A Co-Design Toolkit for Wearable E-textiles

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Figure 1 – (a) a single Wearable Bit, (b) several combined Wearable Bits, (c) a shirt, (d) a pair of pants, and (e) a shoe all made with Wearable Bits

ABSTRACT

Individuals with mobility disabilities face physical and social barriers due to a lack of accessible clothing. E-textiles garments and smart clothing could help make garments more accessible by incorporating assistive technologies directly into clothing, but there are limited methods for co-designing prototypes so that users can be involved in the design process. This is due to the specialized knowledge needed for designing smart clothing (garment construction, e-textiles, computing). To help with these issues I am developing a co-design toolkit for wearable e-textiles called Wearable Bits. Wearable Bits expands upon the swatchbook tradition in e-textiles by making swatches that can connect to form any wearable garment. This document covers the proposed studies I will be doing to evaluate the co-design toolkit and the expected contributions of this thesis project.

CCS CONCEPTS

• Human-centered computing~User interface toolkits

KEYWORDS

e-textile; wearable; constructive assembly; tangible user interface; co-design

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1 Problem Statement

Individuals with mobility disabilities experience social and physical barriers because they cannot access suitable clothing [14]. Physical barriers include whether they can independently put on the garment, and whether it is suitable to their daily needs. Social barriers include whether the garment is suitable for different environments such as the office [14]. Wearable e-textiles and smart clothing provide several opportunities in these areas. Because smart garments are worn throughout the day, they are always available to provide support. This could include technologies to help with dressing and undressing, technologies to increase comfort, assistive technologies, and garments that change based on changing situations. Integrating assistive technologies into fashionable clothing could also help to reduce the stigma of assistive technologies.

Though there are opportunities for smart clothing to help and prototypes are made for individuals with disabilities, rarely are prototypes made with their input but rather evaluated after the prototypes are already built. In my thesis I am exploring how we can use co-design to develop smart clothing prototypes with individuals with disabilities. Co-design is a design process where the user is a partner in research and is involved right from the beginning to ensure that the designed outcome fits their needs [23]. In the area of smart clothing and e-textiles, co-design is often difficult. Wearable e-textiles is a field that requires specialized

knowledge in topics such as garment construction, textile design, hardware design, and computing [25]. My thesis explores how we can make it easier for users, and particularly individuals with disabilities, to be involved in co-design. To do so I am developing Wearable Bits, a toolkit where individual "bits" can be combined to form any e-textile garments (Figure 1).

2 Related Work

In co-design, generative toolkits are scaffolds that allow potential users to express their ideas and imagine different scenarios [24]. In the realm of e-textiles, co-design toolkits include card sorting [18], low-fidelity prototypes [18, 25], and e-textile swatchbooks [7, 9, 22, 25]. Of these, e-textile swatchbooks are particularly powerful because they provide users (who likely have not interacted with e-textiles before) with examples of what is possible and how the interactions with the textile might work. At the same time, these swatchbooks are limited by their format. Though users can try to imagine what it would be like to wear one of these swatches they cannot prototype with them.

In contrast, constructive assemblies, which are tangible user interfaces that can be constructed, deconstructed and constructed again [11, 12], are useful as design toolkits because users can try out different scenarios, components and interactions and continue to prototype until they get their desired result [8]. In the realm of wearables and e-textiles the ones that are the easiest to use tend to be physically stiff and limit the interaction to one area of the body such as LittleBits [1], MakerWear [15] and, MakerShoe [16]. LilyPad [2, 3, 5] is an e-textile Arduino kit with sewable components that can be expanded across the body, but is limited as a constructive assembly since doing and undoing stitches is destructive to most fabrics. Also, the kit acts as an add-on to textiles or garments but is not it itself a tool to build garments. Craftec [13] is an extension of the LilyPad that aims to make the toolkit more accessible to older adults but has the same limitations in terms of garment construction. I*Catch [20], QuiltSnaps[4] and TeeBoard [19] are all textile constructive assemblies that utilize the conductivity of sewing snaps to make the circuits modular, but are limited in their ability to act as co-design tools for any garment since their main purpose is education rather than garment construction.

3 The Wearable Bits Toolkit

The Wearable Bits toolkit builds upon the concept of the e-textile swatchbook by making e-textile swatches wearable. Rather than looking at swatches in a book and imaging possible scenarios, individuals can combine the swatches into a wearable garment.

The Wearable Bits toolkit is made from a tessellated laser cut file and each piece is made of felt, but individual swatches could be swapped out for other materials as long as the pattern is the same. This type of modular fabric design has been used for aesthetic purposes in the work of Hur et al. [10], and taught as a method of avoiding textile waste in textile courses such as Fabricademy [6].

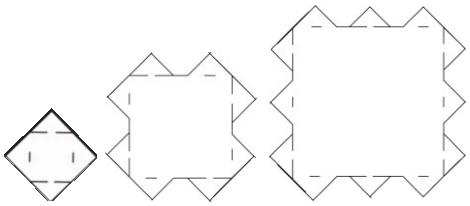

Figure 2 - The three sizes of Wearable Bits that can be connected (a) 1x1 (b) 2x2 (c) 3x3

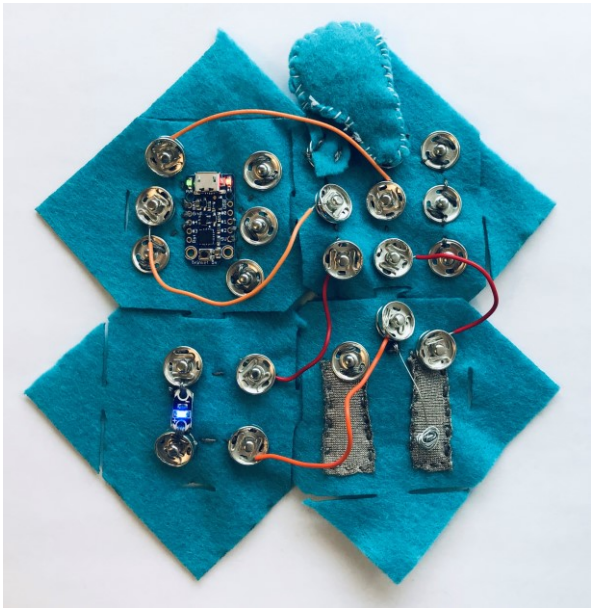

Figure 3 - four connected Wearable Bits – clockwise from top left (a) a microcontroller (b) a breadboard with battery pocket (c) a tilt sensor (d) an LED

There are three sizes of Wearable Bits that all fit into each other (Figure 2). Using modular components rather than clothing patterns makes the toolkit flexible to unique body shapes, disabilities, and assistive devices. Electronic components are then added to the felt pieces through machine embroidery, hand stitching [21], or electronic components from other e-textile toolkits, with enough flexibility that a designer can choose how to build their e-textile swatch while still being part of the system (Figure 3). The circuits are then attached with sewable snaps.

The potential benefits of the Wearable Bits toolkit are:

- It does not require garment construction knowledge for individuals to build garment prototypes
- There is flexibility in terms of the garments that can be made to suit unique body shapes, disabilities and assistive devices.
- It utilizes swatch examples where individuals who may not have seen e-textiles before can then understand what is possible

- There is flexibility in the components that can be added, and similar to a swatchbook or A-Kit-of-No-Parts [21] these can be added continually as the number of swatches expands.
- A modular toolkit allows individuals to prototype garments that change over time, garments that can become other garments, and garments that could change to suit many different occasions.

4 Methodology

There are three studies I am running to build and evaluate the toolkit. The first is a survey of current garment prototyping methods and prototyping gaps for e-textile practitioners and adaptive fashion designers (those who make garments for individuals with disabilities). The second is an evaluation of the toolkit as a constructive assembly, and whether this system works as a toolkit. The third is an evaluation of the toolkit as a co-design tool for individuals with mobility disabilities with the aim of making the toolkit accessible.

4.1 Survey of Textile Prototyping Methods and Gaps

We are currently running online surveys to better understand the prototyping processes of two user groups. One survey is for e-textile practitioners and researchers. The second survey is for adaptive fashion designers (those who design clothing for individuals with disabilities). The aim of these two surveys is to understand how they build their garment prototypes and the current gaps they experience. We are recruiting participants from these two user groups through email. Based on the results of these surveys we will design the Wearable Bits prototype to suit their needs. The analysis of this study will be completed before the doctoral colloquium.

R1: How do these two user groups prototype garments?
R2: What are the difficulties or obstacles these two user groups come across while prototyping garments?

4.2 Constructive Assembly Evaluation

The second study is evaluating whether the Wearable Bits toolkit works as a constructive assembly. We are using the constructive assembly framework proposed by Leong et al. [17] to evaluate a low-fidelity version and a high-fidelity version of the toolkit. We will be inviting individuals in pairs to prototype e-textile garments using the toolkit. During these sessions we will have one individual be the "wearer" and the other individual be the "non-wearer". This study will also help us to evaluate Wearable Bits by the common pitfalls constructive assemblies can fall into, such as the overly block-like aesthetic that many of them have, or that they limit expressiveness and creativity [17]. The analysis of this study will be completed before the doctoral colloquium.

R1: Can individuals build garment prototypes with Wearable Bits and how satisfied are they with their prototypes?
R2: Are individuals comfortable prototyping with Wearable Bits both as the "wearer" and "non-wearer"?

4.3 Co-Design Toolkit Evaluation

I am currently a summer research fellow with Open Style Lab[1] where I am learning how to make accessible clothing and co-design tools for individuals with disabilities. With the insights from this fellowship, I will be improving upon the Wearable Bits prototype so that it is accessible for individuals with disabilities. I will then be evaluating the toolkit as a co-design tool with individuals with mobilities disabilities (during October 2019). During these sessions, individuals will be able to co-design their own garments, as well as co-design new components to add to the kit based on their needs. This study will be occurring after the doctoral colloquium.

R1: Does the toolkit help this user group express their ideas during the co-design sessions?
R2: What components are missing from the toolkit for this user group?
R3: Is the Wearable Bits toolkit accessible for individuals with disabilities?

5 Expected Contribution

This project aims to reimagine the swatchbook tradition within e-textiles to allow for individuals to use swatches as prototyping tools. Having modular components also allows for new garment possibilities to arise such as garments that change over time, garments that become other garments, or garments with exchangeable parts. The expected contribution of this work is an accessible toolkit for co-designing wearable e-textiles that addresses the prototyping needs of e-textile practitioners and adaptive fashion designers. The goal of this research is to involve individuals with disabilities in the design of their own garments so that we can build prototypes that better suit their needs.

AUTHOR BIOGRAPHY

Lee Jones is a PhD student in Digital Media at Carleton University in Ottawa, Canada where she is doing her research with the Creative Interactions Lab supervised by Dr. Audrey Girouard. She is also a research fellow with Open Style Lab, an organization dedicated to the design of accessible garments for individuals with disabilities. Lee started her PhD in September 2016, and her expected completion date is May 2021. Her previous work has involved developing abstract visualizations of biofeedback data for self-reflection, gaming and rehabilitation. Before beginning her PhD, she received her Master of Design degree from OCAD University in Toronto, where she has also taught the Body-centric Technologies graduate course.

[1] https://www.openstylelab.org/

REFERENCES

[1] Bdeir, A. 2009. Electronics as material: littleBits. *Proceedings of the Third International Conference on Tangible and Embedded Interaction (TEI'09)*, (2009), 371.

[2] Buechley, L. 2007. A construction kit for electronic textiles. *Proceedings - International Symposium on Wearable Computers, ISWC* (2007), 83–90.

[3] Buechley, L., Eisenberg, M., Catchen, J. and Crockett, A. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08* (2008), 423.

[4] Buechley, L., Elumeze, N., Dodson, C. and Eisenberg, M. 2005. Quilt snaps: A fabric based computational construction kit. *Proceedings - IEEE International Workshop on Wireless and Mobile Technologies in Education, WMTE 2005* (2005), 219–221.

[5] Buechley, L. and Hill, B.M. 2010. LilyPad in the wild: how hardware's long tail is supporting new engineering and design communities. *Dis 2010*.

[6] Circular Open Source Fashion: *https://class.textile-academy.org/classes/week03/*.

[7] Gilliland, S., Komor, N., Starner, T. and Zeagler, C. 2010. The textile interface swatchbook: Creating graphical user interface-like widgets with conductive embroidery. *Proceedings - International Symposium on Wearable Computers, ISWC* (2010).

[8] Hartmann, B., Klemmer, S. R., Bernstein, M., Abdulla, L., Burr, B., Robinson-Mosher, A., & Gee, J. 2006. Reflective Physical Prototyping through Integrated Design, Test, and Analysis. *Proceedings of the 19th annual ACM symposium on User interface software and technology* (2006).

[9] Hertenberger, A. et al. 2014. 2013 E-Textile Swatchbook Exchange: The Importance of Sharing Physical Work. *Proceedings - International Symposium on Wearable Computers, ISWC* (2014), 77–81.

[10] Hur, E.S. and Thomas, B.G. 2011. Transformative Modular Textile Design. *Bridges 2011: Mathematics, Music, Art, Architecture, Culture*. (2011), 217–224.

[11] Ishii, H. 2008. Tangible Bits: Beyond Pixels. *Proceedings of the 2nd international conference on Tangible and embedded interaction* (2008).

[12] Ishii, H. and Ullmer, B. 1997. Tangible bits: towards seamless interfaces between people, bits, and atoms. *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems* (1997), 3–3.

[13] Jelen, B., Freeman, A., Narayanan, M., Sanders, K.M., Clawson, J. and Siek, K.A. 2019. Craftec: Engaging Older Adults in Making through a Craft-Based Toolkit System. *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '19* (2019), 577–587.

[14] Kabel, A., Dimka, J. and McBee-Black, K. 2017. Clothing-related barriers experienced by people with mobility disabilities and impairments. *Applied Ergonomics*. 59, (2017), 165–169.

[15] Kazemitabaar, M., Mcpeak, J., Jiao, A., He, L., Outing, T. and Froehlich, J.E. 2017. MakerWear: A Tangible Approach to Interactive Wearable Creation for Children. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (2017), 133–145.

[16] Kazemitabaar, M., Norooz, L., Guha, M.L. and Froehlich, J.E. 2015. MakerShoe: Towards a Wearable E-Textile Construction Kit to Support Creativity, Playful Making, and Self-Expression. *Proceedings of the 14th International Conference on Interaction Design and Children* (2015), 449–452.

[17] Leong, J., Perteneder, F., Jetter, H.-C. and Haller, M. 2017. What a Life! Building a Framework for Constructive Assemblies. *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction* (2017), 57–66.

[18] Nevay, S. and Lim, C.S.C. 2015. The Role of Co-Design in Wearables Adoption. *Contemporary Ergonomics and Human Factors 2015: Proceedings of the International Conference on Ergonomics & Human Factors 2015, Daventry, Northamptonshire, UK, 13-16 April 2015* (2015), 109.

[19] Ngai, G., Chan, S.C.F., Cheung, J.C.Y., Kong, H. and Lau, W.W.Y. 2009. The TeeBoard : an Education-Friendly Construction Platform for E-Textiles and Wearable Computing. *SIGCHI Conference on Human Factors in Computing Systems* (2009), 249–258.

[20] Ngai, G., Chan, S.C.F., Leong, H.V. and Ng, V.T.Y. 2013. Designing iCATch: A multipurpose, education-friendly construction kit for physical and wearable computing. *ACM Transactions on Computing Education (TOCE)*. 13, 2 (2013), 1–30.

[21] Perner-Wilson, H., Buechley, L. and Satomi, M. 2011. Handcrafting Textile Interfaces from A Kit-of-No-Parts. *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction* (2011), 61–68.

[22] Posch, I. and Fitzpatrick, G. 2018. Integrating Textile Materials with Electronic Making: Creating New Tools and Practices. *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '18* (2018), 158–165.

[23] Sanders, E.B.-N. and Stappers, P.J. 2008. Co-creation and the new landscapes of design. *CoDesign*. 4, 1 (2008), 5–18.

[24] Sanders, E.B.N. and Stappers, P.J. 2014. Probes, toolkits and prototypes: Three approaches to making in codesigning. *CoDesign*. 10, 1 (2014), 5–14.

[25] Zeagler, C., Audy, S., Pobiner, S., Profita, H., Gilliland, S. and Starner, T. 2013. The electronic textile interface workshop: Facilitating interdisciplinary collaboration. *International Symposium on Technology and Society, Proceedings* (2013), 76–85.