of the True Colors social wearable design in the bodystorming session on site.

That situated bodystorming session revealed the potential needs and design opportunities. For example: enhancing the narrative and improvisational aspects of the game, exploring identity expression, and supporting individual and collective action. More concretely, from the situated bodystorming session on site, two important play mechanics emerged: showing and disguising affiliation/identity using the wearables' lights and triggering uncontrollable "breakdowns."

In addition, during the same bodystorming session, we learned more about the New Gyr larp backstory and some of its characters. We learned that some characters were called the Augments, which would fit most as our target group for the social wearables. In the story, the Augment characters were humans who turned to technological augmentation to improve their bodies. In New Gyr, Augments were unpopular among other human variants, often looked down on as a low class, and treated poorly. This

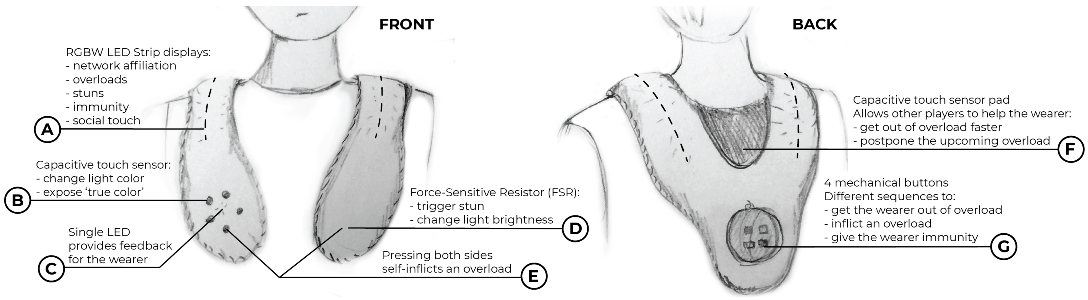


Figure 3.4: True Colors social wearable design, including functionalities and hardware components.

narrative led to painful tension between most Augments and the other human variants. Humans in the New Gyr story would become Augments for health or practical reasons. Their augmentations were extremely expensive and often financed by big corporations, for whom many Augments worked to pay their debt. Augments needed to connect to an Augment Networks (AugNets) controlled by one of the three big corporations to keep their software updated. There were, therefore, three AugNets. In New Gyr, the AugNet a player was part of defined their in-game community.

Thus other players could make assumptions about the Augment's loyalty and "political" affiliation in New Gyr based on their AugNet light colors [34].

The situated bodystorming exploration resulted in additional design modification. We used these insights to improve the design in the second prototype iteration. For example, we added sound effects for more legible feedback. Visiting the site in person helped inform our team of its topography and expected weather. I learned that it is often foggy and cold and that larp players typically play outdoors. To improve the design, I adapted the wearable form factor to be more extensive, robust, and flexible so it would fit on top of warm jackets and adapt well to dynamic play actions, like potential game fights.

The initial prototype had an interactive pad at the back of it. We revised it and gave it a social functionality– it became usable for decreasing the duration of overloads.

In the New Gyr larp world, Augments suffer from inevitable, incapacitating periodic "overloads" of their augmentations. The larp designers expected these overloads to be roleplayed through significant trouble moving and great pain until the overload ends. Short, sharp sound effects signal an overload's beginning and end, evoking a sense of urgency and danger. During the overload, which lasts 4 - 6 minutes, the wearable flashes red lights, similar to emergency vehicles such as ambulances. The frequency of these "naturally" occurring overloads depends on the quality of the augmentation, determined based on the Augment's character sheet. Overload intervals, ranging from 1.5-2.5 hours, were pre-programmed before the larp event. The Augment player can also trigger an overload by pressing both sides at the front of the wearable (Figure 3.4 (E)). Designers included this option if players wanted to trigger an overload to support their role-playing in particular scenes. Other characters, known as Augment Engineers, with hacking or mechanical skills could also trigger overloads by inputting a code (provided by larp designers to selected characters) through the keypad at the back (Figure 3.4 (G)). Clicking on the keypads emitted sounds, which could alert the Augment. Finally, performing "stun" attacks increased the likelihood of suffering an overload. This was implemented through a counter that tracked the number of stuns one performed. Also, we added the back to include a keypad that could trigger instant overloads with a specific

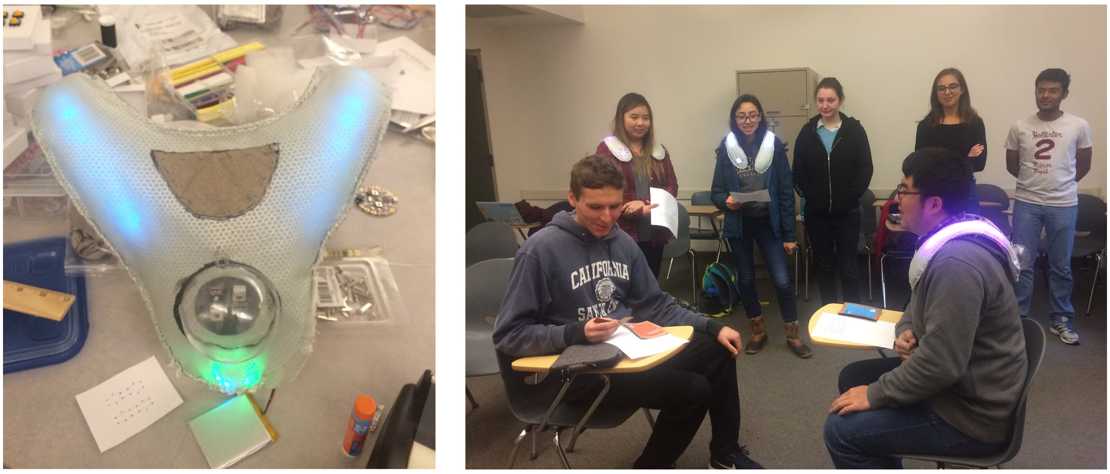


Figure 3.5: Left: The second design iteration of the True Colors protoype; Right: Picture from the playtesting of the second prototype in a Human-Computer Interaction graduate class.

sequence of button presses.

In a subsequent hybrid meeting with the EH team, we used embodied sketching [106] with our second prototype (see Figure reffig:TC-second-Left) to enact potential interaction scenarios and mechanisms for the larp. Among a few options, EH designers selected a timer to trigger the overloads.

Using our prototype, we identified three potentially engaging game scenarios: first, using social touch to prevent or alleviate the Augments' overloads; second, the idea that specialized players with skills could influence actions on the wearable, such as fixing or triggering Augments' overload (see Figure 3.7); and third, developing an action EH designers called the "stun" attack that could align well with the Augments' backstories of heightened physical skills.

Next, I created three additional prototypes of the design. With these prototypes, we implemented these interactions to explore implementations of the game sce-

Figure 3.6: Photos from the New Gyr larp. Left: Player acting as the Augment character, with their True Colors wearable displaying static ‘immunity’ colors; Right: Player wearing device displaying rainbow colors as a result of another player interacting with the back of the device to heal them from the ‘overload’ breakdown.

narios by playtesting them in a Human-Computer Interaction graduate class (see Figure 3.5-Right). The playtesting feedback provided the usability insight we needed before polishing the final design (e.g., adding sound effects as feedback for button presses). We incorporated the feedback and created 15 new models of the prototype’s final design for the New Gyr larp event (see Figure 3.2). Right before the game, we customized the code of each model further customized based on the individual Augment players’ character sheets EH designers developed to match the specifications of each Augment character in-game AugNet affiliation. Each had its specific “true color” light color, and a specific “quality.” The augmentation quality was reflected in the frequency and duration of the prototypes’ overloads.

We included several touch-capacitive sensors that we mapped to simple LED light array behaviors in the design. We designed the front capacitor to be used by the wearer to change the light color and brightness they displayed. The light color symbolized their AugNet's affiliation. With this interaction mechanic, they could display the "real" affiliation (i.e., their "true color") or deceive by displaying a different AugNet color or a neutral white color.

I placed another capacitive sensor on the wearer's back between the shoulders. I made this capacitor with conductive fabric. When other players touched it, it triggered an animated rainbow light effect (see Figure 3.6). With this interaction design, we aimed to mirror how people sometimes support others, for example, when putting a hand on someone's shoulder or back to comfort them. When others touched the pad, it postponed the occurrence of the subsequent overload and shortened the length of time an overload was running.

Finally, the design easily stayed in place and could have been pulled on or off without a buckling or fastening mechanism (see Figure 3.7). More details about all the functions and interactivity of True Colors, the in-game actions and meaning, the out-of-game technical detail, and the roleplaying instructions can be found in the CHI 2019 paper [34] and in the Appendix B.

3.1.3 Study and Results

To study the effect of True Colors social wearables, we deployed 15 copies of the prototypes in a four-day larp event organized by EH. One hundred and nine people participated in the event. Of them, 91 participated as players, 13 of which participated as Augment characters and wore the True Colors design (see Figure 3.1). Another 15 people were non-player characters or staff. Finally, I and two others from my research team participated in the larp event.

The EH larp designers created non-player characters for us to roleplay that matched our out-of-game intention to research the use of the wearables: Humans who were developing and researching the Augment technology in New Gyr. Participating in the larp in character as researchers allowed us to observe, take notes, and document the event without interrupting the players' immersion.

On-site, before the game began, our out- and in-game roles were explained and introduced to all players. Then, we held a briefing session with the Augment player characters and with other players who closely interacted with them in the game. We explained and demonstrated the design features and handed out flyers summarizing their uses and answering questions.

On the event's last day, we conducted 18 semi-structured interviews with all the participants who played the Augment characters and other players who interacted with them. Finally, on the last debrief lunch of the event, we distributed a printed questionnaire with 15 open-ended questions to all players. By the end of that day, we had collected 72 completed questionnaires.

To synthesize the data collected, I applied thematic analysis. I transcribed all the interviews and organized the data in a shared drive, including our field notes and questionnaire responses. Three researchers worked on coding the data individually, and then we met to discuss our codes.

In the interviews, players emphasized the social value of experiencing vulner-

Figure 3.7: Players in New Gyr enact a scene of an Augment Engineer healing an Augment from their breakdown overload.

ability together. The interviews and our observations also revealed that True Colors' breakdown and healing features were most meaningful to the larp participants because they encouraged caring. For example, Augment Engineer characters rarely charge money for their service to heal with the override code, although that was expected of them in the game. Instead, they often rushed to the scene to "fix" the Augments and relieve them from their "overload breakdown" (see Figure 3.7). We were also surprised that the Augment players avoided using the combative possibilities of True Colors (like the "stun" feature) and instead focused on the opportunities the devices afforded for engaging in collaborative and supportive social encounters.

The New Gyr players appreciated the healing function that allowed Augments and other players to care for Augments other from three perspectives: (1) from the wearer's perspective, Augment players enjoyed asking for and receiving care; (2) from the spectator's point of view, players (other than Augments) enjoyed watching Augments being cared for; (3) from other players' perspective, it encouraged them to care of the Augment wearers of True Colors in the game, and provided them with an actionable way to do so [34].

The results of the True Colors study suggest that wearables designed with interactive features geared towards the wearers and other people may be beneficial when intending to support and encourage co-located social experience. In Chapter 4.2, I discussed the main conceptual outcome of this study, identifying the experiential quality for design– including "vulnerability" strategically to support co-located social interaction.

3.2 The Lågom Social Wearable

3.2.1 Description

With the Lågom project [38], I explored social wearables to learn how wearable technology could be used to support the goals of a group. I focused on a commonly occurring situation of people having a group discussion. In these situations, people often find that not all participate; some are more dominant and take over the stage. To support people in these situations– encourage those who participate less to participate more, and grow awareness in people who dominate discussions– the Lågom social wearable provided individual feedback and feedback to the group.

Figure 3.8: The Lågom design prototypes are used in a group discussion. Left: demonstration of use; Right: Four of the prototypes.

My intention behind the Lågom design was to enable people to be more aware of and better regulate their verbal participation in group discussions. With the Lågom, I tried to help each wearer balance how much they verbally contributed to a conversation towards an end shared goal of having all participants of the group discussion share relatively “equal” time of the speaking stage (see Figure 3.8). The design tracked how much each person was speaking by picking up the change in sound levels of their voice. It gave wearers discrete gentle haptic feedback if they spoke quite a lot. It also included visual feedback for the rest of the people in the group by lighting up.

I studied the design in a social context by collecting feedback from nine external users on the prototype. To introduce the design and its function in the discussion, we created a backstory for Lågom. We introduced it as a flower species that fed upon its wearers’ voices and thrived when there were balanced conversations (in terms of how each person verbally participated).

I was interested in people’s opinions about having their verbal participation monitored, displayed, and represented to them and about the feedback modalities chosen. I wanted to know if this feedback impacted their and others' participation in a discussion and if they thought a wearable device like Lågom could increase their awareness of participation and help them modify it.

The contribution of Lågom is the novel design artifact and conceptually considering wearables from an individualistic perspective when embedded in a social context–exploring interaction design that combined feedback mechanism that was both visible and discrete. I Integrated these considerations into the design framework for social wearables, which I developed concurrently with the RtD process of Lågom. Lastly, I presented the Lågom project at CHI 2018 [38].

3.2.2 Prototype Design

Over three months, I engaged in the RtD process to develop the Lågom prototypes. Our team met regularly to discuss and brainstorm aspects of the design. Several times, I iterated the initial prototype by exploring different feedback modalities, vibration patterns, and input sensibility through playtesting during in-lab group discussions by lab members and guests. Following the playtests, I refined the design's interactive features.

To prototype Lågom, I worked with Adafruit's Circuit Playground (CP)[16]. I used its ten built-in LEDs as visual feedback and added a single vibration motor for the haptic feedback. I also added an external microphone for improved audio recognition.

[16]https://tinyurl.com/96pwna7w

The CP recorded the length of time wearers spoke (without capturing their actual voice or speech content). If wearers wanted to compare or discuss their participation levels at the end of the discussion session, they could display the percentage of time they spoke. To do so, they could manually press the CP's built-in buttons, which triggered the LEDs lights to reflect a mapped percentile (e.g., two LEDs would reflect approx. 20% of the speaking time).

The device was designed to be worn like a brooch around the lapel area for several reasons: technically, the microphone required direct orientation toward and close distance from the mouth; the haptic feedback was intended to be felt close to the shoulder to emulate a tap-on-the-shoulder-style reminder; and the visual output needed to be in proximity to the speaker's face/chest area so that others focus on the device would not impede the simultaneous monitoring of the speaker's gestures while speaking. This shoulder and the higher chest area are appropriate locations for wearable feedback [148] and for external attention (e.g., frequent areas for jewels and fashion adornments, such as shoulder pads).

I created seven functioning wearable prototypes of Lågom with only slight formal changes (e.g., the color of the flowers and bugs that camouflaged the vibrating motor). The Lågom aesthetic was inspired by the water-squirting flowers that clowns sometimes wear. One of the study participants described the final design as "a colorful, bulky, and funny looking flower that senses the wearer's speaking and responds with haptic and visual feedback" [38].

I placed the microphone at the center of the flower– the petals helped improve

Figure 3.9: I studied Lågom with nine participants divided in two discussion groups.

the filtering of other noise. I created a flexible stem that lets wearers direct its microphone to their mouths. Playfully, I covered the vibration motor with an insect (e.g., ladybug) detail. I covered the CP with brown felt fabric like a plantar. The LED lights were shining through it.

My intention with the Lågom design was to create them as playful objects to make engaging with them more joyful and to ease potential related social-pressure stress.

3.2.3 Study and Results

I studied the Lågom prototypes with nine participants by holding two group discussions (Group A, and Group B) (see Figure 3.9). Participants were shown how to wear the device and were helped to affix them when necessary. I also explained the feedback Lågom would provide.

I developed a within-subjects type study design: Group A discussed Paper 1 while wearing the Lågom prototypes and discussed Paper 2 without them. In contrast, Group B discussed Paper 1 without the prototypes and Paper 2 with them. Both groups discussed the two papers following the same protocol: a summary of the paper was read out loud by all group participants (a segment by each participant). A discussion about the paper followed this. I used the summary phase to ensure all the prototypes were working correctly. After that, the prototypes were reset to start recording participation time. The total discussion time while wearing the devices was five minutes long.

At the end of the sessions, I asked participants to complete a short open-question survey (e.g., "What were the main noticeable differences between the discussion sessions?"). I then conducted follow-up interviews with seven participants to triangulate their responses.

The study results suggested that devices such as the Lågom design can influence discussion through participants' self-awareness and may help them regulate their participation. For example, some said it encouraged them to participate more in the discussion: "It made me more aware of something I do all the time, and this made me want to do it better (be more confident, loud, assertive - which I often have trouble doing, especially as a feminine - socialized person)" [38].

Finally, the participants liked the flower backstory. For example, one participant thought wearing Lågom contributed positively to the group's togetherness: "it felt like we were more connected due to shared simultaneous experience" and liked the idea "of having a little plant to 'care for' in that way" [38].

The RtD process and evaluation of the Lågom prototype happened concurrently with the development of the design framework for social wearables (Chapter 2). Additionally, using a backstory to contextualize the design playfully inspired my subsequent social wearable design exploration of the Robo-Shoe-Flies case study, which I described next.

3.3 The Robo-Shoe-Flies

3.3.1 Description

In this project, I applied the design framework for social wearables [36] by using questions from it to guide the design process. Similarly to the Lågom design, the Robo-Shoe-Flies is a social wearable design with a backstory. However, with its backstory, I framed the design as an ecosystem of on-body companions in which Robo-Shoe-Flies 'need' movement and social interaction with other creatures of their species occasionally (see Figure 3.11). The Robo-Shoe-Flies are worn on people's shoes. These on-body "companions" signaled to their wearers using sound effects and LED light-animation when they 'needed' care (see Figure 3.10).

While brainstorming this design, I came up with the idea that these wearables would be used in an office or a desk job-like setting (pre-COVID-19)– where people usually spend time sitting in front of a computer. At the time, I theorized that having such an external trigger to care for the on-body creatures might encourage wearers to socialize with others in their environment.

Using the backstory of creatures in 'need of care' allowed me to define the specific activities that would count as caring in the interaction design. By design, I selected activities strategically to be things people may value as meaningful and positive for their wellbeing (e.g., taking breaks to socialize, moving, or standing up after long

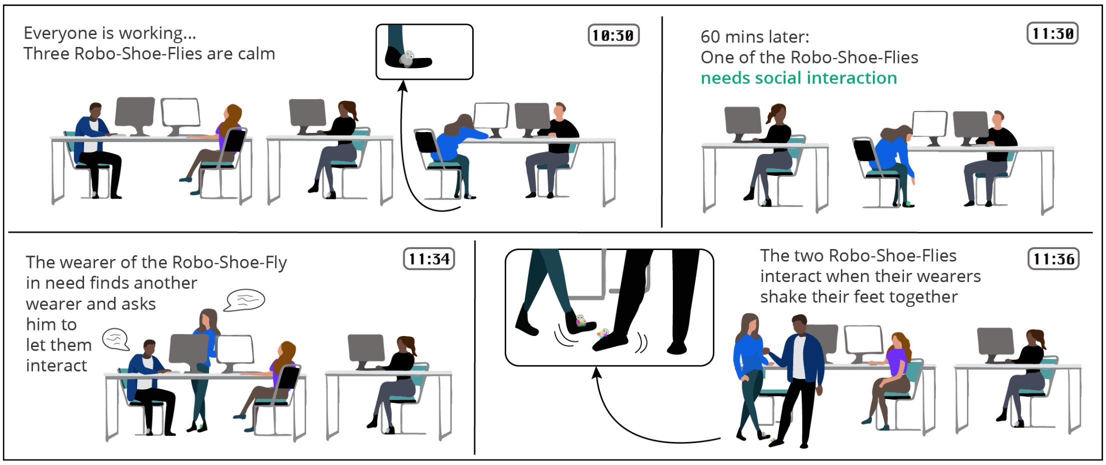


Figure 3.10: This illustration demonstrates the interaction with the Robo-Shoe-Flies wearables.

hours of sitting down). I tried to leverage the design as a facilitator–serving its wearers with a potential short social 'brain break' from their work.

The contribution of the Robo-Shoe-Flies project is the novel design artifact and the insights from its preliminary study. The design adds conceptually to social wearables by suggesting a new approach– developing designs with 'needs' to promote positive activities, such as engaging in social interactions and physical movement.

I presented this project at CHI 2020 [32]. As a result of the RtD process of this design, I arrived at the intermediate level knowledge contribution, the Synergistic Social Technology (SST), a strong concept for design outlined in a full paper (see [33]), which I discuss in Chapter 4.1.

Figure 3.11: The Robo-Shoe-Fly social wearable creature gets worn on the right shoe.

3.3.2 Prototype Design

I initiated working on this project while I mentored four high-school students[17] who worked with me as research assistants over their 2019 summer break (more details about the design process can be found in Chapter 5.1).

Building on my previous work with Lågom [38], I wanted to explore further the design process with a *fictional backstory*. The idea of the wearable prototypes as 'creatures' with 'needs' emerged organically as we brainstormed interactions. Once we settled on this backstory, I asked the group to create mood boards individually on

[17] They participated in the Science Internship Program (SIP). This program "provides motivated, advanced students with a unique opportunity to work and learn at a premier research institution. SIP is a summer-long (10-week) research internship program for high school students in STEM fields. UCSC faculty, graduate students, and post-doctoral researchers provide one-on-one mentoring for these high-school interns. The research projects are real in that they are not made up just for the high-school students; instead, students are inserted into existing research projects here at UCSC." https://sip.ucsc.edu/about

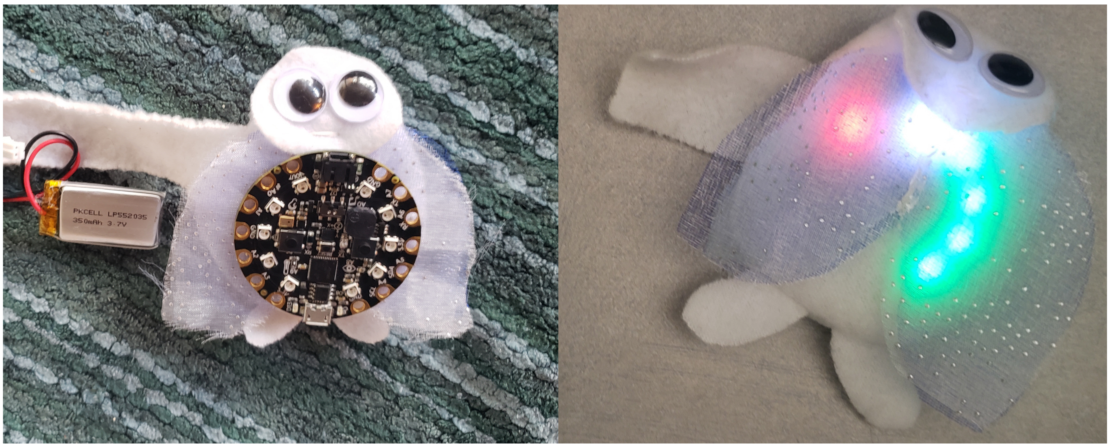


Figure 3.12: Left: The design fits the CPX board and battery; Right: the Robo-Shoe-Flies could light up to show how many times they received (green lights) or not (red lights) the interactions they 'needed.'

Pinterest[18] to inspire the characteristics of the creatures. Then, I integrated the mood boards. We individually sketched out ideas until we settled on one design to prototype.

Inspired by the selected sketch, I made a template pattern to use as I created seven copies of a soft covering of the CPX and the lithium battery (see Figure 3.12). I gave the design a creature-like expression by attaching googly eyes to make a 'face,' and adding two feet. Using three layers of soft fabric to create the wings, I added texture and volume to its aesthetic.

To develop the interaction between the creatures, we utilized infrared (IR) and acceleration sensing–when a creature sensed that it was being shaken (through changes in the accelerometer data), it sent IR signals. Then, if another creature was nearby, it could receive the signals. We used the CPX board's built-in LED ring for visual feedback and its speaker, accelerometer, internal clock, and IR sensing capabilities to

[18]https://www.pinterest.com

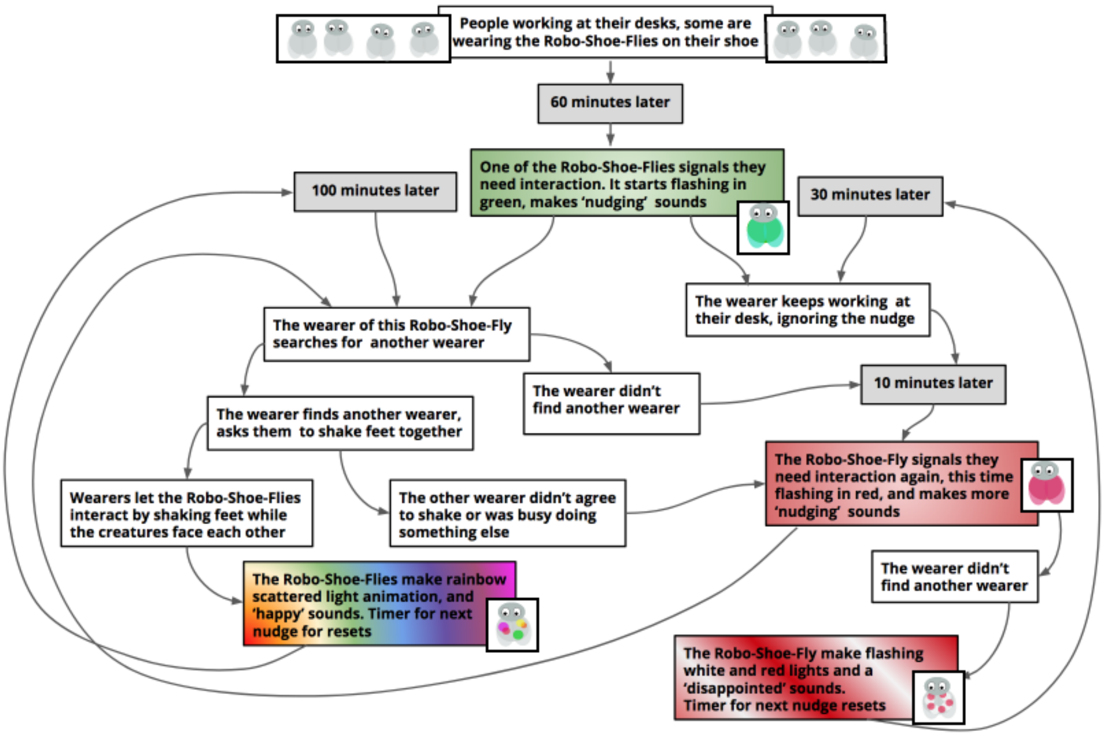


Figure 3.13: This diagram describes the programmed interaction-flow with the Robo-Shoe-Flies.

create interaction among the creatures and their wearers.

An internal timer in the wearables triggered these signals of change in the creature's state. This timer interaction strategy resembled other technologies that use notification methods (e.g., push notifications when receiving text messages) to nudge people to use them. When the creatures would signal, wearers were supposed to care for them. Wearers could find another person who wore a Robo-Shoe-Fly and let their creatures interact. When wearers shook their legs, the CPX detected the changes in IR sensors and accelerometer data, updated its state, and triggered the interaction feedback. Figure 3.13 presents the interaction flow.

3.3.3 Study and Results

The Robo-Shoe-Flies design was created for an environment where some people would wear it and others would not. Since it had expressive feedback, such as light animation and sounds, people not wearing it could have also been affected.

I evaluated the design with 13 participants; in three groups of two to seven people (see Figure 3.14). Participants wore the Robo-Shoe-Flies design over 5-7 consecutive hours. After experiencing wearing the Robo-Shoe-Flies and interacting with others using them, I conducted semi-structured interviews (approx. 20 mins) with all the participants. I collected anonymous responses from an online questionnaire to triangulate their feedback.

I transcribed all the interviews. Then I annotated the transcription with comments. I analyzed the data by clustering the participants' responses in the transcriptions and questionnaires into emerging themes. The results suggested "that wearing the creature encouraged them and gave them external reasons to socialize" [32]. The study revealed that wearables could encourage or direct their wearers towards social interactions to satisfy wearers' personal goals and facilitate interaction that benefits others, too.

Some participants expressed how they felt dedicated to caring for their creatures, individually and collectively. They noted a shift in their mindset from focusing on themselves to caring for their wearable creatures. The Robo-Shoe-Flies case study demonstrated how the design of a social wearable could engage wearers in experiences

Figure 3.14: I made seven copies of the Robo-Shoe-Flies and tested it with groups of participants.

that require them to focus on something "beyond themselves," through "a low stakes dependent relationship" [32].

The backstory of the Robo-Shoe-Flies prototypes and their timer-based interaction created an external trigger to socialize. Study participants said that the creatures signaling their 'need' automatically triggered something that felt like a call to action. As part of its core interaction design, the prototype incorporated caring behavior, which came with a clear guide for interacting and socializing with others around the wearables. This turned out to be a valued strategy. Some participants described it as giving them "a sense of purpose" for the day [32].

Additionally, the study suggests another interaction opportunity related to interdependent design: A reciprocal interaction between wearers. In this type of interaction, one wearer helped another wearer when their device (i.e., their 'creature') required interaction. Then at another time, the roles were reversed [32].

The RtD process and evaluation of the Robo-Shoe-Flies resulted in conceptualizing the synergistic social technology (SST) as a strong concept for design [73]. I will explain this concept more deeply in Chapter 4.1.

3.4 Conclusion

In this Chapter, I summarized the design research case studies encompassing my practice-based contributions. I described aspects of the RtD process of the prototypes' design and highlighted key findings from studying these designs in a suitable social environment.

While developing the design framework for social wearables [36] described in Chapter 2, I designed, developed, and prototyped the True Colors and Lågom designs. Therefore these two projects both informed and were informed by the framework. The Robo-Shoe-Flies is a social wearable design I developed by applying the framework in my practice. It demonstrates how using the guiding questions in the framework early in the design process and utilizing bodystorming can elicit novel interactions and design concepts.

Chapter 4

Conceptual Contribution II: Encouraging Social Connection Through Wearable Technology Design

Here I share conceptual contributions that emerged after developing the design framework for social wearables (Chapter 2). First, I present *synergistic social technology* [33], a strong concept for design that I developed in the process of designing and evaluating the Robo-Shoe-Flies design (Chapter 3.3.3). Next, I present the experiential design quality of *vulnerability* [34], which was identified during the analysis of the True Colors case study (Chapter 3.1).

I describe how I generated from these RtD projects intermediate-level knowledge contributions, which could be used to inspire practitioners and researchers in their work.

4.1 Synergistic Social Technology: a Strong Concept

4.1.1 Overview

My goal to enhance people's experience of interactive technologies by improving design practices that promote community and connection among users led me to develop the Synergistic Social Technology (SST) strong concept [33] (see Figure 4.1). This concept was born from the insights gained during the Robo-Shoe-Flies RtD process, as detailed in Chapter 3.3.3 [32].

A 'strong concept' for design is an intermediate-level knowledge contribution [100]. Höök and Löwgren suggest a focus on intermediate-level knowledge that is generative, such as "knowledge that plays a direct role in the creation of new designs" [73]. They proposed a strong concept to ground design ideas; strong concepts should ground ideas vertically, through comparing and contrasting with related systems, and horizontally through discussing related theory to inspire practitioners in their work [73].

Höök and Löwgren proposed to distinguish strong concepts in interaction design by the following characteristics: "It concerns the dynamic gestalt of an interaction design, that is, its interactive behavior rather than its static appearance; It resides at the interface between technology and people. It is a design element, a potential part of an artifact, and at the same time, it speaks of a use practice and behavior unfolding over time; It carries a core design idea which has the potential to cut across particular use situations and perhaps even application domains; It resides on an abstraction level above particular instances, which means that it can be realized in many different ways

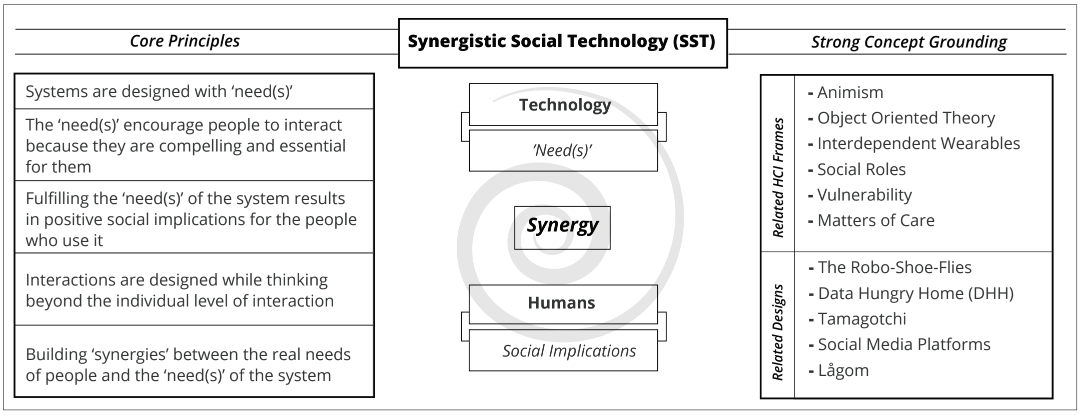


Figure 4.1: The figure presents the SST core principles and their related horizontal and vertical grounding.

when it comes to interface detailing" [73].

During the brainstorming stage of the Robo-Shoe-Flies design process, I had the insight that I could position the technology as needing care. Not just care at an individual level but at a collective level across devices and multiple users. Then, when I evaluated the design with people in a social setting, I found that this care may help foster connection and community among people who engage with the technology.

The SST strong concept suggests that when technologies have their own 'needs' for interaction, this could motivate people to engage with the tech. It could also, and perhaps more importantly, engage people to interact with others synchronously and collaboratively. Then, when the technology meets its 'needs,' end-users benefit from social interaction, hence the synergistic-social quality. The SST concept is comprised of five core principles:

1. Systems designed with 'needs.'

2. The ‘needs’ encourage people to use the system to interact.

3. Fulfilling the system’s ‘needs’ results in positive social implications.

4. The interactions are designed while thinking beyond the individual level.

5. Building ‘synergies’ between real human needs and the ‘needs’ of the system.

4.1.2 Identifying the Synergistic Social Technology as a Strong Concept

I followed the theoretical framing of strong concepts described as “design elements [that are] abstracted beyond particular instances which have the potential to be appropriated by designers and researchers to extend their repertoires and enable new particulars instantiations” [73]. To articulate SST, I took a few steps. First, I defined the strong concept; second, I grounded it *horizontally* in the context of related HCI theory; third, I included the design-focused observations that inspired the concept development (based on the Robo-Shoe-Flies RtD study); finally, I grounded the concept *vertically* by relating it to other systems.

4.1.3 The Synergistic Social Technology’s Core Principles

The core principles of the SST emerged from the RtD process of the Robo-Shoe-Flies. In Figure 4.2, I outlined how its system design is connected to the design dimensions I identified while synthesizing the case study’s findings. Then I drew the connection between the design dimensions and potential design implications. These

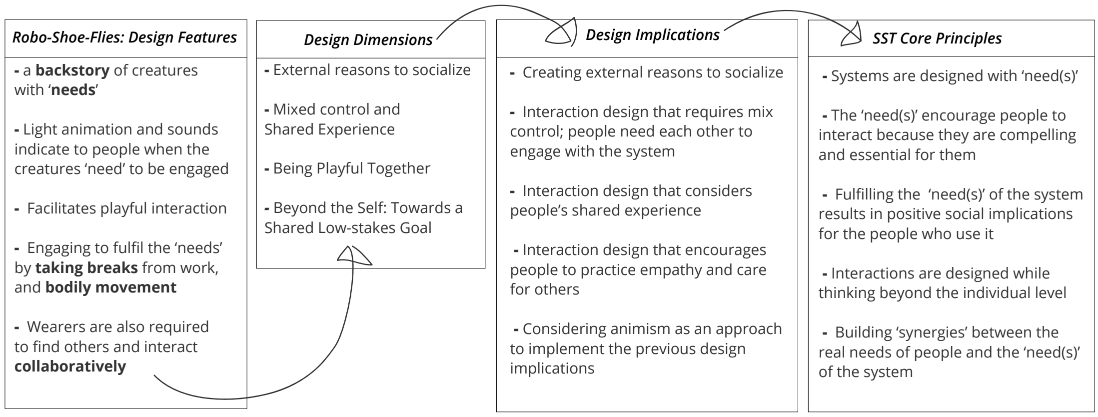


Figure 4.2: The figure describes how the SST principles emerged from the Robo-Shoe-Flies RtD process.

implications were the foundation for developing the core SST principles.

As mentioned in Chapter 3.3.3, the Robo-Shoe-Flies social wearable design had a fictional backstory of creatures who dwell on people's feet and 'need' to interact with other creatures of their species by moving together. This framing story of creatures with 'needs' enabled designing the interaction around a simulated inner life. This suggested to the users compelling and essential interactions. The framing story created synergies between the system's 'needs' and people's (presumed need) to engage in social interaction.

The framing story created *an external reason for the wearer to engage with it and with other wearers*. The 'needs' of the creatures provided an external reason for wearers to socialize as the system suggested wearers work with others towards a shared goal. This is also related to the concept of *interdependent wearables* [80]: wearers were keener to interact with each other because they needed others to help them care for their wearable creatures. The *mixed control supported a shared experience*. Caring for their creatures together created a pre-agreed-upon invitation to interact. It also had socio-spatial implications as it encouraged wearers to move closer in their space toward each other, impacting the proximity between them.

The Robo-Shoe-Flies system design introduced a synergy between the creatures' social 'need' and its possible effect on wearers' social interaction. It focused the interaction *beyond the individual* and *towards a shared low-stakes goal.* Participants expressed how they felt dedicated to caring for their creatures– individually and collectively. A relationship formed between each wearer and their creature: the wearer cared for their creature while the creature supported them to engage in presumably beneficial activities. It created a combination of the caretaker with an assistant/companion relation paradigm [40].

The Robo-shoe-flies also shifted participants' mindset from focusing on themselves to caring for their companions. Another relationship formed between the wearers, who, together with others, became one community of people who collaborated to fulfill their creatures' needs. The wearers became a small community of carers who could benefit from their shared responsibility. They coordinated their actions towards a shared goal to satisfy the needs of their creatures.

In the following section, I present how I came to identify 'vulnerability' as an experiential design quality.

4.2 Vulnerability: an Experiential Design Quality

4.2.1 Overview

Experiential qualities represent a type of abstraction consisting of intermediate-level knowledge that pertains to people's experience of interacting with an artifact (a product or service) instead of elements of the artifact itself [99, 100]. Similarly to strong concepts, experiential qualities are design elements that are abstracted beyond particular instances and reside in the intermediate-level knowledge space [73].

However, differently than strong concepts, experiential qualities are focused on the users and their first-person experience of interacting with a design and do not necessarily reside at the interface between technology and people. Experiential qualities do not need to be situated in the context of related HCI theory (i.e., "horizontal grounding" [73]), compared to other systems (i.e., "vertical grounding" [73]), and include "a core design idea" [73] that would potentially influence different situations cutting across application domains.

Interestingly, *vulnerability* as a design quality is rarely embraced in technology design and HCI. Traditionally HCI has focused more on reducing human vulnerabilities with the notion that "technological innovation could confidently resolve any social issue" [85], and we find "technological fixes" (Winberg cited by [85]) that systematically try to "solve" the vulnerability issue in an attempt to make us feel safe, strong and protected.

Vulnerability is a common experience in everyday life: people deal with uncertainties, risk, and emotional exposure in diverse life arenas. For example, when presenting ideas at work meetings; when engaging in leisure activities; when initiating a new relationship; when having a difficult conversation with a loved one [12]. The vulnerability may be experienced as uncomfortable or unpleasant, yet research suggests it serves an essential function as "the core, the heart, the center, of meaningful human experiences"; a key for wholehearted living among others[12].

Through the case study of True Colors (described in Chapter 3.1), I found that when incorporated into technology design strategically, vulnerability can be a valuable experiential quality from a social-emotional standpoint [34].

4.2.2 Identifying Vulnerability as an Experiential Quality

Vulnerability catalyzes compassion, human connection, and ultimately meaningful experiences and a meaningful life [12]. Vulnerability as an experiential quality emerged through the RtD process and evaluation of the True Colors social wearable design (described in Chapter 3.1):

The design of the True Colors had many interactive features, some made for the wearers to use and some for other players to interact with. True Colors supported multiple social interactions and leveraged physical and social bodily practices, such as social touch, for comfort and bonding. Even though True Colors had various interactive features, the players in the New Gyr larp reported that it mainly worked to support them being vulnerable with each other. Further, the players considered this vulnerability a source of meaningful personal and social experiences.

The True Colors social wearable devices offered those who played the Augments characters, as players and as their characters, opportunities to initiate action and take control of situations they were involved in. E.g., characters could decide to express/disguise affiliation colors or "stun" someone. They could also decide to let their characters "take a hit" and suffer an overload whenever they choose by triggering it. Yet Augments did not exploit the stun attack function nor reported cases of being forced to expose their true color. While the stun function was barely mentioned, the overloads and social healing functions were frequently mentioned as the players' favorite aspects of the device. Augment characters embraced vulnerability over power and control as resources to co-create interesting co-located social interactions. Far from being perceived as a burden to players, the vulnerability was understood as a source for meaningful personal and social experiences.

While players were roleplaying overloads with an expression of pain and showing a lack of control, they were "daring greatly," [12], having the courage to expose their weakest selves to others. Players risked being unattended to and cast away, as New Gyr's backstory dictated, suffering this painful situation alone. This is not what happened. Players who roleplayed other characters came to the Augment players' help, and the Augments welcomed this help. Augments trusted others would act with compassion, they trusted others would work towards mitigating their pain, and they trusted others would respect their boundaries. We observed and were told this happened– resulting in feelings of acceptance, compassion, connection, and belonging and the development of strong bonds and relationships, often unexpected and against all odds.

The overload's features triggered in players a strong and unexpected call for action and care for other players. It resulted in overriding animosities across human variants stipulated in New Gyr's world. The overloads' interactive features in the True Colors wearable ultimately changed the characters' perception of Augments and their augmentations. They brought characters together and helped them bond and develop relationships, an unexpected phenomenon the players embraced and appreciated. Subsequently, we identified 'vulnerability' and experiential design quality that, when included in the design considerations, can lead to designs that elicit positive social interaction.

4.2.3 Incorporating vulnerability strategically

Here, I will outline the key design strategies that focus on enhancing the experiential design quality of vulnerability when creating social wearables for larps, based on the insights from the True Colors study.

4.2.3.1 Supporting 'Big Feels'

Designers can consider the social and performative impact of light and sound colors and patterns in social technologies, as well as the potential of appropriate social touch. With the True Colors wearable, the device's overloads evoked strong reactions from the players through design features such as sound effects and flashing red lights, which prompted wearers to play out and feel immersed in a breakdown situation, demonstrating an emotional resonance affordance [105]. As a result, players demonstrated social signaling and spectator sensitivity [105]. When the wearable to amplified expressively the Augment characters' signs of pain, it attracted the attention of co-present others and triggered an instant help response in those who had an in-game close relationship to the Augment, but also other players, who were not obligated to respond.

Similarly, the healing function of the device had a dual affordance of emotional resonance and social signaling [105]. From the perspective of the player engaged in social touch, the soothing pulsating rainbow lights resonated with their desire to help and their feelings of sympathy and compassion. From the Augment-player's perspective, these lights expressed the kindness and warmth of the physical contact and its therapeutic effect. The change in the light color from flashing red to pulsating rainbow represented bonding and the soothing effect of physical contact.

Hence, the lights resonated with the bonding experience of those involved, which magnified an already emotionally moving scene from an audience's perspective, showing spectator sensitivity [105]. Visibility from a first, second, and third-person perspective was essential to emotionally impact the Augment player, the respondent, and the audience present.

4.2.3.2 Supporting Authentic Self-Presentation

Designers can consider ways to accurately and appropriately (e.g., with consent) signal aspects of a person's authentic state to others, toward enhanced social interaction and mutual support. In the case of the True Colors wearables, our larp designers provided Augment characters' sheets which described them as having various 'qualities'. We used this information to program each wearable such that it would reflect this in the device– we adapted the frequency and duration of the overloads, to relatively match the quality of the augmentation. Augment players could also trigger the overloads in the larp manually, as much as they wanted. However, they chose to let their wearables decide when these moments of the crisis should happen; they chose to let their wearables accurately represent the quality of their augmentation.

We interpreted the fact that players didn't trigger overloads as a sign that they found the externally controlled timing of the overloads fitting with their character; supporting an authentic character presentation. As this is congruent to the strong links between vulnerability and authenticity, we argue that players chose to present their character's authentic self. From a roleplaying perspective, acting upon externally controlled stimuli instead of a personally controlled one may help the player better roleplay an unexpected scene and connect with their character's experience (social signaling and emotional resonance affordances [105].

4.2.3.3 Overcoming Difficulties Together

Designers can consider providing well-demarcated and bounded opportunities for people to help one another by using social technologies to encourage cooperation and collaboration.

The social touch function was easily accessible. It was triggered by other players through a marked and well-delimited action area. This was the capacitor touchpad at the back. The device also provided clear feedback from the social touch by changing to pulsating rainbow lights. The interaction happened at a social level; it brought people together and encouraged them to connect.

The True Colors wearables' design provided a specific mechanism to offer co-present others the opportunity to express their compassion and kindness and alleviate the situation of the wearer. It provided specific mechanisms for social exchanges, it indicated how and when to act by providing audio-visual feedback during an overload. Then, the vulnerability was embraced not as a situation of complete lack of control, but instead, as a situation that could be controlled with the help of others.

4.2.3.4 Information, Choice, and Consent

Designers should consider how affordances and the frame of engagement around social technologies can build a safe engagement space for those who use the technology. Aspects of appropriateness, approval, and consent are essential when designing technology that is worn on the body, that supports close physical contact, and through which users embrace vulnerability. These aspects were explicitly addressed by design, both in the larp event and our True Colors wearable. Regarding the former, the larp organizers and larpers worked hard towards jointly creating a safe larp event, e.g., in workshops through meta-techniques to help players let others know their boundaries.

Players who used the True Colors design were informed about the device's functions, interaction modality, and interactivity of the device before the game. These formed part of the magic circle of play [76] that these players voluntarily accepted when agreeing to participate as Augments. Augment players could revisit this agreement in-game during the larp event and modify the social appropriateness affordance [105] accordingly. For example, they could, and some did wear clothes on top of the device, remove it at any time or use larp meta-techniques (e.g., hands signals learned during the workshops before the larp) to help other players regulate their interactions.

Regarding the wearable's design, the body position and the area marked for social touch were considered to be socially acceptable [148]. Design qualities mentioned to increase appropriateness and acceptance were the delimited area of interaction, and social touch without direct skin contact, including material qualities such as the "puffiness" of the device.

Regarding choice, Augments could decide to trigger an overload and how to roleplay them, impacting how others perceived a call for help. Other players could also decide if and how to respond to overloads. By design, any contact with the back's pad, and of any duration, would positively impact the overload. This resulted in diverse interactions, from brief to longer social encounters. Also, others who wanted to support an Augment during their overload could call for more help from the knowledgeable character players (Augment Engineers), who could input a code to stop the overload immediately.

4.2.4 Forming Vulnerability as a Strong Concept

I grounded the SST strong concept [33] in related HCI theory, including vulnerability. Vulnerability as an experiential quality is focused on the felt experience of people who use the designs. In my articulation of vulnerability as an experiential quality, I identified design strategies; applying these strategies may result in designs that elicit aspects of experiencing vulnerability in their users [34].

Vulnerability in interaction design was not yet constructed such that it can be argued to contribute *to better* interaction design in a generative sense, and there would be value in forming vulnerability as a strong concept. If we would do so, we would need to unpack vulnerability from the perspective of the relationship between technology and the people experiencing it. We would consider how the relationship itself reflects vulnerability. To do so would build on the design strategies I identified for vulnerability as an experiential quality and develop them into core principles to encompass the system design holistically.

When forming vulnerability as a strong concept, we would need to focus on similarities and differences to related theories to ground it horizontally to clarify its range of applicability. We also need to consider related design instances to ground it vertically in other systems, asking "Is the strong concept present in other known instances?" [73].

The final step in constructing vulnerability as a strong concept would be to validate whether it is "contestable, defensible and substantive" [73]. To form it as such, it would need to be a novel concept for the interaction-design research community and deemed relevant. Since it would not be completely novel, due to its articulation as an experiential quality in [34], the research process leading up to the strong concept would need to be articulated and show rigor and critical reflection, including the reporting of the procedures and key decisions, to allow knowledgeable readers judge the strength of vulnerability as a concept.

To become substantive, vulnerability needs to be grounded further in a way that would support the creation of new instances, including considerations for the system design and the interaction with the system as a whole.

4.3 Conclusion

In this Chapter, I described my conceptual contributions that resulted from my RtD process of the Robo-Shoe-Flies and True Colors design processes, which included study design and evaluation of the prototypes in a social environment.

I began by presenting and discussing the concept of synergistic social technology, which suggests that technologies designed with 'needs' for interaction may motivate people to engage with them. This may foster connection and community among users. The SST concept is comprised of five core principles that ground design ideas. I describe how the core principles of the SST emerged from the Robo-Shoe-Flies design process and how the design of the Robo-Shoe-Flies system introduced a synergy between the creatures' social 'need' and its possible effect on wearers' social interaction.

Then, I presented vulnerability as an experiential design quality, which can be strategically incorporated into technology design to elicit positive social interactions. Vulnerability is the experience of uncertainty, risk, and emotional exposure, which can lead to compassion, human connection, and ultimately meaningful experiences and a meaningful life [12]. However, vulnerability as a design value is rarely embraced in technology design and HCI, which traditionally focused on reducing human vulnerabilities.

I identified vulnerability as an experiential quality through the case study of the True Colors social wearable design. The design of True Colors leveraged physical and social bodily practices, such as social touch, for comfort and bonding, and players reported vulnerability as a source of meaningful personal and social experiences. I outlined key design strategies that focus on enhancing the experiential design quality of vulnerability when creating social wearables for larps based on the insights from the case study.

Chapter 5

Translational Contribution: From Theory Generation to Developing Instructional Materials

In this chapter, I discuss what it is like to apply theory in practice. I reflect on the steps I took towards creating instructional materials that educators can apply to teach social wearables design. My goal here is to showcase how I bridged the theoretical contribution of my dissertation with its practical implementation, creating instructional materials that educators can apply in their practice.

Here I describe how the theory I generated was applied to create a tangible and meaningful outcome in the form of computational design education. With my colleagues, I drew from the social wearables design framework [36] (described in detail in Chapter 2) when we developed instructional material. This instructional material was used to encourage middle school girls' computational interest in the context of an edu-larp camp[19].

With this camp, we aimed to encourage technology exploration and self-efficacy in youth from under-served communities through edu-larp experiences, including designing social wearables for the characters they played in the edu-larp. With the help of external evaluators, we analyzed the first camp deployment; results are summarized in a 2022 DIS paper: [49]).

The development of the instructional materials for the camp happened in a few phases. In the summer of 2019, I hosted a group of four high-school students who participated in the science internship program (SIP) in our lab. Working with them was when I first attempted to teach others how to design social wearables. I used the design framework for social wearables to create a design workshop to brainstorm ideas for a new project. In Chapter 3.3, I outlined the result of this workshop, the development of the Robo-Shoe-Flies social wearables prototypes, and its study.

After this workshop ended, I reflected on the activities we engaged in. I applied learnings from the experience of leading this workshop to develop an embodied co-design sensitizing workshop online. I led two online workshops with my colleagues with a Youth Advisory Committee (YAC). The YAC was a group of middle school girls we recruited to participate in co-design workshops to help us develop the in-person edu-larp camp curriculum. We used insights from the design exercises in these online workshops

[19]The edu-larp camp experience and the co-design workshops were made possible by a generous grant from the National Science Foundation (award #2005816).

to create an "embodied design class."[20] This class was made to provide instructional materials for the in-person edu-larp camp's instructors. It was created to support the design activities in the camp as a whole [49].

Here I describe the process, from applying aspects of the framework with the SIP interns in the Robo-Shoe-Flies, through the YAC, the camp deployments, and the iterations of the instructional design materials. I consider in more detail what worked and didn't work as planned and what changes I made to the supporting materials provided to the camps' facilitators. I also include reflections on the design artifacts from the camps' deployments.

5.1 Applying the Design Framework For Social Wearables in an Embodied Design Workshop For the First Time

I presented the design framework for social wearables [36] in Chapter 2. I created the framework by surveying over fifty wearable designs from research, industry, and art. I searched for design implementations focusing on the co-located social space (excluding wearable assistive technology as we consider it a separate category). With my colleagues, we individually worked to thematically analyze this collection by reading design descriptions, articles, press releases, and reviews and by watching promotional videos when available. We eliminated designs that were not intentionally affecting the co-located social space. Then we created an annotated portfolio, highlighting "family

[20]The paper summarizing the results and insights from this process was submitted and under review at the time of writing

resemblances" between designs [59, 100], which resulted in the social value areas introduced in Chapter 2. These delineated the existing and potential roles of social wearables designs. My colleagues and I discussed and identified two value areas in the social wearables design space: (1) augmenting existing social signaling and (2) intervening in the social situation proactively.

This discussion led to the formulation of design considerations as guiding questions. We articulated these questions to help designers and researchers design and evaluate social wearables.

The two social wearables design case studies, Lågom [38] and True Colors [34] described in Chapter 3, were created concurrent to the development of the design framework, and both impacted and were impacted by it. In my practice, I found the framework's questions helpful when discussing results from past projects and driving ongoing projects. These questions helped me identify technical considerations (e.g., sensing, actuating, shape, etc.) and consider critical social implications.

In the summer of 2019, I approached my third social wearables design project. I took the knowledge I gained from my practice of designing and evaluating social wearables with participants and the questions from the design framework to an in person embodied design workshop. My goal from this workshop was to teach and practice social wearable design with a group of four high school students. These students participated in a research internship program, and I hosted them at my lab (details mentioned in Chapter 3.3.2).

First, to sensitize the interns to social wearables design, I presented the slide deck I prepared and presented at DIS 2019 about the design framework for social wearables [36]. I also created a list of project references they should look at (see Appendix C.2). Then, to begin the RtD process, I developed an in person embodied design workshop to develop potential design ideas with them. In this workshop, I engaged the interns in aspects of embodied sketching method including bodystorming and sensitizing (more about the method is mentioned in Chapter 1.2.2).

As mentioned earlier, I used questions from the design framework for social wearables (Chapter 2) to guide our inquiry during the workshop. For example, I asked them: *What is being sensed? What means or gestures are required? Does activating the device happen automatically or require people's intentional input? Is the output/feedback noticeable? By the wearer? By others? What is the interplay between devices? In what social environment does interaction occur? What is the best on-body location for the wearable to bring people together?* These questions helped shape our design process and experiment with the under-explored value area in which the wearable design could *intervene in the social situation proactively* [36].

In my design practice, I appreciated using Adafruit's Circuit Playground Express (CPX)[21] prototyping flexibility since it allowed us to add and subtract interactive features and iterate on designs. For this reason, I brought multiple CPX prototyping boards to the embodied design workshop.

To support the ideation process, I also included play-based activities, to help us generate thoughts around different bodily experiences, such as movement. I utilized

[21]https://www.adafruit.com/product/3333

the PLEX cards [101] to encourage this playful exploration. PLEX Cards are considered a valuable source for brainstorming inspiration when designing for playfulness [6]. I leveraged these cards to keep an open mind by taking a loose approach to the process. Each of us picked a card and then we placed the cards on a table and reviewed them as a group while discussing ideas for possible interactions.

Then, the interns and I took turns deciding which on-body locations to explore together, while connecting it to the ideas we discussed. Each of us took a turn to tape a CPX board to the selected on-body location. Then, we began to move around the lab and interact with each other playfully. We took a similar approach to the one advocated by Tomico and Wilde [138]. We examined the bodily experience of wearing the boards on different on-body locations and explored opportunities for new interaction among us.

I wish I had documented the process more thoroughly. Mainly I took videos and pictures of us playing around with the CPX on our bodies and moving around the room (see Figure 5.1). This workshop was a success. It led us to a social wearable design prototype that we further developed and studied [33]. This design, the Robo-Shoe-Flies [31], is described in Chapter 3.3.2.

After that summer, my colleagues and I started to work on a book on the topic of Playful Wearables, a forthcoming publication with MIT Press in 2023. The embodied workshop I led with the interns inspired the practical design exercise I created for those interested in exploring how to develop social wearables based on bodystorming principles. I included it in the Chapter on social wearables design (see exercise details as they will appear in the book in Appendix C.1).

Figure 5.1: An image collage from my workshop with the SIP interns. In the workshop, we applied the design framework for social wearables and bodystormed ideas on where to locate it on the body, while playing with the PLEX cards.

5.2 Developing Instructional Material through Embodied Co-Design Workshops Online

During the early days of the COVID-19 pandemic, my colleagues and I led participatory design workshops online with youth to inform the development of the in person edu-larp camp experience. A paper describing the eight workshops and our findings is in progress. To prepare for these workshops, I applied my experience leading the embodied design workshop with the SIP interns, the knowledge I gained through my

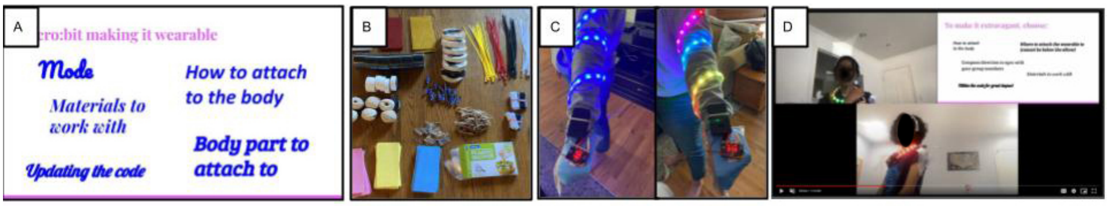


Figure 5.2: (A-C) Material exploration design activity; (D) Using the background as a “whiteboard” in the breakout rooms to remind the youth advisors what their design choices were.

design experience, and developing the design framework for social wearables.

In two workshops, our primary goal was to co-design the camp's planned design activities with youth participants. The camp's design activities required physical materials. Since we wanted to co-design these activities with the workshop participants, we wanted them to learn like the campers would about social wearable design by experimentation, exploring materials, and embodied design 'hands-on.'

5.2.0.1 Online Design Workshops

My colleagues and I aimed to use the workshops as a co-design platform where we could develop and evaluate the actual design materials we would use in the camp. Towards this goal, we explored ways to facilitate embodied design exercises that encouraged design thinking, crafting, and integrating different materials to make wearable designs.

We prepared and shipped the materials to the workshop participants' homes. These materials included hardware (i.e., Micro:bit[22] (paired with Microsoft MakeCode[23], a free online learn-to-code platform), USB cable, LED strand, battery pack, and alligator cables), and a mix of various malleable crafting materials sourced from a general store (e.g., fabric, strings, elastics, plastic gloves, tin foil, etc. (see Figure 5.2-B).

In the first design workshop, we focused on embodied material exploration. We prepared by creating pre-programmed interactions in MakeCode, which we called "Modes." We created these to demonstrate options for more advanced capabilities they

[22]a prototyping board (https://microbit.org/code/)
[23]https://makecode.microbit.org/

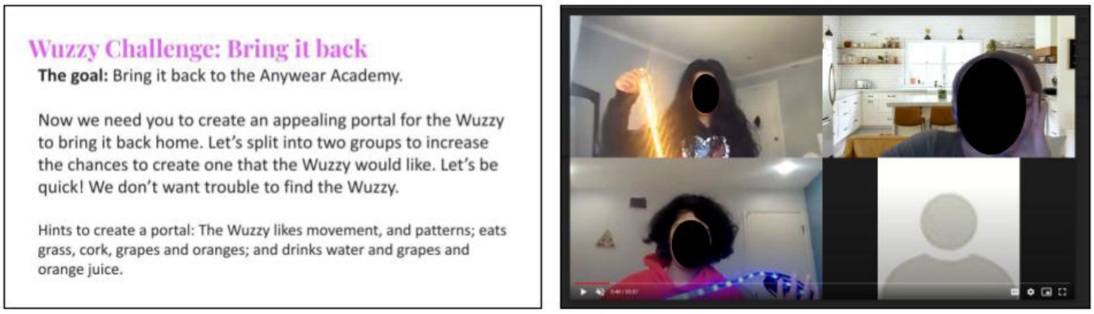


Figure 5.3: Left: the Wuzzy challenge was presented to create a framing story that encourages collaboration between participants to meet a design challenge. Right: participants work in a breakout room to coordinate the activation of their design.

can create using the Micro:bit.

We took guidance from the design framework for social wearables (see Chapter 2) to highlight areas where participants could decide about their design. In a presentation slide, we highlighted all these design choices while the participants explored the materials and crafted their designs. The list included thinking through: what body part to attach the design to, how they would attach the wearable to their body, and what crafting materials they would use. And deciding which interaction "mode" to code (e.g., see Figure 5.2).

The participants used our shipped materials to prototype a wearable design during this activity. They worked in the Zoom meeting, and then we hosted a show-and-tell round to reflect on and discuss their experiences.

In the following design workshop, we engaged the participants in embodied design to explore ways of incorporating design exercises while developing the larp story, that would accompany the in person edu-larp camp. We iterated on the previous workshop session's design challenge. The participants were instructed to use the same physical materials we sent them (see Figure 5.2-B).

However, this time, we also introduced them to a narrative reason for designing a wearable. This narrative included a reason for them to work together to encourage social interaction and foster connection. This design challenge required participants to program their LED light strands to attract the attention of a fictional character called the Shapeshifter (see Figure 5.3-left). To resolve the challenge, each remote participant needed to create something "extravagant" and then they all needed to **synchronize their movements** to "help release energy,"[24]. The participants worked in the Zoom breakout rooms in teams of two people (see Figure 5.3-left).

Our goal in these design workshops was to develop 'building blocks' for the design process. We believed this could work as potential prompts to guide the design activities in the camp.

In this second workshop, we created more elaborate pre-programmed blocks of code that could activate different sensors (e.g., compass, light sensing, etc.) and feedback (e.g., LED light color or pattern). We hoped workshop participants could use

[24]For this exercise, we told the participants this story: *"Welcome back explorers-in-training to the Anywear Academy! As you know, the Anywear Academy is the secret headquarters where Earth connects to other worlds. The only people who know about these worlds are the heads of governments, the United Nations, and the students, as explorers-in-training of the Academy. Our job is to collaborate with the other worlds to trade goods and services and, most importantly, to maintain peace and ensure that monsters or evil creatures in another world don't leak over into ours. After you rescued the Wuzzy earlier this year, the Wuzzy pulled you to the Fairy World. Now that you have finished your business there, you need to get back to the Anywear Academy Headquarters urgently. In the Fairy World, the Shapeshifter is the one who opens portals. They can help you open a portal to get back. For that, they need ENERGY, which they get from VERY extravagant designs that work in sync, and face the same direction – otherwise, the energy won't flow and it is useless. When the energy flows, part of the path opens. You need the whole path to be open so you can get back to the Headquarters. For that, you need to work together as a group."*

these building blocks, without fully knowing how to code, by modifying and downloading the code to their Micro:bit to start designing interactions quickly while exploring other embodied design aspects.

5.2.0.2 Takeaways For the Camp's Design Exercise

When we reflected on the workshops, we noticed that the embodied design activities were kept simple and easy enough to work through because we presented a limited set of hardware prototyping options. This constrained what the participants could create, but the coding and prototyping were sufficient for planning and evaluating the design activities for the camp. It also worked well within the time limit (two hours) that we had for each online workshop.

We learned from the first workshop that the mix of crafting materials, pre-programmed code, prototyping board, LED strands, and encouraging bodily exploration helped inspire creativity. It helped participants, who were novices to programming and designing to quickly prototype wearables with some interactions (e.g., Figure 5.2-C).

We noticed that since we provided all the materials, including the Micro:bit prototyping board and the Modes we created, participants were designing around the Mode's functionalities and focused more on the technology. This made us consider that future embodied design workshops for wearable technology might benefit from starting with the crafting materials without the prototyping technology first. This is to avoid setting constraints before participants get the chance to explore and imagine using the materials on their own.

Perhaps unsurprisingly, we found that participants in this workshop had difficulty developing a "purpose" or a story for their design prototype without more contextualization. When we introduced the developing larp story in the second workshop, we included narrative reasons in the design challenge that required participants to design together and synchronize their designs. This approach seemed to be fruitful for supporting social wearables design. We took this learning when we planned the camps' design challenges that were introduced in the missions (see next section 5.3).

Based on positive feedback from the workshops participants regarding the material exploration and bodystorming activities, I developed the embodied design and material exploration into a standalone class for the camp. I took the building blocks idea we introduced in the workshops and used it to sensitize the campers to the design material they had at hand– their bodies, the crafting supplies, and their intention for the design. I left the Micro:bit board out of this exercise, to allow campers to explore their desired aesthetic experience and possible physical affordances before shifting their focus to the prototyping technology.

5.3 Camp Deployments: Observing, Reflecting and Iterating

There were four separate deployments of the in-person edu-larp camp that happened from August 2021 to July 2022. In these deployments, we iterated its design, including the larp narrative, activities, crafting materials, and the camp's facilitators' instruction guidelines. We used observations from each camp to refine and improve the camp design and the instructional material in each cycle.

The camp's larp narrative centered on the "Anywear Academy." Campers took on the role of "agents in training" as part of the academy, a secret organization tasked with traveling to different dimensions to establish diplomatic ties and right wrongs. Campers use wearable electronics they program to accomplish a variety of different "missions" (e.g., going to the Fairy dimension to identify poisoned fruit using LEDs or traveling to a space station to solve an electronics-based puzzle that restores power). Campers' time was split between these missions, where they actively role-played, and unstructured activity time, where campers were programming or crafting, as well as core classes in which they learned basic programming skills.

Campers used the Micro:bit hardware platform to program a variety of wearable electronics that they would then use when traveling to different dimensions and completing missions in the context of the larp. We incorporated the Micro:bit platform in the camp due to its connections to other commercial maker platforms and hardware. It has a low barrier of entry with MakeCode's block-based interface, but it can just as effectively be programmed in Python, Javascript, or the Arduino version of C++ [50].

We prefabricated bolt-on connectors to the Micro:bits for rapid prototyping. These connectors allowed the campers to attach different types of hardware to the prototyping board. They could connect the Adafruit Neopixel Dot LED strand or servo motors. We chose these additional hardware components to provide the most flexible utility at a relatively low cost.

Figure 5.4: An Image of the campers crafting designs for their missions. Between missions, campers had access to tables arrayed with crafting supplies to iterate or create new costumes and wearable elements to prepare for the next challenges.

Throughout the camp's classes, campers learned how to use the built-in sensors and buttons to change the colors and patterns of addressable LED strands, produce monophonic audio, and send and receive radio signals. Campers were introduced to these concepts in short, 30-minute classes, in which they followed along with the instructor, who guided them through a structured exercise. These classes were intentionally short to allow the campers more time to explore the concepts they were learning independently and in design challenge missions.

We designed the camp's curriculum to be flexible, allowing campers to explore coding, crafting, designing, and roleplaying. Under their role as agents in training, campers were given a foundation of coding knowledge. They could freely switch between the different activities based on their interests (see Figure 5.4). Their days were divided between classes and missions that immediately called on the skills they learned in the classes. There were no specific goals or outcomes for the campers to achieve with their designs, except for the design constraints they were given within the context of the missions. This allowed them creative freedom to develop expressive designs when they created and programmed wearable technology to accomplish various missions.

We aimed to encourage computational interest, expose campers to hands-on design activities and foster a pleasant and engaging social environment. We wanted the campers to feel safe to explore new concepts, learn, and socialize. Through a series of design prompts for the camp's missions, the campers were encouraged to think about concepts such as wearability, the secondary user experience, and creating a cohesive design.

5.3.1 Camp I

The first in person edu-larp camp was deployed in a community center in a US city in July of 2021. A non-profit organized this first camp, which ran for five days from 9 AM to 4 PM. It was facilitated by four staff members with backgrounds in education, larp, and theatre. One of them served as the primary instructor of the classes. The other facilitators shifted roles based on the need at the time, acting as non-player characters during missions, supervising crafting activities, providing design feedback, and handling set design and construction. This deployment is analyzed in depth in our published paper [49].

5.3.1.1 Bodystorming Design Exercise and Materials

As mentioned in the section 5.2.0.2, the online design workshops with the youth advisory committee informed the development of the design class and the design materials we provided in the camp.

The goal of the bodystorming design class was to give the campers an opportunity to explore the materials that were available to them throughout the camp before having specific design challenges to solve on missions. It was developed to provide the campers with some foundation in designing for the body and to help them consider the various design choices they could make when they design wearables. Our goal with this class was to sensitize the campers to a design process. It was meant to introduce the campers to rapidly and playfully designing a "wearable," without technical knowledge.

When creating this class we were inspired by Höök et al. Somaesthetic approach to interaction design [74]. Therefore in the exercise, we sensitize campers to their bodily movement in space, before starting to design. We instruct the campers to notice how their bodies move while focusing on different body parts (for the complete design exercise see Appendix C.4).

I adapted the building blocks for the design process (explored in the online workshops with the youth advisors, see section 5.2.0.1) to focus on the body, the craft material, an aesthetic, and a mood/feel. To convey mood, I introduced visual inspiration for the design activities. I created image collages as inspirational moodboards that could help guide the campers' design process. We called these image collages "Vibe Cards" (see Appendix C.4.2).

The crafting materials we supplied for the online workshop participants worked well in those sessions. It consisted of familiar materials (e.g., rubber gloves, tin foil) and crafting supplies like glue and scissors. From my previous design practice and the participants' responses, I found these materials to be a helpful starting point when prototyping new designs. These materials are familiar enough, therefore, not intimidating, but can spark the imagination if they get re-contextualized during the design process. Together with traditional crafting supplies, it enriches the materials to design and 'think' with.

Therefore, we supplied the campers with various materials for design exploration activities. The supplies included: sticky tack, popsicle sticks, coffee stirrers, ribbon, temporary tattoos, butterfly wings, pre-made superhero costumes (capes and base-masks), glitter glues, hot glue guns, batting/polyfill, Velcro circle stickers, fabric scraps (various print patterns), organza fabric in various colors, packing perforated paper, foam sheets and packing foam pieces for construction, and tin foil pieces. This variety of crafting supplies was accompanied by manipulation tools, including scissors, types of glue, Sharpies, and tape (see Figure 5.4).

5.3.1.2 Reflecting through Observation and Design Artifacts

The campers indeed engaged in designing, crafting, and developing wearables. We took the artifacts they made (i.e., their computationally infused crafted designs) and our observation of their behavior to reflect on the design exercise, materials, and challenges we provided.

From analyzing this data, we found that while campers didn't always use the hardware to create wearables that augmented their social experiences in the ways we expected, their designs were a constant feature of their costumes.

The campers did make use of them in interesting ways. However, in a few notable instances, campers' designs tapped into the collective social experience. For example, campers used the addressable LEDs for social and performative purposes to show their group affiliation. In another instance, the campers used their wearables to display their state–showing others when a camper's superhero or magic ability was active.

The designs the campers created were a reflection of the pre-scripted edu-larp narrative but also of the narrative that was emerging from their shared play experience. To prompt social wearable designs, we incorporated missions in the larp narrative that provide social challenges that required campers to work together, for example, by syncing their design in some way. Using the larp narrative, we included a reason for the campers to work together and collaboratively plan their designs. When going on missions, they traveled through a portal. Campers were told to sync their wearables' lights to the portal's color to open it. As a result, all the campers that wanted to go on a mission had to match their color to the portal's color. As a result, campers synchronized their LED lights color, and this interaction happened as a group (see Figure 5.5).

We noticed (and campers reported), that the crafting aspect of the camp created a fun and engaging environment to experiment with materials and develop wearable costumes (see Figure 5.9). Campers explored different ways to wear and use their de-

Figure 5.5: Images of the campers going on two different missions. Each time they had to synchronize the color of their wearable design LED lights to the color of the portal.

Figure 5.6: Images from missions at the Earhart Space Station. In these missions, campers investigated a mysteriously abandoned Academy space station. Because this station's life support was shut down, it prohibited verbal communication. Therefore, the campers needed to use their wearables to communicate through nonverbal communication to coordinate cooperative puzzle-solving.

Figure 5.7: Images from missions that took place in the fairy-themed world. Missions here involved campers trying to make diplomatic ties with the fairy prince while hiding that they are not fairies. They created costumes that used LED displays to represent their magic and augment their social displays to the non-player characters (NPCs) of that world.

signs. For example, unprompted, campers started constructing small shoulder bags to wear under their costumes to carry the bulky battery pack. In other cases, campers incorporated music into their superhero costumes to signal that they were doing heroic acts. Campers gravitated toward the material affordances of the LED strands. Often they used it by wrapping it around their neck to create a kind of scarf or a necklace.

We noticed that some campers did not wear their designs, instead, they held them in their hands. This made us realize that perhaps providing pre-made options for the campers to attach/wear their design on their bodies would help them design wearables.

5.3.1.3 The Initial Narrative Role of the Critters

In this first camp deployment, in one of the missions, the narrative included the "Critters." These were two-wheeled remote control robots with the narrative role of serving as a plot device and prop for campers to interact with as part of the larp. Within that context, the Critters were a set of sensitive probe robots that were used to scout new worlds by the Anywear Academy.

When they were introduced to the campers, the larp narrative described them as malfunctioning. Campers were introduced to the challenge of needing to fix them by using wearable technology that they would design collaboratively, to create a rhythmic display. While this challenge engaged the campers as we hoped, to our surprise, a subset of the campers picked up the Critters after the mission, cut their boxes open, and began to re-program and redesign them. From a form factor perspective, this "Critter v2" had

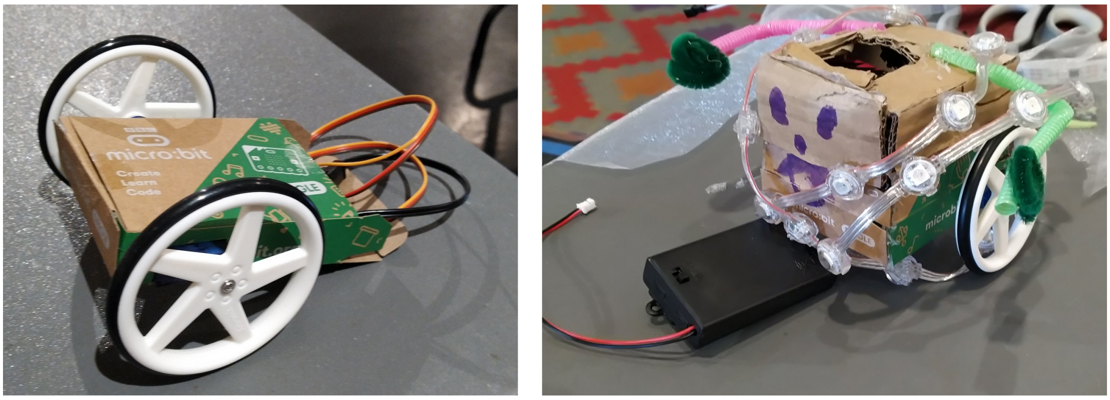


Figure 5.8: On the left is an image of the Critter as it was introduced in the camp. On the right side, the image shows the Critter v2 as it was modified by campers, a project that they drove.

a modified casing made from spare cardboard to accommodate a larger battery to power both the servos and LED strands. The campers added character elements like a face and arms made with plastic tubes (see Figure 5.8).

This impromptu involvement of some campers in adapting the creatures created a fractured experience for the group, with one of the campers at the end of the camp reporting that they felt they were less able to make use of the computers to reprogram their wearables because they "weren't part of the coding group." This wasn't the intent of the campers that were customizing the robot. The campers gave the robot to the Anywear Academy at the end of the experience stating that "they wanted the next group to use it for their missions."

5.3.2 Camp II

The second camp deployment occurred over two weekends at another site in February 2022. The camp classes and edu-larp narrative stayed the same as in the first

Figure 5.9: Campers went straight to the crafting tables as they arrived in the morning.

deployment, with only a few changes.

As in the previous camps, the design activities had loose constraints. The campers could choose what kind of input and output interaction they wanted to create (e.g., to include a motor and/ or a light output and how to activate the design). As before, there was no final goal in terms of the campers' designs and their functionalities (see section 5.3). Based on observations and reflection on the first camp deployment, feedback from the instructors, and the campers' resulting design artifacts (i.e., the designs the campers created), I realized that many of the campers were challenged by making designs to stay on their bodies as they leaned on the affordances of the LED strands to wrap it around their necks. Therefore, I decided to add to the crafting materials items that could be used to connect or 'mount on' their designs to the bodies, such as belts, headbands, and clips (Appendix C.4.1).

In addition, after reflecting on how campers engaged with the Critters in the first camp, we decided to iterate the larp narrative, to slightly adapt the role of the Critters. In the second camp, we reinforced their role as props and tried to make them less available for crafting projects. During the mission that included the Critter props, the facilitators provided a narrative justification that kept the campers from working on them. We did this to avoid creating a division within the campers as in the first camp deployment. The campers were told to leave the props for another Academy team to recover and that the Critters needed more time to rest following the experience that led to their malfunction.

Further, I developed additional instructional materials for the facilitators, which I hoped would support the edu-larp design challenges by prompting considerations that focus more on the social aspects of wearable design. These materials included adapted guiding questions based on the design framework for social wearables (Chapter 2) and short design activities (see Appendix C.5).

5.3.2.1 Reflections

The camp we designed had a lot of content that the facilitators had to review. This content included the larp narrative, plans for the set design, and all the classes to teach. The facilitators took part as pages and as teachers. Therefore, the additional instructional design materials I created for the facilitators were not taken to use. The camp already had so much content that the facilitator had to review as they prepared that, in the end, the new materials were not utilized.

When we reflected on the design activities and the artifacts made by the campers in the second deployment, we realized that a similar phenomenon occurred as in the first camp; a subset of the campers looked for a different crafting experience. The campers asked for more design challenges, which suggested they wanted to engage with more than what was offered in the structured missions' challenges.

In addition, campers used the new materials in the camp to mount some of their designs to their bodies. They also created designs that had animistic and creature-like features (see Figure 5.10). One created something like a pirate's parrot or animal companion. They developed a backstory for this design, it was said to communicate danger or opportunity and detect strong magnetic fields, and it spent much time on the camper's body. Other campers created a design they named 'Puffkins.' This design was constructed of pom-pom balls and seemed like a family of creatures. These designs inspired a new direction for the larp narrative that would encapsulate the concept of companion on-body creatures in the subsequent iterations of the camp design.

5.3.2.2 Results: Adapting the Role of the Critters

Based on our observations and findings from the two camp deployments we were inspired to reconfigure the "Critter" piece in the edu-larp narrative in the next camp deployments. We did this to use to better encourage computational community building.

We took inspiration from the campers' creations and the prototype of the Robo-

Figure 5.10: Campers in the second camp deployment created designs that had creature-like qualities.

Shoe-Flies [31] (Chapter 3.3.3) to develop a new framing for the Critters to become wearable, social, robot-inspired creatures that are more open-ended, flexible, and fit can into the larp narrative more clearly. We created a guide for the larp designers who created the narrative to adapt the role of the Critters by giving them new characteristics as the “Familiars” so they would serve as design prompts for social wearables (see Appendix C.6).

5.3.3 Camp III and IV

The third and fourth camp deployments occurred in the summer of 2022 at two locations.

Our goal was to allow campers to engage in more open-ended coding activities if they were feeling too constrained or disengaged with the other camp offerings while still creating wearables with social meaning. We aimed to connect the design challenges to the larp narrative such that it would inspire campers to create designs that are made to be worn on-body and have social meaning. The wearable aspect was vital to the camp experience.

The main update from the first two camps was the narrative adaptation of the Critters to Familiars. The Familiars were framed as companions to graduates of the Academy. They were presented as creatures that need to stay close to the body of their human partner (i.e., wearable) and are intrinsically sensitive–they can be used to detect things that are beyond what humans typically can sense. However, their sensitivity makes them quickly overwhelmed, needing support and care from their human partners (the campers). This meant that the campers would become the Familiars' human partners, and they would be asked to help craft and guide their Familiars' development.

5.3.3.1 Developing Training Materials for Facilitators

As mentioned in section 5.3.2.2, we adapted the edu-larp narrative to include the Familiars. Since the camp's facilitators also participate in the narrative as part of the edu-larp, we worked with them during a training session first. I had the idea to use the Familiars as part of the instructional materials for the facilitators in this training.

I repurposed them to introduce and sensitize the new group of camp facilitators to the camp's computational curriculum. With the framing of the Familiars. I created instructional materials for preparing Familiars (see Appendix C.7 and C.8). I used my previous experience designing the Robo-Shoe-Flies to create new instructional material. This material introduced the camp facilitators to the specific larp narrative, larping (by developing the character they would play in the edu-larp), to learning how to use

MakeCode and the Micro:bit, and finally, designing and crafting their own Familiars.

In addition, since these Familiars were made before the camp sessions started, going through this exercise also helped the facilitators prepare and establish their characters in the edu-larp. Then, the Familiars that the facilitators created were used as exemplars for the campers to draw inspiration.

5.3.3.2 Introducing the Familiars in the Camp

The Familiars were intended to be creatures that live close to the body, so worn in some way or held. We made the design brief for creating the Familiars intentionally open-ended, as we aimed to provide the campers the freedom to explore and customize their designs to fit their own desire.

Campers were given a bit of starter code to kick-start the programming process. For example, this code included abilities to react to a radio signal broadcast on a pre-decided band. However, the way the campers chose to program the Familiars to react was up to them to decide. Some campers chose to display an icon or text on the Micro:bit's LED grid, while others chose to play custom audio jingles or control a servo.

In one of the camp's new scripted narratives, the Familiars of the facilitators were shown to be overstimulated and needed to take time to recover. This scene was created to prompt the campers to begin creating their own Familiars. The idea was that the Familiars' capabilities would be helpful to the campers when they went on the larp's narrative missions.

5.3.3.3 Results: The Campers' Familiars

This instructional material for making the Familiars was embraced in the third and fourth implementations of the camp (see Appendix C.8). The facilitators were prepared to instruct the campers, and their designs helped inspire the campers too. Affording the campers the freedom to create Familiars as they wish fostered a sense of ownership over their creations. It encouraged their deeper engagement with the camp's edu-larp narrative and crafting materials.

The campers inspired each others' creations and shared knowledge. This led them to develop creative instantiations of the Familiar design (e.g., Figure 5.11). In addition, during these camp deployments, the campers iterated on their designs, each time adapting them further for use in the camp's narrative missions.

In some cases, they developed technical design ambitions; for example, one camper wanted to improve their design so their Familiar, which was a cow with rotating ears, would be able to move its ears in synchrony (a physical computing challenge to coordinate between two servo motor movements that were spinning the "cow's ears"). In other cases, campers engaged in conversations outside the bounds of the camp to draw inspiration for their design; for example, one camper said they discussed the Familiar design with their mother, who suggested their dog's bark as an inspiration. Several campers used the LED lights to display an RGB[25] pattern and others programmed their Familiar to send/receive radio signal waves.

[25]"RGB (red, green, and blue) refers to a system representing the colors used on a digital display screen." [24]

Figure 5.11: Images of Familiars campers created in the third deployment of the camp.

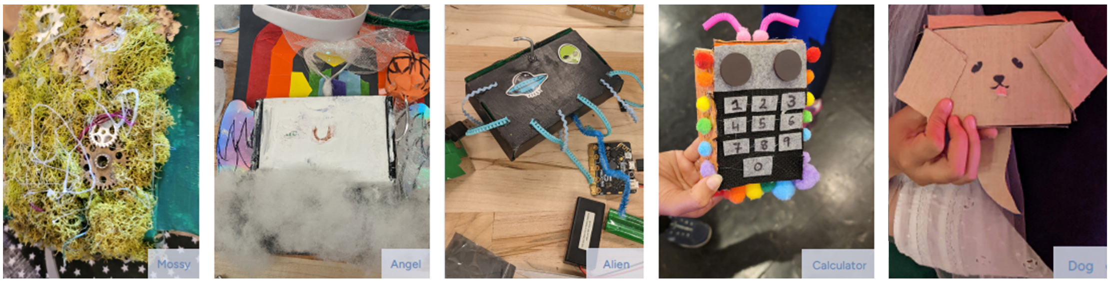


Figure 5.12: The campers developed their Familiar designs to connect back to the characters they were developing and playing as part of the Anywear Academy. For example, one created their Familiar as a sci-fi-themed robot to connect to their space suit design (Alien). Another camper created the Familiar as a gadget to fit the 'mad scientist' superhero character they created for themselves (Calculator). Other campers even designed their Familiar to connect to their out-of-game interests: one created a Familiar to be a version of their dog (Dog), one camper carried through the visual design of another prop (Mossy) while another created a Familiar to be an angel that can spin a basketball on the top (Angel).

The on-body framing of the Familiar may have helped facilitate a personal connection, as campers considered their Familiars an extension of themselves. Some campers designed their Familiars to be tied to the design of their existing costumes/props that they had created until that point in the camp and the narrative of their character, and some changed their design direction. For example, a camper created a 'cow' in the fourth deployment. This design drastically differed from the dark, Gothic concept they initially pursued in their in-game character. Designing their Familiar allowed campers the space to pivot their design direction and aesthetic. They could even retroactively update the character they were playing within the larp. The Familiars' framing allowed campers to customize and create personal stories around them (e.g., Figure 5.12).

Creating the Familiars also prompted them to make their designs more "wearable." The campers' incremental learning of programming and hardware skills throughout the camp resulted in changing and adjusting their designs to implement freshly learned skills. Instead of trying to reach a "perfect" state in their designs early on, campers experimented with different design ideas. For example, when one of the campers was done crafting their Familiar, they continued to work on the designs in many ways, such as adding aesthetic details, expanding the ways they could wear their design (e.g., making a wearable attachable via Velcro when it already had a strap to be worn) or making the LED lights/motor perform specific actions. The open nature of the camp seemed to support this iterative design and design thinking amongst the campers.

5.4 Conclusion

In this chapter, I reflected on steps I took to develop instructional materials that can guide activities to elicit social wearable design. I leveraged my social wearables design practice and utilized the conceptual understanding I gained from the design framework for social wearables and the insights from studying my social wearables design prototypes in social settings to generate new social wearable design concepts in the embodied storming workshop. I unpacked the process of translating knowledge from design practice and the development of conceptual frames to creating instructional materials that may benefit educators and design researchers in their practice.

I also worked to develop design exercises that would support hands-on interactive teaching of social wearables design. I described several of the artifacts campers created in the context of the different camp deployments as a result of using those instructional design materials.

While reflecting when writing this chapter, I noticed the affordances of backstories in guiding and driving the design process. Using backstories helped ground the design exercise in the online workshops, and it helped to surface the social aspects. Its usefulness came through again when we worked to adapt the edu-larp narrative, which directly impacted the campers' design artifacts. I believe that designing social wearables should be a value-driven process that considers the social environment where the design would be used. The backstory helps to contextualize the design in that environment. It is also helpful as a design constraint to elicit creativity in the process.

Embodied design, and specifically, embodied sketching methods, help anchor the design development in the physical world. It helps designers to explore bodily affordances that can sometimes be unexpected. This approach was valuable and inspiring in my design practice and when I used it in the design workshops with the SIP interns in person and the youth advisors online. It was helpful to incorporate it into the instructional materials of the camp as well.

Finally, my work exposed a few limitations that exist in creating instructional materials to support social wearables design education. Even though prototyping boards such as the Micro:bit or the CPX size is small and lightweight enough to "wear," prototypes still require additional hardware, wires, connectors, and battery packs. All these together amount to a design that can no longer be "easily" worn. Wiring a device such that all connections are stable and flexible is not easy. This is a challenge in creating instructional design materials, as part of the process is prototyping devices that can readily be worn, especially if design researchers want to evaluate their designs in social settings with durable prototypes. I tried to overcome this challenge by providing materials campers could use to "attach" their prototypes to their bodies, e.g., belts, headbands, and clips. This is a step in the right direction, but more work and exploration are needed.

Chapter 6

Final Thoughts and Future Work

I began my dissertation work interested in exploring ways technology design could draw people's attention to one another and encourage connections. In my dissertation research, I narrowed the scope of this broader goal by focusing on 'social wearables,' building on my professional and educational background in fashion design, psychology, and interactive storytelling.

6.1 Contribution

My first research question, *what design opportunities for wearable technology exist to support and encourage co-located social connection?* focused on opportunities to advance current technology design. It drew my research to understand the design space of social wearables, which I approached first by collecting design exemplars, mapping the space by developing the annotated portfolio. Then I explored this question with hands-on design– I designed, developed, and evaluated social wearables in relevant social environments.

The second research question *what concepts and theoretical frames could designers and researchers use to explore the design space of social wearables?* informed my inquiry to uncover design insights such as the guiding questions, concepts and experiential qualities. Beyond the conceptual frames that I developed from the case studies, I created instructional materials for educators, so they could explore with students, the design space for social wearables.

The contributions of this dissertation are reflected in three types of knowledge generation. First, the social wearables design instances presented in Chapter 3's case studies provide a practice-based knowledge contribution. Second, the design framework for social wearables, its annotated portfolio, and guiding questions (Chapter 2), the SST strong concept, and the experiential design quality of vulnerability (Chapter 4) provides intermediate-level knowledge contributions. Third, in Chapter 5, the instructional materials I developed for the edu-larp camp that educators can use to practice and teach social wearable design serve as translational contributions.

The social wearables design instances contribute to this design space as design instantiations–exemplars that have been studied. In contrast to this, many of the other extant design prototypes that I reviewed when developing my framework served as singular 'proofs of concept' without having been tested in social situations. For each of my design exemplars, I developed a study to evaluate the prototypes with people who wore them while interacting, using the designs in a social setting.

I synthesized reflections from the RtD process and the data from these studies.

This resulted in developing my conceptual contributions. Studying the Robo-Shoe-Flies, carefully reflecting on the design process, and thematically analyzing the data from the interviews and questionnaires resulted in identifying the strong concept of synergistic social technology. The concept abstracts the design elements of the Robo-Shoe-Flies beyond this particular instance. To formulate SST fully I surveyed the literature to ground the concept in related theories and reviewed other design instantiations to ground it vertically (Chapter 4).

With the True Colors design instantiation, I created fifteen copies of the prototype to study it in a larp (Chapter 3.1). Thirteen players wore the design during the four-day event. The data collection included observing, reflecting, interviewing, and collecting feedback through questionnaires. The RtD process and the thematic data analysis resulted in identifying the experimental design quality of 'vulnerability.'

Together with the insights from the study of the Lågom design (Chapter 3.2), these case studies influenced the conceptual contribution, in the form of guiding questions, in the design framework for social wearables.

The social wearables design framework identifies key areas in the design space of social wearables. This contribution stems from an analysis of existing literature and a careful review that compares and contrasts state-of-the-art designs. The framework also offers critical questions to guide the process of designing social wearables. These questions can also be applied when designers and researchers want to evaluate social wearables design artifacts.

Finally, the third contribution of my doctoral research was based on reflexively examining my previous practice designing social wearables and the conceptual framing I developed to unpack this process for others. With the Robo-Shoe-Flies (Chapter 3.3), I translated the framework's conceptual contribution into my design practice. Then I used it to develop instructional materials (Chapter 5.1). I applied the framework to brainstorm ideas for a new social wearables project by using the framework's guiding questions to accompany the embodied design workshop I hosted. In the edu-larp project (Chapter 5.3) I developed instructional materials that educators used to teach and facilitate design workshops, and support activities that encouraged campers to design, develop and create social wearable designs.

In evaluating my dissertation contribution, I take Gaver's perspective on RtD process who points to its generative potential [61]. The work that resulted from aiming to answer the first research question includes generative knowledge that provides inspiration and motivations to further explore the design space of social wearables, by identifying the gaps in the space, providing guiding questions, and instructional material to inspire others to create social wearable designs. The RtD process also meets some of the requirements articulated by Zimmerman, Forlizzi, and Evenson [149] who suggested that "artifacts that provide concrete embodiments of theory and technical opportunities" [149] are worthy RtD contributions. In addition, they expected the *process* to be rigorous, which it was: it included multiple cycles of iterations, playtesting, and refinements. The social wearables design applications I developed were novel, and were evaluated with people to draw design insights, meeting Zimmerman, Forlizzi, and Evenson's requirement related to *invention*.

Overall, my practice-based and conceptual contributions serve as nuanced socio-emotional guidance and inspirational starting points for designers and scholars who research design opportunities for wearable technology, to enhance co-located social interaction.

6.2 Reflection

While writing this dissertation, I noticed a few through lines that I will share in this section. With each of my RtD projects, evaluating the resulting social wearables prototypes in an appropriate social context allowed me to dig deeper into their meaning, surfacing intermediate-level knowledge contributions.

In addition, I noticed that all my RtD prototypes were backed by a story– a fictional backstory that helped to ground and contextualize their meaning to study participants. Further, the experiential quality of *vulnerability* was embedded in all these backstories, shaping the participants' experiences and inspiring the social wearable design prototypes.

6.2.1 Evaluating Design Prototypes in Social Environments

With each of the social wearables design case studies, I engaged in RtD process and evaluated the design prototypes in social environments. These environments were ecologically relevant to fit the stipulated use of the design prototypes.

The Lågom design was made to support people when they engage in group discussions. I evaluated it during a graduate student class. I created a study where the participants discussed research papers that could have occurred with or without the prototypes. I took the True Colors design prototype into an actual larp event that engaged participants in social play. The prototypes were worn and used by players as part of their game. The design evaluation happened within this context, and as we participated in the larp as page (non-player character) researchers, we aimed to keep the players' immersion in the game. Finally, I recruited participants from neighboring labs and undergraduate students to evaluate the Robo-Shoe-Flies and asked them to work on their laptops as they would 'normally.' When I grouped participants for the study, I aimed to match participants who commonly shared lab space to stay as close as possible to the office-type social environment they are used to. I did this to evaluate the functions of the prototypes in a similar setting to the participants' everyday social environment.

Conducting studies to evaluate the social wearables design prototypes in the relevant social environment–collecting data through observations, interviews, and questionnaires and then thematically analyzing it–was a crucial part of the RtD process.

For example, the synergistic social technology strong concept (Chapter 4.1) was developed due to the overall RtD process of the Robo-Shoe-Flies. Creating multiple prototype copies allowed me to study the design with 13 participants, and it was only when I synthesized the qualitative data from that study that I could surface this concept.

6.2.2 Using Backstories to Contextualize Design Prototypes

In my work, I used fictional backstories to contextualize the use of social wearable design prototypes. In all my research projects, creating the backstories helped our study participants engage with the design prototypes in a social environment such that their feedback and reflection provided deep insight that could be abstracted further.

The Lågom had the flower species backstory of a flower species that fed upon its wearers' voices and thrived when there were balanced conversations. The Robo-Shoe-Flies' story was about an ecosystem of on-body companions that 'need' movement and social interaction with other creatures of their species. True Colors story was set in the science fiction narrative of the New Gyr larp, which informed the design development and the interactions. During my work to create instructional materials, I utilized the edu-larp narrative to contextualize the design challenges to explore social wearables design. The narrative was written to facilitate design reasons for the technology to be on-body and to hold a social role.

The backstories may lead to meaningful and unpredictable insight, as happened with the True Colors social wearable. The backstory of the New Gyr larp was a complex narrative, with many actors, functions, and design opportunities. When we co-designed the True Colors, we took a user-centered approach: we intentionally developed it with multiple features, and hoped to learn about what the study participants would actually use. We found that the caring interactions around the Overload feature were appreciated. This led to the insight about the experiential quality of vulnerability (Chapter 4.2). In this case, the backstory played a crucial role in the outcome, however it did not dictate it. It worked as a facilitator for this study exploration, and supported the participants in interacting by using the design.

I found the use of backstories significant in my exploration of the design space of social wearables. It allowed me to study design prototypes, that otherwise would not make sense to the participants. Using the backstories also supported exploring design dimensions that could encourage social connection. For example, the design backstory of the Robo-Shoe-Flies (Chapter 3.3), involved interdependencies, and vulnerability between the wearers. The use of the backstory led to unpacking design dimensions such as creating external reasons to interact, and mixed control and shared experience, and ultimately to identifying the synergistic social technology as a strong concept (Chapter 4.1).

Using backstories to contextualize a novel design, such a social wearable, within the environment, created a bridge from the current state, in which the design does not yet exist, to a new fantastical state, in which the design has a reason to be. This seems especially useful, when the meaning or purpose of the design is still forming. In my design research projects, the backstories helped facilitate the exploration of the novel design, and provided shared language around it. The backstories worked like a stepping stone in the process of unpacking affordances of the design space.

6.2.3 Including Aspects of *Vulnerability*

I identified *vulnerability* as an experiential design quality due to the RtD process of creating True Colors. However, reflecting on my dissertation work, I have since noticed it in all three social wearables case studies (Chapter 3). It emerged again when we developed the larp narrative of the edu-larp camps (Chapter 5.3.2.2). For example, in the Lågom projects, the backstory of the devices incorporated a sense of vulnerability since it presented the design as a flower species that 'feeds' on balanced discussion. Therefore, the social wearables themselves were vulnerable to the use of their wearers, and the wearers, as participants in the discussion, had a role in collectively caring for this 'species.'

With the design of the Robo-Shoe-Flies, I employed vulnerability more strategically by using the fictional framing story to guide the wearers to interact with others. The vulnerability was present on two levels: first, in the backstory of the creatures who 'needed' interaction with other creatures and depended on their wearers to achieve this interaction. The creatures were 'vulnerable' because they needed other creatures. They also relied on their wearers to be able to fulfill this need. The wearers practiced being empathetic to their creatures 'needs.' Second, when the wearers wanted to help their creatures, they relied on other wearers to coordinate meetings and move together. This engaged the wearers' sense of vulnerability as they depended on others' willingness to collaborate.

As I mentioned early in the dissertation, my research inquiry was value driven.

Specifically, focusing on the value of social connection was key to surfacing 'vulnerability' as an experiential quality.

6.3 Beyond Social Wearables and Future Work

At a high level, my research goal was to identify key concepts, synthesize theory, and create guidelines for best practices for technology so that future designs would support the people who use them and the social environment they're made for. My research in this dissertation focused on social wearables as a design space[26]

In future research, it would be interesting to explore further using backstories as a design material in embodied technology development. As I mentioned, I noticed that all of my RtD projects utilized a fictional backstory that helped frame the context of use and inspired the design prototypes. Future research could focus on learning more about the potential impact these stories can have on the final product and the co-located social and embodied experience of the people who would use the technology.

For example, it could be interesting to prototype social wearables with multiple functionalities and use different framing backstories when the prototypes are presented to study participants to draw insights on what aspects of the backstories impact the participants' co-located social interactions, their embodied experiences, and emotions. It could be interesting to use different backstories for the same design prototype to explore how they may lead to different design insights, user experience, and, how these different

[26] Along with my Ph.D. work, I also took an interest in and led research through design projects that focused on other technologies, e.g., drones in [121] and augmented reality in [30], to enhance in-person social interaction.

backstories could impact aspects of social connection. It would be also interesting to use the same backstory for different design prototypes, to explore how the backstory manifests in the interaction using these different prototypes.

In addition, exploring utilizing Artificial Intelligence (AI) in the story generation stage of this process could be interesting. Another direction to consider is using backstories as "boundary objects" (or call it *boundary backstories*) in participatory design sessions to ground bodystorming in potential future scenarios of co-located interaction with technology.

Another exciting path of exploration would be around the design dimensions and insights I found in my studies. It would be interesting to research these concerning future social wearables design and other technologies that could enhance co-located social interaction. For example, from the Robo-Shoe-Flies RtD and prototype evaluation developing new backstories that incorporate other *external reasons to socialize*. It would be interesting to consider how interaction can be designed with *mixed control for a shared experience*, or how to design technology that offers a focus *beyond the self*. Additionally, it would be interesting to explore what is a *low-stakes shared goal* that can elicit and enhance co-location social interaction. Also, understanding opportunities to create *reciprocal interaction* between users.

The conceptual contributions I presented in this dissertation include the design framework for social wearables, the synergistic social technology strong concept, and vulnerability as an experiential design quality. When I developed the instructional materials for the edu-larp camps, I drew from these to develop activities that novices to technology design could engage in to create social wearables in no time. These instructional materials worked well in the context of the edu-larp camps deployments, as campers could design, create, and develop wearable technology. However, more instructional materials could be developed to help novices better consider design opportunities when creating social wearables. It would be interesting to consider the differences and impact of teaching novices “wearable technology design” versus “social wearables design,” embedded in a backstory, as happened in the edu-larp camps project (Chapter 5.3.2.2).

To summarize, in the dissertation work, I conveyed how I used design practice to inform theory generation and used the resulting conceptual contributions to further inform design practice. My design practice and the evaluation of the design prototypes allowed me to generate intermediate-level knowledge contributions for design. Then, I leveraged these insights when I developed instructional materials for the edu-larp camp curriculum, which was also evaluated.

Appendix

Appendix A

List of Contributions

I have included a list of my research output toward completing my Ph.D. dissertation. I include my practice-focused, conceptual, and translational contributions regarding social wearables and research that I completed on other topics, including articles from my industrial research internships (Snap Inc. 2020, Google 2022).

	Title	Venue	Contribution			First Author	DOI
			Practice	Conceptual	Translational		
Dissertation related research	Synergistic Social Technology: Designing Systems with 'Needs' that Encourage and Support Social Interaction	DIS 2021 Full Paper Honorable Mention	V	V	—	V	https://doi.org/10.1145/3461778.3462021
	Design Framework for Social Wearables	DIS 2019 Full paper	V	V	—	V	https://doi.org/10.1145/3322276.3322291
	Designing 'True Colors': A Social Wearable that Affords Vulnerability.	CHI 2019 Full paper	V	V	—	V	https://doi.org/10.1145/3290605.3300263
	Designing Future Social Wearables with Live Action Role Play (Larp) Designers	CHI 2018 Full paper	—	V	—	—	https://doi.org/10.1145/3173574.3174036
	Playful Wearables: Understanding the Design Space of Wearables for Games and Related Experiences	MIT Press 2023 Book	V	V	V	co-authorship	https://mitpress.mit.edu/9780262546911/playful-wearables/
	Co-Designing an In-Person Tech Camp for Girls	DIS 2023 Full paper	V	—	V	V	under review
	Now that's what I call a robot(ics education kit)!	DIS 2023 Pictorial	V	—	V	—	under review
	Anywear Academy: A Larp-based Camp to Inspire Computational Interest in Middle School Girls	DIS 2022 Full paper	V	—	V	—	https://doi.org/10.1145/3532106.3533532
	Flippo the Robo-Shoe-Fly: A Foot Dwelling Social Wearable Companion.	CHI 2020 Work in Progress	V	—	V	V	https://doi.org/10.1145/3334480.3382928
	`Not Too Much, Not Too Little' Wearables For Group Discussions.	CHI 2018 Work in Progress	V	—	—	V	https://doi.org/10.1145/3170427.3188500
	Co-located Social Engineering Through Novel Technology Design.	DIS 2020 Doctoral Consortium	—	V	—	V	https://dl.acm.org/doi/10.1145/3393914.3395834
	A social wearable that affords vulnerability.	UbiComp/ISWC 2019 Demonstration	V	—	—	V	https://dl.acm.org/doi/abs/10.1145/3341162.3350767
	Workshop presentation of a social wearable that affords vulnerability.	UbiComp/ISWC 2019 Extended abstract	V	V	—	V	https://dl.acm.org/doi/abs/10.1145/3341162.3345614
other research topics	Chasing Play with Instagram: How Can We Capture Mundane Play Potentials to Inspire Interaction Design?	CHI 2020 Work in Progres	—	V	—	—	https://doi.org/10.1145/3334480.3382913
	Social Media as a Design and Research Site in HCI: Mapping Out Opportunities and Envisioning Future Uses.	CHI 2021 Workshop organizing	—	V	—	—	https://dl.acm.org/doi/10.1145/3411763.3441311
	``I just let him cry...'': Designing Socio-Technical Interventions in Families to Prevent Mental Health Disorders.	CSCW 2018 Full paper	V	—	—	—	https://doi.org/10.1145/3274429
	Design (Not) Lost in Translation: A Case Study of an Intimate-Space Socially Assistive ``Robot'' for Emotion Regulation.	CHI 2022 Article	V	—	—	—	https://doi.org/10.1145/3491083
	Drawing From Social Media to Inspire Increasingly Playful and Social Drone Futures.	DIS 2021 Pictorial	—	V	—	—	https://doi.org/10.1145/3461778.3462020
	Project IRL: Playful Co-Located Interactions with Mobile Augmented Reality	CSCW 2022 Article	V	V	—	V	https://dl.acm.org/doi/10.1145/3512909
	The Cloakroom: Documentary Narratives in Embodied Installation.	TEI 2018 Extended Abstract and Installation	V	—	—	V	https://dl.acm.org/doi/abs/10.1145/3173225.3173297
	The Cuteness Factor: A Collaborative Design Framework for Artists, Designers, and Engineers	DIS 2023 Pictorial	—	V	—	—	(forthcoming 2023)
	A Qualitative Study on Building and Sustaining Highly Diverse Software Engineering Teams	FSE 2023 Full paper	—	V	—	V	(forthcoming 2023)

Appendix B

More about True Colors

B.0.1 True Colors Interactions

Below I detail the functions and interactivity of the True Colors social wearable, including their in-game actions and meaning, the out-of-game technical details, and the roleplaying instructions:

Affiliation and expressive color. All wearables had a "true color," corresponding to the distinctive color of the AugNet corporation that the wearable connected to. This was pre-programmed based on the wearer's character sheet. By touching the capacitive touch sensors on the front of the wearable (Figure 3.4 (B)), Augments could choose to display this color, any of the other AugNet colors, or a neutral white light. In-game, this choice allowed players to signal an authentic, fake, or no affiliation. Augments could reveal their character's actual AugNet affiliation by touching the capacitive sensor for three seconds. This feature allowed players to play scenes questioning the Augment's loyalty and motivations, perhaps even forcing them to expose their "true" color. The larp designers stipulated that players could change their true color only once during the game, which in-game would require roleplaying a long and intense scene with researchers participating in the larp (This was motivated by the fact that to change the "true color" of a device required re-programming it on-site). Finally, players could momentarily control the lights' brightness (Figure 3.4 (D)) by pressing briefly on the left side of the wearable. The in-game meaning of this function was left open to players' interpretation, and it was rarely used.

Attacks. Augments could inflict a "stun" on others by pressing on the front left of the wearable (Figure 3.4 (D)). This would trigger flashing white, yellow, and blue lights and an accompanying sound effect. The larp designers stipulated that Augments had to physically contact other players to stun them. A stunning attack would also take a toll on the Augment, increasing their likelihood of experiencing a breakdown.

Breakdowns. In the New Gyr larp world, Augments suffer from inevitable, incapacitating periodic "overloads" of their augmentations. The larp designers expected these overloads to be roleplayed through significant trouble moving and great pain until the overload ends. Short, sharp sound effects signal an overload's beginning and end, evoking a sense of urgency and danger. During the overload, which lasts 4 - 6 minutes, the wearable flashes red lights, similar to emergency vehicles such as ambulances. The frequency of these "naturally" occurring overloads depends on the quality of the augmentation, determined based on the Augment's character sheet. Overload intervals, ranging from 1.5-2.5 hours, were pre-programmed before the larp event. The Augment player can also trigger an overload by pressing both sides at the front of the wearable

(Figure 3.4 (E)). Designers included this option if players wanted to trigger an overload to support their role-playing in particular scenes. Other characters, known as Augment Engineers, with hacking or mechanical skills could also trigger overloads by inputting a code (provided by larp designers to selected characters) through the keypad at the back (Figure 3.4 (G)). Clicking on the keypads emitted sounds, which could alert the Augment. Finally, performing "stun" attacks increased the likelihood of suffering an overload. This was implemented through a counter that tracked the number of stuns one performed.

Healing. Although an overload passes with time, others can decrease or end its duration. Social touch (Figure 3.4 (F)) through skin contact with the capacitive sensor at the back of the wearable shortens an overload. It changes the overload's flashing red lights to pulsating rainbow lights. Social touch can also be beneficial between overloads, delaying them. Augment New Gyr larp designers gave engineer characters healing codes, input through the keypad, that immediately ended overload (Figure 3.7). The larp designers expected this service would have an in-game service charge, which Augment Engineers could waive for friends or as a pro bono gift to other players.

Immunity. Very few Engineers were given a unique code they could input in the back of Augments to provide them with overload immunity for the day. "Immunity" status was visible to others through rainbow color lights permanently displayed instead of affiliation colors on the Augments' wearables (Figure 3.6). Engineers could charge Augments an extremely high service fee for this procedure in-game.

B.0.2 True Colors Technical Implementation

True Colors was prototyped with the Circuit Playground (CP) microcontroller. We chose to work with the CP because adding components to extend its interactivity is easy. The CP has an ATmega32u4 processor and can be powered with a Lipoly battery. It has a micro USB port to support programming and debugging with Arduino IDE. It has multiple inputs, such as two push buttons and eight pads that can act as capacitive touch inputs, as well as light, temperature, motion sensors, and more. In terms of output, it has ten mini addressable NeoPixels and a mini speaker (magnetic buzzer). The technical design was an iterative process that went hand in hand with the design of its function in the New Gyr larp. As mentioned above, the design was iterated in multiple rounds. The final design signaled its state to players and wearers (its output) by displaying bright colors on its LEDs and accompanying audio tunes during specific events (e.g., breakdowns see Figure 3.7 or immunity states, see Figure 3.6). It had RGBW 10 LED strips on each side (Figure 3.4 (A)), as well as an extra sequin LED light at the center of the five capacitive stud sensors (Figure 3.4 (C)), all of which were also connected to the CP with wires running inside the wearable. The final design's interactive inputs included multiple sensors. The CP was placed at the bottom of the center back. Its pins are wired to a 3.5 x 1.75 inches square force-sensitive resistor (FSR) on the front left of the wearable (Figure 3.4 (D)). This sensor had two functions: a long press would start what was called in the larp a "stun" sequence, displaying blue and white lights and particular sound tunes; a short press would change the brightness of the LED lights momentarily.

The CP was also connected to two capacitive sensors. One was placed in the front right and split into five metallic studs (Figure 3.4 (B)). Any studs worked as the same button, and any tap on them would switch the color displayed, rotating between four color options. These studs, if touched for more than a few seconds, could also expose the "true color" of the wearable. We included a fabric pad that could fit a hand's palm at the top of the center back (Figure 3.4 (F)). This pad was made of conductive fabric and was a capacitive touch sensor. Making this sensor was one of the more challenging elements of integrating the hardware into the soft material of this wearable. The team used wire, and not conductive thread, to connect the fabric pad to the CP because, from their previous experience, conductive thread connections are not always stable.

People could interact with the wearable through four tactile press buttons. When the team first tested them on the fabric, it didn't work because there was no counter resistance, so they carved holes in small cardboard boxes to mount the buttons. Hidden inside the structure, I used boxes to create the physical resistance needed while the buttons were pressed (Figure B.1; Figure 3.4 (G)). Three sequences of five button-press combinations were defined in the code, each with a different function in the game. One combination gave players immunity and resulted in a static show of rainbow lights. Another combination healed players from breakdown mode; a third could put players in that mode.

When designing True Colors, the team had to plan for different shoulder sizes because they did not know who would wear them in the larp. This is why they created an

Figure B.1: A collage of photos taken of the True Colors prototyping process.

internal wire structure that made it slightly flexible and adaptable to fit any wearer. The designers used eighth-inch foam sheets to mount hardware components onto, which also helped to drape the wearables around the shoulders while creating a base structure (Figure B.1). They used polyester batting cut to shape to diffuse the LED lights and make the wearable look more robust and structured while keeping it relatively lightweight. The CP board and battery were positioned at the center back. After mounting all the hardware components on the foam sheets, the design team noticed a weight imbalance that meant the wearable tended to drop backward. Therefore they used three large flat glass marbles as counterbalance weights in the front.

Because this wearable would be deployed in a larp, the designers aimed to make the wearables aesthetically fitting and authentic since larpers and larp designers curate props and technology using this value to support players' immersion [105]. Therefore the designers chose to use a sci-fi-appropriate color palette, such as light-colored metallic printed cotton fabric, that was not too thick or dark to block the LED lights; that choice also avoided adding unnecessary weight to the overall design. Enclosing the hardware within the fabric was challenging, as the designers could not treat it as a traditional garment or a cushion. Wires had to run in and out and connect to pieces mounted on the outer surface to allow for interaction with various kinds of switches. They ran under the surface to connect the hardware components too. The designers chose to finish the edges with a thick metallic embroidery thread so they could stitch after all the hardware was intact. The designers also hand-painted the switch caps in two metallic nail polish colors and placed the buttons through a metallic card cut into a circle (Figure B.1).

Then they covered this with a removable clear half-plastic bubble to mark the position of the buttons and make it more futuristic. Overall, the design worked well in New Gyr larp; not all the players who used the wearable as part of their costumes as Augments appreciated the aesthetics. In addition to the True Colors wearables, players had their costumes with their color scheme, and some preferred a darker look than the one they presented.

The True Colors wearables were extensively used in New Gyr by many players and were later presented at the Exploratorium and demoed at UbiComp 2019 conference. Even though these wearables are made of fabric with a thin foam and wire structure, they were robust enough to be used throughout the game and still hold. Only one wearable broke due to increased perspiration, and all the wire connections and functionalities are still usable.

Appendix C

Bodystorming Future Social Wearable Designs

C.1 Bodystorming Exercise

This exercise[1] takes inspiration from Tomico and Wilde, who apply notions of situatedness and personal meaning-making to discuss the opportunities and challenges of designing soft wearables. They suggest that the design ideation stage involves "exploring materials on, with and through the body in context [which] can allow meaning to emerge directly from interaction" [138]. Using our bodies in this stage helps us understand the range of possible movements and how we would feel when wearing and moving with them. Let's go through the following steps:

- **Step one.** Identify potential context scenarios where you would like to use the wearables. For example, you can choose scenarios such as hanging out in a pub

[1] This exercise should be done by at least two people.

or bar, walking around the neighborhood, riding the train, working in an office, or any other situation where you can explore opportunities for social interaction using wearables.

- **Step two.** Grab Scotch or masking tape and a couple of small objects that you can easily find multiples of in your environment (for example, pens, paper cups or plates, straps).

- **Step three.** Pick an object and take turns choosing where on your body to tape it. Tape it and think back about the context scenario you chose. Role play wearing these "wearables" (the object you taped to the chosen body location) while moving and "living" in this environment. Let yourselves be playful and silly. Try moving in unexpected ways and placing the objects in various places. Ask yourselves: What would the wearables be used for? Would they augment existing social signaling, or would they intervene in the social situation proactively? How would the wearables get activated, and what and who will control them? What would their feedback be? And what would the people who wear them, or others in their environment, need to do as a result of it? Repeat this step with different objects and different scenarios.

- **Step four.** Document your exploration by recording short videos, taking photos, or sketching the scenarios. Add your reflections and personal observations on each social wearable design concept you conceptualized and played with.

C.2 Sensitizing Resources

Watch

Wearable Design Playlist

- https://www.youtube.com/playlist?list=PLJJsyq_XkQtFFvD2oUhOYaW6Y5lTKmxrl

Read

Why The Human Body Will Be The Next Computer Interface - https://www.fastcompany.com/1671960/why-the-human-body-will-be-the-next-computer-interface

The social age of wearable tech: From Quantified Self to emotional second skin- https://www.wareable.com/wearable-tech/the-social-age-of-wearable-tech-beyond-the-quantified-self

Biomimicry- https://www.core77.com/posts/31264/Design-for-All-Life

Books

Fashionable Technology - Sabine Seymour
Experience Design Technology for All the Right Reasons - Marc Hassenzahl

Additional resources

A brief history of wearable computing - https://www.media.mit.edu/wearables/lizzy/timeline.html#1268:

Intro to soft circuit workshop guide (simple LED circuit) http://alumni.media.mit.edu/~emme/guide.pdf

circuit playground express course https://core-electronics.com.au/tutorials/circuit-playground-express-workshop-for-beginners-and-educators.html

Arduino basics w/Becky Stern https://www.youtube.com/playlist?list=PLxW5bBHPfdByrF_TANdThbw6VXuKRx9eL

Light up led ring, with just a coil https://makezine.com/projects/make-a-secret-light-up-led-ring/

Hi-fi controller (Lara) https://www.instructables.com/id/High-Five-Collector/

Laser jacket tutorial https://www.instructables.com/id/Laser-Spiked-Jacket/

Videos

https://www.youtube.com/watch?v=Emm2WuC7Ss8 (Despina)
From Thinking to Making: Weaving Technology in Everyday Life

https://www.youtube.com/watch?v=X7ui-iAp8Pc
Kate Hartman: The art of wearable communication

2017 CAST Symposium BEING MATERIAL: Hussein Chalayan and Michelle Finamore, WEARABLE https://www.youtube.com/watch?time_continue=737&v=oVaPDhNYMkI

https://www.youtube.com/watch?v=BXqTnLPC7cQ - Implantables -
Wearable technology: Rami Banna at TEDxLondonBusinessSchool
Designing for the Augmented Body: Fashion and Wearable Technology | Amanda Parkes | TEDxFultonStreet **https://www.youtube.com/watch?v=u109YbO4rn4**

Autoethnography
https://onlinelibrary.wiley.com/doi/full/10.1111/j.1749-8198.2009.00279.x
A Quantified Past:Fieldwork and Designfor Remembering a Data-Driven Life
https://www.dropbox.com/s/30g9r7e7dnk0zfb/Hard-Copy%20Thesis%20%28Print%29.pdf?dl=0
On-World Computing Enabling Interaction on Everyday Surfaces
https://www.robertxiao.ca/pubs/Thesis2018.pdf

Design
Designing the spectator experience
https://dl.acm.org/citation.cfm?doid=1054972.1055074

Playful or gameful?- creating delightful user experiences-p34-lucero

Beyond Generalization: Research for the Very Particular
https://dl.acm.org/doi/10.1145/3289425

Prototyping: Fake It Till You Make It -
https://developer.apple.com/videos/play/wwdc2014/223/

Designing intuitive user interface
https://developer.apple.com/videos/play/wwdc2014/211/

Designing fluid interfaces for iPhone x
https://developer.apple.com/videos/play/wwdc2018/803/

The qualities of great design
https://developer.apple.com/videos/play/wwdc2018/801/

C.3 Presentation Slides of the Online Design Workshops

Workshop 1

Welcome Advisors!

Sunday, June 6 2021

What are we doing?

- Informal learning grant (NSF)
- Designing an Educational Live Action Role Play camp for middle school girls
- Collecting feedback from you → useful for our Game Academy designers
- Goal: a great camp

What are we doing?

- How will we be working together?
- What will you do? Feedback
- What is your role? Advocate for the future campers! :)
- Gift card (take home activity)

What are we doing today?

- Work with a premade micro:bit code that has a few modes
- Material exploration design activity

Take short breaks to get the blood flowing

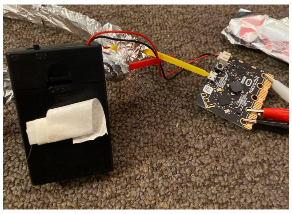
- Show and tell discussion
- Introduce take home activity

Here's a copy of the code!

Open the link in chat and select "Edit Code" near the top

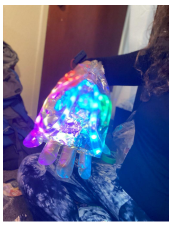
Micro:bit making it wearable

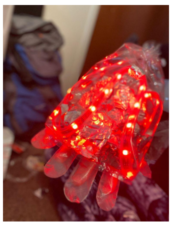
Micro:bit and battery pack

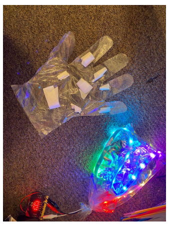


Crafting with the Micro:bit

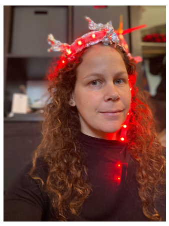
Micro:bit making it wearable - example #1





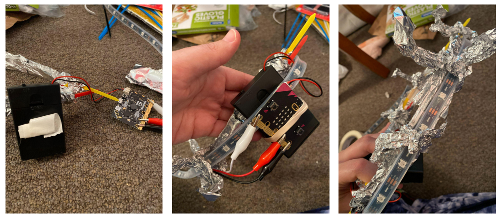


Micro:bit making it wearable - example #2

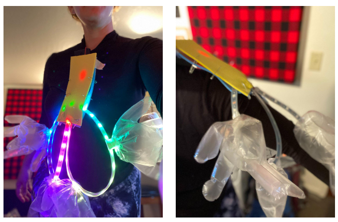


Micro:bit making it wearable – example #2

Micro:bit making it wearable – example #2

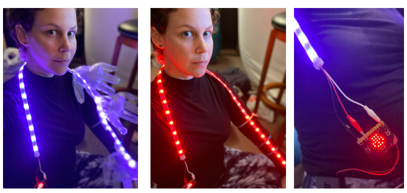


Micro:bit making it wearable – example #3



Micro:bit making it wearable – example #3

Micro:bit making it wearable – example #4



Micro:bit making it wearable

Explore on your own!

Micro:bit making it wearable

Mode

Materials to work with

Updating the code

How to attach to the body

Body part to attach to

Confused Sudden Tough Hideous

Happy Spectacular Delicious

Tiny Sneaky Chunky Murky

Prickly Fabulous Obnoxious

Gross Random Outrageous

Funky Icky Dizzy Grouchy

Break until ???

Micro:bit making it wearable

Discussion

Design Cards Exercise

Side A

Interdependence

Wheelbarrow race, three-legged race…

I played this game with XXX when…, and where...

It made me feel...

Side B

Interdependence

Side A

Interdependence

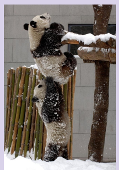
Standing on somebody's shoulder to get something from a really high shelf.

This happened to me (or somebody else) when… where...

It made me feel...

Side B

Interdependence



Side A

Interdependence

Carry a heavy object together.

This happened to me (or somebody else) when…

It made me feel...

Side B

Interdependence

Take Home Activity

Design Cards Exercise

- Side B: For all the cards, find an image on google that you think would give someone a sense of the concept. Drop it into place on the card. If you find more than one image you think works well, you can duplicate the slide and create another version of this card.
- Side A: Choose 3-5 of the concepts, and explain them with concrete examples.

Reflection on the Exercise

Please fill out the survey to let us know how we can improve the experience for the campers!

Thank you!
See you next week

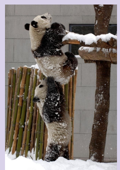
Side A

Interdependence

Giving someone a boost up.
This happened to me (or somebody else) when…
It made me feel...

Side B

Interdependence



Side A

Interdependence

Standing on somebody's shoulder to get something from a really high shelf.

This happened to me (or somebody else) when… where...
It made me feel...

Side B

Interdependence

Workshop 2

Story Recap

Welcome back explorers-in-training to the Anywear Academy!
As you know, the Anywear Academy is the secret headquarters where Earth connects to other worlds.

The only people who know about these worlds are the heads of governments, the United Nations, and of course, the students and explorers-in-training of the Academy.

Our job is to collaborate with the other worlds to trade goods and services, and most importantly to maintain peace, and make sure that monsters or evil creatures in another world don't leak over into ours.

The Fairy World

After you rescued back the Wuzzy earlier this year, the Wuzzy pulled you to the Fairy world. Now that you have finished your business there, you need to get back to the Anywear Academy Headquarters urgently.

In the Fairy World, the Shapeshifter is the one who opens portals. They can help you open a portal to get back. For that, they need ENERGY, which they get from **VERY extravagant** designs that work **in sync**, and **face the same direction** -- otherwise the energy won't flow and it is useless.

When the energy flows, part of the path opens. You need the whole path to be open so you can get back the Headquarters. For that, you need to work together as a group.

Teamwork

To make it extravagant, choose:

How to attach to the body

Where to attach the wearable to (cannot be below the elbow)

Compass direction to sync with your group members

Materials to work with

Utilize the code for great impact

Naming yourself

Witty
Sudden
Powerful
Confused
Tough
Lazy
Happy
Spectacular
Tireless
Rebellious
Fantastic
Sneaky
Chunky
Tiny
Murky
Prickly
Fabulous
Obnoxious
Stubborn
Random
Gross
Dizzy
Outrageous
Radical
Funky
Tense
Sensible
Proud
Grouchy

Break until 10:53

We, Explorers-in-Training, are gathering to design very extravagant wearables to send energy to the Shapeshifter, who will help us find the path back to the academy 10...9...8...

To make it extravagant, choose:

How to attach to the body

Where to attach the wearable to (cannot be below the elbow)

Compass direction to sync with your group members

Materials to work with

Utilize the code for great impact

Come back at 11:20

The shapeshifter appears...

Now, we will stop being explorers-in-Training to be our usual selves in 10...9...8...

Discussion

Social design cards

Interdependence
Caring
Surprising
Celebrating
Monitoring
Checking In
Empowering
Invitating
Gifting
Building On
Reciprocating
Negotiating
Contacting
Resonating
Sharing
Offering
Overcoming

Camp's advertising materials

Reflection on the Exercise

Please fill out the survey to let us know how we can improve the experience for the campers!

Thank you!

C.4 The Camp's Bodystorming Design Exercise

BODYSTORMING DESIGN CLASS

Mandatory: Y
Level: 1

Micro:bit skills: none
IG Application: designing and crafting with the body
OOG Skills (standards):
Terminology keywords (words to try to incorporate as much as possible): iteration, design thinking, prototyping, refinement

Min/max# students: 1/20
Duration: 30m
Equipment needed to teach: 1) various craft materials (see list) ; 2) print and cut below tables and fold into 3 separate containers
Badge/patch indicator: n/a
Mission Ties: (names of missions that use this class) all missions

Demonstration Code:
Classroom Code / Project:

Lesson:
Learning about design basics, brainstorming with the body (bodystorming) and **iterating** and developing ideas collaboratively. This is a foundational class for designing wearables, to practice developing costumes to wear and quickly prototyping them with the craft materials.

Lesson text in non-italics
Notes to the facilitator in italics

PART 1 (total 15 mins)

A. **Individual Practice in Soma Design (5 min)**
   - *in a box or hat cut and fold in the body parts (see below print, cut, and fold before the class starts). Ask campers to draw **1 piece at random.***
   - *Tell the group to experience the body part while walking in the room. Write on a board while you read to the group questions they should ask themselves:*
     - *"How does it feel when you move?" Does it feel light? Does it feel heavy?*
     - *Then ask them to stop walking and move that body part in different ways. Ask a (and write on the board) the questions:*
     - *"What can it do?"*
     - *"How does that feel?"*

B. **Exploring Material Qualities (10 min)**

- *in a box or hat cut and fold the list of words that describe material qualities (see below print, cut, and fold before the class starts). Ask campers to* ***draw 2 pieces*** *at random*
- *Pose the challenge: make a piece of wearable costume for the body part you got and use the two material qualities to choose from the craft materials to make your design. Tell them this is a short exercise and let them know how much time they have to make it.. (quick and dirty rather than a refined design)*

PART 2 (total 15 min)

C. Show and Tell (2min)

- *Facilitator divides the campers in groups of 2 people (and if odd one group could have 3 people). Then they ask campers to be in their new groups and let each other know what they made by stating what body part they got and what material qualities they got. Facilitator writes on the board :"I got this <body part> and <these material qualities>."*

D. Co-creation & iterative process (8 min)

- *Facilitator poses the challenge: "Make a design that conveys a vibe together" you can make it through the way it looks, how it feels, how you move with it, or how you interact with each other when you wear it.*
- *in a box or hat cut and fold in the "vibe" words (see below print, cut, and fold before the class starts). Ask that 1 person from each group would draw* ***1 piece*** *at random.*
- Facilitator tells the group not to share with other groups what vibes they got.
- *Facilitator instructs the group to:*
  - *i.* make the wearable design reflect the vibe they got:
  - *ii.* They can combine or start from scratch together. Present the options of: create a single costume; separate pieces that work together; can merge the previous merge; choose some parts from what you made earlier and combine them together; or leave them separate but make them work together somehow..
  - *iii.* They can also add new things to the design:
    1. Working with the craft materials
    2. Working with their bodies see what they can do

- Facilitator spreads **Vibe Boards** on a table (we will print them for you) for inspiration and says:
  - *they can check the boards for inspiration, but don't pick up the ones that relate to your vibe, to not expose to other groups what vibe you're working with.*
  - Tell them that designers create moodboards. Sometimes they work on them for a while before designing a piece for inspiration.

E. **Show and Tell (5 mins)** - Make sure all groups have a chance to present and talk about their work. Manage the time based on the number of groups
    - One group presents at a time while the rest of the group tries to guess the VIBE word that inspired the shared project. With every turn, after a few guesses have been made, the facilitator tells the group presenting: *Tell us how you chose to work together, and how you hoped to convey the vibe you got. Do you feel it radiates the vibe you got picked?*

PART 1 - A) BODY PARTS to cut ✂ and fold into one hat/basket/container

Head	**Head**
Neck	**Tail Bone**
Shoulders	**Lower Arms**
Upper arms	**Lower Back**
Upper back	**Wrists**
Waist	**Elbows**
Hands	**Ankles**
Knees	**Feet**
Thighs (Upper legs)	**Shins (Lower legs)**

PART 1 - B) MATERIAL QUALITIES ✂ and fold into one hat/basket/container (2 pages)

Soft	**Rough**
Sparkly	**Spiky**
Clear	**Stretchy**
Stiff	**Structured**
Versatile	**Sticky**
Thick	**Thin**
Ordinary	**Smooth**
Opaque	**Transparent**

Cheap	**Luxurious**
Delicate	**Flimsy**
Waterproof	**Spongy**
Shiny	**Matte**
Patterned	**Malleable**
Cold	**Warm**
Fused	**Flexible**
Absorbent	**Hanging**

PART 2 - D) VIBES to cut ✂ and fold into one hat/basket/container

HAPPY	SAD
DARK	VIBRANT
ROMANTIC	RELAX
AGGRESSIVE	DARING
BRIGHT	SCARY

C.4.1 Material List

https://www.michaels.com/home?cm_mmc=SearchBrand-_-google-_-MICH_Search_US_N_Brand_Trademark_Branded_Exact-_-Trademark+-+Branded+Core+Term&kenshoo_ida=tm_brand&kpid=go_cmp-324266651_adg-24658685771

TOOLS						
Scissors	large	small				
Variety types of glues	school glue	glue guns	glue sticks	tacky glue	glitter glue pens	
Sharpies	black	colorful	fine tips	thick tips	gold + silver + white markers	
Tape	scotch	doublesided	invisible	masking tape	colorful duct tape	variety of wash tapes
Mirrors for students (wearable tailoring)						
MATERIALS						
Foam sheets	https://www.michaels.com/search?q=foam%20sheets					
Variety of glitters						
Card stock	colorful					
Yarn	a few different colors					
Threads, needles, and pins						
Fabric variety	Stretchy white/black	printed (variety of colorful scarps)	soft and transperant			
Velcro with sticky back	prefferable on a roll					
beads and buttons variety						
Variety of neutral abstract colorful stickers						
Craft wire						
Tin Foil	no need to buy (we have extra)					
poly fill	no need to buy (we have extra i think)					
Plastic golves	no need to buy (we have extra)					

C.4.2 "Vibe Cards"


Sad


Happy


Brave


Playful


Dark


Romantic


Vibrant


Aggressive


Calm

C.5 Additional Materials for Supporting Design Activities in the Camp

Guiding Questions to Reflect on

Designers use tools, to design. You can use these as questions

- To explain your designs: how do you communicate to others about your design.
- To design your features, decide how it will work and what for.
- To think through what you're making

Social Context

1. In what social environment does the interaction occur? What are the personal and social commitments required? What degree of focused attention is required from the wearer and others?
2. Is wearing the design considered socially acceptable? Are the sensing/activation and actuation/feedback of the design socially acceptable?
3. How many wearables are working together? What is the interplay between them? Are they interdependent?
4. What is the best on-body location for the wearable to bring people together?

Activation and Control

1. How is the design activated?
2. What is being sensed, and what triggered it?
3. How do you use your body to make it work? What means of activation or gestures are required?
4. Does activating the device happen automatically or require people's intentional input?
5. Who controls the wearable activation and who controls its deactivation? Is it the wearer, the wearer with others, or others alone?

Feedback

1. What feedback (output) do people experience?
    a. For example, is it visual such as lights, auditory sounds?
    b. Is it noticeable or not?
    c. Who would notices it: the wearer, others, or maybe both?
2. Is the feedback happening in real-time or is it delayed from the activation?
3. If something about the wearer is being sensed, do other people notice this? Do they have access to the feedback?
4. What is the interplay between the activation and the feedback? Can the mapping between sensor and actuator be deciphered?

Mini Design Exercises For Social Wearables

Rely on each other

1. Design wearables that are interdependent– need each other to work, or compliment each others function–for example, light up together.

2. Design to need your peers to make it work
    - Example 1– if a design is worn on the back, someone else might need to press the button.
    - Example 2– Needing to synchrnize in order to activate using the compass

Narrative & social purpose

1. Design to surprise your peers

2. Design to deceit

3. Design to communicate with others or signal something

4. Design to disguise (for example, make it work only for movement)

Experimenting with bodily affordances

1. Design something that you can activate without using your fingers (can use shaking it, can have someone else press the buttons... etc.)

2. Design something that is worn somewhere waist down

3. Explore attachment methods (and where on the body it is worn)
    a. use the props (headband, belts, etc.) as mounting bases for this exploration.

b. try unconventional placements (for example on one's thigh, side of the wais, shoulder, or back)

Mix design ideas

1. Challenge to merge designs ideas in small groups (for example– make it into a hi tech "useless design")

2. Challenge to develop together the design, produce copies of it and wear together in the mission

3. Design for someone else's mission

Body storming class: Low tech exercise design without the microcontroller

C.6 The Familiars: Narrative Driven Design

‘

Design Principles

Making Wearables for Missions' Challenges

1. The designs the campers make to solve mission challenges, need to be worn. The larp story should guide the reasons for that. *Why do they need to make it a wearable?*
2. The stories behind the missions' challenges frame a **need** for making wearables that can get used only *WITH* each other, ie, wearables that need more than one person.
3. The wearable design challenges should require that campers create wearables that are activated by some kind of **coordination** between them.
4. There would be a discussion about how the wearable designs work between people, how, when a camper is designing their wearable, other campers could be involved in activating it, or responding to it with their wearable design. This results in campers thinking of the rest of the group when they work through the wearable design challenges.

Note: Making wearable designs that are merely costumes for the character and don't function beyond that in the story is not enough.

Pre-Existing Mission Elements to Keep in Writing in the Story

1. Transporting into the worlds by synching the wearables' LED colors to the gate's color worked well for that. This shold be written in the story. Campers can be encouraged to create a toggle button between colors to easily change it before they go into a mission.
2. The communication challenge in the space station world: The non-verbal challenge should be written in the story to overcome using the wearables. The wearable project challenge is to make devices that can communicate. It could be as easy as pressing a button and turning light on and off (morse code type) or change the LED color to convey a message. Other options could be more challenging like sending radio frequencies to trigger others' wearables, or sending a written message.

‘The Familiar’: New Elements to Write in the Story

The species of the “critters” that were previously moving robotic car-like things need to be worn on the body. We are creating a tutorial for the facilitators to use and make their own creature to wear. However, we need you to write the story behind them.

- What is their role in Anywear Academy?
- Who uses them (trainers/Anywear Academy instructors),
- How are they using them?
- Why are they using them?
- How could they facilitate interaction between people in the camp?

Ideas for the Interaction possibilities:

- The Familiars can be triggered by touch, sound, or shaking
- The Familiars can trigger change in light color, move a servo (for example wiggle their tail, or turn a propeller on their head), or play sound tunes.

Inspiration for Mission Challenges (Narrative backstory needs writing)

- Coordinate body movements:
  - a design is worn on the back, someone else might need to press the button to turn on
  - Everyone needs to direct their bodies to the same direction (using the compass) to trigger the wearable.
  - Campers need to coordinate a jump at the same time to trigger the wearable
  - Shaking the wearable on the body (e.g. waving the arm)

- The result will be changing the light color, changing the light pattern, or making sound tunes.

- Challenge to design wearables that need others to make it work, or compliment each others’ function– Examples: trigger sounds together, light up together create a light pattern like a rainbow where each wearer is representing one color of the rainbow.

How is the Wearable being Activated?

1. How is the design activated?
2. What is being sensed, and what triggered it?
3. How do you use your body to make it work? What means of activation or gestures are required?
4. Does activating the device happen automatically– is it always ON, or require people’s intentional interaction?
5. Who controls the wearable activation and who controls its deactivation? Is it the wearer, the wearer with others, or others alone?

What Happens when the Wearable is Activated?

1. What feedback (output) do people experience?
    a. For example, is it visual such as lights, auditory sounds?
    b. Is it noticeable or not?
    c. Who would notices it: the wearer, others, or maybe both?
2. What is the interplay between the activation and the feedback? Can the mapping between sensor and actuator be deciphered?

Social Purpose Written into the Narrative:

1. Design to surprise others
2. Design to deceive others
3. Design to communicate with others or signal something
4. Design to disguise (for example, make it work only for movement)

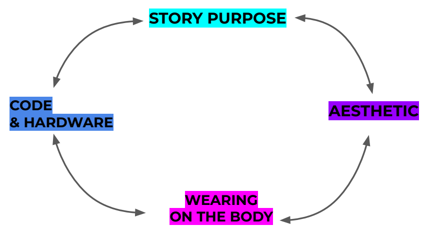
Challenging and Experimenting with Bodily affordances

1. Design something that you can activate without using your fingers (can use shaking it, can have someone else press the buttons… etc.)
2. Design something that is worn somewhere waist down
3. Explore attachment methods (and where on the body it is worn)
    a. use the props (headband, belts, etc.) as mounting bases for this exploration.
    b. try unconventional placements (for example on one’s thigh, side of the wais, shoulder, or back)

C.7 Edu-larp Wearable Design Activities Guide

Guiding Design Activities in the Camp

Before starting to design, consider your choices



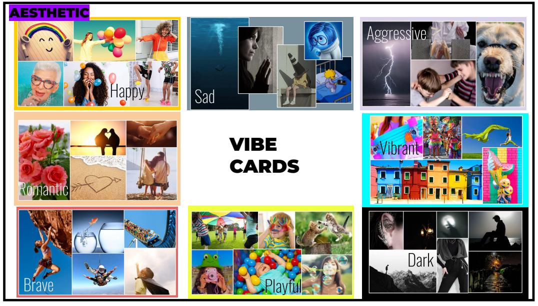
1. STORY PURPOSE

1. What is the in-game meaning, how does your design fit in the story?
   —> in which story world of the Anywear Academy the design will be used?
2. When designing for a mission, what challenge are you trying to overcome? How can wearing/using your design help you do that?
3. How can your design help overcome challenges with others? In other words, can you design in a way that would make your collaborate with others when you try to solve a mission?

AESTHETIC

1. What aesthetic could work well with the story?
   → Reference the vibe cards for inspiration
2. What materials should be used?
   → Reference material affordances list for inspiration
3. What color palette would fit this design best?
   → you can explore color palettes for inspiration, e.g., https://coolors.co/palettes/trending

AESTHETIC

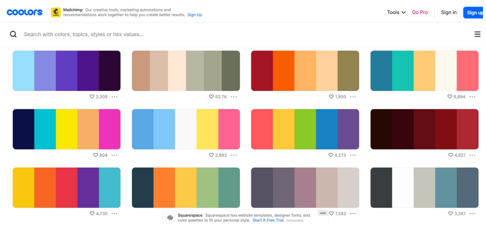


AESTHETIC

Soft	Rough	Cheap	Luxurious
Sparkly	Spiky	Delicate	Flimsy
Clear	Stretchy	Waterproof	Spongy
Stiff	Structured	Shiny	Matte
Versatile	Sticky	Patterned	Malleable
Thick	Thin	Cold	Warm
Ordinary	Smooth	Fused	Flexible
Opaque	Transparent	Absorbent	Hanging

AESTHETIC

Color Palette Reference



WEARING ON THE BODY

1. Where on the body the design will be worn?
   → *Reference the list of body parts*
2. How can this body part move? How would it feel when the body moves? How can I wear it on this part of the body–how do I actually wear it there (what material I need to connect it to my body)?
3. How wearing it on this part of the body could be used in the design? How can it be connected to the input or output?
4. How can the wearable interact with other people when it is place on this part of the body?

WEARING ON THE BODY

Top of the Head	Forehead
Neck	Tail Bone
Shoulders	Lower Arms
Upper arms	Lower Back
Upper back	Wrists
Waist	Elbows
Hands	Ankles
Knees	Feet
Thighs (Upper legs)	Shins (Lower legs)

CODE & HARDWARE

INPUT

- Touch: connect conductive material such as tin foil to extent (change default Resistive pin to capacitive)
- Shake
- Jump ('Free Fall' block)
- Tap ('3G', '6G', or '8G')
- Compass ('Compass Heading' block)
- Radio signal (receive) *in pairs

OUTPUT

- LED lights (static colors)
- LED lights (changing color pattern/animation)
- UV lights
- Servo motor
- Sound tunes
- Radio signal (send)*in pair

C.8 The Familiars: Facilitators' Training Materials

Facilitator's Training

Making your social wearable: "The Familiar"

Context: what is the "Familiar"?

Familiars are a key component of what it means to be an Explorer for the Anywear Academy. Separate from the Micro:bit used by Explorers in the field for their own social signaling, disguise, and problem solving needs, Familiars act as companions and partners.

Their sensitivity is their strength but can also result in over stimulation.

Partners to familiars provide a calming influence while Familiars provide an early warning to potential threats.

Context: what is your "Familiar"?

Just as you created your character, now imagine your Familiar, what's it's personality? What will it do? What would it look like? What is a mission you've taken it on? Does it have a name?

Look at the slide deck to guide you. This deck should be helpful to guide campers in their own design exercises:

https://docs.google.com/presentation/d/14HylFWG2gxr6UtvXpH30zsZWnGv2khJ2_s-vgOmEDyQ/edit#slide=id.g132d063e057_0_0

Thinking about your design choices to make your Familiar

Working with the micro:bit and MakeCode

1. Familiarize your with the micro:bit and prepare bolting connections

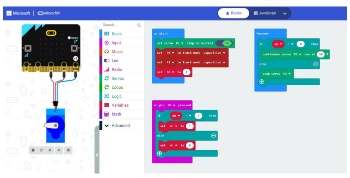
   Check out this slide deck

2. Use the "Introduction to Micro:Bit" lesson found here to learn about MakeCode.

3. Look at this document, and choose which code you want to use, rewrite in on MakeCod and download to your micro:bit.

Servo code

https://makecode.microbit.org/_HvDi8w9DrYue



Rainbow LED Version

https://makecode.microbit.org/_5iU7XvX36e76

Making your “Familiar”

The Familiar is made of a box containing:

- micro:bit
- the battery pack and batteries
- servo motor or LED lights connected to it

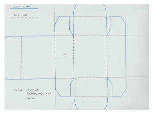
The box is packaging the hardware and needs to attach to something that would connect it to the body, so that the creature could accompany you in the camp.

The LEDs/Servos and any capacitive Tape needs to be accessible

Making your “Familiar”: Boxing the hardware

- Print this template and cut out
- Trace it on your chosen material (card stock)
- Download it from here:

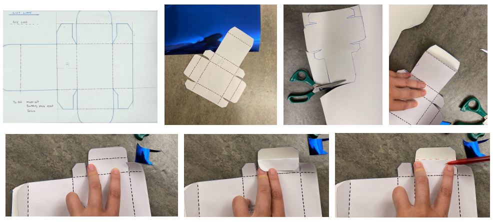
  https://drive.google.com/file/d/1ODWayXPdSgAOGTZhG97iSVJbYHRdnECU/view?usp=sharing

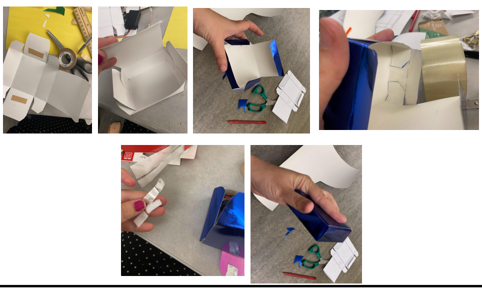


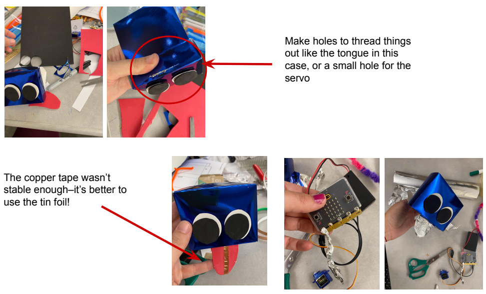
Tips for crafting the “Familiar”

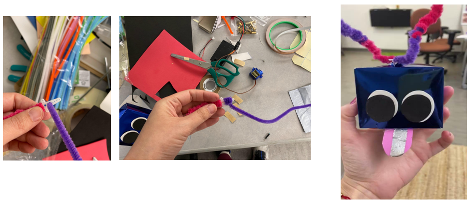
- Double sided tape is your friend! Use it.
- DO NOT TAPE CLOSE THE BOX

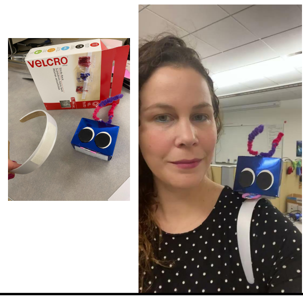
Use velcro tape to seal it. This will allow you to open and close the Box and be able to access the button on the battery pack











Design your "Familiar"

- Your "Familiar" will be interactive. Depending on its backstory that interaction will be designed by you. You need to choose what are its input and output.
  - The code (MakeCode) and the hardware (what will start the interaction– touch (capacitive sensing) or shaking… etc. and what it will do, using Servo or LEDs?) determine the interaction
- Explore what it could feel like having it connected to different places, even when moving around by attached the box you made to your body to different places (you can use tape for this exercise). This will inform how you design your Familiar.
- Use the backstory you created and look again at the design guide deck to help you define your Familiar's aesthetic.
  - Choose the materials that would best convey it.
- Start making your Familiar. Craft and make it your own. You can start by sketching your ideas or just by getting inspired from the materials on the go. .
- You might need to redo things or changes things around. That is part of the iterative design process. This is normal and expected.

E N J O Y !

We hope this help you make your Familiar. Please add you comments or suggestions on how we can improve this guide for future camp instructors/facilitators/interns!

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