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I, Jensin E Wallace , hereby submit this original work as part of the requirements for the degree of Master of Design in Design.

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Exploring the Design Potential of Wearable Technology and Functional Fashion

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Exploring the Design Potential of Wearable Technology and Functional Fashion Design

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Abstract

Wearable technology is a growing field at the intersection of fashion and technology. Apparel and technology designers are unsure of how best to merge the strengths of their independent fields to create products that can be easily integrated into an individual's lifestyle. The aim of this research is to create a conceptual framework that combines functional apparel design values with interaction design values in a model that could theoretically be used inter-disciplinary for the future development of wearable technology products. Project-based research was conducted to create a wearable technology prototype that explored the potential of a multifunctional and technologically enabled knitted garment. The framework was developed using the findings from this process with an emphasis on user centered design techniques.

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Introduction

Technology and apparel designers have struggled to create wearable technology (wearables) products that people can easily embrace and adapt into their lives. Technologists and engineers have been at the forefront of wearable's development. In result, many wearables are absent of the attention to aesthetic details that make a product more desirable to a customer. Details such as form, line and texture are basic principles in a fashion repertoire.

Fashion designers and industry professionals have the ability to fill the gap in the design process and help create products that are accessible and adaptable by providing insight into a customer's identity and culture. The fashion industry depends upon comprehensive knowledge, gathered by trend researchers and analysts, of their target consumers. This data portrays a view of a consumer group that is influenced by social, political and creative movements and enables a fashion designer to connect with a customer's identity and lifestyle.

The rapid growth of technology has lead to the rapid growth and understanding of human computer interaction. Consumer electronics have metamorphosed from simple tools and objects that we interact with everyday to extensions of our functionality and lives. They effect how people interact and build relationships because people rely on technology to keep them informed and connected to the world and their communities. Over time, technology has become more intuitive in its design. Haptic feedback and have high levels of visual and operational clarity foster a connection between the user and the device, which eventually turn into a dependent relationship. Moreover, we assume that technology can more efficiently provide us with multiple services or enhance a experience, which causes us to raise our expectations and continually want a newer or more up-to-date model.

In contrast, for centuries the various symbolic aspects of dress have enabled fashion to communicate a variety of messages about the wearer that are culturally motivated and assessed by the perceiver. This communicative quality of fashion is linked to the expressive and aesthetic needs of the consumer. Most often consumers look for garments that convey a particular message about themselves (Lamb, 1992) as well as their personal vision of beauty. Apparel designers have use the elements such as line, form, color, texture and pattern to create aesthetically appealing traditional and modern design (Lamb, 1992). Technology exists in a realm packed with functional expectations and fashion exists in an inverted realm constantly responding to shifts in cultural standards of beauty and normality. These standards only begin to function as fashion given a determined environment and recognition from those within it.

When technology and fashion are combined into a single product such as wearable technology, a new set of expectations is created as well as a new system for the product's existence. The criteria are no longer purely utilitarian or concerned with expressions of beauty. The new criteria should strive to link the richness of fashion's aesthetic design culture with the functional capabilities of technology (Dunne, 2005) by creating a harmonious correspondence between fashion and technology.

Methodology

Wearable technology can be defined as the seamless integration of technological and electronic devices into the fabric of our daily lives. Footwear and accessories are presently the most popular of these hybrid products to emerge on the market, but apparel has also shown potential for more growth. Adidas, Nike and Google are some of the first companies to successfully introduce wearables into the market. Their achievements are marked by the integration of technological elements into the user's natural behavior. Products such as Google Glass, the Nike Fuel band and Adidas's miCoach exhibit an understanding and awareness of three different design methods that could be vital to the future development of wearables: participatory design, inclusive design and user centered design. These three methods share sensitivity to the importance of a product's design to any potential user's needs or lifestyles. However, this does not mean that a designer should aim to design something that everyone will want or can use. Instead, these methods push designers to not design according their perceived needs of a customer. This paper will focus on the implementation of user centered design methods in the design of wearable technology products. Core principles such as co-creation or participatory design techniques, which insist on the involvement of the customer in the creation process, can/will be used to facilitate a connection between the customer and designers. Because the success of a wearable device is not completely reliant on how well it performs a task or function steps need to be taken within the design process to ensure a device can be adapted into a customer's lifestyle in the simplest and most straightforward manner.

Wearable technology devices also need to exist within a system that allows them to make the most of their multifunctional capabilities. Nike, Adidas and Google all took an approach to their products that employed the use of the device as a tool to connect the customer to the *internet of things* or other data and notification systems. The internet of things was first formally introduced by Kevein Austin in 1991. It can be described as linking the elements of our daily lives in a virtual interconnected structure. In the future it will be essential for wearables to have interrelate abilities in order to stay connected and up to date with the customer. Sam Gaddis cited the need for user motivation as the main disconnect between the physical device and the ability of the device to improve a user's daily life. Today, a growing number wearable technology designers and developers are realizing that building the technology is only the first challenge (Gaddis, 2013). The greater challenge is verifying real-world functionality and relevance in the customer's life.

For the purposes of this project a conceptual framework was developed that could theoretically be used interdisciplinary between apparel and technology designers for the future development of wearable technology products. The framework is the result of a project-based research project in which an electronic knitted textile was designed to explore the aesthetic and functional phenomena of light. The e-textile was used to make an aesthetically appealing garment that offers greater visibility for cyclists at night.

The project-based research shares some core values with the project-based learning educational model. It is a useful technique for researching wearable technology design and development because it requires the researcher to create a need to know essential information, use problem solving and various forms of communication and incorporate feedback and revision. Wearable technology is an emerging field and industry thus there is still a lot to be learned about how wearables can be designed, developed, marketed and innovated upon on a higher level.

1 Interdisciplinary Boundaries

1.1 *Technology in Everyday Life*

The most difficult challenges for designers of electronic objects now lie not in technical and semiotic functionality, where optimal levels of performance are already attainable, but in the realms of the metaphysics, poetry and aesthetics where little research has been carried out.
-Hertizian Tales, Anthony Dunne

When creating technology that is to be used in people's everyday life is to create an "integrated circuit" or interface that is the catalyst of interactivity as a partnership between people and machines (Dunne, 2005). Consumer electronics are often conceived based off of human factors and pre existing material or media relationships. This means that the aesthetic and expressive potential of an electrical device is often stunted because the familiar physical world, which is merely superimposed on new electronic situations (Dunne, 2005). This superimposition delays the possibility of new culture through the desperate desire to make things that are familiar (Dunne, 2005). In order to discover and create new and unique experiences using wearable technology fashion designers should strive to find a technological aesthetic voice and technology designers should strive to connect with the culture of a potential customer. The horseless carriage did not do the work of the horse, it abolished the horse and did what the horse could never do (McLuhan, 1970).

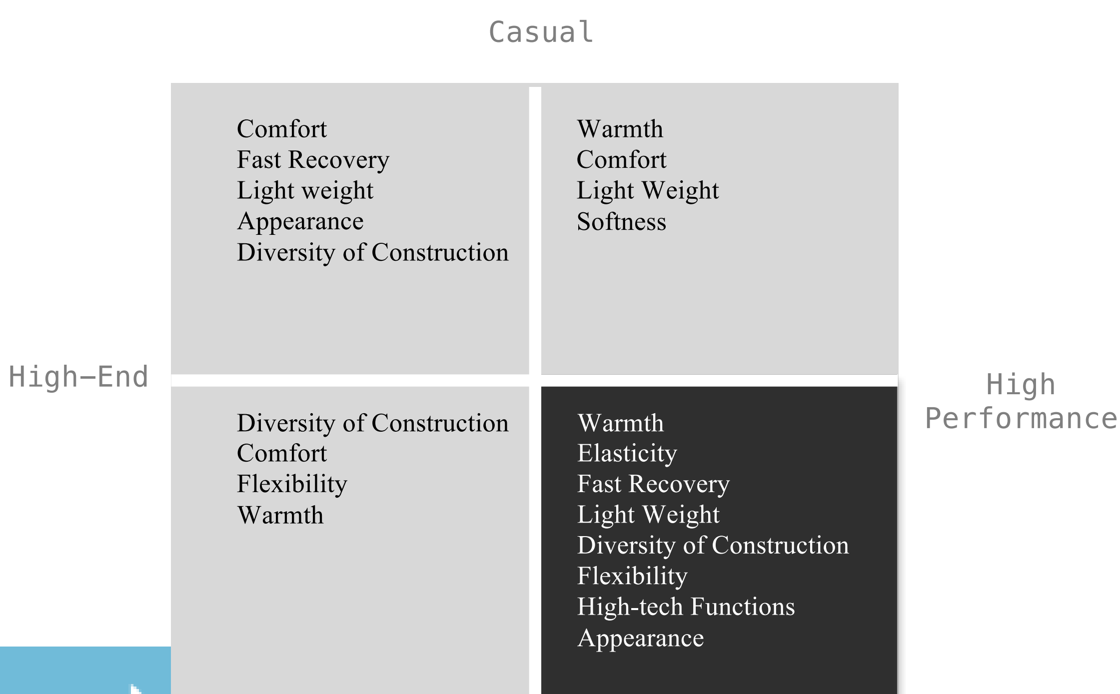
The design of wearable electronic apparel differs from typical electronics because it does not rely on a screen or object to act as an interface between the user and the machine or device. The idea of creating a "package" for electronic technology has been most prevalent in the commercial design of electronic goods. However, electronic textiles do not rely on physical icons or graphics to communicate with the user thus it does a wearable electronic garment require the same type of visual interface. The electronic elements are integrated as seamlessly as possible into the textile. Because electronic materials do not have screens and graphics to interact with a designer is challenged to a method in which a person can communicate with a material or garment. This new class of human computer interaction transforms a material into an interface between a wearer and technology. The lack of familiar media means that a person's interaction with a technological garment is based off of their pre-existing relationship with clothing. The incorporation of electronic elements in apparel should be strongly inline with the manner in which people use and interact with their garments today.

1.2 *Knitwear: Traditional Craft to High-tech Future*

The craft of knitting has been around for nearly 2000 years. Its origins can be traced back to the Middle East where knitted fragments have been found in Egyptian burial sites as early as the 5th-6th centuries (Scarce, 2004). It is a very diverse, practical and creative craft that has continued to be innovated upon. New computer technology and fibers have propelled knitting into a new era that is interested in knitted materials dual functionality as an object of beauty that has stemmed from a traditional craft as well as a highly utilitarian material that can be engineered to serve a specific purpose. Initially, knitwear designers drove the technological development of knitted materials by continually trying to innovate and introduce new concepts such as the seamless garment or cobweb sweaters that became an icon of the punk-rock era, into the mainstream market. Today, technology is able to afford a vast range of opportunities to knitwear designers, but designers need to work more closely with technical developers to fully understand the potential of the machinery and technology that is currently available to them.

In 1993 Raz defined knitting as "an intermeshed system in which a continuous single yarn is inter-looped to form a garment." The structure's inherent qualities such as comfort, elasticity and fast recovery, lightweight and diversity of construction have allowed for a variety of different applications over knitted garment’s history. There are four design and developmental periods of knitting’s transformation from a traditional craft to an innovative and experimental medium: hand knitting, industrial, commercial and multi-functional. Knitwear is best known for its ability to enhance appearance, keep warm, protect the body with flexibility and softness, [and] high-tech function. These qualities have made it a leader in casual, leisure, sports, high-end and high performance apparel (Li, 2010). There are many factors that contributed to the innovative development of knitted materials. The industrialization of the knitting process as well as material engineering have lent knitwear the ability to respond and expand upon societal trends phenomena. Knitwear’s flexibility has deemed it the textile material of choice for the future development of technological textiles and electronic materials. Figure 1 compares knitwear’s best known abilities with its inherent characteristics in order to show which category of knitted apparel benefits most from the development of knitwear as a traditional craft to a multidiscipline utilitarian material.

Figure 1.1



The space between the knitted apparel categories of High-Performance and Sport indicates that there is potential for the growth of multi-functional knitwear, which is the most current phase of knitting's developmental history. Multi-functional knitted garments are the most able to take advantage of some of knitting's strongest abilities. The potential of high-tech functionality is a defining feature of knitted materials today. Scientist, designers and technologists have found new ways to enhance knitted materials and garments using chemical engineering, complex construction techniques that involve advanced machinery and by reimagining the form of technology in people's life.

1.2.1 *Knitwear Industrial Period*

According to Scarce (2004), the Industrialization of knitting began with the invention of the stocking frame by William Lee, a Clergyman in Nottinghamshire in 1589. The stocking frame machine is significant because it relieved the pressures of production from hand knitters. However, the release of these pressures was initially viewed as a threat to the success of the hand knitting industry, which made it hard for Mr. Lee to obtain a patent in the early stages of the stocking frames development. Knitting was considered a traditional craft in England. Hand knit stockings were coarse and took a considerable amount of time to make. The stocking frame made it possible to produce stockings more efficiently with better quality and eventually stockings with more decorative qualities. The frame also catalyzed a shift in the workflow from products that were mainly produced by a single individual to a team of domestic workers (typically a family) that was in charge of renting a knitting frame, supplying or spinning the yarn as well as finishing the stocking once the piece of shaped knitting was complete. By the late 1700s framework knitting had spread to many counties in London, but most of the framework knitters lived in almost poverty and were trapped in a cottage industry, which allowed a middle man to take a cut of the worker's salary and for the wealthy men that owned and rented the machines to charge higher rental fees without market demand (Ellis, 2013).

As knit production became more mechanized with inventions such the circular knitting by Henry Griswold in the late nineteenth century, the knitting industry began to respond to the changing needs of consumers. Fancy lace and stockings fell out of favor when the stocking became a functional item worn under one's clothing and thus not seen, instead of as a decorative accessory that was associated with visual aesthetic of noblemen's dress. This social shift caused industrial knitwear production to focus on creating underwear or undergarments, while hand-knitting was used mainly to create protective garments such as gloves, hats socks and sweaters for fisherman.

1.2.2 *Knitwear Commercial Period*

In the early 20th century knitwear had transitioned from underwear to outerwear with styles that were more streamlined, relaxed and comfortable. Designers such as Coco Chanel created garments for women that were casual and practical. In addition, the entire knitwear industry experienced a shift from constraining clothes to clothing that could be worn for sporting activities and more leisurely in everyday life. Through out the 20th century knitwear cultivated its identity as an expressive apparel piece breaking away from its foundations in basics and classics such as the Twinset that were run-of-the-mill pieces in one's wardrobe.

By the end of the 20th century and into the 21rst century apparel designers began to use more unconventional materials and experimental processes to their designs with the desire to according to Black (2002) "[break] down the barriers between craft, art and fashion." Knitted fabrics were rubberized, coated, laminated, felted and heat-formed amongst a number of other processes and treatments. The result of this experimentation was one-of-a-kind textiles that were used primarily in the couture arena. Eventually these techniques appear in mass production, which has resulted in an increase in the range of textile processes available to the general public (Black, 2002). During this time designers were strongly focused on challenging assumptions and the aesthetics of established taste in order to make way for new ideas about knitwear construction, production and design (Black, 2002). A new modern and avant-garde language was being created, which birthed ideas such as raw and unfinished edges, distorted body silhouettes, shrunken or over-sized proportions and original fabric treatments that have become mainstream elements of fashion today. The Japanese designer, Yohji Yamamoto, is well known for his unconventional approach to fashion design. In 1997 Yamamoto and Dai Fujiwara launched APOC (A Piece of Cloth), which was an experimental design collection that examined new technology and traditional processes (Black, 2002). An entire outfit for a man or woman could be cut out of a single piece of knitted material. This approach meant that there was no waste and a minimum amount of seaming and finishing processes. The APOC project was also enormously innovative in the way in gave the wearer the power to customize mass produced apparel.

1.2.3 *Wearable Technology for Cyclists*

In 2013 Gaddis predicted, “by the year 2017 an estimated 170 million [wearable technology] devices will be in the global market”. Current marketable wearable technology devices range from health and wellness monitoring systems such as Adidas miCoach or the Nike Fuel band to hands-free devices such as Google Glass. These devices share the desire to improve an aspect of people’s everyday life by integrating technology as seamlessly as possible into people’s daily routines, habits and their surrounding environment.

In the United States cycling as a form of transportation is increasingly becoming a popular choice for environmentally and socially conscious people. The effects of oil production on the environment as well as the effects of the oil industry on the developing nations that are producing oil are evidence that this deplete-able natural resource is not part of a sustainable future. In order to encourage more people to take steps towards a more sustainable lifestyle, such as biking to the local market instead of driving to the larger warehouse style grocer, we need the sustainable option to be something that does not disrupt peoples day to day living. Despite the overwhelming facts on the increasingly negative effects of the oil industry on the people, communities and countries that produce it as well as on the environment the majority of people commute by car. When cyclists and non-cyclists alike were asked to comment on bicycling, as a mode of transportation the issue that repeatedly reappeared was safety. There are a lot of factors that contribute to why people don’t feel safe as a cyclist on the road. Most importantly however, was the issue of visibility.

Fifteen cyclists that live either in small or large cities in the US or Europe were interviewed about their commuter experiences. All most all of the cyclists shared stories that revealed the vulnerable, hyper aware and tactical nature of cycling. Many of the cyclists experienced being outnumbered by cars, not provided with adequate bike lanes or being simply ignored by law enforcement. At the very top of all of the cyclists list of concerns was their ability to be seen by drivers on the road. Visibility for cyclists can be the difference between life or death on the road, especially if a driver is not ware of your presence. Most drivers are not accustom to looking for cyclists in the road and do not always know how to interact with a cyclist if they do see one. To a cyclist a car feels like a weapon on the road, thus they will do whatever it takes to make their presence known. If an accident were to occur the consequences are very likely to be fatal for the cyclists.

However, if visibility is the overarching issue of cyclist's safety why don't more cyclists wear the high visibility and reflective gear that is already available today or utilize lights that can be attached to the front and back of their bikes? Most cyclists are not satisfied with the gear that is currently available because cycling is not just a mode of transportation it is a something that affects your lifestyle and becomes a way of living. Bike lights are easily and often stolen off of bikes and sometimes require repeated battery changes and only light up the bike and not the rider. High visibility gear such as neon safety vests or reflective strips work only when light is shown on them and stigmatize the wearer when they are off of their bike in a typical social setting such as a workplace environment. Cyclists are looking for products that seamlessly combine visibility and lifestyle concerns such as practicality and style.

2 Integrating Apparel and Technological Design Values

2.1 *How Apparel and Technology Design Values Differ*

In his research Watkins (2005) states clothing and electronics are marketed in contrasting ways, clothing being driven by design and aesthetics and electronics by functionality and performance. The result of engineered lead wearable technology development has lead to high-tech devices and garments that are more awkward than usable. Instead of feeling empowered a customer may feel uncomfortable and/or self-conscious about adapting the new product.

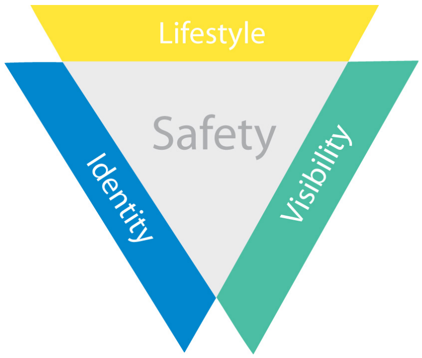
The FEA model, created by Jane M. Lamb and M. Jo Kallal in 1992, illustrated that "people do not want functional garments that are unappealing or that convey a stigmatized image" (p. 41) The three tenants of the model, expressive, aesthetic and functional are meant to be equally considered throughout the design process. Even though, fashion design is often strongly associated with the expressive needs of a customer the FEA model was intended to be applied to all types of apparel design. It combines a cultural context with the expressive, aesthetic and functional needs of a garment. In this space multi-functional and multi-purpose garments can exist.

Figure 1.2

Figure 1 depicts the FEA conceptual model. While this model addresses the criteria needed to create apparel that incorporates both utilitarian and stylistic concerns it does not address how the wearer is to interact with a garment. Most garments provide protection and are an outlet for people's individual expressive identities. The interaction is very simple, all a person needs to do is put the garment on. However, when technology is added to a garment it becomes part of a larger experience as an assistant to technology in performing a function.

Current wearable tech devices consider the added value of the device in an open-ended context. They are designed around the general context of a potential user's life and are can typically be incorporated without any extra effort or major adjustments into their every day living. This emphasis on the functionality of the product is important, however, wearable technology devices should also be considered within a cultural context with the aesthetic and expressive concerns of a customer. The unfamiliarity amongst fashion designers and technology and vice versa has lead to the development of wearables that are mostly experiential and lack the marriage of purposeful function and aesthetic appeal that a consumer can embrace.

Figure 1.3



Lifestyle
Practical, convenient, versitile

Visible
Increased presence on road

Identity
Status, self-esteem, art-elements

For this reason a second framework using the interviews mentioned in chapter 1.2.3, was adapted from the FEA model to express how a cyclist's culture and aesthetic, functional and expressive values can be jointly considered with the functionality of an electronic material. Safety is in the center of the model because it is the most influential element of their daily routine. The first value, Lifestyle refers to the ability of a garment to become a practical, convenient and versatile addition to a cyclist's wardrobe. The second value, Visibility refers to the ability of the electronic textile to provide visibility that will bring more presence to the cyclist on the road. The third value, Identity represents the personal message that the cyclist wishes to communicate through their dress. This message can be communicated through the use of color, pattern, style as well as other art and design elements. It is a combination of the Aesthetic and Expressive values in the FEA model.

***2.2** Crossing Boundaries: Google Glass*

Li (2010) identified five categories of wearable technology leisure & fashion wear, personal protective and casual wear, sport and healthcare wear, communication future wear and wear for fun. Until recently, wearable technology has most often been designed and developed by engineers because, the majority of fashion designers are not equipped with working knowledge of electronics (Li, 2010). Since engineers have been at the forefront of wearables development, health and wellness, fitness tracking and communication devices have been thoroughly explored, yet the aesthetic and aesthetic potential of wearable technology has experienced little maturation through design.

Google successfully launched the wearable technology device Google Glass in February of 2013 and has already begun to realize the necessity of aesthetic appeal to the importance of mass adaption. Consumers have shown that they are intrigued and excited about the potential of the new technologically enhanced facial accessory. Glass's ability to operate almost completely in the background of our lives is an appealing new role for future of wearables. However, their appearance lacks the look of something that could easily be an addition to someone's personal identity. When Glass first launched it received negative feedback due to the stigmatizing affect it had on wearers.

Glass does not have much competition yet, but companies such as LaForge Optical have begun to try to fill the gap between hands-free wearable technology devices and aesthetic appeal. According to Paul Briden (2014), the company's founder Corey Mack stated that LaForge's goal is to offer a more conventional option for those that wear prescription glasses. Their design incorporates the technology into a pair of *normal* glasses so that a customer does not have to wear two pairs of eyewear at once.

In January of 2014 Google launched a more fashion forward version of Glass, which was designed for the early majority and late majority of technological adapters. This modular version featured eyeglass frames for those who wear prescription glasses that are available in four different styles. The redesign received acceptance from high end fashion brands such

Diana Von Furstenburg and Vogue (Greenfield, 2014) and lead industrial designer on the Glass team, Isabelle Olsson has been accredited with the transformation of the computer on your face (Keywell, 2013) to a thing o beauty. Although Glass has not been on market for long Google has been able to learn a great deal about the devices innovative potential and future from consumers. The company may or may not have foreseen the need for a connection to fashion, however the relevance of Glass to the everyday consumer is greatly diminished with out it.

3 Preliminary Studies

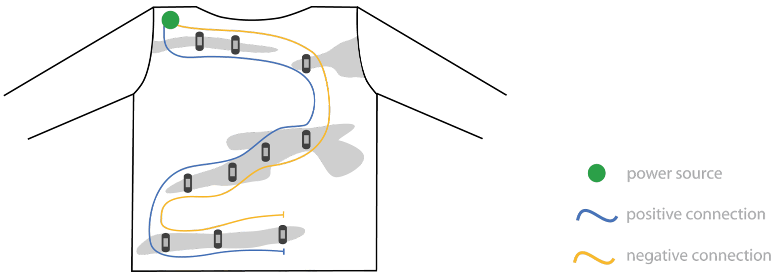
3.1 *Study 1*

Image 3.1

The purpose of Study 1 was to experiment with using conductive thread and LED lights in a knitted garment. The garment was hand knit from a machine knitted yarn and the electronic components where added after the garment was completed.

The expressive inspiration for the garment stemmed from the effect of light hitting a spider's web after a rain storm. A large gage stocking stitch was used to knit the front and back panels and a drop stitch pattern was used for the sleeves. Black monofilament yarn was chosen to create a sense of space and areas of transparency in the knitting. The rayon yarn was chosen because of its sleek drape like qualities. Figure 3 outlines the circuit paths in the garment.

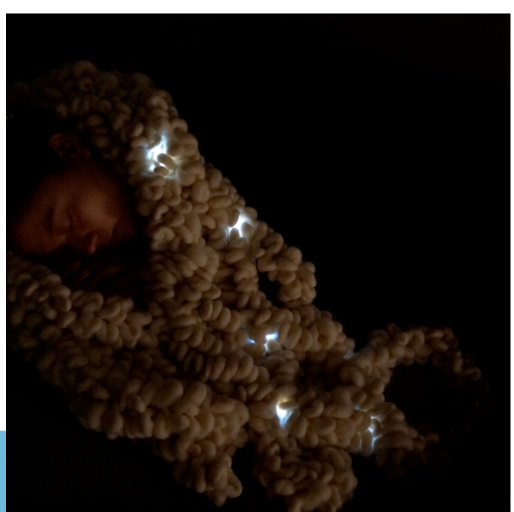
Figure 3.4



Once the garment was completed the circuit paths for the LEDs were mapped out on paper according to the shape and most dense areas of monofilament in the garment. Because the dense monofilament naturally arose due to the space-dyed like quality of the yarn the circuit paths were not direct and often cut across large areas of space. Once the paths were completed the LEDs were hand sewn into the garment on a flat surface using stainless steel conductive thread. The connections were and tested and proved to be stable. All of the LEDs lit up when the garment was connected the power source and laid on a flat surface. However, when the garment was lifted or dramatically moved the circuits shorted and the lights turned off completely. This happened as a result of the open knitted structure and slinky nature of the rayon yarn. The positive and negative paths crossed voluntarily throughout the whole garment as the yarn was stretched and pulled by its own weight or by a potential wearer.

***3.2** Study 2*

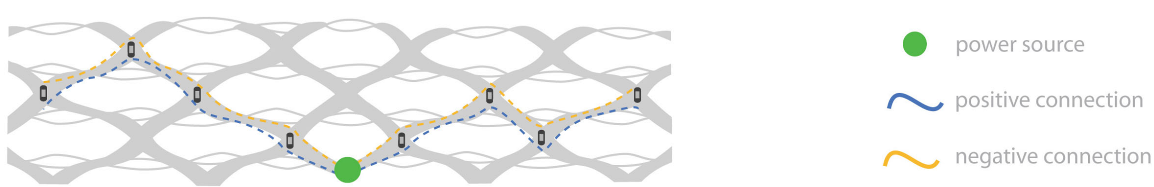
Image 3.2



Study 2, seen above in Image 2, drew both aesthetic and structural inspiration from the deep sea water creature Marrus Orthocanna. The Orthocanna is a gelatinous creature that has a colonial live style and uses bioluminescence to communicate. This means that the Orthocanna relies on the strength of a community to hunt and to provide protection. The creatures link together to form long chains thus maximizing their ability to hunt and fend off predators.

A chunky, un-dyed hand-spun wool yarn was used to create long lengths of the lofty structure. The yarn was rehung on a flatbed knitting machine using a loop technique that caused the lengths to spiral into themselves. The resulting stands were linked together by hand to mimic the Orthocana's chain like structure and colonial nature. Once the knitted piece was completed LEDs were sewed into the piece at the joints connecting each strand and along the edges of each individual length. A 3v lithium coin-cell battery was used as the power source and was positioned in the center of the knitted piece so that the entire piece could by powered through two strands of LEDS as suppose to a single continuous circuit. Figure A-2 below depicts the layout of the LEDs and circuit paths.

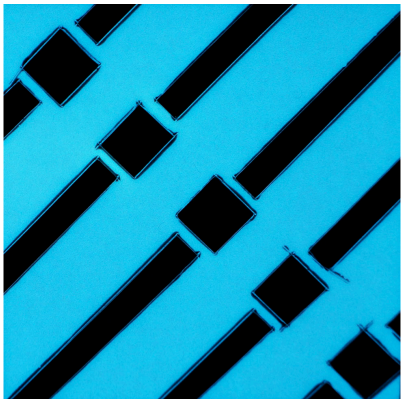
Figure 3.5



This study succeeded in creating stable electrical connections and integrating the LEDs in a manner that was non-disruptive to the aesthetic design of the piece. Even though LEDs strengthened the pieces resemblance to the Marrus Orthocanna their appearance lacked the dispersing quality that natural light sources have. The thick and lofty chunky wool yarn was not enough to soften the LEDs to the point of a natural glow.

3.3 *Study 3*

Image 3.3



In Study 3 electroluminescent panels (EL) were considered as an alternative electronic light source because of the perceived possibility of more 2D design potential. However, further research uncovered technical difficulties that limited their practical and creative use in apparel. EL panels are made using a standard screen-printing process. Conductive phosphorus, silver and dielectric inks are layered on a transparent ITO (Indium Tin Oxicide) film. In a standard screen-printing process a stencil or multiple stencils are created and used to print artwork, pattern or design. Thus, it should be possible to print EL panels in custom patterns and designs as well. Currently, novice EL panel users focus their creative attention on the ability of the EL to be cut into various shapes and sizes as shown in image? One can also create a stencil to layer over the panel to achieve graphic patterns or designs. But, because the overall size of the panel is limited by the efficiency of the power source the largest size currently available on market was only 10x10". The EL panels also require that the energy be converted from AC to DC power. This requires the use of an inverter, which can be a cumbersome and sometimes even noisy addition to a garment.

The company Oryon Technologies has made several improvements to the EL panels that have made it much easier to adapt into a garment. Oryon's panels are flexible and adhere to soft and hard material surfaces. The electrical connections are also flexible and the entire panel (when disconnected from the battery) is washable. However, these panels are currently only available in smaller sizes and cannot be cut into custom shapes or designs.

The EL panel in Image A-3 was easily made. The pattern was drawn on the backside of the 4x4" panel using a permanent marker and then segments of the panel were cut out using an x-acto knife. An experienced screen-printer could easily make an EL panel. The only disadvantage is that the materials are expensive and

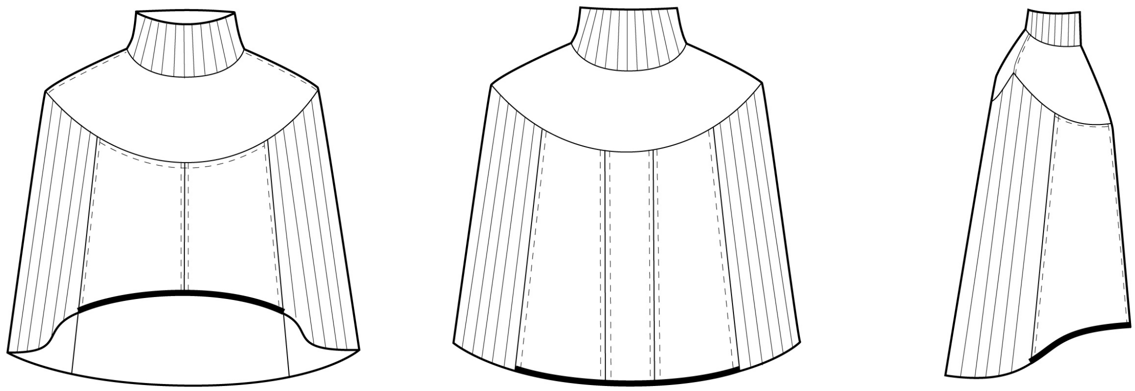
4 Designing for Fashion and Technology

4.1 *Process and Development*

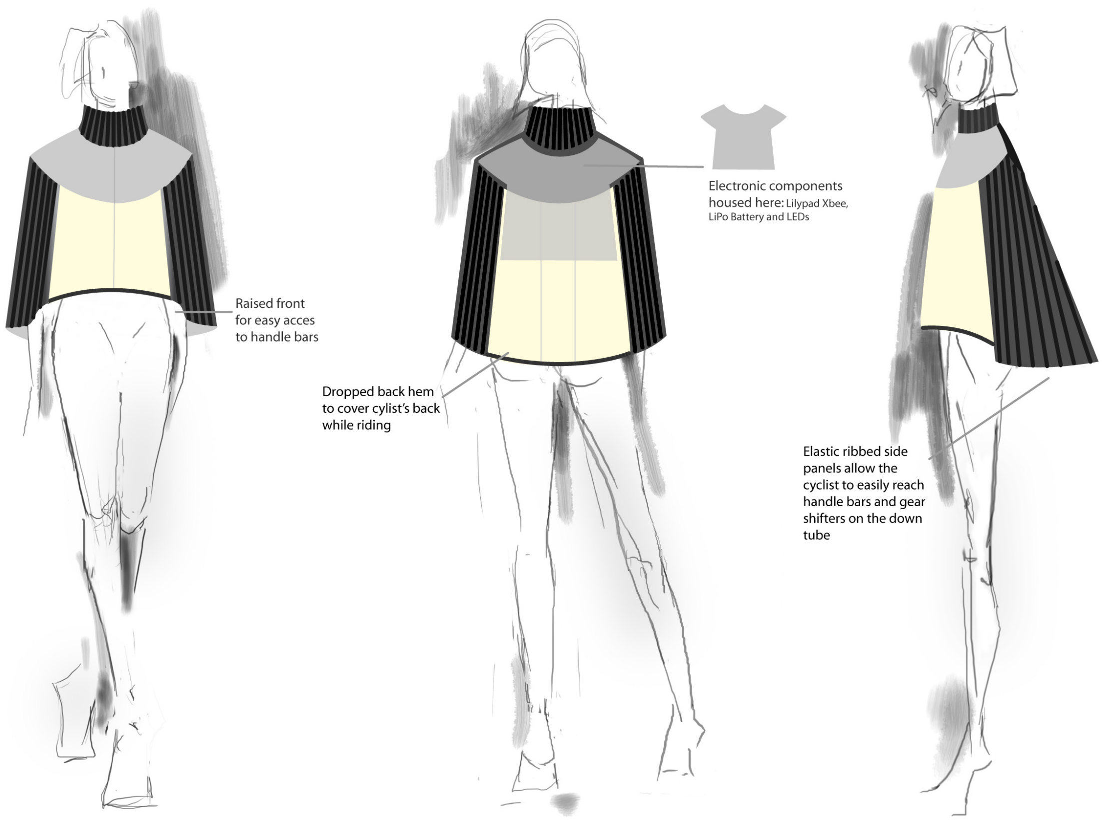
A number of types and styles of garments were considered before the final selection was made. Some factors that had to be considered were the season and weather conditions the garment would be worn in. Outerwear was chosen because people are more dependent protective apparel such as a winter coat, rain jacket or thermal sweater to shield them from the elements. are usually not duplicated in ones wardrobe. It is more likely that someone would wear the same coat everyday rather than the same shirt, dress or blouse. Cyclists are already dependent upon protective garments to shield their skin and bodies from the cold air and wind while riding, however, these garments usually only provide a minimal of added visibility and do not compliment the personal identity of the wearer.

The aim of this prototype was create a practical and aesthetically appealing garment that provided an extra level of safety through visibility. The cape is designed for use at dusk, which can be generally measured as the hours between 4pm and 8pm. The cyclist controls the lights using a wireless remote control. When he or she holds the button on the remote the LED lights flash rapidly on the upper back of the garment. There are also custom design elements such as shape and material details that aim to make the garment versatile enough to be worn while riding or in a casual setting. Figure 4.6 depicts the technical cape design. Temperature regulation is a common issue among cyclists. Even during cold weather cyclists still have to be aware of how their body is responding to the rigor of their ride. Often cyclists prepare by wearing clothing that can easily unzip or snap. For this reason, the garment was designed with an open and raised front to let air in while riding and to allow the cyclist easy access to the handlebars.

Figure 4.6

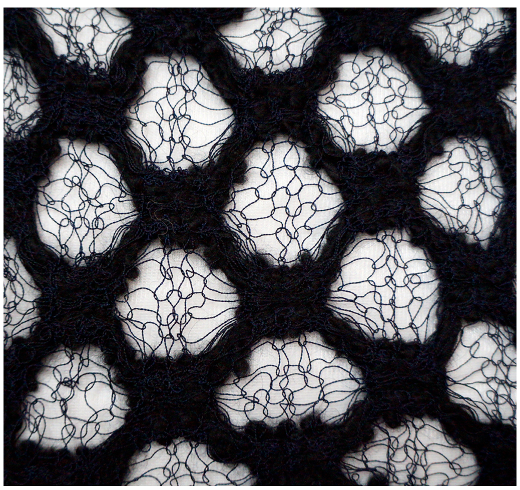


Front **Back** **Side**



Once the style and type of garment was decided upon the next step was to consider what materials would be used to create the garment. The e-textile was designed with large areas of transparency and loosely knit threads using wool and silk yarn. It did not retain warmth well and was better suited as a decorative focal point rather than the main material for the body of the garment. The LED lights were sewn into the e-textile after the material was made. Image 4 shows the design of e-textile. Merino wool and a merino and alpaca wool blend were used to knit the front, back and side panels of the garment.

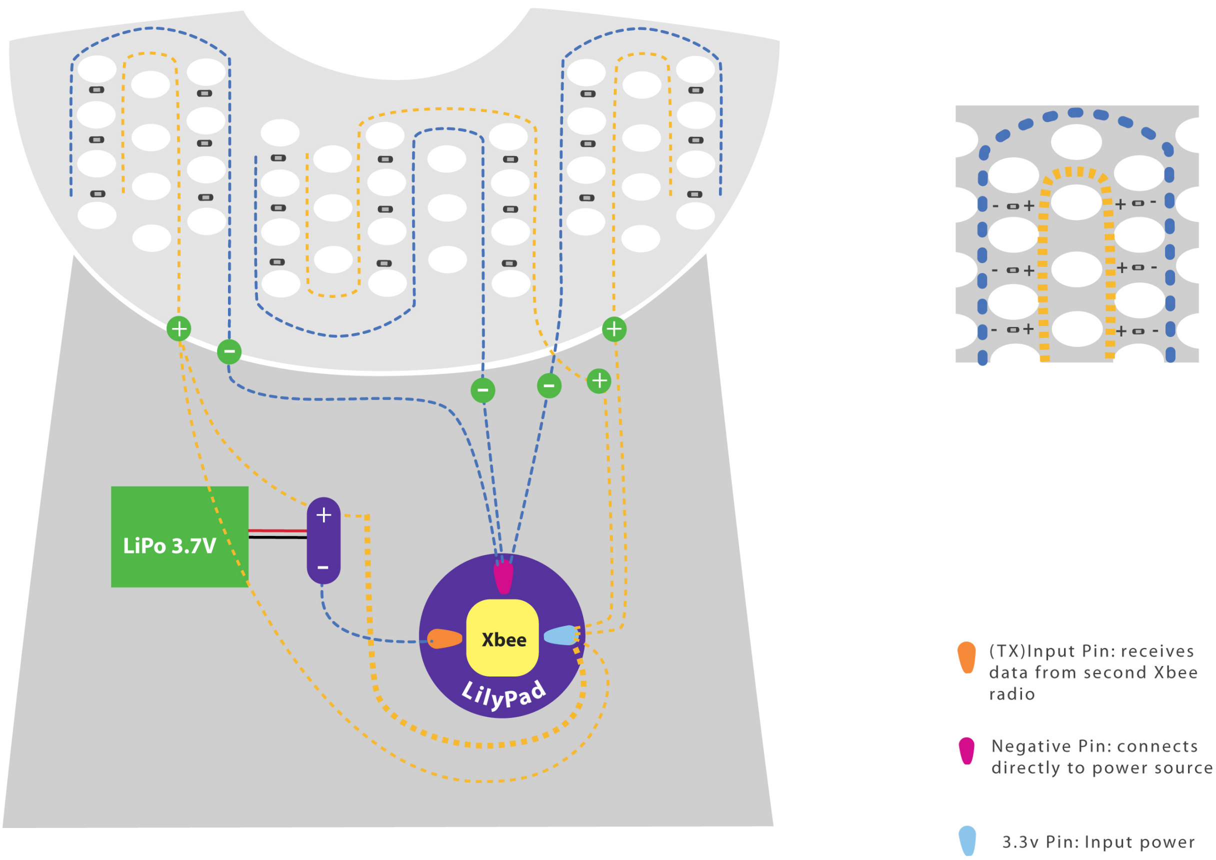
Image 4.4



Before the e-textile could be sewn into the garment a material swatch was created to test different light patterns. The physical placement of the LED lights and various flashing and fading Arduino programs were used to manipulate the pattern of light. Once a pattern that was both unique and perceived to be captivating enough to capture a driver's attention was achieved the wireless Xbee radios were programmed and tested with the e-textile.

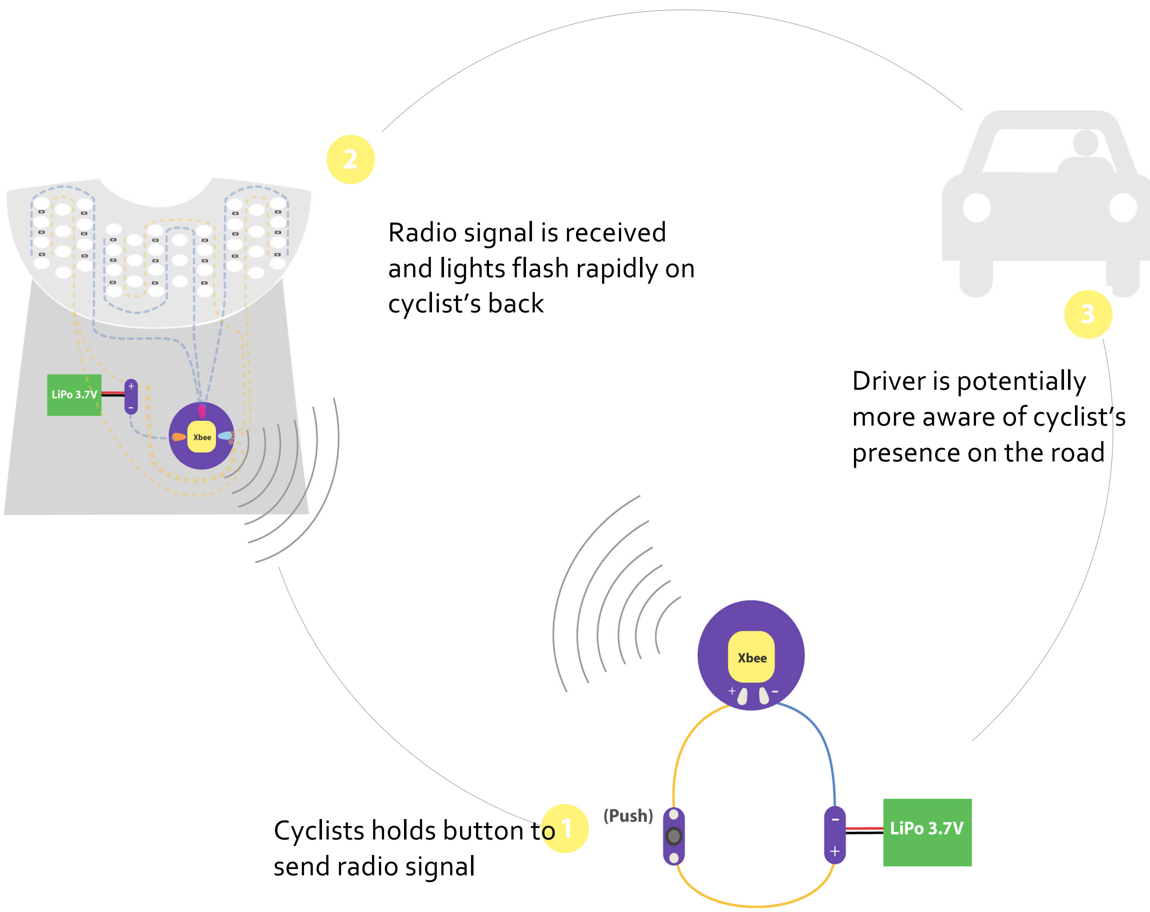
After the all of the pieces were knitted and assembled the rest of the electronic components were added to the garment. The series of LED lights was connected to a power source, on/off switch and a LilyPad Xbee circuit board. All of the components were hidden on the inside of the garment and because of their weight were not noticeable from the outside of the garment. Figure 4.7 shows the layout for all of the electronic components of the garment's design.

Figure 4.7



The last stage of design was to visualize the interaction between the cyclist, the technology components and the driver. This stage was helpful in assessing the most basic functions of the garment. An electronic device responds to the external stimuli (a cyclist holding a button) by flashing the lights on the cyclist's garment. In return a driver may become more alert and aware of the cyclist's presence. Or in other words, the cyclist uses a remote control device to control a series of lights on the back of her or his garment. Figure 4.8 is a visualization of these events.

Figure 4.8



***4.2** Prototype Testing and Findings*

The final prototype was evaluated by 5 female cyclists and was assed according to the safety and lifestyle concerns of commuter cyclists that was previously established in the research and was visualized in Figure 2. Once the participants were shown how the garment was meant to function they were able to try it on and use it while riding their bicycle. The participant's interaction with the garment on and off of their bicycle was observed and recorded. Next, the participants were asked questions about the style of the garment, the practicality of the garments use in their everyday lifestyle and the value of the visibility the LED lights provided.

Image 4.5

4.2.1 *Identity*

The front of back views of the final cape design can be seen in Image 1. The importance of identity was recognized as a key element of safe cycling values because cyclists often felt that currant safety gear available forced them to compromise their individual personalities. This idea relates to importance of the expressive and aesthetic values in the FEA framework. Most cyclists viewed neon vests with reflective stripes as an unattractive option for cycling safety. Many of the styles and colors of current cycling garments do not reflect the expressive identities that cyclists carry around with them everyday. The message that an individual cyclist expresses through his or her dress is completely overshadowed by boisterous neon and reflective apparel. In order to avoid the use of overpowering fabrics an optical pattern was chosen to create the front and back pieces of the cape. The shape of the garment were influenced by cyclist's desire for more variety amongst their cycling wardrobe and cyclist's inability to wear black while riding because it is less visible at night.

The success of the expressive characteristics of the cape design were judged by the appeal of the garment to the cyclists when they were in a casual setting such as work or a coffee shop as well as how unobtrusively the light pattern and electronic materials were incorporated. The cyclists did see evidence of any electronic devices from the outside of the garment. They were curious about where the garment would light up. The respondents used words such as "fashionable and pretty" to describe how they felt about the garment and one participant even felt she could wear the cape to a bar or to work. The cyclists appreciated the bold patterning and believed it would attract a driver's attention. They also enjoyed the visual interplay between the surface patterns on the front and back panel of the cape and the pattern of light.

Image 4.6

4.2.2 Practicality

The second value of safe cycling gear identified by cyclists was practicality. Image 2 displays the cape's flexible style. Cycling was a lifestyle choice for most of the cyclists interviewed. Typically, a cyclist's daily routine that involved preparation for the commute to and fro work or school. Cyclist's preparation often includes checking the weather conditions for the entire day, packing a change of clothes, shoes and possibly food and water as well as being prepared for unexpected circumstances. Cyclists were asked to wear the cape on a short and leisurely bike ride over an out fit they would typically wear while cycling. The cyclists liked the garments function as outerwear apparel. They felt they were likely to wear the garment more often, but would need more options in the future for different seasons and types of weather. The elastic side panels provided most of the cyclists with generous arm movement. The handlebars and gear shifters on the down tube of the bicycle were easily accessible. However, one cyclist commented that she felt if she were riding in a straight back position she may not have enough flexibility. The cape successfully covered all of the cyclists' backs while they were riding, which was a small detail that was not commonly found amongst current cycling gear.

Image 4.7

4.2.3 *Visibility*

The third and final value of safe cycling gear was visibility. Cyclists need to be visible to drivers at all times. Many drivers are unaware of cyclists on the road and do not receive any type of feedback that holds them accountable for poor driving habits. According to Vanderbilt (2008), most drivers rank their skills as above average and attribute their lack of accidents to good driving skills, when in fact they have only figured out how to get away with poor driving habits.

One of the goals in creating this electronically interactive material was to extend the role of the surface from just an embellishment of the tectonics to communicative devices (Dumitrescu, 2010). Traditionally, textiles use a variety of artistic surface design techniques to create materials that have strong pattern or textual characteristics. The e-textile's expressive design was received well by the participants. Because the material is also electronically reactive it was important that a new "grammar of ornamentation" was used to incorporate the LED lights. The light pattern was designed to accommodate not only the intended functionality of the garments but also to further the garment's expressive capabilities. The light pattern is captivating enough to grab a driver's attention but also novel enough as to not blend in with the surrounding scenery of a city environment.

The intent of the electronic interface was to give cyclists direct control of the light. At the touch of a button the cyclist becomes wirelessly in charge of his or her light display. The lights flash at an exceedingly fast pace when the button is held down and turn off when the button is not pressed, which provides visibility directly on the body of the cyclist. Once the cyclists were shown how to use the wireless remote to control the lights they were given three options of possible ways to interface with the lights using the wireless remote. They were also asked how they felt the lights would be most useful in their daily lives.

The cyclists were enthusiastic about the lights believed they would be a good addition to traditional bike lights that are on the front and back of the bike. Most of the cyclists felt the lights would be most useful in situations were the driver is approaching a cyclist from behind for example at a stoplight or changing lanes. In this situation cyclists are often over-taken or hit by the car from behind. They also felt the lights would be helpful in preventing a "right hook". Often drivers make a right turn into the bike lane cutting off the cyclist who is travelling straight ahead. The cyclists felt that a driver may be likely to see them because the lights on the cape were at eye-level and flash very quickly. The lights, however do not address the issue of side visibility. The cyclists expressed the need for lights on the side as the cape as well as for the lights to be brighter.

When the participants were asked how best they believed they would use the lights most of the answers suggested that the technological component of the garment have more multi-functional capabilities. Some of the cyclists wanted to be able to simply turn the lights on and off as well as have the lights incorporated into their brake system or their handlebars and have a turn signal system. It seemed that if the cape was able to do one of these things it should be able to do them all. The participants expressed the most interest in integrating the wireless remote into their bike handlebars or a glove. The seemed to be more necessary for simple interactions with the lights such as on, off or flashing and potentially turn signals, while if the remote was integrated into the handlebars then the cyclists would expect it to connect to both front and back brakes.

5 Wearable Technology Conceptual Framework

The future of wearable technology is moving towards the development of multifunctional and multi-purpose garments that exist in the spaces between the five categories of wearable technology, leisure & fashion wear, personal protective and casual wear, sport and healthcare wear, communication future wear and wear for fun (Li, 2010). The boundaries dividing these categories will become blurred as wearable technology devices are realized an interdisciplinary realm combing fashion and technology. If fashion and technology designers begin to work together there is the potential for more products to be made that are useful, appealing and can be easily integrated into a customer’s everyday life. Doing so requires both fashion and technology designers to include a potential customer in the design process as much as possible. The conceptual framework below, Figure 5.9, aims to guide fashion and technology designers through a collaborative design process for wearable technologies products.

Figure 5.9

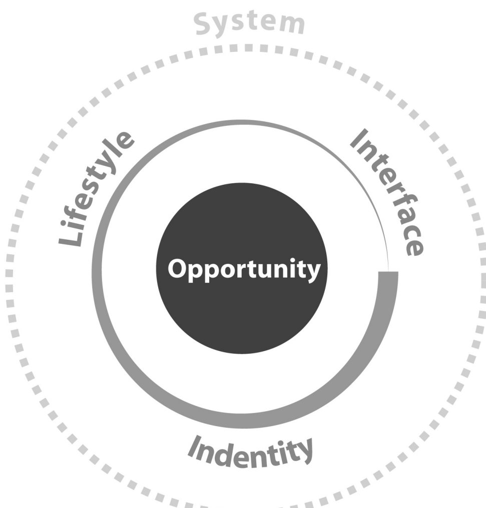
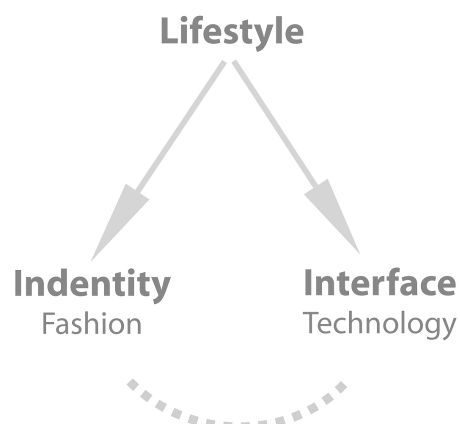


Figure 5.10



At the center of the model is Opportunity. It is representative of a space were a multiple of solutions may be found. By identifying a space with many potential solutions the designers will be able to work in a much larger context. Giving the product or idea more ability to become a multifunctional part of the customer's life. Potential solutions will arise through out the product's development that may or may not be relevant to the aspect of a design. Although, this prototype was tested with only cyclist it is important to realize that there are other applications for the technology that should be tested as well. The potential of a concept to fulfill a diverse range of functional needs such as social, communication and expressive should not be ignored. In phase two the Lifestyle and Identity of the user are observed. A fashion industry professional would be responsible for the uncompromised identity of the customer and the technology designer would be responsible for the creation of a natural interface between the wearer and the technological device. Designs and interfaces will be created based off of the user's habits and routines. However the goal is not merely to mimic an established behavior, but rather to understand and present a logical modification of behavior if necessary.

Figure 5.10 depicts the nature of the relationship between fashion and technology in the design process. The fashion and technology designer will work iteratively together to ensure that an accessible and adaptable product is designed. During this phase of development a constant conversation between the designers is mediating the relationship between the customer and the device. A means by which a designer can make a product may be made more commonly available to potential customer's would be to incorporate modularity into the concept of the design. Modular components that allow a user to separate the style and technological elements of a product will provide a wider range in which the product can be experienced. Both fashion and technology designers will continually check their work against each other's to unsure that technological elements do not become an overpowering element of the aesthetic design as well and to confirm that the technical design of the product does not hinder the functionality and performance of the electronic components. The goal for both designers is to create a product that can be seamlessly integrating into a customer's lifestyle.

During the last phase of the model the potential of an idea to connect with preexisting devices or systems relevant to the user's lifestyle is considered. This task may be the most difficult and take the longest to accomplish. It requires the designers to have a multi-perspectival view of the value of the idea in potentially more than one aspect of the user's life.

There may also be opportunity for the idea to connect with opportunities that have been identified in another system.

The Cycling Cape prototype was a useful tool in beginning to understand how to design a wearable technology product. It demonstrated how knitted electronic materials are capable of exhibiting expressive and functional values, which can de-stigmatize the role of technology in a wearable device as well as increase the utilitarian value of a product. This prototype specifically began to address the potential of a responsive electronic material, however other types of interactions are applicable too. The use of user centered design techniques in the development of the prototype provided insight into the personality and lifestyle of a customer and aloud for the final product to reflect the aesthetic and functional needs of a wearable technology product.

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