THESIS

# THE EFFECTS OF CODESIGN ON CONSUMER ACCEPTANCE OF A WEARABLE TECHNOLOGY USING THE LILYPAD ARDUINO

Submitted by

Kristen Emily Rogers

Department of Design and Merchandising

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Master's Committee:

Advisor: Juyeon Park

Ruoh-Nan Yan
Cyane Tornatzky

ABSTRACT

THE EFFECTS OF CODESIGN ON CONSUMER ACCEPTANCE OF A WEARABLE TECHNOLOGY USING THE LILYPAD ARDUINO

Wearable technology is increasing in popularity, but research shows that significant challenges still exist in user acceptance. Meanwhile, new tools and design and development contexts are becoming accessible to the average consumer, through which they may more actively engage in the creation of products. This experimental study utilized a mixed-method approach to examine the effect of a codesign context on user acceptance of a wearable technology using the open-source wearable microcontroller, the Lilypad Arduino. Data were collected via two codesign sessions held for 17 adult participants in a western region of the United States; each session comprised a hands-on codesign activity, focus group discussion, and pre- and post-assessment surveys. Direct content analysis was conducted based on the extended Technology Acceptance Model (perceived ease of use, perceived usefulness, and perceived playfulness) as a theoretical framework upon which qualitative data from focus group discussions were arranged; paired-samples comparison analyses were conducted for survey data. Results from both the quantitative and qualitative data revealed that the codesign activity prompted a positive increase in all variables tested; implications are discussed as well as recommendations for further study.

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# CHAPTER ONE: INTRODUCTION AND BACKGROUND

Wearable technology is anticipated to grow 32.78% between 2013 and 2018 (Wood, 2014). The use of wearable electronics is increasing and will become more integrated into our lives in the future (Baurley, 2004). Baurley (2004) quotes Philips Electronics as saying, “our environment of the future will consist of invisible interactive systems that will be embedded in our living spaces and clothing, creating an ambient intelligence that could form a natural part of our life” (p. 274). For this to happen, however, changes will need to be made in the design of technology that is to be integrated into our lives, and most pertinent to this work, to technology that is worn on our body, otherwise known as “wearables.” The industry is currently confronted by a challenge, as consumer acceptance of wearable technology over the long term is still lacking (Wood, 2014). Specifically, research shows that although many consumers purchase wearable devices, they stop using them after a short period of time (Cobb, 2014). This reveals that more research is needed into consumer needs and wants regarding the sustainable use of wearable technology (Chan, Estève, Fourniols, Escriba, & Campo, 2012). As consumers access an increasing number of tools used to customize their consumption, and also considering the specificity with which a wearable device must match user needs and the unique interface formed by the human body (Gemperle, Kasabach, Stivoric, Bauer & Martin, 1998), an investigation into user acceptance of wearable technology could yield important insights on user requirements and desires regarding this product category.

Unlike other electronics, wearable technology forms a unique connection to the human form; it depends on the human body as its primary interface. (Gemperle et al., 1998). The user makes decisions about how to use the wearable as he or she is experiencing the built environment and various stimuli through his or her own body. As Baurley (2004) writes in a discussion on interactive design in smart textile products, "consumer requirements of products are changing, gravitating towards higher order needs that stimulate the intellect, such as experience and sensory and emotional fulfilment, and are set to become the new commercial imperatives in the developed world" (p. 274). Because of the unique and relatively new sets of needs imposed upon smart/wearable electronics, the process experienced by consumers that would lead to a behavioral intention to accept new technology may differ from that followed by the same consumer for other more traditional technologies.

One way to elicit feedback from a consumer is to allow him or her a voice in the product development process by implementing the human factors design approach known as codesign (Sanders & Stappers, 2008). Because of the specificity with which a wearable must meet the needs of its wearer, the codesign approach, in which a consumer is given the opportunity to contribute to the design process on an equal playing field with the designer, may allow for the transfer of key pieces of information between the designer and user. When the insights gleaned from a codesign process are implemented into a wearable product's design, the resulting product may ultimately be more acceptable to a user over the long term by offering customized design features that meet the needs of its user. Furthermore, as pointed out by Baurley (2004), "intelligent materials will improve our control over our material environment and facilitate our creative interaction with it as we seek to be co-creators, tailoring experiences to correspond to our various moods" (p. 276). This, therefore, may imply that smart materials could lend themselves to a codesign environment more effectively and seamlessly than other types of materials because they are designed to engage with their user from the shared creative outset.

In the contemporary context, there are growing numbers of product users known as creative consumers (Nuttavuthisitt, 2010), Do-it-yourself consumers (Wolf & McQuitty, 2011) or prosumers (Knott, 2013), who modify proprietary offerings to varying degrees. This diverse pool of users make modifications that often deviate from or are outside of the context of the actual product development or design process. In many cases, companies do not know of these modifications, so cannot capture the reasons that the consumer chose to modify, nor are they aware of the specific characteristics a given consumer selected for alteration. Additionally, as the marketplace evolves and more tools are available on the market with which consumers may make modifications, consumers may exhibit a greater willingness or even expectation to participate in a codesign process. Recent generations, such as generation Y, have the expectation that they can engage and disengage in the design process at will (Nuttavuthisit, 2010), which allows them to make a number of decisions about their own experience with a given product and as consumers. Although codesign appears in various studies and is beginning to be practiced by some companies such as Nike (Yu & Park, 2014), much work must be done before it will be implemented on a large scale. Codesign requires the reworking of the product development structure and represents a type of democracy of design (Atkinson, 2008), as it entails the leveling of the playing field between the designer and actual users (Sanders & Stappers, 2008). Designers are set on the same level as consumers, which may sometimes be met with resistance on the part of all groups involved; codesign requires that designers relinquish control of the process and consumers must adopt the notion that they and all people are creative and have something to contribute to the design process (Sanders & Stappers, 2008). One outcome of the proposed study is that its results will provide high-quality insights into a codesign context, such that companies who might otherwise be hesitant to take further steps towards codesign will be prompted to consider it as a realistic option. Codesign may be one way for a company to improve its exchange with consumers and allow it to maximize on the ideas generated by its own target market, as consumers are given an opportunity to provide feedback through their modifications or creative contribution to the design of products. Another aim of the researchers is to provide users with the representative tools that they would need to conceive of a wearable device that would fit their needs and that they would have the intention to accept, thereby allowing them an opportunity to illustrate its characteristics, placement, and ultimately, the physical and conceptual space it would occupy during the performance of a particular function.

## Purpose statement

The purpose of this study is to investigate the effects of codesign on consumers' behavioral intention to accept new wearable technology. Specifically, this study will seek to gain insights into the effect of codesign on user attitude/perception of a wearable technology in terms of ease of use, usefulness, and perceived playfulness.

## Research Questions

To address the research inquiry, I adopted the Technology Acceptance Model (TAM) as a conceptual framework; however, to facilitate in-depth insights into the matter, I designed and implemented a codesign space, in which participants were guided to a democratic environment of creative idea exchange with others to develop a wearable electronic product to enhance the visibility of cyclists at nighttime. The research design was qualitative in nature, since it was similar to the case-study method. However, brief surveys – a pre and a post codesign survey- were administered to supplement the interpretative approach. Consumer behavioral intention towards the use of wearable technology was assessed in a codesign context, in which participants had the opportunity to use representative "mock" materials (e.g., 3D-printed Lilypad Arduino for an actual electronic device, stickers in lieu of sewn-on lights) to ideate and build a low-fidelity prototype to visualize their concept of a system and address the cycling scenario they were given. Questions for which this study sought a resolution are as follows:

RQ1: How does the experience of codesign affect the user's acceptance behavior of a wearable technology?

RQ1a: How does the experience of codesign affect the user's *perceived ease of use* (PEOU) of the wearable technology?

RQ1b: How does the experience of codesign affect the user's *perceived usefulness* (PU) of the wearable technology?

RQ1c: How does the experience of codesign affect the user's *perceived playfulness* (PP) of the wearable technology?

RQ1d: How the experience of codesign affect the user's attitude toward the wearable technology?

RQ1e: How does the experience of codesign affect the user's behavioral intention toward accepting the wearable technology?

## Limitations

Several limitations existed in this study. One limitation was that the usage of the technology acceptance model in a qualitative study is less common, and therefore has not been validated to the extent that it has when used in quantitative studies. To remedy this limitation, the researcher devised a supplementary means of data collection (i.e. surveys) to triangulate the data, with the intent of rendering issues of validity less detrimental. Another significant limitation was the short length of time in which this study was carried out, which meant that the study was not able to explore the TAM to the point of long-term user acceptance of wearable technology. Instead, TAM was used as a conceptual model to the point of behavioral intention towards accepting the wearable technology. The data gathered in this exploratory study could provide insights to explain the effectiveness of codesign as a viable tool to encourage the sustainable use of wearable technology.

Additionally, participants in the codesign context did not all have equal ability with electrical engineering concepts and design. Although this is true to the notion of codesign, in which individuals of various backgrounds are brought into the creative design process, for this study, representative materials were used in place of electrical engineering components (Heimdal & Rosenqvist, 2012) because the participants had varying levels of expertise. Although the resultant systems were not (and were not intended to be) functional, the outcome of the low-fidelity prototype created using representative materials allowed participants to freely explore product design concepts pertinent to a wearable system without being constrained by their level of experience with circuitry and electronics design.

As no study has been done that explores the effect of codesign on user acceptance of wearable technology, this was an exploratory study. The study was largely qualitative in nature and the sample size was small. Thus, it was difficult to validate the results as quantitative research does. Insights resulting from the study reveal that codesign may have been able to succeed in facilitating playfulness on the part of codesign participants, which in turn may have increased the likelihood that participants would accept and sustain the use of new technology. Codesign may have also helped participants in their perception of PEOU, PU, and PP and also positively influenced attitude and behavioral intention. These questions were addressed through this research.

## Definitions of Terms

Lilypad Arduino: a microcontroller board designed for wearables and e-textiles. It can be sewn to fabric and similarly mounted power supplies, sensors, and actuators with conductive thread ("Lilypad Arduino", n.d. para. 1).

Arduino: an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board (Arduino, n.d. para 1).

Soft computation: the design of electronic technology that is composed of soft materials such as textiles and threads, as well as predicated on traditional textile construction methods, such as sewing, embroidery and applique with various conductive and active materials to create interactive fabrics. (Berzowska & Bromley, 2007)

Smart textiles: materials that can sense and respond in a controlled or predicted manner to environmental stimuli, which can be delivered in mechanical, thermal, chemical, magnetic or other forms (Tao, 2001) (also known as etextiles or electronic textiles)

Wearability: the interaction between the human body and the wearable object. (Gemperle, Kasabach, Stivoric, Bauer, & Martin, 1998)

Dynamic wearability: the interaction between the human body in motion and the wearable object. (Gemperle, Kasabach, Stivoric, Bauer, & Martin, 1998)

Codesign: the creativity of designers and people not trained in design working together in the design development process. (Sanders & Stappers, 2008)

Open-source: the practices of releasing product source code or recipes for the public to scrutinize, study, change, share, distribute and re-distribute the original and/or modified work. (Lin, 2014).

# CHAPTER TWO: REVIEW OF THE LITERATURE

## Technology Acceptance Model

Since its initial development and implementation by Davis in 1986, the Technology Acceptance Model (TAM) has been used to provide clarity regarding the extent to which a given user accepts a particular type of information technology or system (Lee, Kozar & Larsen, 2003) and "to predict user behavior before obtaining experience of the system" (Yu et al., 2005, p. 966). TAM is based on Ajzen and Fishbein's Theory of Reasoned Action (Ajzen & Fishbein, 1980) which holds that "behavior is determined directly by the intention to perform, because people, in general, behave as they intend to do, within the available context and time" (Moon & Kim, 2000, p. 218). In its original form, as proposed by Davis (1985), TAM makes the assumption that the extent of an individual's acceptance of a system or technology depends on two variables (Lee et al., 2003). These two variables are perceived usefulness (PU), which is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance," (Davis, 1989, p. 320) and perceived ease of use (PEOU), which is "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). According to the model, these two variables lead to attitude, then behavioral intention, and finally technology acceptance (Lee, Kozar, & Larsen, 2003). Although TAM has been tested and validated in a variety of ways using many different types of technologies and information systems since its development by Davis in 1985, Lee et al. (2003) assert that TAM research should expand to include the analysis of systems that involve multiple users, teams, and less simplistic technologies. Additionally, according to Lee et al., (2003, p. 767), "more efforts to examine the broader environmental factors including emotion, habit, personality difference, technology change, even going beyond individual acceptance to organization and societal acceptance are necessary." According to Moon and Kim (2000), most research on technology acceptance has been carried out from the vantage point of extrinsic motivation, despite the fact that, as found by Igbaria, Schiffman, and Wieckowski (1994), the use of a system is impacted by both intrinsic and extrinsic motivators. Although intrinsic motivation characteristics require further study to be fully validated, in an acknowledgement of the role of intrinsic motivation in user acceptance of new technology (Yu et al, 2005), Davis, Bagozzi, and Warshaw (1992) explored the effect of perceived enjoyment. They found that, along with perceived usefulness, perceived enjoyment "mediated the influence of perceived ease of use on intention," (Moon & Kim, 2000, p. 218) and could explain variance outside of what is accounted for by perceived usefulness (Moon & Kim, 2000). Davis et al. (1992, p.) explain perceived enjoyment as "the extent to which the activity of using (designing) the technology is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated." Perceived enjoyment may be used as a variable in circumstances in which perceived usefulness and perceived ease of use cannot sufficiently explain a technology characterized as entertainment. Perceived enjoyment could serve as an important variable in situations where the use of a technology for entertainment purposes is also motivated intrinsically (Yu et al., 2005). In their research, which extended the TAM for a t-commerce system and attempted to identify and compare the factors that determined its adoption by consumers, Yu et al., (2005, p. 973) found that "perceived enjoyment is the most important factor affecting attitude and behavioral intention toward t-commerce." Meanwhile, Hsu and Lu (2003) discovered that attitude, flow experience, and subjective norms played a prominent role in users' acceptance of online games. Flow experience describes "the holistic experience that people feel when they act with total involvement," and was first developed into a theory of creativity named “Flow” by sociologist Mihaly Csikszentmihalyi (1991). Hsu and Lu (2003) used Csikszentmihalyi’s definition to divide the state of flow into four characteristics, which are “control, attention, curiosity, and intrinsic interest” (Hsu & Lu, p. 856, 2003), and prove useful in the study of various contexts, including recent analyses of user technology acceptance and the behavior of consumers (Hsu & Lu, 2003). Moon and Kim (2000) ran a study using the World Wide Web based on the premise that PEOU and PU may not adequately describe a given user’s internal response toward new technologies, such as the World Wide Web. They asserted that factors related to intrinsic motivation must indeed be considered because the World Wide Web is used for both work and pleasure, unlike other technologies tested using TAM, which focus solely on aspects of productivity (Moon & Kim, 2000). However, instead of perceived enjoyment, they developed the term “playfulness” because they observed that previous measurements of perceived enjoyment did not fully include all necessary components characterizing intrinsic motivation (Moon & Kim, 2000). Playfulness can be defined as either a trait or as a state of being; as a trait, playfulness is stable and unresponsive to changes in stimuli, whereas a state of playfulness is a short-term change and is influenced by environments and interactions (Moon & Kim, 2000). Moon and Kim (2000, p. 219) describe the three dimensions of perceived playfulness as “the extent to which the individual perceives that his or her attention is focused on the interaction with the www, is curious during the interaction and finds the interaction intrinsically enjoyable or interesting.” Moon and Kim (2000) found that the extent to which an individual accepts the World Wide Web was connected to both intrinsic and extrinsic motivators. Based on their finding that the variable of playfulness is an important intrinsic motivator in user acceptance of the World Wide Web, they concluded that designers of user interfaces and information systems should consider intrinsic factors such as concentration, curiosity, and enjoyment when implementing future systems (Moon & Kim, 2000).

## Codesign

Codesign is a concept found in the context of human factors design and involves “the creativity of designers and people not trained in design working together in the design development process” (Sanders & Stappers, 2008, p. 6). Design that involves individuals other than designers is becoming increasingly more common; in this approach, design is an activity in which people participate in a public space instead of being constrained to the hierarchy within a given institution (Bjorgvinsson, Ehn, & Hillgren, 2010). This is an evolution from other product development processes in which professional designers are set apart and situated in the world of active design while consumers are set as passive recipients of the design output. For consumers, codesign allows a balance to be struck between situations in which they are positioned to passively consume and those in which they actively determine their own consumption experience; consumers themselves are more frequently seeking out the latter (Sanders & Stappers, 2008). When the realms of design and that of consumers are combined, Lee (2008, p. 33) refers to the resulting space as the “realm of collaboration.” Codesign constitutes a space that extends from the beginning to the end of the product development process (Sanders & Stappers, 2008). This type of intensive collaboration is increasingly more available to consumers as new tools for production are developed and users are positioned as the experts that drive the process (Bjorgvinsson et al., 2010). Although there are benefits to consumers who participate in codesign, there is also a cost involved (Etgar, 2008). Time is a resource that a consumer must expend when participating in co-production. According to Etgar (2008), this means that a consumer with more spare time will be more apt to participate. Specific skillsets on the part of a consumer may also condition the coproduction experience and his or her proclivity towards this kind of activity (Etgar, 2008). Additionally, it should be noted that codesign may not be equally effective for all products (Etgar, 2008). Because customization of a given service or product is one objective of codesign, goods and services with greater customizability may be more attractive to a consumer wishing to participate in the coproduction process; the characteristics of these kinds of products may also lend themselves more easily to the process (Etgar, 2008). Consumers have the expectation of a positive experience through the codesign interaction, which is combined with their expectations regarding the creation of a unique product (Yu & Park, 2014) that will have a positive impact on their day-to-day lives or experience (Etgar, 2008). According to Etgar (2008), a technological device, such as a personal computer, is one example of an item that may lend itself to the process of coproduction, given the large number of options a given consumer may have for customization. Apparel is another industry that could be among those which provide products likely to be customized by consumers (Ulrich, Anderson-Connell & Wu, 2003), because of their extreme potential for customizability. In the shoe industry, companies such as Nike and Adidas are devising systems and tools that allow the customer to participate in a segment of the design process independent of the supplier, thus constituting a form of codesign (Berger & Piller, 2003). The approach that these companies have adopted is in line with the premise asserted by Park, Morris, Stannard, and Hamilton (2014), which holds that future users of a product should be allowed a say in its design. Because of the increasing consumer interest regarding participation in codesign, and also because of the number of tools and processes being developed to this end, "more apparel businesses are likely to try codesign for mass customization" (Ulrich et al., 2003, p. 410).

## Wearable technology

The use of wearable technology is increasing, which signifies that the control consumers are able to exert over their environments will increase as well (Baurley, 2004). In this way, the technical function of a wearable item will become more important than its role as a fashion statement or in generating aesthetic appeal (Baurley, 2004), which has often been the central focus of an item worn on the body in times past. Wearable technology can perform one or more of four distinct functions: it can monitor health functions and vital signs, help improve the physical performance of athletes or rehabilitation patients, provide feedback through stimuli in one's environment, and finally, it can create new opportunities for aesthetic enhancement and decoration in the apparel industry (Berzowska & Bromley, 2007). Because of the variety of functions afforded by wearable technology, this type of technology presents a multitude of opportunities for new product development (Ariyatum et. al, 2005). Along with new products themselves, the components which comprise the products are increasing in terms of diversity, efficiency, and consumer accessibility. For monitoring health, for example, wearable technology may be attached to wearable devices in the form of an accessory, an electronic patch, an armband, a chest belt, clothing itself, shoes, glasses, or gloves (Chan et al., 2012). Other means by which wearable technology may be carried on the body include form factors such as implants, devices embedded in the user's clothing, or objects carried by an individual on a regular basis (Chan et al., 2012). One aspect of wearable technology that differentiates it from other types of technology is the requirement that it must be compatible with the body in motion (Gemperle et al., 1998). Gemperle et al. (1998) assert the existence of an obvious need to understand the way the human in motion affects wearable product design. They highlight the need for a focus on "designing for wearability," which involves the development of wearable systems that consider "wearability, the physical shape of objects, and their active relationship with the human form," (Gemperle et al, 1998, p. 1) Gemperle et al. (1998) developed twelve guidelines for wearability, which address issues of placement, form language, movement, proxemics, and sizing and attachment, some of which are also acknowledged by other researchers such as Chan et al. (2012) who cite fit, weight, cost, size, and the possible psychological discomfort of using a wearable device as some of the most likely reasons consumers do not adopt them. The researchers assert that more research is needed to obtain the feedback and preferences of consumers on wearable technology. Chan et al. (2012) also highlight that aspects impacting the commercialization, market penetration, and adoption of wearable technology by users still need to be addressed. However, Ariyatum et al. (2012) argue that there is a pressing need for a clear design approach for wearable technology and a better understanding of the consumers.

## The Lilypad and DIY culture

The Lilypad Arduino is a sewable microcontroller used in e-textiles and based on the open-source programming and prototyping platform called Arduino. It was originally designed to be a pedagogical teaching tool, used to expose a variety of users to basic computing and electronics skills through a system of embedded computing (Buechley & Eisenberg, 2008). Users can sew the Lilypad into a textile-based project and connect components with conductive fabric and thread (Buechley, Eisenberg, Catchen, Crockett, 2008). It was created in large part to expand on what its creators saw as an expressive extension to already existing themes of technology as entertainment and technology as automation (Buechley, Eisenberg, Catchen, & Crockett, 2008), which in turn has prompted the creation of a new demographic within the traditional engineering community (Buechley & Hill, 2010). The creators of the Lilypad state that there is a third dimension of human computer interaction and technology use that centers on whether users can do or express aspects through the use of a particular technology that would not have been possible previously (Buechley, Eisenberg, Catchen, Crockett, 2008). Thus, the Lilypad is described by its creators as “an expressive medium for textile-based ubiquitous computing” (Buechley, Eisenberg, Catchen, Crockett, 2008, p. 424).The Lilypad’s developers put an emphasis on its usability, but they also focused on its aesthetic appeal and sewability, which were not issues with which a typical hardware designer would concern him or herself; they based their decision to focus on these aspects on their assertion that fashion plays an important role for users and the way the Lilypad looked would affect the appeal and experience of the kit for users (Buechley, Eisenberg, Catchen, Crockett, 2008). Another difference between the Lilypad and more traditional interfaces is grounded in its accessibility; one can easily purchase the device online from Sparkfun, a company based out of Niwot, CO. Upon purchasing the device, a person can research potential projects and learn how to use the device by accessing various tutorials on YouTube, instructables.com, and the Arduino website itself. Buechley and Hill (2010) state that the mass consumerism characterizing the $20^{th}$ century will soon give way to a context in which niche users maximize what they find on the internet to create, locate, share, and consume content that fits their unique interests and needs. This shift is driven by an expanding population of participants in the Do-it-yourself (DIY) community, who participate in and expand upon what Tanenbum, Williams, Desjardins and Tanenbaum (2013, p. 2604) refer to as “democratized technological practices,” representing a significant change in the way users interact with technology and engage with it in their lives. This type of technological practice is characterized by utility, expressiveness, and playfulness (Tanenbaum et al., 2013). Although it relies on more traditional manufacturing infrastructures for some items, it also stimulates interest and demand in new tools and types of knowledge (Tanenbaum et al., 2013). When facilitated through open source tools and interfaces, it can be accessed by those outside of the traditional circles of design and engineering. This results in the creation of more innovation resources (Lin, 2014) and design opportunities as a greater diversity of users take part (Tanenbaum et al., 2013; Lin, 2014), as well as the creation of products that would not yet have been sponsored or produced by larger-scale corporations (Buechley & Hill, 2010). Given the increasing interest of corporations and governmental entities outside of the sphere of DIY (Tanenbaum et al., 2013), the effect of DIY is no longer relegated to the pursuit of hedonistic pleasure or recreation; it has larger implications for commercial and consumer culture (Tanenbaum et al., 2013). The Internet has facilitated the fast spread of DIY concepts to the larger population; open-source tools such as Arduino allow for collaborations and sharing to take place easily and quickly, and are increasingly prevalent in manufacturing architecture and design disciplines (Lin, 2014), which creates a context in which consumption is no longer passive. Instead, it is an opportunity to generate one's own creative experience and may lead to a change in the attitudes and behaviors characterizing the larger consumer population (Lin, 2014).

# CHAPTER THREE: METHOD

## Research Design

To address the research questions, this study designed and implemented a codesign space as an open creative platform for potential product users to explore the practical usage and benefits of a wearable technology through a hands-on project. In the codesign space, participants were asked to design and conceptualize a wearable electronic system to address the issue of cyclist visibility at nighttime, which was a significant safety concern expressed by area cyclists and one to which they could all personally relate given the inclusion criteria of this study, discussed in subsequent paragraphs. The TAM (Davis, 1986) was used as a conceptual map around which specific research questions were formulated. Although TAM has predominantly been used in quantitative studies, I used the theoretical framework in the context of codesign, which corresponded to the case study approach. Therefore, in this study, the TAM was used to guide the researcher in understanding the overall relationships of the external variables – perceived ease of use (PEOU), perceived usefulness (PU), and perceived playfulness (PP) – in the codesign context, in terms of user acceptance and behavioral intention towards the use of a wearable technology product. To help offset any potential validity issues prompted by the use of the TAM in a codesign context, a mixed-methods approach (i.e. a pre- and a post-codesign survey (quantitative) and focus groups (qualitative), was adopted to triangulate the data. A similar approach to using TAM was adopted in DeVreede, Jones & Mgaya's (1999) study, in which they conducted a qualitative investigation that used the TAM to frame external factors that were revealed in the data collection process, while the grounded theory approach was applied for interpretative content analysis. In their research design, the researchers also included mixed techniques of data collection (both quantitative and qualitative), to increase the validity of their data. This mixed-method approach is widely supported by other researchers because more in-depth results are uncovered than what would be revealed with one method (Lee et al., 2003).

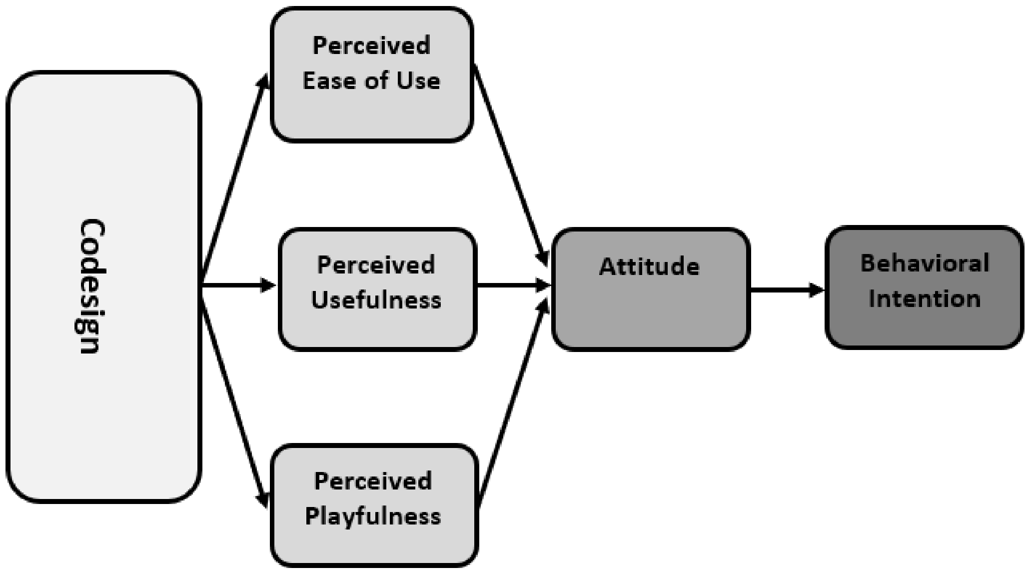


***Figure 3.1:*** *Proposed extension using TAM as a conceptual model*

The case study format was selected for this study because "case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real time context" (Yin, 2003, p. 1). The case study was also elected as a method because design is a practice-oriented field, to which Johansson (2003) argues a case study approach may contribute value. He states that "the ability to act within professional practice is based on knowledge of a repertoire of cases" (Johansson, 2003, p. 4), and "a designer's work is based on comparisons between known cases from the repertoire and the actual design situation" (Johansson, 2003, p. 4). A case study approach was appropriate for this study because it allowed the researcher to elect a particular case based on the possibility that it would be "information rich, critical, revelatory, unique or extreme" (Johansson, 2003, p. 8). In this particular study, a case study characterized by a codesign exercise may have been especially effective in facilitating playfulness for participants, as it put participants in the position of experimenting, building, and playing with the tangible objects to bring their ideas to life. In the codesign context, participants were encouraged to be curious and involved in the creation process, which are elements that bring about playfulness (Moon & Kim, 2000). Although the case study has the benefit of allowing a researcher to select the phenomenon that he or she intends to study, the selection of a particular case signifies that the researcher plans to generalize what he or she finds (Johansson, 2003). The generalization of a case study is one area in which case studies have received criticism because they are not based on statistics; instead, case studies rely on the researcher to analyze the data (Johansson, 2003) from his or her perspective and are therefore subjective. Given this, "one major feature of case study methodology is that different methods are combined with the purpose of illuminating a case from different angles" (Johansson, 2003, p. 3).

This study examined questions concerning user behavioral intention toward accepting wearable technology in the context of codesign. Wearable technology is unlike other traditional information technologies, largely because it interfaces directly with the human body in a way that constitutes a more intimate and personalized interaction. As of yet, no study has tested the effect of codesign on PEOU, PU, and PP, user attitude, and user behavioral intention toward a new technology, particularly one that is worn on the body. Given the specificity with which wearables must meet consumer needs in terms of fit, expressiveness, and functionality, as well as the way codesign allows a consumer to provide input directly, the consideration of codesign as an antecedent may have resulted in a product that is more geared toward consumer needs, and may therefore have positively affected user behavioral intention.

## Population and Sample

A total of 17 participants were recruited for this study. The population and sample sought for this study were separated into *two* different groups based on schedule compatibility with the times/dates of sessions offered. One group comprised 6 participants and the other, 11. The selection criteria for study participation were as follows: individuals cycled more than three times a week, were 18-65 years old, and had experience riding at night. The topic of cyclist visibility at night was selected as the scenario's focus because it is arguably the most significant safety concern for commuter cyclists, per statements from participants in this study and a set of recent statistics showing that between 2010 and 2017, nighttime cyclist and pedestrian deaths increased by 46%, 70% of which were attributed to conditions of poor visibility (Maciag, 2019). While the area in which participants of this study resided was recently ranked first out of 480 cities in terms of being bike-friendly (Trevino, 2018), nationwide statistics revealing an increase in cycling deaths while motorist deaths remain the same (Short, 2019) show the importance of a continued focus on cycling safety. Further, the primary researcher's work at the Fort Collins Bike Coop, personal experience as a cyclist, and work at a local cycling apparel company all underscored the importance of addressing this issue. Both groups participated in all components of the study experiment, which included the a) pre-survey, b) codesign exercise, and c) post-evaluation (post-survey and focus group).

## Data collection

### Pre-Survey

The pre-survey was intended to measure initial user attitude and user behavioral intention toward accepting a wearable technology, participant experiences with wearable technology, aspects of wearable technology they felt were important, as well as demographic and psychographic information of the participants. The same pre-survey was administered to both groups.

**Codesign Exercise**

Following the pre-survey, participants took part in the codesign exercise. For the codesign context, two separate 3-hour sessions were offered, during which the same content and activities were presented; participants elected to attend one of the two based on their schedule availability. During the session, each group was exposed to the same prototyping kit in the same order and time-frame. The prototyping kit included a 3-D printed disc covered with a sticker to serve as a representative Lilypad Arduino (i.e., a sewable microcontroller) that could attach via earth magnets, stickers printed with designs to resemble sensors, a cycling jersey, small round stickers that participants could color to serve as LEDs, diagrams of the human body and a human form riding a bike, and large pieces of newsprint, markers, and pencils for sketching out ideas. The participants were given the design challenge of developing a Lilypad-integrated cycling jersey using the prototyping kit to address issues of nighttime visibility for cyclists. The codesign session opened with approximately 30 minutes of instruction on the Lilypad Arduino to provide participants with a baseline understanding of its capabilities and potential usage in the scenario. The Lilypad Arduino was selected as the specific technology for this study because it is readily available for purchase and is designed for novice designers to easily utilize in developing wearable products (Buechley, 2008). Participants were put into pairs or groups of three and were asked to visualize potential solutions to resolve the issue posed in the scenario.

This experimental design was drawn from the approach adopted by Heimdal and Rosenqvist (2012) in which codesign groups were provided with representative materials and tools with which they were expected to achieve a prototypical design outcome. In the present study, participants were not required to create an actual prototype because the amount of time, instruction, and resources that were provided would not have been sufficient for them to develop a realistic working prototype within the given scope. Instead, the anticipated outcomes of the codesign exercise were that the participants would develop and visualize their ideas using the prototyping kit, including mock components, markers, paper, and actual bike jerseys for scale.

The primary researcher circulated the room to assist codesign participants with any questions. Following a half-hour instruction, participants were given one hour to generate ideas and solidify their conception of the best design; they were allowed to adopt a variety of approaches during this time to test out their ideas, such as trying on the jersey or riding a bike around outside. When 15 minutes were left in the session, the researcher warned the group that their time was almost up and that they should finalize their designs. When the teams had gathered sketches, prototypes, and other materials that were used to generate ideas, they were given the opportunity to share with the group to receive feedback. Upon obtaining the participants' permission, the session was monitored by an ethnographer in addition to the primary researcher herself.

**Post Evaluation**

Upon completion of the codesign exercise, participants convened for a focus group session. Prior to the focus group, the post survey was administered to all individuals participating in the codesign context. For this segment of the data collection process, the same questions were asked as those posed in the pre-survey to measure any change to PEOU, PU, PP, attitude, or behavioral intention toward the wearable technology resulting from the codesign exercise. The focus group discussion was conducted with the participants to evaluate the effects of codesign on the four TAM variables, as well as gauge the participants' experience during the codesign exercise.

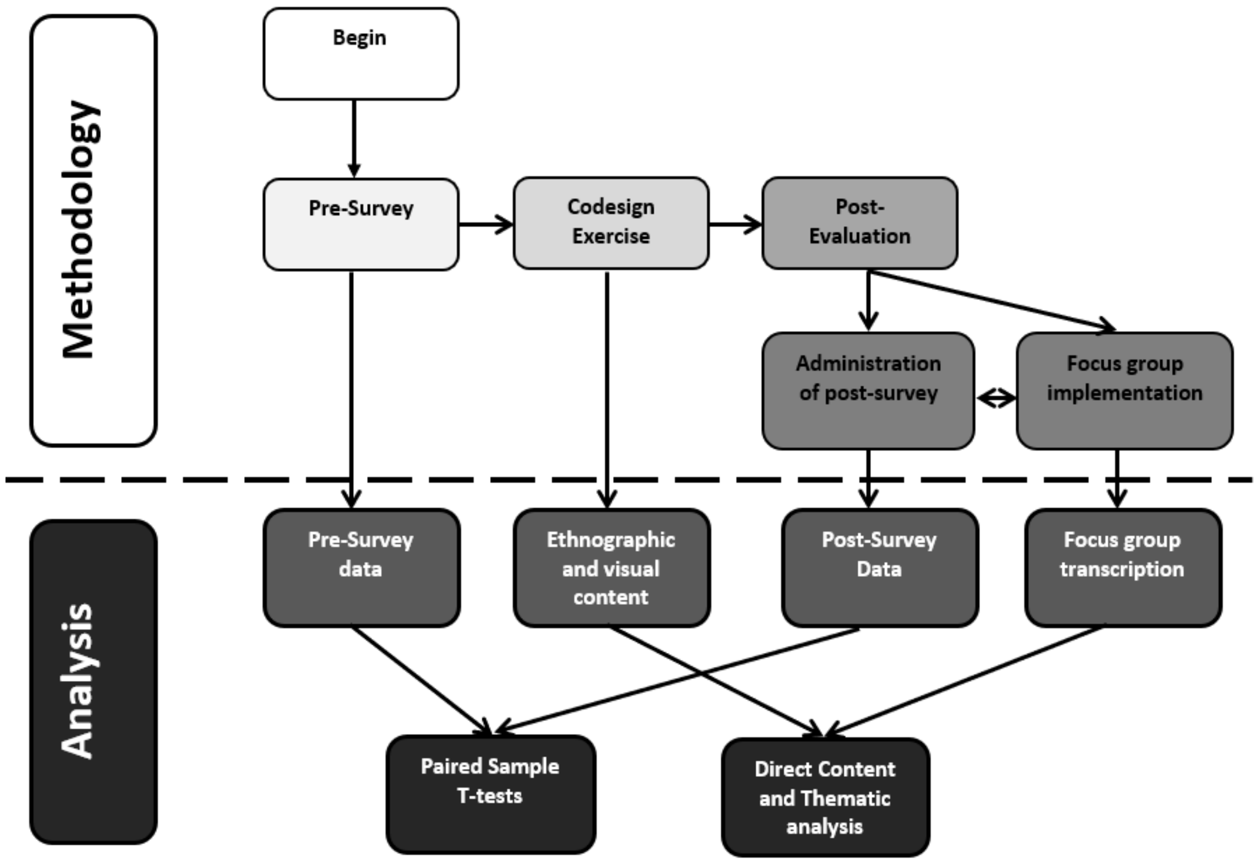


***Figure 3.2:*** *Diagram of methodology and analysis*

**Data Analysis**

Data were collected from multiple sources, including the surveys, focus group discussions, field notes, the researcher's memos, videos, and photos from the codesign session, all of which were collected to triangulate the data. Given the sample size and nature of the study, I used focus group discussions as the primary data and surveys as the secondary data. The remaining data sets provided supplementary support towards a holistic understanding of the study results.

The focus group data were transcribed verbatim and direct content analysis was conducted. The use of this analysis method was considered appropriate because the experimental research was designed based on an existing content analysis method (Hsieh & Shannon, 2014). While the TAM has been widely adopted in quantitative research, other studies have also used TAM as part of a qualitative analysis method (for example, see De Vreede, Jones, & Mgaya, 1998). For this study, the five main TAM variables were used in the analysis of the focus group data as main themes into which the qualitative data were organized. Inductive reasoning was also allowed in the data analysis when emergent themes were observed; in this study, similar to the approach adopted by DeVreede, Jones, and Mgaya (1998), additional thematic analysis was performed using constant comparison (Glaser & Strauss 1967; Strauss & Corbin, 1998; King, 2004) to explore the emergence of any additional themes beyond those provided by the TAM theoretical framework. The themes were then organized into a coding guide that the researchers used to classify the data until all categories became saturated (Strauss & Corbin, 1998). Using the coding guide, the primary researcher conducted the initial coding of the focus group data, and the coding scheme was discussed with the researcher's adviser. When disagreement occurred, the researchers discussed until a consensus was negotiated. To enhance the trustworthiness of the coding process, per the approach outlined in Park (2015) which drew from Miller (1992), a trained researcher who was not part of the research project (i.e., a peer graduate student) helped perform an audit of the focus group data, in which the initial application of the coding guide by the authors was checked and validated. The audit resulted in an interrater reliability of 92.9%, which was calculated based on the method developed by Marques and McCall (2005).

To compare the effects of the codesign experience on the participants' acceptance of the Lilypad Arduino as a specific wearable technology tool, paired-sample t-tests were performed using IBM SPSS 25.0. Specifically, the five mean composite scale sets representing the TAM variables – PEOU, PU, PP, ATT, and BI – were used to perform mean comparisons between the survey data obtained at the baseline and during the post-evaluation following the codesign session. Statistical significance was evaluated at $p < .05$.

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# CHAPTER FOUR: MANUSCRIPT

As information and communication technology has continued to develop, the number of people using wearable devices has increased and the wearable technology global market is anticipated to expand from 15.74 billion in 2015 to 51.60 billion by 2022 (Kim & Chiu, 2018). Between 2016 and 2022, an annual growth rate of 15.51 percent is projected (Markets and Markets, 2017). The implications of this growth rate on our daily lives are significant; indeed, according to Rackspace (2013), wearable technology allows users to complete tasks unobtrusively and in a socially acceptable manner to enhance both their productivity and enjoyment. However, changes will need to occur in the design of technology that is integrated into our lives, and more specific to this work, to technology that is worn on our body, which is otherwise known as “wearables.” The industry is currently confronted by a challenge, as consumer acceptance of wearable technology over the long term is still lacking (Wood, 2014). A statement provided by the CEO of Health 2.0 asserted that although one in ten adults owns wearable devices, 50% do not use them, and one-third of users stop using them after six months (Cobb, 2014). This implies that more research is needed on consumer needs and wants as they relate to the sustainable use of wearable technology (Chan, Estève, Fourniols, Escriba, & Campo, 2012). As consumers access an increasing number of tools for customizing their consumption, and given the specificity with which a wearable device must match user requirements and the unique human body as its interface (Gemperle, Kasabach, Stivoric, Bauer, & Martin, 1998), an investigation into user acceptance of wearable technology could yield important insights on post-purchase user behavior regarding wearable technology.

Unlike other electronics, wearable technology forms a unique connection to the human form because it depends on the human body as its primary interface (Gemperle et al., 1998). The user makes decisions about how to use the wearable as he or she is experiencing the built environment and various stimuli with his or her own body. As Baurley (2004) writes in a discussion on interactive design in smart textile products, “consumer requirements of products are changing, gravitating towards higher order needs that stimulate the intellect, such as experience and sensory and emotional fulfillment, and are set to become the new commercial imperatives in the developed world” (p. 274). Because of the unique and relatively new sets of needs imposed on smart/wearable electronics, it is possible that the process experienced by consumers that would lead to a behavioral intention to accept new technology may differ from that followed by the same consumer for other more traditional technologies.

One way to elicit feedback from a consumer is to allow him or her a voice in the product development process by implementing the inclusive design approach known as codesign (Sanders & Stappers, 2008). Steen and his colleagues (2011) asserted that in business and organizational contexts, codesign brings certain benefits to help people accomplish specific objectives in their projects. Some of these benefits may include enhancing the loyalty of customers, greater customer sense of wellbeing, and creative processes that are more optimally structured. Because of the specificity with which a wearable must meet the needs of its user, the codesign approach, in which a consumer is given the opportunity to contribute to the design process on an equal playing field with the designer, may allow for the transfer of key pieces of information between the designer and user. Thus, when implemented into the product, design features resulting from a codesign approach may render a (wearable) product more acceptable to a user over the long term by offering designs that are more original and more accurately align with his or her requirements and needs (Kristensson, Magnusson, & Matthing, 2002) Furthermore, as pointed out by Baurley, (2004), as smart devices allow us to enhance our ability to manage and creatively interact with the world in which we live, we will seek more participatory roles as co-creators, pursuing circumstances that match our changing needs and desires. This, therefore, may imply that smart materials could lend themselves to a codesign environment more effectively and seamlessly than other types, because they are designed to engage the user from the shared creative outset.

In the contemporary context, there are growing numbers of product users known as creative consumers (Nuttavuthisitt, 2010), do-it-yourself (DIY) consumers (Wolf & McQuitty, 2011) or prosumers (Knott, 2013), who modify proprietary offerings to varying degrees. These users make their modifications in contexts outside of the actual product design and development process. Through their voluntary and independent creative design activities, these consumers may be well-positioned to positively affect their perception of a given product through their activities, particularly as it relates to the PEOU of the product, because of their direct experience with it (the product). The effect of direct experience on PEOU has been discussed in the literature and explained in terms of "anchoring" and "adjustment" in the context of Behavioral Decision Theory (Slovic & Lichtenstein, 1971; Tversky & Kahneman, 1974); according to this framework, the user's previous direct experience with the device serves as his or her anchor. Even in a new context, the user will make his or her evaluation of PEOU based off of this prior experience (Venkatesh, 2000). When making an adjustment, the more contextual information the user can glean about the device in the new setting, the more he or she will base the evaluation of PEOU off the current context instead of that of his or her previous experiences (Venkatesh, 2000). Because the type of consumer who modifies a proprietary offering gathers new experience with the object by building with it, if that experience is positive, an adjustment may occur for his or her anchor and PEOU may increase.

Further, as the marketplace evolves and more tools are available on the market with which consumers may make modifications, consumers may exhibit a greater willingness or expectation to participate in a co-creation process at will (Nuttavuthisit, 2010), which will allow them to make many decisions about their own experience with a product. Further, consumer participation may even be motivated by their desire to invest themselves in the object itself (Belk, 1988) which is "the idea that we make things a part of self by creating or altering them" (p. 144). This investiture in an object is related to Belk (1988)'s concept of extended self, in which "knowingly or unknowingly, intentionally or unintentionally, we regard our possessions as parts of ourselves" (p. 129). If carried out during a codesign context, the investiture of one's identity may occur in conjunction with a design approach known as "designing for the self" Ozenc, Brommer, Jeong, Shih, Au, & Zimmerman, 2007) and defined as "opportunities where interactive products can more explicitly engage people in identity construction activities" (p. 393). These may occur in tandem because codesign provides opportunities for both interaction/exchange and the projection of oneself onto the creation of a proprietary offering during the process.

Although the concept of codesign appears in various studies and is beginning to experience partial adoption by some companies such as Nike (Yu & Park, 2014), there is still work to be done before it can be implemented on a large scale. Codesign requires a reworking of the product development structure and represents a type of democracy of design (Atkinson, 2008), in that the playing field is leveled between the designer and the users (Sanders & Stappers, 2008). Designers are set on the same level as consumers, which may sometimes be met with resistance on the part of all groups involved; codesign requires that designers relinquish control of the process, and consumers must adopt the notion that they (and all people) are creative and able contributors in the design process (Sanders & Stappers, 2008). The renegotiation of identity in the social context of codesign is related to Kleine, Kleine, and Kernan's (1993) concept of Social Identity Theory, which comprises three aspects: a social role (how a person perceives society's conception of a role's meaning); social identity (a person's perception of him or herself as he or she carries out a particular role); and ideal identity (a person's idea of the person he or she would like to be in the particular role he or she is carrying out). When viewed from a constructionist viewpoint of context that prioritizes the user or "local" perspective, which David, Sabiescu, and Cantoni (2013) state "emphasizes the key role of the local people in defining meanings, understandings, and usages of technology as they interact with it…"(p.159), the codesign environment itself may facilitate an evolution in participant identity, perhaps even to the point at which participants take ownership of the design of the product as well as the solution. Although a direct line should not be assumed to always exist between a consumer's participation in the design of a technology and ownership (David et. al, 2013), in alignment with Ramirez (2008), David et. al (2013) emphasized that: "by participating in the design of technology artefacts, a community may be prone to develop a sense of owning the artifact, which quickens the process by which it is appropriated and integrated in its practices" (p. 160). In other words, one aspect of the community's social norm (Venkatesh & Davis, 2000) becomes focused on the ownership of the artifact. Here, it should be clarified that although the social norm comprises several types, such as injunctive, descriptive, perceived, and collective (Lapinski & Rimal, 2005), the unique dynamic inspired by codesign may promote the latter of the four types, a collective norm. Drawing from the concept of Betterhausen and Murnighan (1985), Lapinski and Rimal (2005) provide the following explanation as follows: "collective norms emerge through shared interaction among members of a social group or community and the manner in which norms emerge is dependent on, among other things, how they are transmitted and socially constructed" (p.129).

The purpose of this study was to investigate the effects of codesign on consumers' behavioral intention to accept new wearable technology. Specifically, this study sought to gain insights into the effect of codesign on user attitude and perception of a wearable technology in terms of ease of use, usefulness, and perceived playfulness. To facilitate in-depth insights into the research inquiry, we created and implemented a codesign experimental context, through which participants were invited to participate in a flexible design environment in which creative idea exchange with others was facilitated to develop a wearable electronic product. The research design was qualitative in nature but was guided by the Technology Acceptance Model (TAM) as a conceptual framework.

## Literature Review

### Technology Acceptance Model (TAM)

Since its inception (Davis, 1989), TAM has been used to provide clarity regarding the extent to which a given user accepts a particular type of information technology or system (Lee, Kozar, & Larsen, 2003) and to anticipate user behaviors before their use of the technology (Yu et al., 2005). TAM is based on Ajzen and Fishbein's Theory of Reasoned Action (Ajzen & Fishbein, 1980), which holds that intention directly determines behavior; this in turn aligns with the intention of a given individual at a particular place and time (Moon & Kim, 2000). In its original form, as proposed by Davis (1989), TAM assumes that the extent of an individual's acceptance of a system or technology depends on two variables (Lee et al., 2003). These two variables are perceived usefulness (PU), which is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance," (Davis, 1989,

p. 320) and perceived ease of use (PEOU), which is “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p. 320). According to the model, these two variables lead to attitude, then behavioral intention, and finally technology acceptance (Lee et al., 2003).

Although TAM has been tested and validated in a variety of ways and using a multitude of technologies and information systems since its development, some researchers (e.g., Lee et al., 2003) have asserted that TAM research should expand to include an analysis of systems involving multiple users, teams, and less simplistic technologies. However, in addition to extrinsic motivators, such as productivity and workplace performance, intrinsic motivators may also have a significant role in technology use (Chung & Tan, 2004). Based on Chung and Tan (2004), intrinsic motivators can affect user acceptance and are discussed by psychologist Mihaly Csikszentmihalyi in his book, *Flow* (1991); this type of motivator plays a key role in creating “the state in which people are so involved in an activity that nothing else seems to matter” (p. 4). Agarwal and Karahanna (2000) named the characteristics of flow as deep concentration, a sense of having control, decreased self-consciousness, and a transformation in time. These dimensions are reflected in the work of Trevino and Webster (1992), which argues that flow allows for better comprehension of the exchange between technology and humans and provides the basis for attitudes about technology (Agarwal & Karahanna, 2000). Based on the concept of flow (Csikszentmihalyi, 1991), Moon and Kim (2000) ran a study using the World Wide Web (WWW) on the premise that PEOU and PU may not adequately describe a user’s internal response toward new technologies such as the Internet. In their study, they argued that most research on technology acceptance has been carried out from the vantage point of extrinsic motivation, despite the fact that, as found by Igbaria, Schiffman and Wieckowski (1994), the use of a system is impacted by both intrinsic and extrinsic motivators. The researchers (Moon & Kim, 2001) felt that the measurements of perceived enjoyment performed by Davis, Bagozzi, and Warshaw (1992) did not comprehensively encapsulate all states characteristic of intrinsic motivation; some they felt should be included were “activity absorption, exploratory behaviors, curiosity, and arousal” (p. 219). Instead, in their study, they proposed the term “playfulness,” and described it as “the extent to which the individual perceives that his or her attention is focused on the interaction with the WWW (an environmental stimulus), is curious during the interaction, and finds the interaction intrinsically enjoyable or interesting” (p. 219). The outcomes of the study by Moon and Kim (2001) demonstrated that the extent to which an individual accepts the WWW is connected to motivators that are intrinsic and extrinsic in nature; based on their finding, the variable of playfulness is an important intrinsic motivator in user acceptance of Internet technology. As the variable of playfulness encapsulates the hallmark characteristics of flow (Csikszentmihalyi, 1991), Moon and Kim’s (2001) findings reflect a view similar to that of Hoffman and Novak (1996), who also stated that flow can positively affect user’s engagement in using websites, as well as that of Yang and Hsu (2011), whose study revealed that, together with perceived aesthetics, perceived playfulness played a primary role in conditioning users’ intention regarding the use of “fashion” technology.

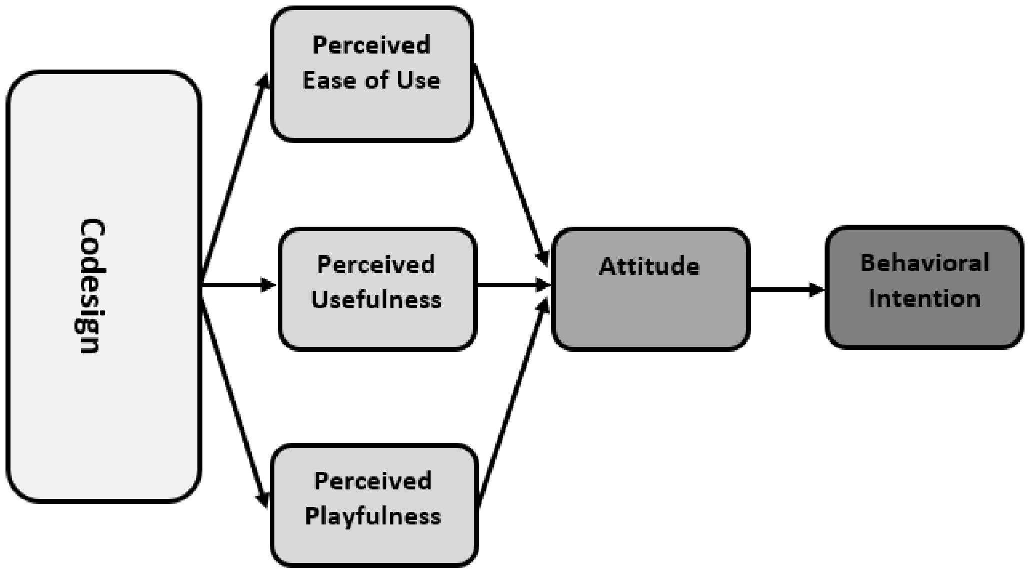


***Figure 4.1:*** *Proposed extension using TAM as a conceptual model*

**Codesign**

Codesign is a concept found in the context of human factors design and involves “the creativity of designers and people not trained in design working together in the design development process” (Sanders & Stappers, 2008, p. 6). Design that involves individuals other than designers is becoming increasingly more common, where design is an activity in which all may participate in a public space instead of being constrained to the hierarchy within a given institution (Bjorgvinsson, Ehn, & Hillgren, 2010). According to Sanders (2002), there are three ways to engage with customers involved in design: “say”, “do” and “make.” This three-part process can be described as follows: when people vocalize their design approach or idea, others can listen, participants in a codesign process can observe the activities of others and the ways they are using or building with the objects involved, and in group settings, participants can experiment together and make manifest more subtle needs to explore alongside their peers; as such, this approach allows participants to more effectively structure their collective ingenuity (Sanders, 2002). This is an evolution from other product development processes in which designers in the professional world have been set apart in the world of active design while consumers are set as passive recipients of the design output. For consumers, codesign allows for a balance to be struck between situations in which they are positioned to passively consume and those in which they actively determine their own consumption experience; consumers themselves are more frequently seeking out the latter (Sanders & Stappers, 2008). When the realms of design and that of consumers are combined, Lee (2008, p. 33) refers to that space as a "realm of collaboration." Codesign constitutes a space that extends from the beginning to the end of the product development process (Sanders & Stappers, 2008). This type of intensive collaboration is increasingly more available to consumers as new tools for production are developed and users are positioned as the experts that drive the process (Bjorgvinsson et al., 2010). However, a codesign context must be approached carefully, as users' treatment can encourage or discourage their willingness to contribute (Rijn & Stappers, 2008). When implemented appropriately, Steen, Manschot, and De Koning (2011) found that codesign can contribute positively in various ways: it can facilitate an enhancement to the creative process, it can enhance the quality of the product (target of the design activity) itself, it can allow those implementing the codesign endeavor to improve their processes through observation of dynamics and learnings from the session, and finally, it can enhance the impact of the product and codesign endeavor on an industry or societal level over the long-term. Further, in the study of Rijn and Stappers (2008), which focused on how psychological ownership is stimulated through the design process, they found that participants in a participatory design context feel ownership if three criteria are met: they have a means to express themselves through either a "toolkit for expression," which is intentionally ambiguous, or "script-providing tools," which provide greater control for the participant; the end product obviously visibly reflects their contribution; and finally, if the results contain their own unique message or content.

However, although there are benefits to consumers who participate in codesign, there is also a cost involved (Etgar, 2008). Time is a resource that a consumer must expend when participating in coproduction. According to Etgar (2008), this means that a consumer who has more spare time will be more apt to participate. Specific skillsets of a consumer may also condition the coproduction experience and his or her proclivity towards this kind of activity (Etgar, 2008). Additionally, it should be noted that codesign may not be equally effective for all products (Etgar, 2008). Because customization of a given service or product is one objective for codesign, those goods and services with greater customizability may be more attractive to a consumer wishing to participate in the coproduction process; the characteristics of these kinds of products may also lend themselves more easily to the process (Etgar, 2008). Consumers have the expectation of a positive experience through the codesign interaction, which is combined with the expectations they have of creating a unique product (Yu & Park, 2014) which will have a positive impact on their day-to-day lives or experience (Etgar, 2008). According to Etgar (2008), a technological device, such as a personal computer, is one example of an item that may lend itself to the process of coproduction, given the large number of options a given consumer may have for customization. Apparel is another industry that could be among those which provide products likely to be customized by consumers (Ulrich, Anderson-Connell & Wu, 2003), because of their extreme potential for customizability. In the shoe industry, companies such as Nike and Adidas are devising systems and tools that allow the customer to participate in one segment of the design process independent of the supplier, thus constituting a form of codesign (Berger & Piller, 2003). The approach that these companies have adopted is in line with the premise asserted by Park, Morris, Stannard and Hamilton (2014) which asserts that future users of a product should be allowed a say in its design. Because of the increasing interest of consumers in terms of codesign participation, and also because of the number of tools and processes being developed to this end, "more apparel businesses are likely to try codesign for mass customization" (Ulrich et al., 2003, p. 410).

**Wearable Technology and Lilypad Arduino**

The use of wearable technology is increasing, which signifies that the control consumers are able to exert over their environments will increase as well (Baurley, 2004). Wearable technology can monitor health functions and vital signs, help improve the physical performance of athletes or rehabilitation patients, provide feedback from stimuli in one's environment, and create new opportunities for aesthetic enhancement and decoration in the apparel industry (Berzowska & Bromley, 2007). Because of the variety of functions afforded by wearable technology, this type of technology presents a multitude of opportunities for new product development (Ariyatum et. al, 2005).

The Lilypad Arduino is a sewable microcontroller used in textile-based wearable technology and runs on Arduino, an open-source programming and prototyping platform. It was originally designed to be a pedagogical teaching tool, teaching diverse users basic computing and electronics skills through a system of embedded computing (Buechley & Eisenberg, 2008). Users can sew the Lilypad into a textile-based project and connect components with conductive fabric and thread (Buechley, Eisenberg, Catchen, Crockett, 2008). It was created in large part to expand upon what its creators saw as an expressive extension to already existing themes of technology as entertainment and as automation (Buechley et al., 2008), which in turn has prompted the creation of a new demographic within the traditional engineering community (Buechley & Hill, 2010). The creators of the Lilypad state that there is a third dimension of human computer interaction and technology use that centers on whether users can perform tasks or express themselves in ways that were previously thought impossible by using a particular technology (Buechley et al., 2008). That is, people can easily purchase the device online and teach themselves how to use it through various open-source tutorials. Buechley and Hill (2010) state that the mass consumerism characterizing the $20^{th}$ century will soon give way to a context in which niche users maximize internet resources to create, locate, share, and consume content that fits their unique interests and needs. This aligns with Smelik, Toussaint and Van Dongen's (2016) stance, which holds that the relevance of wearable technology will only grow when users are able to engage with the design and discover new values and significance through it. This shift towards increased engagement is driven by an expanding population of participants in the do-it-yourself (DIY) community, who participate in and expand upon what Tanenbum and colleagues refer to as "democratized technological practices" (Tanenbum et al., 2013, p. 2604), representing a significant change in the way users interact with technology and engage with it in their lives. This type of technological practice is characterized by utility, expressiveness, and playfulness. The Internet has facilitated the fast spread of DIY concepts to the larger population; open-source tools such as Arduino allow for collaborations and sharing to take place easily and quickly, and are increasingly prevalent in manufacturing architecture and design disciplines (Lin, 2014), which creates a context in which consumption is no longer passive. Instead, it is an opportunity to generate one's creative experience and may lead to a change in attitudes and behaviors characterizing the larger consumer population (Lin, 2014).

# Method

## Study Participants and Recruitment

We recruited 17 codesign participants through an email invitation, snowball sampling, and flyers, and they each met the following inclusion criteria: a) 18-65 years old; b) cycled more than three times a week, and c) had experience riding at night, to ensure that participants were adult cyclists of both genders and could draw from their experiences to design a system that properly addressed the issue of nighttime cyclist visibility posed in the codesign session. The topic of cyclist visibility at night was selected as the focus of the scenario due to its significance in the cycling community; a set of recent statistics show that between 2010 and 2017, nighttime cyclist and pedestrian deaths increased by 46%, 70% of which were attributed to conditions of poor visibility (Maciag, 2019). While the area in which participants of this study resided as recently ranked number one out of 480 cities in terms of being bike-friendly (Trevino, 2018), nationwide statistics revealing an increase in cycling deaths while motorist deaths remain the same (Short, 2019) show the importance of a continued focus on cycling safety. Further, the primary researcher's work at the Fort Collins Bike Coop, personal experience as a cyclist, and work at a local cycling apparel company all underscored the importance of addressing this issue. The average age of the participants was 39.53 (SD 13.96), ranging from 25 to 63 years old. All indicated that they were road bikers; among these, five reported that they participated more frequently in other types of cycling, such as mountain or cross biking (see Table 1). As an incentive for their participation in the session, participants were given a cycling jersey donated in-kind by a cycling apparel manufacturing company headquartered in Colorado.

***Table 4.1:*** *Participant Demographics*

| Gender | Ethnicity | Age | Occupation | Education | Type | Purpose |
|---|---|---|---|---|---|---|
| F | Caucasian | 52 | retired | Bachelor's | road | recreation |
| M | Caucasian | 55 | retired | Bachelor's | road | recreation |
| F | Caucasian | 55 | retired | Master's | road/mountain | commuting/ recreation |
| M | Caucasian | 57 | retired | Bachelor's | road | commuting/ recreation |
| F | Caucasian | 26 | product development | Master's | road | commuting/ some recreation |
| F | Caucasian | 25 | student | Master's | road | commuting/ recreation |
| F | Caucasian | 29 | ecologist | Master's | road | commuting/ some recreation |
| M | Caucasian | 25 | researcher | Bachelor's | road | commuting/ recreation |
| M | Caucasian | 35 | bike shop mechanic | Master's | road/ mountain | commuting/ recreation |
| M | Hispanic | 26 | student | Some college | road | commuting/ some recreation |
| F | Caucasian | 34 | bike shop employee | Bachelor's | road | commuting/ recreation/ exercise |
| F | Caucasian | 53 | self-employed | Bachelor's | road | commuting |
| F | Caucasian | 51 | RN | Bachelor's | road/ mountain | recreation |
| M | Pacific Islander | 63 | engineer | Ph.D. | road | recreation |
| M | Caucasian | 30 | computer technician | Master's | road/ mountain/ cross | commuting/ recreation/ competition |
| M | Caucasian | 26 | mechanical engineer | Bachelor's | road/ mountain | commuting/ recreation |
| F | Caucasian | 30 | student | Bachelor's | road | commuting/ recreation |

**Procedures**

The data collection procedures consisted of the following three steps: the pre-survey, codesign exercise, and post-evaluation (post-survey and focus group), as shown below in Figure 4.2.

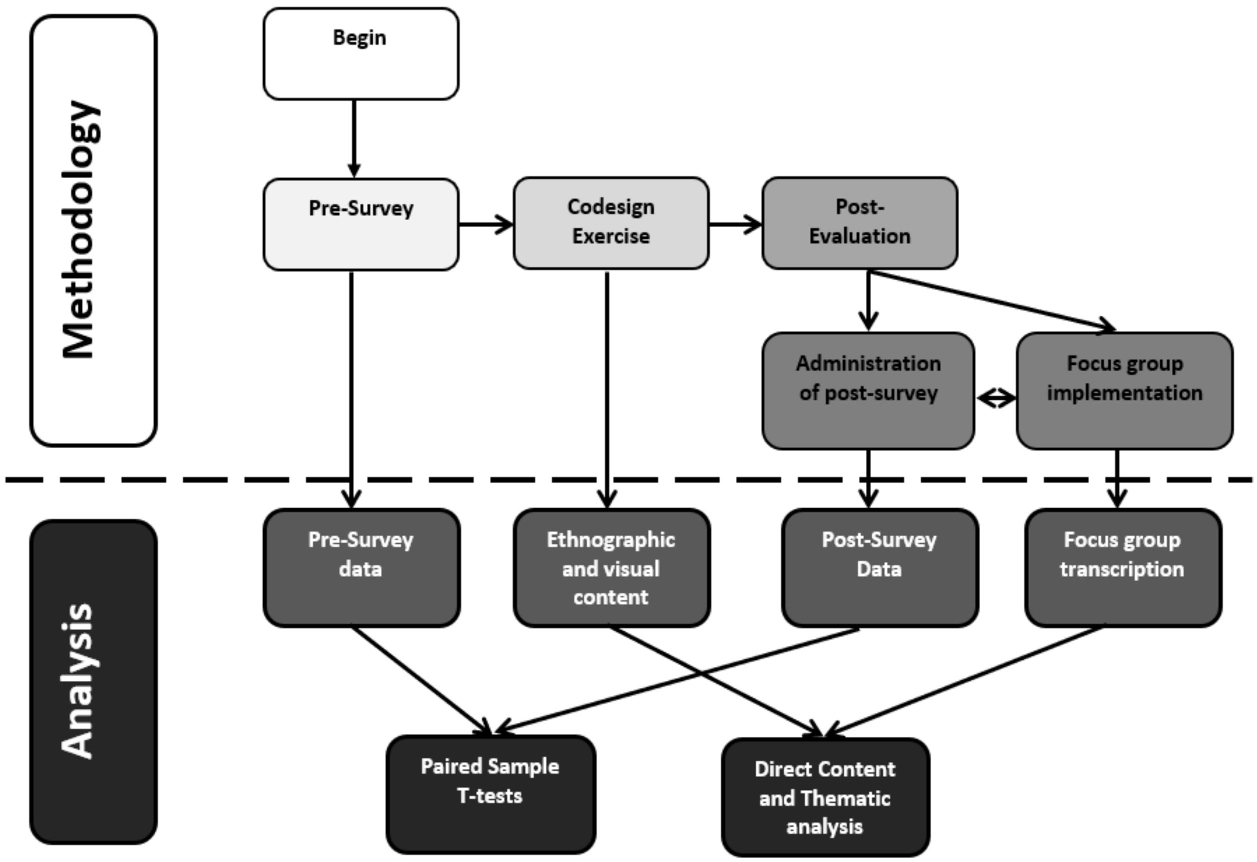


***Figure 4.2:*** *Diagram of methodology and analysis*

**Step 1: pre-survey.** For the pre-survey, a questionnaire was developed by the researchers and administered to the study participants to gauge their initial attitude and behavioral intention toward wearable technology, previous experiences with wearable technology, and perceived importance of wearable technology, as well as demographic and psychographic information, before participating in the hands-on codesign exercise. The portion of the questionnaire addressing TAM comprised 25 questions on a Likert scale from one to five, with five being "Strongly agree" and one being "Strongly disagree." The survey was subdivided into sections comprising five questions each for PU, PEOU, PP, Attitude, and Behavioral Intention, respectively.

**Step 2: codesign exercise.** Following the pre-survey, all participants took part in one of the two codesign sessions assigned based on their availability: one group consisted of 6 participants and the other, 11 participants. Both sessions lasted about 3 hours each and provided the same codesign context and structure. The participants were introduced to the codesign activity utilizing Heimdal and Rosenqvist's (2012) approach in which representative materials were used to visualize and illustrate concepts freely, allowing participants to remain unhindered by the more technical details of the system's real-life implementation. Given the diverse background of participants, it was assumed that their previous experience with wearables, especially with more advanced concepts such as designing or sewing circuits, would not be the same. Per the experience of participants in Heimdal and Rosenqvist's study (2012), the use of representative materials in this context could allow participants to explore concepts pertinent to a wearable system without being constrained by participants' individual level of experience with circuitry and electronics design.

To level the playing field and ensure that the codesign activity was accessible for all participants, the first author designed and provided a "prototyping kit" (see Figure 4.3), which comprised a cycling jersey, circular stickers with crayons (for colored "LEDs"), stickers printed with images of circular sensors, three 3D printed discs with a printed Lilypad Arduino graphic that could attach to the jerseys via earth magnets, three 2D diagrams of the human body and individuals riding bikes for visualization, and large sheets of graphing paper and pencils for sketching out ideas. An actual road bike, a helmet, cycling shorts and cycling shoes were made available for people who wished to use them for the codesign activity.

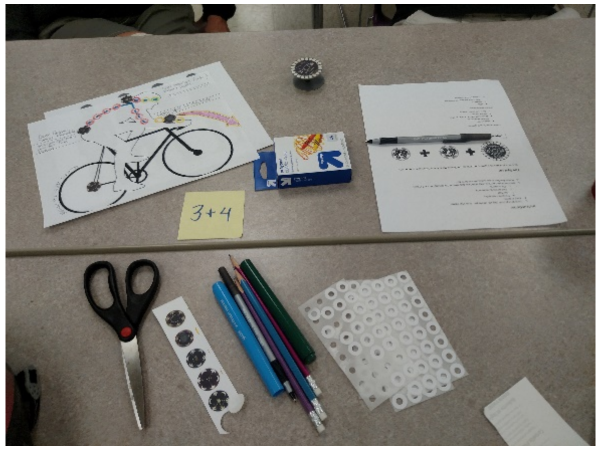


***Figure 4.3:*** *Components of Prototyping Kit*

The structure of the codesign activity shared similarities with that of Rijn and Stappers (2008), who used a context-mapping technique in which users were positioned as experts of their own experience and invited to share their design ideas through the building of actual items and then provide a verbal explanation. This approach was selected because it not only resulted in the collaborative design itself; it can also encourage psychological ownership on the part of the participants (Rijn & Stappers, 2008). The participants were given a scenario to develop a Lilypad-integrated cycling jersey using the prototyping kit to address issues of nighttime visibility for cyclists. The codesign session opened with approximately 30 minutes of instruction on the Lilypad Arduino to provide participants with basic information about the device's capabilities and potential usage. The instruction included a PowerPoint presentation and a handout with Lilypad specifications, along with a two-minute Youtube video on various Lilypad Arduino applications. After the instruction, participants were put into small groups of two or three and asked to collaboratively generate ideas and visualize potential design solutions to address the issue posed in the scenario for an hour. During the hands-on codesign practice, the participants were encouraged to explore ideas and approaches freely, such as trying on the jersey or riding the bike provided for prototyping. The primary researcher was present in the room to assist the participants with any questions, and an ethnographer, who had academic training in deriving the meaning and significance of body movements in space and non-verbal communication in the context of modern dance, took notes documenting observations of the codesign space. After the completion of the codesign exercise, participants were invited to share their designs with the group for feedback. Upon obtaining participants' permission, the prototypes and sketches were collected and photographed (See Figure 4.4).

***Figure 4.4:*** *List-making, sketching, and full prototyping*

**Step 3: post-evaluation.** After the codesign exercise, the post survey was administered to assess any changes in PEOU, PU, PP, attitude, or behavioral intention toward the wearable technology. The focus group discussion allowed participants to share their experience through the codesign exercise, through which the effects of codesign on the TAM variables were evaluated.

**Data Analysis**

Data were collected from multiple sources, including the surveys, focus group discussions, field notes, and the researcher's memos, videos, and photos from the codesign session, all of which were collected to triangulate the data. Given the sample size and nature of the study, we used focus group discussions as the primary data and surveys as the secondary data. The remaining data sets provided supplementary support towards a holistic understanding of the study results.

The focus group data were transcribed verbatim and direct content analysis was conducted. The use of the analysis method was considered appropriate because the experimental research was designed based on an existing content analysis method (Hsieh & Shannon, 2014). While the TAM has been widely adopted in quantitative research, other studies have similarly used TAM as part of a qualitative analysis method (for example, see De Vreede, Jones, & Mgaya, 1998). For this study, the five key variables of TAM were used in the analysis of focus group data as main themes into which the qualitative data were organized. Inductive reasoning was also allowed in the data analysis when emergent themes were observed; in this study, similar to the approach adopted by DeVreede, Jones, and Mgaya (1998), additional thematic analysis was performed using constant comparison (Glaser & Strauss 1967; Strauss & Corbin, 1998; King, 2004) to explore the emergence of any additional themes beyond those provided by the TAM theoretical framework. The themes were then organized into a coding guide that was used to classify the data until all categories became saturated (Strauss & Corbin, 1998). The primary researcher used the coding guide to conduct the initial coding of the focus group data, and the coding scheme was discussed with the researcher's adviser. When disagreement occurred, the researchers discussed until a consensus was negotiated. To enhance the trustworthiness of the coding process, per the approach outlined in Park (2015), which drew from Miller (1992), a trained researcher who was not a part of the research project (i.e., a peer graduate student) helped perform an audit of the focus group data, during which the initial application of the coding guide by the authors was checked and validated. The audit resulted in an interrater reliability of 92.9%, which was calculated based on the method developed by Marques and McCall (2005).

To compare the effects of the codesign experience on the participants' acceptance of Lilypad Arduino as a specific wearable technology tool, paired-sample t-tests were performed using IBM SPSS 25.0. Specifically, the five mean composite scale sets representing the TAM variables – PEOU, PU, PP, ATT, and BI – were used to perform mean comparisons between the survey data obtained at the baseline and in the post-evaluation following the codesign practice. Statistical significance was evaluated at $p < .05$.

## Results

### Product Outcomes of the Codesign Exercise

As shown in Figure 4.4, the physical results of the codesign exercise varied in form and type by group, and the results could be classified into the following three groups: list-making/written brainstorming, 2D visualization (sketching/coloring), and 3D rapid prototyping implemented to scale. The participants wrote out lists that detailed the components of a given system and their function, as well as the problem that they addressed. They also used the diagrams of the human body provided to sketch the device placement or created free-form drawings of their system design. Finally, four out of the eight small groups developed full-scale prototypes that used the cycling helmet, jersey, and road bike provided, as if they themselves were wearing their "ideated" wearable system (refer to Figure 4.4). Although some groups came up with ideas that were entirely unique, several themes, such as buttons for turn signals on the handlebars, lights that flash more quickly when a cyclist is slowing down or stopping, and proximity sensors to detect when cars are approaching and alert the cyclist, emerged repeatedly in the participants' verbal descriptions of their designs and the features of the prototypes themselves. These repeated themes could represent an opportunity for manufacturers of bicycle safety and equipment and apparel, as they are the stated needs of cyclists and evince the ideas that they might find easy to use, useful, and perhaps even fun, as a collective.

**Survey Results**

The results from the paired-samples t-tests revealed significant differences between the mean scores collected from the pre-survey and those from the post-survey. Specifically, of the five TAM variables – PEOU, PU, PP, ATT, BI – the mean scores of all five variables showed significant increases after the codesign exercise, compared to pre-exercise scores at the 95% confidence level (Table 2). Overall, these results suggested that following the codesign session, participants perceived the technology as easier to use, useful, and more enjoyable, and demonstrated their positive attitude and willingness to adopt it.

***Table 4.2:*** *Survey Results*

| Variable | Pre | Post | Significance |
|---|---|---|---|
| | x̄ (sd) | x̄ (sd) | p |
| PEOU | 3.24 (1.18) | 4.12 (.70) | 0.004** |
| PU | 3.39 (.82) | 4.29 (.51) | 0.000** |
| PP | 3.80 (.99) | 4.31 (.53) | 0.045* |
| ATT | 3.48 (.56) | 4.02 (.48) | 0.001** |
| BI | 3.45 (1.03) | 3.95 (.78) | 0.024* |

Note: * $p < .05$; ** $p < .01$

**Focus Group Results**

To gain deeper insights into the effect of the codesign experience on technology acceptance, we analyzed the focus group data. We organized the qualitative data using the five TAM variables: PEOU, PU, PP, ATT, or BI, as well as the subthemes identified from the constant comparison analysis within the TAM framework.

**Variance in initial perceived ease of use (PEOU).** Participants' initial PEOU varied widely and seemed to be closely related to their self-perception regarding technology aptitude. While participants shared during their focus group discussion that the codesign experience was helpful overall in allowing them to demonstrate ideas and perceive greater ease of using the wearable technology device, some narrated their initial fear of using the "rather unfamiliar" technology to design and build a system (rather than simply using it), which is how the Lilypad is intended to be used: "I mean, when I read through the description you handed us, the first sentence, I was like, 'I don't recognize half of these words, I don't know what it was for." On the other hand, some demonstrated their relatively comfortable feelings about using the technology before participating in the codesign session, as revealed by a statement from one participant:

> "Seems like it would be relatively straightforward overall. My background, at least what I knew about it already. I had some friends who played around with it, and told me things about them and forwarded me the website of Arduino, so I already knew some of the capabilities so it was more like, oh ok, if I were to design something, this is how I would put it together."

Despite the initial confidence of some participants and the growth in confidence experienced by others owing to the codesign session, participants' experiences during the session did not fully counteract the strength of their self-perception related to general technology use, which still adversely affected their perception of the device in terms of designing a working system:

> "conceptually I feel a lot better about it, but if I were to have to execute on it, I mean whoa whoa…I would have to have a huge manual to tell me step-by-step. It would take a lot I think for me to execute the idea." For participants with technical backgrounds, their perception of ease of use at this stage was not substantially affected either positively or negatively, although the codesign activity did open their eyes to the device in other ways, which will be discussed in another section.

**Complexity of technology, confidence, and PEOU.** While the ease with which participants might be able to build a system using the device was questionable for some, they perceived the ease of using the device as a finished system (designed and programmed by someone else) more positively, because all participants had at least some exposure to wearable technology from a consumer perspective (as opposed to a maker perspective). Participant perception of the device's ease of use prior to the codesign session was more positive and even more so following the session. Following the codesign session, several participants expressed a positive perception of the device's ease of use as long as it was already "set up," while expressing hesitation about the ease with which they would be able to make adjustments, if needed. One participant said:

> "I think I would buy something like this if it was already set up for me, but at the same time, if I had multiple jerseys or jackets and like, wanted to switch it out, that would be an issue. But to start out, I would buy something that's already completed for me. So, I can get an idea about how it works. But then I would feel a little bit more comfortable trying to maybe create my own if I could have an example."

The idea of having an example or point of reference with which a participant could build their confidence that they were using it correctly came up repeatedly. As one participant stated, “Yeah, I wouldn’t want to just buy it and figure it out. If I had purchased something and it was already set up, it would make it less intimidating to make it on my own.” Thus, the answer that may be supplied for research question one based on the results is complex and contingent on which aspect of its ease of use is referenced; the codesign activity did not help participants perceive the ease of use of the device at the design phase more favorably, but it did seem to augment their interest and confidence in its ease of use as a finished product or system.

**Collaborative learning environment and increased Perceived Usefulness (PU).** Overall, participants expressed that their knowledge of the device’s potential increased due to the codesign activity and they felt they understood its uses, benefits, and functions more clearly. They indicated that the hands-on ideation of the codesign activity allowed them to gain a more realistic grasp of the potential applications of the device, thereby allowing them to perceive it as more useful. Particularly, in a collaborative learning context generated by codesign, participants’ perception of usefulness seemed to improve. One participant stated that although she had an assumption of usefulness, she did not know enough about the device to be sure until she had a chance to work with it; “I thought, it was probably useful, but I have no idea how. This is an awesome little piece of circuitry but I have no idea what it does or how it works or what I can do with it. Well that’s great.” Another participant acknowledged that his understanding increased through building and ideating with the device in the codesign session: “I think once we got to use it, and talk about it, it certainly made it easier to try and understand the applications.” Group collaboration and idea generation augmented participants’ individual experience, paving the way for them to view its usefulness in a more optimistic light: “just being able to hear everybody’s visions was awesome. Made it come alive. That it could do a lot of things." More specifically, building allowed participants to experience the components' interaction firsthand, which led to greater understanding and confidence and enhanced participants' ability to conceptualize its potential applications. As one participant stated:

> "Well, it was helpful to have to implement it in the physical reality of the world as opposed to just like talking about it or conceptualizing it. Without your little prototyping kit to mock it up, we wouldn't have come across the challenges of like, ok, where are we going to place this particular sensor? And so that was helpful. To see that challenge."

A fellow group member added, "yeah, and there were a couple of times when in trying to decide where we were trying to place things, we were like, wait a second, we don't want to put this one too close to this one because it could interact adversely."

**Interdisciplinary exchange of ideas and improvement in PU.** Given the variance in participants' backgrounds, their collective understanding of the technology during the codesign session was driven by an exchange of diverse perspectives; regardless of individual background, participants experienced a positive benefit from working with others and any contrasting perspectives seemed to have the effect of deepening and broadening participant comprehension of the device's usefulness rather than becoming points of contention. This is in accord with the findings of Venkatesh and Davis (2000), who discovered that the social norm could dramatically affect perceived usefulness in the context of the TAM. This was expressed by one participant when she said, nodding in the direction of her teammate, "It was really good to have her. She understood it a lot more, so she could explain it to me." Interestingly, all study participants with engineering backgrounds highlighted that their teammates helped them expand their concept of its potential uses because the teammates did not know enough about electronics to be aware of the constraints and were thus freer to explore ideas. One participant expressed: “So, I got to where she was (indicating teammate), but at the onset, my brain shut that down, a lot of ideas, here are the outputs and inputs that I know, and then bouncing things off them, it opened things back up.” This was echoed by another participant: “Because I have that engineering background, my brain went to like, “okay, here’s my limitation’ and then talking with my [teammates], it was like, ‘oh, peel that back for a second. What can we do with it and at the end, reapply it?’” In response to the question about how the codesign session had allowed him to see the usefulness of the device, he said, “Yeah, a lot faster than it would be for me to just sit here by myself and do it. And or talk to another engineer. Because again, we would be focused on one vector and just drill down into something. It would take us longer to get to a greater value of it.” He emphasized that because the codesign groups were interdisciplinary, they were able to conceive of design ideas more closely matched to user needs rather than simply following traditional approaches to systems design, which he asserted is the tendency for a person with a more technical background. He described the scenario as follows:

> “…if we had a designer here that was down in the Arduino bits and bytes, and someone who was in systems design, they would be trying to jump to a solution…if they were in this group of users where we’re saying, ‘oh, it needs to have bells and whistles’ and they were saying, ‘it needs to only have five inputs,’ we could draw them out of that limitation and just that design realm and bring them into, ‘well, what is the value of any of these design improvements and design features that you can put in there.’”

**Comparison of ideas and new possibilities in product use (PU).** During the codesign session, participants drew comparisons between their proposed systems and those of other groups; participants expressed surprise and admiration at the diversity of ideas and the fact that hearing the ideas of others helped open their minds to other possibilities they had not previously considered. In addition to the interdisciplinary interplay within groups, participants revealed a consciousness of other groups' approaches, knowledge, and ideas, and drew comparisons, which served to augment their own motivation and understanding. In this regard, the significant effect of the social norm on perceived usefulness (Venkatesh & Davis, 2000) was particularly evident. One participant shared that the ideas of other groups he had overheard had opened his mind to other ideas of how the device could be used, saying:

> "We came up with a pretty long list, and at the end there, we were kind of racking our rains to continue adding to that list, but then every single group came up with something that wasn't on our list, and that was not only impressive but almost surprising to me that we didn't think of the same thing that these other guys did. We're pretty smart guys but evidently not as smart as we thought."

One participant revealed an observation of his group's emphasis on practicing the application versus that of other groups, which was seemingly on simply having fun:

> "…they were actually in tune with where they wanted each sensor to go, and how it would be incorporated into the clothing and were really having a lot of fun with it, whereas we more, 'kay, input and output and practical application…[let's decide] where this would go and then let's take a look at it on paper, and think what the natural next step would be. Let's see where we can actually put it next as far as the practical application goes. We are the slow kids in the class."

**Collective playfulness, creativity, and experimentation (PP).** Participants' ability to experience the element of playfulness together during the codesign session led to greater creativity and experimentation and in general, they perceived the device as more fun. During the focus group discussion, when asked how "fun" they had thought the device was before the codesign session, participants used words like "foreign" and "intimidating" to describe the device; however, when discussion centered on how they felt after the codesign session, their perception had changed significantly to varying degrees and was largely more favorable. Over the course of the codesign session, as the participants realized that the objective was more about playing with the device than actually endeavoring to create functioning designs at high stakes, it became clear that group playfulness facilitated both creativity and experimentation. Participants began to collaborate more freely and their excitement grew. One participant shared that he

> "definitely got more excited the more we talked about it. It was an apprehension at first, about like, 'oh man this is sort of a contest to see who is going to come up with the best thing,' and as it progressed, it was sort of like, 'oh, this is sort of a collaborative excitement that we're sort of building something together rather than competitive.'"

The value of the excited and playful dynamic shared between group members was echoed by one participant when she said, "I think if I had been working on it alone, I would not have had as much fun."

**Low-stakes environment and impact on PP.** Because participants were not required to concern themselves with developing a working prototype and could instead conceptualize and explore multiple ideas in an unconstrained fashion, PP was positively impacted. Interestingly, the level of fun was particularly augmented for participants at opposite ends of the technical experience spectrum: in particular, for those with the most and those with the least experience with electronics, the codesign environment allowed them to play with ideas and have fun with group members in a low-stakes environment; they knew that they were working with representative materials and essentially playing make-believe, so there was no "wrong" answer.

Participants observed that this had a positive effect on their ability to enjoy themselves. One participant, who did not have a background in design, said:

> "I think also, and you didn't really talk about how the wires would come together, and I think because you didn't do it that way, it really fueled the creative process, because if you had to worry about how the wires got from point a to point b, and down the body of the shirt, that would be really restraining, so taking that practical side out of it really made it a lot of fun, actually."

On the opposite end of the spectrum, another participant, whose day job was designing and developing apparel, expressed her delight at the freedom to play with concepts without any repercussions during the session: "I work in design and development, so that's like, this was like, let's just put bikes everywhere." Another participant described the effect on her experience of having fun in a collaborative environment specifically in terms of how it encouraged greater creativity:

> "What I was finding is that you can kind of get more creative with it because we were joking around the whole time. I don't know, you just get really silly ideas that can work out, and a few of ours, we were like, that's too ridiculous, but I don't know. Maybe work because you felt more creative."

Participants also indicated that group playfulness facilitated overcoming challenges they experienced on the plane of reality, which were their own intimidation or lack of knowledge. One participant shared that, for him, the device was initially "…inaccessible or intimidating, and then once we got all our ideas flowing, it was like, 'oh well, maybe it's still a little intimidating, but I'm willing to take it on because I want this so bad because it's going to be so awesome.'" Another participant echoed this sentiment: "Yeah, I would say overall, just like the bouncing of ideas around that. The excitement that that generated overcame the hesitancy of the imposing nature of the device."

**Positive attitude toward technology and future willingness (ATT).** Following the codesign activity, participants' positive attitude toward the technology was revealed in their willingness to consider the device as a viable option for future projects. Meanwhile, before the codesign session, participants' attitude toward the device varied widely, ranging from outright dislike of the device to admiration; regardless of the starting point, all participants reported that they felt differently towards the device following the session. Participant attitude changed significantly regarding their increased willingness to explore and use the device both during and outside of the session. Their motivation shifted from a focus on completing the activity to one characterized by innovation and further exploration after the session. Participants also developed a new fondness or kinship with the device itself through building during the codesign session. Before the session, participants used words such as "foreign" and "intimidating" to describe their feelings. One participant admitted to feeling almost unwilling to participate, because it "sounded like work." This reluctance towards working with the device was shared by another participant when she said, "I mean, it wasn't shooting sparks at me or anything, but that's all it would have taken and I would have been out the door." This contrasts sharply with her attitude following the codesign session, which she summarized as follows:

> "There's a part of me that's just like 'God, can I just borrow someone else's brain that knows about this stuff? So, I can make this stuff because I want it? … Some of the ideas that are coming up are like…yeah, I can make that, sweet. Teach me how!"

One participant described his own evolution as follows: "I don't know if you'd call it feelings, but the idea of, 'ok, this is a task in the beginning' to 'I now have buy-in and ownership of the results. I went through all of those phases to, I'm excited about seeing somebody do this." This same evolution is revealed in another participant's statement where he shares his newfound willingness to connect the device's functions to scenarios in his own life "…a lot of the fear from riding at night comes from experience. When we were riding a car was backing out of a driveway, and I was like, 'hey we're riding here.' I almost got hit the other day. So, a light up party-on-the-bike jacket would be really helpful." Meanwhile, it is important to note that although the codesign activity favorably affected all participants' attitude, some still thought of the device as an "occasional-use" type of item and were not as eager to use it on their own:

> "I think of it more as a novelty item unless it was manufactured into a helmet or something like that, where it had that option where you could just light it up, but as far as installing it yourself, I don't think I would think of doing that. I might now, but…"

**Codesign experience and behavioral intention for technology adoption (BI).** Following the codesign activity, some participants expressed the intention to research the device further, to purchase it, and continue to build out some of the ideas that had begun with the codesign session. Once they had worked with the device during the codesign activity, participants developed a familiarity with it, and could identify with the device as an extension of themselves; the device's embodiment of functions selected by participants allowed them to project aspects of their identity onto it. One participant expressed this phenomenon as follows:

> "I guess if I were to say that you showed me this, I would be going, ok, this is glass with aluminum wrapped around it. Fine. Press a button and all of a sudden, I can listen to music and it can tell me things and it's smarter than I am at times and the application and usefulness is expanded. So, I look at this, and it's a controllable but with some ideas in

Regards to lights or signals or sensors, oh my gosh, it's more than that, it's now an extension of the body on the bicycle at night."

Another participant shared that the ability to customize the Lilypad to reflect his own identity and priorities caused his perspective to shift from reluctance towards using wearables because they would not be useful in his own life to one where he felt a kinship with it; this shift was evident in this dialogue between participants:

*Participant A:* I have been really slow to adopt wearable tech. A lot of people are wearing Fitbit and I just don't see a need for it. But occasionally I'll use Strava. Because it's cool to see where you rode and how far. But, as far as my everyday life, I just don't want that. That's too much data for me but something like this where I could just take it and make it my own. I dunno. There's something more simple about that, which is kind of exciting to me. That's why ours was centered around the saddlebag. I don't have to put it on me. I can forget about it when I'm riding and it's simple like that.

*Participant B:* You feel like you're a part of it?

*Participant A:* Yeah.

One aspect of extended self was the appeal of customization for some participants, who expressed that their attachment to their own designs or constructions was stronger than their attachment to something made for them that they merely used. One participant expressed, "if I can build something and make it, even if it's complete garbage compared to what's on the market, I will love that thing." The attachment to an item developed through one's active role in its construction was strong enough to counteract any inconvenience owing to otherwise poor quality or design:

> "Honestly, from big projects down to small things. Sewing extra pockets on pants because I wore through them biking too much. People tell me to throw away those pants but I love those pants. Really simplified, but if I can make it and it's like partially my design and creation, I'm a way bigger adopter of that then buying something off the shelf."

**Comprehension of technology and future purchase behavior (BI).** Participants' level of comprehension of the technology seemed to affect their stated future purchase behaviors in various ways; in particular, those with high comprehension explicitly stated their intention to research the device further and consider its purchase to build out various projects, including those unrelated to cycling, while participants who were still hesitant adopted a slightly more passive approach and were more interested in observing progress that might be made by others in the projects they planned to undertake with the device. One participant, who fell into the latter category, shared his excitement related to post-session intentions to use the device, saying:

> "I think we came up with more ideas for sounds or vibrations, or things like still we have no idea how it could actually work in real life, but I think that, like you said, it's still evolving, and so it would be really cool to see how some of these go."

Participants connected their new intention with what they had experienced in the codesign session. One participant shared, "well, I had seen videos similar to the one you showed us highlighting it, and I wasn't making any plan to pursue it further, but tonight I would say I'm going to get on google and check it out." Another participant expressed the way sketching had motivated him to think beyond the codesign session itself: "I mean, outside of this study, not just biking, after we put our ideas on paper, my brain was still firing, what other things can I do with this, even just around the house?" However, for some participants, although the codesign session opened their minds to the possibilities, they lacked confidence in their ability to use it correctly and were still uncomfortable with the idea of purchasing the device. As one participant said,

> “I think I would need to better understand the execution before I could purchase it. I can play and have a good time, but actually getting it to work, the whole electronics stuff, the creativity goes out and the execution challenges come in and if it's really challenging, then I'm not gonna spend the time. That's just me. If it's not easy to use, I'm just not going to spend the time to deal wth it."

## Discussion

Across all variables, the survey results showed that the codesign activity caused an increase in participants’ favorable perception of the wearable device. That is, after the experience of codesign, the participants showed positive changes in their perceived ease of use (PEOU), perceived usefulness (PU), perceived playfulness (PP), attitude toward technology (ATT), and behavioral intention to adopt the technology (BI), to a statistically meaningful degree with 95% confidence.

The findings from focus groups provided additional insights into the effect of codesign on the participants’ perspectives regarding the prototyping kit to which they were introduced for the creation of a wearable product. During the codesign session, it became apparent that participants’ ability to perceive the device as easy to use at the “making” level, with which few participants had direct experience, was divergently different than their ability to perceive it as easy to use in a finished system. Here, the effect of direct experience on PEOU illustrated by the concepts of anchoring and adjustment from Behavioral Decision Theory (Slovic & Lichtenstein, 1971; Tversky & Kahneman, 1974) have significant implications for the objectives of this study; most participants had little to no experience working with the Lilypad beforehand, and depending on their self-perception and experiences related to technology before the session (their anchor), they were initially intimidated; they perceived the concept of building a system with the device as difficult, as evinced by participant discussion and the values from the pre-survey. As participants had the opportunity to explore with the technology in the new context introduced by the codesign session, their PEOU improved; according to Venkatesh (2000), this is in alignment with the interplay of these two concepts, as, "with increasing direct experience with the system, individuals adjust their system-specific PEOU to reflect their interaction with the system." (p. 345) Owing to the codesign context, participants had a largely positive experience with the system and were thus perhaps able to make a small positive adjustment in their PEOU. On a more granular level, the aspects of control, intrinsic motivation, and emotion may have affected PEOU during the session (Venkatesh, 2000); given the increase in positive experience with the device, participants felt a stronger sense of control or efficacy in their use of the technology. The level of emotion (anxiety) they experienced also decreased, thereby allowing their PEOU to improve. Meanwhile, participants with engineering or programming experience were more likely to perceive the technology as easy to use at the design phase because they came into the session with a largely positive anchor and did not have to undergo an emotional transition during the session itself to achieve it; any adjustments they made resulting from codesign only served to enhance their initial anchor. In line with this, because almost all participants have experience using a wearable as a consumer, according to the quality of their prior experiences, their perceived ease of use of a finished system was initially slightly more positive, although the new volume of information yielded by the codesign session still prompted participants to make positive adjustments to the PEOU that was informed by their preexisting anchors.

For perceived usefulness, focus group results indicated that the codesign activity had a positive effect on participants' perception of the device's usefulness. In the focus group discussion, participants of all backgrounds indicated that their ability to work with the device together and in a hands-on way allowed them to perceive its potential applications and usefulness more clearly. Given the manner in which the codesign activity situated users to work alongside one another and interact frequently during the session, the social norm may have been a factor, as it can affect perceived usefulness (Venkatesh & Davis, 2000). More specifically, the concept of a collective norm (Lapinski & Rimal, 2005) was obviously in play; the codesign session created a new context for users within which they were called upon to interact around the creation of a product in an entirely novel environment. Although some aspects of participants' usual social norms still applied as the means by which their behavior was regulated and socially controlled (Koury & Yang, 2014), the newness of both the device and the experience positioned all participants in groups that were completely equal, in which none was an expert over all aspects of the session and they contributed to the product's design as a collective. This augmented the extent of the social learning that was able to take place, which, according to Sanders and Stappers (2008) constitutes the fundamental element of evolutions in the current design paradigm, which yields novel types of creativity from the collective. The diverse backgrounds of participants seemed to enhance rather than take away from the favorable outcomes and participant benefit from the exchange. Instead, they leaned on each other to test their ideas by building them out and confronted their initial fear of the device in a team-based setting; in building the device, they learned as a group and constructed a collective norm of behavior specific to the codesign context. Different backgrounds and skillsets became assets rather than points of conflict and helped groups remain open to ideas that were perhaps more targeted to the identified needs of the system rather than a function of a given designer's habitual attachment to a particular design or approach.

The codesign session and the representative materials presented a low-stakes opportunity to experiment and play; participants were able to become immersed in the activity in a light-hearted space that Lee (2008, p. 33) calls a "realm of collaboration, in which design and consumers are combined." In alignment with Csikszentmihalyi's concept of flow (1991), participants could lose themselves in the interactions, drawn in by the collaborative dynamic to focus only on the task at hand. Interestingly, the codesign participants who seemed especially apt to experience flow were those who either had prior experience with the device itself or a technical background, or had confidence building other types of products and systems with their hands and could therefore feel freer to experiment at a level that allowed them to develop more comfort with the device. Both of these types of participants could experience flow because they were able to establish a baseline comfort level through familiarity with at least one major element entailed in building the system; in alignment with Csikszentmihalyi's theory (1991), this baseline comfort level allowed them to be neither bored nor challenged to the point where they felt anxiety when building with the device, and through either prior experience or the confidence that exploring in a hands-on manner during the session helped them develop, they could therefore lose themselves in the process and experience curiosity, arousal, and the other intrinsic benefits of flow (Csikszentmihalyi, 1991). As these participants explored alongside their teammates, the device became more familiar and appealing; similar to the findings of Hsu and Lu (2003) in their study of user acceptance of online games, subjective norms, and attitude, participants' ability to experience flow played a significant role in their ability to ultimately express an intention towards accepting the device. Meanwhile, for participants who did not fall into either of these two categories, although they did not experience flow or arousal the way others did, the low-stakes nature of the activity did inspire them to play, albeit with caution; in cases where they did not feel confident enough to express or generate ideas of their own, the collaborative dynamic of the group allowed them to occupy roles as not only creators of designs, but also as evaluators of the designs of others (O'Hern and Rindfleisch, 2009). Thus, while the precise manner in which participants' perception of playfulness was altered by the codesign context differed, all participants did experience a positive effect; through their active engagement in the codesign activity, participants provided innovative ideas for the system design, feedback in the form of evaluation, and voiced opinions on the final prototype that helped ensure its suitability as an answer to the scenario and a product of potentially significant market appeal (Son, Sadachar, Manchiraju, Fiore, and Niehm, 2012). It is significant that following codesign, all participants were able to perceive the device as more playful, albeit to differing degrees, as some studies have shown that in the context of website technology use, playfulness impacts user behavioral intention more significantly than usefulness (Davis et al., 1992; Heijden, 2004; Sledgianowski and Kulviwat, 2009) The ultimate result of this collaborative, fun exchange was that all participants learned more about the device's potential uses while enjoying themselves and began perceiving it more favorably.

Before the codesign session, participants' attitude was conditioned by their individual experiences and for some, was constrained by the clash between their identity and technology aptitude. After the session, participants indicated increased curiosity in outcomes of exploration with the device outside of the codesign session; their initial reluctance and hesitation towards the device gave way to a willingness to explore the ways the device could be relevant to their own lives and it became clear that some participants were embodying the concept of designing for the self (Ozenc, Brommer, Jeong, Shih, Au, & Zimmerman, 2007). In this sense, as participants were navigating their learning of the device alongside others, they were also developing a further understanding of themselves and the process of building their future identity as technology users, creators, and cyclists, thereby revealing the interplay of roles from Social Identity Theory (Kleine et. al, 1993). Certain subtle relationships that connected the participants, the prototypes, and the creative activities they undertook (Dourish, 2004) may have affected participants' ideal identity, in particular: first, participants were situated alongside others who may have known more than they did; second, participants were confronted by feelings of inadequacy in their current social identity/role when confronted with a task they did not know how to perform on their own, and third, participants became more attached to the device and more excited through building with it. These three effects of the codesign session may have prompted participants to wish for an evolution in their social self towards their idealized self, the latter of whom would be capable of maximizing the use of the wearable device. The codesign context's approach of "research through design" (Ozenc et. al, 2007, p. 396) may have augmented this effect, as this approach focuses on "how interaction designers can integrate technical opportunities with behavioral theory in a context grounded by ethnographic findings, thereby making novel artifacts that transform the world from its current state to its preferred state" (p. 396). As participants explored the device, their perception of the product began to shift in terms of the TAM variables, but their self-perception also evolved, owing to their more active positioning as creators of a system that they would find relevant in their own lives; in so doing, they not only became co-creators of a wearable system but also participated in generating their future idealized selves and experiences as cyclists and technology users/creators. Following the codesign session, while the extent to which this perspective applied to participants varied in degree, and some were only open to using the device if it was “set up for them,” all participants saw the device more favorably and as more relevant to their lives.

In accordance with the change in participants’ attitude toward the device and “designing for the self,” participant behavioral intention was also favorably affected by the codesign session. Many participants indicated their intention to explore the device further; most notably, concepts of ownership and extended self emerged. As participants became more engaged in the design of the technology, their sense of ownership over the outcome and even the technology itself also seemed to increase (David et. al, 2013). Participants seemed to develop greater investment in the resolution of issues they encountered in building out their system and rather than relegating the implementation of the solution to the bounds of the codesign session, began discussing options for pursuing their ideas outside of the data collection session. The participants’ act of making meaningful contributions to the outcomes they had identified from the design’s inception, identifying its objectives, and then pursuing appropriate solutions demonstrated their ownership of the problem while also being involved in resolving it (Ramirez, 2008) Meanwhile, it is noteworthy that although most participants exhibited ownership of the end result in some way, others did not; one possible explanation may have been that they did not discover as much significance in the activity or did not feel that their contribution was meaningful to the extent that they would choose to invest more deeply in it as owners of the outcome (David et. al, 2013; Ramirez, 2008).

Relatedly, the aspect of extended self (Belk, 1988) emerged as a significant factor in participants’ behavioral intention towards the device. As participants developed their ownership of the device, they may have also arrived at the point of viewing it as their proprietary contribution and attached to it as an extension of themselves. The customizability offered by the

Lilypad itself may have facilitated this evolution because its successful use is contingent on a user programming it to meet a specific need or expressive purpose he or she has identified, which could be construed as an extension of him or herself, or more specifically, “investing self in objects” (Belk, 1988, p. 144). Indeed, participants responded with great excitement and curiosity at the idea of building their own unique solution to meet their specific needs set, not only to address the scenario at hand, but for other projects as well. In alignment with Belk, 1988), as participants invested their identity into the design of the system, their attachment to it became particularly strong. Interestingly, in the focus group discussion, this phenomenon seemed to be at work to an extent that was almost illogical; participants expressed that even in circumstances where the item they have made or altered is less effective or of poorer quality than an item offered for purchase, they would still choose to use the former. This insight has particularly salient implications for members of the wearable technology industry, who are still seeking sustainable ways to increase user acceptance of wearables; if participants are allowed to customize elements comprising the design of a product, the likelihood that they will accept it over the long term is increased, owing to their perception of it as an embodiment of elements of their own identity.

Given the extent to which various user characteristics and dynamics in the codesign context itself seemed to affect user perception of the TAM variables, the visual representation of TAM and the codesign context used in this study is provided below in Figure 4.5 to illustrate their interplay and provide fodder for future researchers to build on the insights of this study.

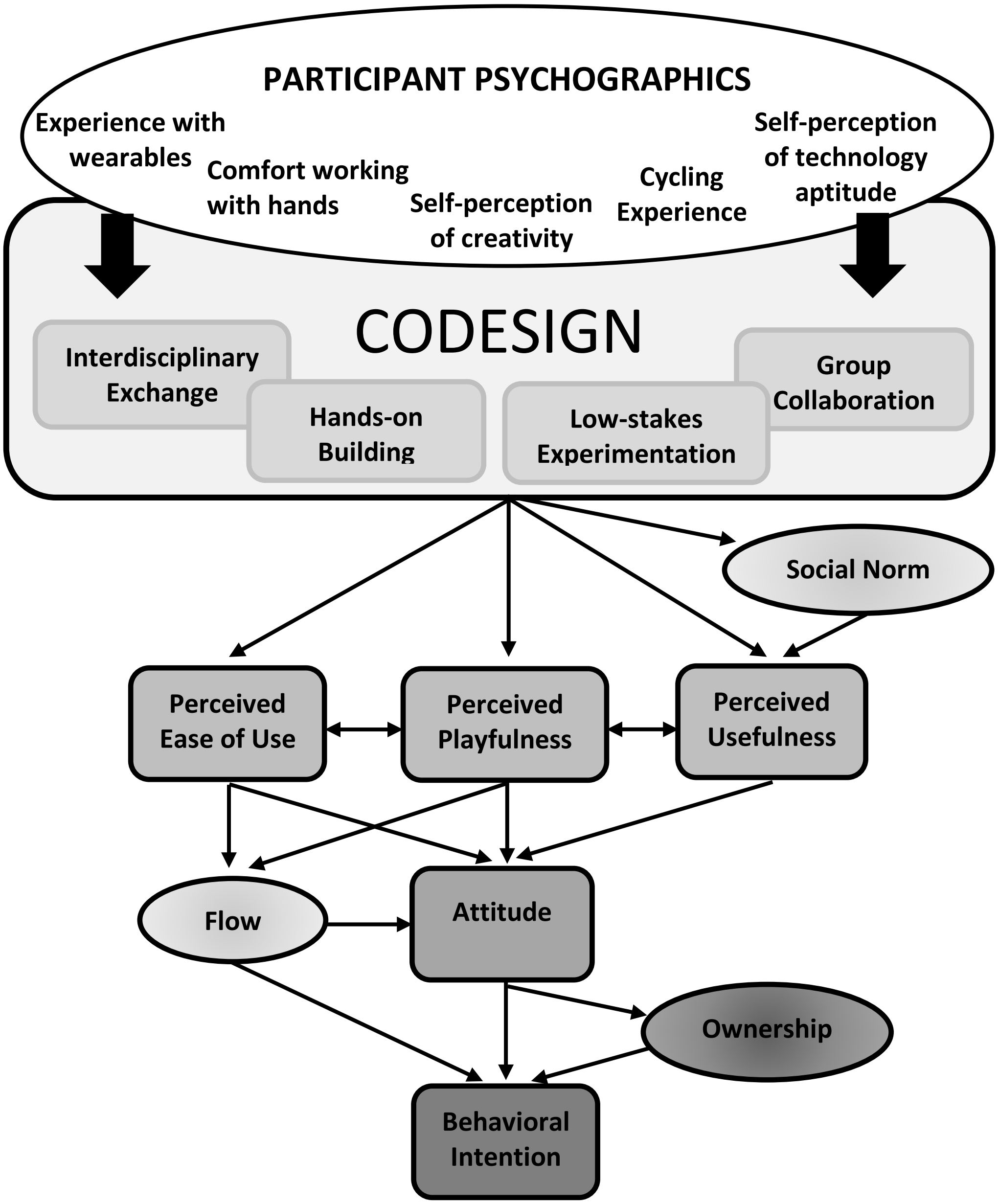


***Figure 4.5:*** *Revised TAM model*

## Conclusion

As little research has been done that explores the effect of codesign on acceptance of wearable technology using the Lilypad Arduino, this study is exploratory in nature and presents several limitations. First, the sample size was small, with only 17 codesign participants. Although the sample size is considered reasonable for the experimental setting of codesign, it can be viewed as a study limitation. Additionally, the usage of the TAM in a qualitative study is less common, and therefore has not been validated for use in this way as thoroughly as in quantitative studies. As such, the researcher devised supplementary means of data collection (i.e., surveys) to triangulate the data, with the intent of rendering issues of validity less detrimental. Another significant limitation was the short length of time in which this study was carried out; the study could not explore the TAM to the point of long-term user acceptance of wearable technology. Instead, TAM was used as a conceptual model to the point of behavioral intention towards accepting the technology.

Despite the optimistic projections of the increased use of wearable technology (Kim and Chiu, 2018), it is still confronted by challenges in terms of long-term user acceptance (Cobb, 2014). Nonetheless, the data gathered in this exploratory study provide insights into how the codesign approach may encourage user acceptance of wearable technology by inviting potential product users into a hands-on creation process. Further, the outcomes of this study helped to advance the existing understanding on aspects affecting user acceptance of wearable technology, thereby yielding important implications for the industry. Specific skillsets on the part of the consumer may condition his or her proclivity towards a codesign activity, and goods and services with greater customizability (i.e. the computer) may lend themselves more easily to the codesign process (Etgar, 2008). Devices like the Lilypad Arduino bring the opportunity to design with a wearable device into the consumer sphere; codesign opportunities may become increasingly available to consumers as new tools for production are developed and users are positioned as the experts driving the process (Bjorgvinsson et al., 2010).

This study has demonstrated that the element of creativity and the experiential collaborative learning introduced by codesign did, in fact, increase participants' perceptions of the device’s ease of use, usefulness, and playfulness; further, participants’ attitude and behavioral intention were both more favorable towards the device following the codesign activity. However, several areas related to the results of this study should be explored further. Future studies could utilize a larger sample size for quantitative analysis and ensure the participation of individuals from various regions. A longitudinal study could also be conducted to examine the longer-term effects of codesign on technology acceptance, as well as a study in which full wearable prototypes are developed during a codesign session that assigns participants based on background, which would ensure that all participants can provide a unique but pertinent contribution to the design of the target product. As the use of codesign in product development processes continues to increase, industry leaders may benefit from practices that involve consumers early on in the design process, allow them to participate in activities through which they may bond with the product, and provide a hands-on means by which they can communicate their needs and ideas through ideation and building as “experts of their experience” (Sanders and Stappers, 2008).

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# APPENDIX A: INVITATION TO PARTICIPATE

Sent via email:

“Hello, my name is Kristi Rogers. I am a student at Colorado State University. I am conducting a research study about codesign of wearable electronics, specifically with regard to the design of wearables worn while cycling at night. I am emailing to ask if you would be interested in participating in a three-part study as a codesign participant. This means that you would have the opportunity to work together with other study participants as a codesigner, contributing your ideas and knowledge to the conceptualization of safety cycling apparel which incorporates wearable electronics. Your full participation would entail the filling out of a brief pre-survey, a codesign session where you were asked to generate ideas and a mock prototype on the best means of incorporating electronics into a cycling jersey for nighttime riding, a post-survey and a focus group session. Your participation would take approximately three hours total, during which time food and beverages will be provided.

If you would be interested in participating in this project, please reply to this email and indicate your availability by filling out the below schedule so the most optimal time can be selected for the session.
(chart with all days of the week and morning, afternoon, evening options or each day here***)

I hope you will choose to participate; we will have fun and learn something in the process! For any questions or concerns in the meantime, please email me at agirlcalledk@gmail.com or call at 480.392.8381.”

# APPENDIX B: CODESIGN SESSION OUTLINE

Session Outline:

- Introduction to project and concept of codesign: 10 minutes
- Pair designation and introduction: 5 minutes
- Materials introduction and prototyping tips/suggestions (including Lilypad): 20 minutes
- Ideation: 45 minutes
- Prototyping with representative materials: 1 hour
- Pair presentation: 20 minutes
- Pair design adjustment (if desired): 15 minutes

***Transition into post-evaluation

Supplies list for Prototyping Kit used during codesign session:

Each group received the following items:

- 2 strips of 10 sensor stickers
- 2 pages of notebook reinforcers ("lights")
- 3 markers
- 1 package of 12 crayons
- 2 pencils
- 2 black pens
- 1 diagram of the human body standing at various angles
- 1 diagram of a person riding a bike
- 3 3d printed lilypads with magnets
- 1 cycling jersey
- 1 lilypad product spec sheet
- 1 description of requirements for activity
- 1 large piece of newsprint for largescale sketching

The whole group shared the below items for additional visualization, as-needed:

- 1 pair long cycling pants
- 1 pair cycling shorts
- 1 road bike
- 1 pair cycling bibs
- 1 helmet
- 1 pair cycling shoes

# APPENDIX C: VERBIAGE OF SCENARIO

“In this codesign context you will work together with your group to create a cycling jersey that could be used to improve cyclist visibility at nighttime. We will not be assembling the actual jersey with working components. Instead, your task is to draw on your own collective experience and knowledge, using the materials provided to you to create a concept of the way you think the electronic components would best be incorporated into the jersey. Use your own creativity and the materials to communicate a representative model of the effect you think would best promote cyclist visibility and safety at night. Provide as much detail as you like and please feel free to ask any questions that come up as you go. ”

APPENDIX D: PRE-SURVEY AND POST-SURVEY

**Pre-survey**

| Section 1: Background and work information |
|---|

1. Gender: M _____ F_____
2. Age: ___________
3. Level of Education: (Please check one)

   □ High School
   □ Some college
   □ Associate’s degree
   □ Bachelor’s degree
   □ Graduate degree
   □ Ph.d

4. Ethnicity: (Please check one)

   □ Hispanic
   □ Caucasian
   □ African American
   □ Native Indian
   □ Asian
   □ Pacific Islander
   □ Other ______________________________

5. What is your occupation?

   ____________________________________________________

Please answer the following questions about your background on a scale of 1 to 5, where 5 is strongly agree and 1 is strongly disagree.

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| 1) **I consider myself to be a creative person**. | 1 | 2 | 3 | 4 | 5 |
| 2) **I like to make things.** | 1 | 2 | 3 | 4 | 5 |
| 3) **I like to work with others to make things**. | 1 | 2 | 3 | 4 | 5 |
| 4) **I make or modify my own technological devices**. | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| 5) **I sometimes use an electronic device differently than how it is intended to be used.** | 1 | 2 | 3 | 4 | 5 |
| 6) **I have purchased a wearable device. (e.g. a fitness tracker)** | 1 | 2 | 3 | 4 | 5 |
| 7) **I use a wearable electronic device on a regular basis**. | 1 | 2 | 3 | 4 | 5 |
| 8) **I repair or build bikes on a regular basis.** | 1 | 2 | 3 | 4 | 5 |
| 9) **I have a thorough understanding of bicycle mechanics.** | 1 | 2 | 3 | 4 | 5 |
| 10) **I am passionate about cyclist safety at night.** | 1 | 2 | 3 | 4 | 5 |

**II. Wearable Technology**

When answering the below questions, please base your answers off of your perception of the device that you have in front of you. 5 is strongly agree and 1 is strongly disagree.

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| 1) **When viewing the wearable device, I am confident in my ability to use it correctly.** | 1 | 2 | 3 | 4 | 5 |
| 2) **I think the wearable device will be easy for me to use.** | 1 | 2 | 3 | 4 | 5 |
| 3) **When looking at the wearable device, I readily understand how to use it.** | 1 | 2 | 3 | 4 | 5 |
| 4) **It is difficult for me to use this device without expert help.** | 1 | 2 | 3 | 4 | 5 |
| 5) **It will be easy for me to become skilled at working with this device if appropriate instruction is given.** | 1 | 2 | 3 | 4 | 5 |
| 6) **I think this type of wearable device is useful.** | 1 | 2 | 3 | 4 | 5 |
| 7) **I feel that this type of wearable device can enhance my quality of life.** | 1 | 2 | 3 | 4 | 5 |
| 8) **I can think of tasks that would be made easier by the use of this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 9) **If I adopted this wearable device, it would improve my efficiency at accomplishing some tasks.** | 1 | 2 | 3 | 4 | 5 |
| 10) **I can think of a variety of uses for this device.** | 1 | 2 | 3 | 4 | 5 |
| 11) **I think *working* with this wearable device will be fun.** | 1 | 2 | 3 | 4 | 5 |
| 12) **I am curious about how this wearable device works.** | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| 13) **I would enjoy working with this wearable device on my own time.** | 1 | 2 | 3 | 4 | 5 |
| 14) **This device stimulates my imagination.** | 1 | 2 | 3 | 4 | 5 |
| 15) **I could envision myself losing track of time when working with this device.** | 1 | 2 | 3 | 4 | 5 |
| 16) **The idea of using this type of wearable device is intimidating.** | 1 | 2 | 3 | 4 | 5 |
| 17) **Using this type of wearable device is a good idea.** | 1 | 2 | 3 | 4 | 5 |
| 18) **I like this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 19) **I believe I would like *using* this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 20) **Using this wearable device would be a positive experience.** | 1 | 2 | 3 | 4 | 5 |
| 21) **In the future, if I could purchase this device, I would *work with it* on a regular basis.** | 1 | 2 | 3 | 4 | 5 |
| 22) **In the future, if I could purchase this device, I would *wear it* on a regular basis.** | 1 | 2 | 3 | 4 | 5 |
| 23) **I would recommend this wearable device to others.** | 1 | 2 | 3 | 4 | 5 |
| 24) **I want to purchase this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 25) **If I owned this device, I know I would use it soon after purchasing it.** | 1 | 2 | 3 | 4 | 5 |

**Post-survey**

**II. Wearable Technology**

When answering the below questions, please base your answers off of your perception of the device that you have in front of you. Questions are arranged on a scale of 1 to 5, where 5 is strongly agree and 1 is strongly disagree.

| | Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|---|
| 26) **When viewing the wearable device, I am confident in my ability to use it correctly.** | 1 | 2 | 3 | 4 | 5 |
| 27) **I think the wearable device will be easy for me to use.** | 1 | 2 | 3 | 4 | 5 |
| 28) **When looking at the wearable device, I readily understand how to use it.** | 1 | 2 | 3 | 4 | 5 |
| 29) **It is difficult for me to use this device without expert help.** | 1 | 2 | 3 | 4 | 5 |
| 30) **It will be easy for me to become skilled at working with this device if appropriate instruction is given.** | 1 | 2 | 3 | 4 | 5 |
| 31) **I think this type of wearable device is useful.** | 1 | 2 | 3 | 4 | 5 |
| 32) **I feel that this type of wearable device can enhance my quality of life.** | 1 | 2 | 3 | 4 | 5 |
| 33) **I can think of tasks that would be made easier by the use of this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 34) **If I adopted this wearable device, it would improve my efficiency at accomplishing some tasks.** | 1 | 2 | 3 | 4 | 5 |
| 35) **I can think of a variety of uses for this device.** | 1 | 2 | 3 | 4 | 5 |
| 36) **I think *working* with this wearable device will be fun.** | 1 | 2 | 3 | 4 | 5 |
| 37) **I am curious about how this wearable device works.** | 1 | 2 | 3 | 4 | 5 |
| 38) **I would enjoy working with this wearable device on my own time.** | 1 | 2 | 3 | 4 | 5 |
| 39) **This device stimulates my imagination.** | 1 | 2 | 3 | 4 | 5 |
| 40) **I could envision myself losing track of time when working with this device.** | 1 | 2 | 3 | 4 | 5 |
| 41) **The idea of using this type of wearable device is intimidating.** | 1 | 2 | 3 | 4 | 5 |
| 42) **Using this type of wearable device is a good idea.** | 1 | 2 | 3 | 4 | 5 |
| 43) **I like this wearable device.** | 1 | 2 | 3 | 4 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| 44) **I believe I would like *using* this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 45) **Using this wearable device would be a positive experience.** | 1 | 2 | 3 | 4 | 5 |
| 46) **In the future, if I could purchase this device, I would *work with it* on a regular basis.** | 1 | 2 | 3 | 4 | 5 |
| 47) **In the future, if I could purchase this device, I would *wear it* on a regular basis.** | 1 | 2 | 3 | 4 | 5 |
| 48) **I would recommend this wearable device to others.** | 1 | 2 | 3 | 4 | 5 |
| 49) **I want to purchase this wearable device.** | 1 | 2 | 3 | 4 | 5 |
| 50) **If I owned this device, I know I would use it soon after purchasing it.** | 1 | 2 | 3 | 4 | 5 |

APPENDIX F: FOCUS GROUP QUESTIONS

1. How did you like the codesign session? How do you feel about the idea of codesign now?

2. General impressions: What was your impression of the Lilypad before this session? How did working with the prototyping kit affect what you thought about the Lilypad?
   -in terms of readily understanding how the device works?
   -in terms of your confidence that you are able to use it correctly?

3. General impressions: What about the usefulness of the device? How did you perceive the usefulness of the device before the session? Did the codesign session change the way you saw the device in terms of how useful it could be? Thoughts on before versus after.
   -what uses or ideas did you start to think about?
   -What specific tasks could it make easier? do you think it's possible that it could make certain tasks, like signaling at night, easier?

4. Emotional aspect of codesign session: Was the codesign session fun? What about working with the Lilypad? What emotions did you experience while working with the Lilypad? Before versus after. How do those emotions connect with how you feel about the device now? Did codesign change how fun you thought it was?
   -in terms of having fun while working with it (curious, engaged etc.)
   -like device? (before versus after)
   -consider wearing this device? (before versus after)
   -consider purchasing this device? (before versus after)

5. Actual use: Now think in terms of actually using the device. Did codesign change how you felt about actually using it?
   -in terms of your intention towards using it for a long time?
   -in terms of your intention to wear this device?
   -in terms of how likely you would be to incorporate this wearable technology into those that you already use.

Any additional comments?