176 Style before technology: rethinking the design process for E-textiles garments

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Abstract

This paper recommends the inclusion of E-textiles in fashion not necessarily as the addition of electronic components onto the fabric, but as the integration of working mechanisms into the textile and garment design, in order to fulfil aesthetic and functional design requirements. This paper describes the preliminary research into haptic feedback textiles, to illustrate a methodology that can be undertaken to develop E-textiles garments with a closer integration of fashion and function.

E-textiles garments can often be considered as a less than seamless combination of fashion and electronics. Existing examples in fashion often appear to simply apply electronic components to a finished fashion garment, rather than an integrated design process. The inherent change of the two fields, soft fabrics versus rigid printed circuit boards, contributes to this situation.

This paper reviews research that has brought the two fields closer together: the development of E-textiles construction kits, textiles-based electronics components and embodied design using E-textiles. E-textiles construction kits, while readily available, are targeted towards teaching and learning, rather than as a tool for design. Textiles-based electronic components have primarily been researched from the technological perspective, with the latest developments seeming far removed from the field of fashion and textiles design. While the embodied design process can be used to create more meaningful human garment interaction, it does not address E-textiles within a fashion design process, a process that must balance different design requirements, outlined in Lamb and Kallal (1992) Functional, Expressive and Aesthetic model.

This paper has sought to address the complex nature of E-textile in a fashion design process by presenting a hypothetical E-textiles fashion methodology. It has been developed following a review of design processes undertaken within fashion and E-textiles design, as well as original preliminary practice-based research.

Introduction

Fashion and electronics are arguably two disciplines that exhibit very different creative approaches. Fashion is often driven by a prevailing aesthetic, differentiated via self-expression. Electronics, on the other hand, brings to mind prescribed functionality driven by logic and problem solving. In view of such unlikely collaborators, E-textiles garments, also referred to as smart clothing, can perhaps be seen as an uneasy marriage of the two. The design and manufacturing process of fashion and electronics each have their own set of established materials, techniques and design criteria. There are currently three main strategies identified as successful approaches for integrating electronics and garment design: Textiles-adapted, Textiles-integrated and Textiles-based (Bosowski et al.,2015).

Textiles-based E-textiles components have been developed from a technical, and a design perspective. Research from the technological field has created advanced E-textiles, from yarns embedded with microelectronics (Dias and Ratnayake,2015) to textiles-based electrodes (Erdem et al., 2016, Sumner et al., 2013), while exploration from the design perspective has ranged from the creation of textiles-based components, to its incorporation into a full garment. However, prominent examples of E-textiles garment seldomly use this method of integration.

In early smart clothing, garments were adapted to fit electronics (Textiles-adapted), the ICD+ jacket by Philips and Levi's is a key example. It is a garment designed to fit a mobile phone and a MP3 player and it connects these devices through a wired harness. Tommy Hilfiger and Junya Watanabe have both designed solar power garments using the Textiles-adapted principle, by featuring removable solar panels that allow the wearer to charge their mobile device. Conventional electronic components, while readily available, are not designed to be integrated into the fabric. With these garments, it is fashion design that literally has to make way for the electronics, through the use of strategically placed pockets and attachment areas.

Textiles-integrated E-textiles is a level of integration in between Textiles-adapted and Textiles-based, as this strategy features 'an interconnection between electronic elements and the textiles within' (Bosowski et al., 2015). E-textiles construction kits can be used to create Textiles-integrated E-textiles. Designed to aid the creation of E-textiles, these construction kits can provide both the knowledge and the components for E-textiles creation, although the construction kits themselves can be restrictive. This paper discusses the current limitations with E-textiles construction kits when employed in a fashion design process and proposes a hypothetical methodology, with the aim of addressing the design of E-textiles in a fashion design process.

E-textiles Construction kits

E-textiles construction kits are designed to facilitate a straightforward integration of electronics and textiles, offering an accessible platform for the blending of skills from both disciplines. The Lilypad Arduino (Buechley and Eisnberg, 2008) is well-known example, although other E-textiles components and kits have also been produced by Adafruit and Kitronic. E-textiles construction kits mount small electronic components onto rigid printed circuit boards (PCBs) which are designed with holes at the connection points (Fig. 1). E-textiles components can be stitched onto the fabric in a similar manner to a button or a sequin, while conductive thread can be used to create embroidered circuitry. E-textiles construction kits are beneficial in that they can give the designer an introduction to electronics. E-textiles construction kits are often directed towards use in Science, Technology, Engineering and Mathematics (STEM) education (Ngai et al., Buechley et al., 2008). As such, the kits can vary in complexity, with basic kits focusing on creating illuminated textiles using sewable light emitting diodes (LEDs), to more advanced kits allowing the user to programme the functionality using a microcontroller, such as different lighting patterns according to light levels or movement patterns.

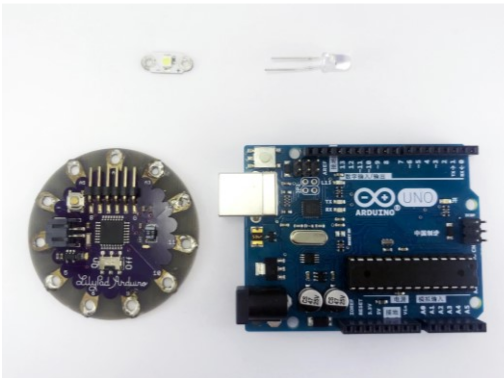

Fig 1. Top Left: Sewable LED (Electro-fashion by Kitronic), Top right: 5mm LED, Bottom Left: Lilypad Arduino microcontroller, Bottom Right: Arduino Uno microcontroller

Potentially due to the construction kit principally being used as a STEM teaching tool, it can be difficult to place the E-textiles construction kit within the fashion or textiles design process, namely the prototyping phase. Conventional electronics fit into electronics' own prototyping process. Electronic components are available with pins, which allows them to be used in the prototyping stages with a breadboard and jumper cables (Fig. 2). This allows for the quick but temporary connection of parts.

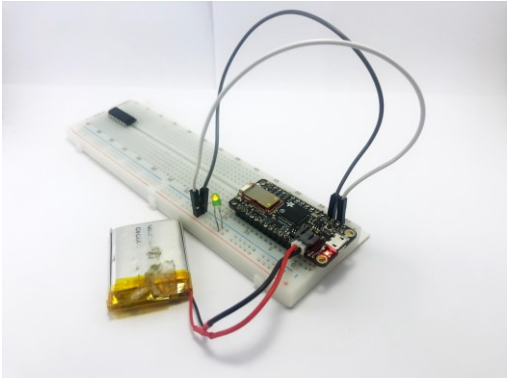

Fig 2. Example of breadboard with jumper cables and electronic components

On the other hand, E-textiles kits are designed to be stitched onto fabric, which is a more permanent attachment method. E-textiles components are standard electronic components that have been adapted for attachment to textiles. In order for an E-textiles construction kit to be used in the prototyping stage of a garment, there needs to be a stable, temporary method of attaching the components to the fabric, and for connecting the components to each other. The breadboard approach has been adopted in the Teeboard (Ngai et al., 2009). A t-shirt based breadboard is used in conjunction with snap button textiles based cabling for the quick creation of wearable electronics. While it allows for prototyping on the body, it does not allow for prototyping on the actual garment. Fabrickit, an E-textiles construction kit by Despina Papadopoulos (Quinn, 2013) offers more flexibility when prototyping onto the garment, through the sole use of snap button connections and textiles-based cabling. However, the Fabrickit is limited to creating illuminated E-textiles and is currently considered to be a retired product (Sparkfun, 2018). A more accessible method of creating temporary connection is through the use of crocodile clips, used in conventional electronics prototyping. The main disadvantage of this method is that the crocodile clips are prone to slipping off the PCBs (Chen, 2017).

E-textiles design as part of Fashion design

Although E-textiles construction kits contain electronic components that are useful building blocks for creating an E-textiles garment, they are restrictive in that components are utilitarian in appearance in comparison to the ever-changing variety of fasteners, beads, yarns and fibres a fashion designer expects to work with. The range of E-textiles components is a small element of the electronics industry and it can be observed that conductive yarns are also limited in terms of their appearance and texture. This is particularly a problem for a designer who may not have any experience in the wider field of electronics, as the kits may set a limit to their design exploration.

The limitation is not only a physical, material restriction, but also a mental restriction. When discussing the design of a construction kit, Resnick and Silverman (2005) stated that the design of the construction kit ‘determines, to a large extent, what ideas users can explore with the kit – and what ideas remain hidden from view’. Through a construction kit, the designer can learn about circuitry design, and programming in more advanced kits, but the working principles behind individual electronic components are not explored in the E-textiles construction kits. Concealing the inner workings of the components is beneficial in the introduction of E-textiles, so as to not overwhelm the designer with information. Yet a fundamental understanding of the working principles of an electronic component can open up further possibilities for more textile-based E-textiles. Working principles can be applied to the construction of E-textiles components that can better merge design aesthetic with functionality.

This notion has been explored in E-textiles development from the design perspective. In the Kit-of-no-parts (Perner-Wilson et al., 2011), the working principles behind electronic components such as switches and potentiometers, were recreated in textiles, handcrafted from conductive textiles materials. Kobakant (2012), Tomico and Wilde (2016) and Joseph et al. (2017) went further, applying the crafted E-textiles components to artistic performance pieces. The Crying dress (Kobakant, 2012) cries through a series of textiles-based speakers, embroidered in a decorative manner over the garment, while the Sound Embracer (Tomico and Wilde, 2016) utilises knitted stretch sensors to create a musical instrument that envelops the body. While these projects are encouraging explorations into E-textiles garment design, the textiles-based components used in them are relatively basic when compared to the wider research into the field of E-textiles components, and they have not developed much further beyond the work by Perner-Wilson et al. (2011). The textiles-based components that have been used in the previous research are primarily sensors, relying on resistive sensing, in which the sensor stimuli (e.g. stretch, pressure) causes a detectable change in the resistance of the material.

The projects by Tomico and Wilde (2016) and Joseph et al. (2017) have demonstrated the use of the embodied design process, for E-textiles garments, a process that puts the relationship between the body and the garment at the forefront of the design process. However, while the process may can be used to develop E-textiles garments with a more intimate, meaningful relationship between the wearer and the garment, this does not necessarily mean that the process can be used to create garments that put fashion styling ahead of the technical elements of the garment. In ‘Where Embodied Imagination Meets Digital Materiality’ (Joseph et al., 2017), context emerged from exploration. In this project, a cloak was designed to create ‘a sense of bodily awareness’, developed through observation and material exploration. Felted pressure sensors sensed the body’s posture and movements, and vibration motors activated accordingly. However, particularly with functional fashionable garments, the context is fixed. According to Tomico and Wilde (2016), the exploratory nature of this design process means that design exploration can become self-absorbed, and the context of its use may be neglected. Therefore, the methodology undertaken by Joseph et al (2017) and Tomico and Wilde (2016) may not be applicable to the field of fashion design.

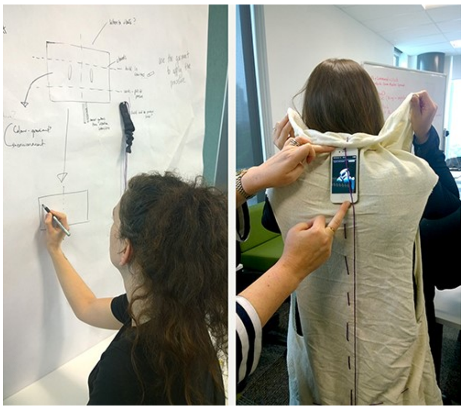

Fig.3 Embodied interaction experimentation, using mobile phone vibration (Joseph et al., 2017)

Balancing Fashion Design with Technical development

To address the gaps summarised in the existing research, the author proposes a hypothetical methodology for the design of E-textiles garment. The aim of the proposed methodology is to consider E-textiles design as part of a fashion design process. This methodology has been drafted following the author's preliminary practice-based research into E-textiles components, and a review of literature concerning fashion design. This methodology adapts the Functional, Expressive and Aesthetic (FEA) design framework by Lamb and Kallal (1992), which been employed in the design of functional non-E-textiles garments. This framework highlights the need to create criteria in order to effectively evaluate the design. In this methodology, the classification of aspects of the garment into functional, expressive and aesthetic elements allows the designer to better identify how the inclusion of technology is contributing to the design, with the intention of encouraging them to consider E-textiles components in terms of their underlying function. The proposed methodology aims to support material exploration within a predefined context to allow for the development of new textiles-based E-textiles components.

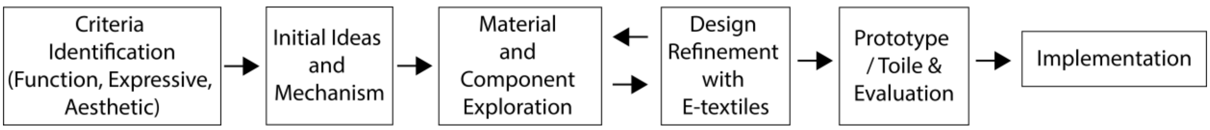

Figure 4. Proposed Design Methodology for E-textiles Fashion Garments

Criteria Identification

It is beneficial for the designer to outline the key objectives of the garment in order to form a criteria. Lamb and Kallal (1992) emphasise this in the Functional, Expressive and Aesthetic (FEA) model, as the criteria is used to evaluate future design iterations. By strategically splitting up the garment into these three elements, the role of electronics within the garment can be identified. For example, electronics may serve to enhance the aesthetic element of the garment, or it may be used for functional purposes. Its role may be expressive, and the electronics are used to convey a socio-cultural message. Once this has been identified, the designer can better pinpoint the types of mechanism are required to fulfil that role.

Initial Ideas and Mechanisms

During the Initial Ideas and Mechanisms phase, the designer may find numerous options within electronics that can be used to produce the desired effect. However, the direct attachment of conventional electronics can have a negative impact on the garment's comfort and appearance. In order to create more textiles, and thereby garment friendly alternatives, learning the working principles behind the electronic components can help the designer to broaden their options. Design and research projects in the field of wearable technology show that there can be a number of different options for producing single function (Table. 1). It should also be noted that there are some technologies that do not require the use of electronics i.e. thermochromic material and shape memory which react to heat. Depending on the use case for garment, it may be that these materials can be integrated in isolation. However, connection to electronics can create more complex functionality, as demonstrated by My Heart on My Dress by Jingwen Zhu (2016).. This garment is designed to visualise the wearer's experience, converting digital diary entries into patterns and shapes on the garments. Thermochromic ink is printed on the top layer of the dress, while a middle layer contains heating pads that will heat up to make particular motifs visible. Bluetooth is used to communicate the diary entries from the wearer's mobile phone to the garment.

Table 1. Examples of functions and their underlying mechanisms

Function	Mechanism	Examples
Touch sensing	Resistive sensing	Felt Pressure sensor, Stroke sensor (Perner-Wilson et al., 2011)
	Capacitive sensing	Project Jacquard (Poupyrev et al., 2016); The Musical Jacket (Orth, 1998)
Colour change	Illumination	Light Emitting Diodes (LEDs) (CuteCurcuit,

		2017), Electroluminescent wire (Elektrocouture, n.d.) Polymeric Optical Fibre (POF) (Tan, 2015)
	Thermochromic material	My Heart on My Dress (Zhu, 2016)
Motion sensing	Resistive sensing	Knitted stretch sensor (Perner-Wilson et al., 2011)
	Electromyogram (EMG)	Athos training clothes (2018)
Haptic feedback	Vibration motor	Maptic – Sensory devices for the visually impaired (Farrington-Arnas, 2017)
	Electrical Muscle Stimulation	Let Me Grab This (Pfeiffer et al., 2014), TENS garment for therapy (Li et al., 2010)
Heat generation	Conductive material	KnitWarm (KnitWarm, 2018), My Heart on My Dress (Zhu, 2016)
Movement	Motors/Electromagnetism	Live:Scape Bloom (McMillan, 2016)
	Shape Memory material	Skorpions garment collection (Berzowska and Mainstone, 2008)

Material and Component Exploration

After researching functions and their underlying mechanism, the options need to be narrowed down according to the FEA criteria and other garment construction considerations. Firstly, the designer needs to determine if the principle can be created in textiles. The next consideration is ease of integration into the fabric and the garment. Materials that are in a form commonly used in textile design are relatively easy to integrate, i.e. yarns, inks and fabrics. Thermochromic inks and conductive materials are examples. Conductive materials have been applied using a range of textiles and garment construction processes to create a range of textiles-based components. The Musical Jacket by Maggie Orth (1998) uses embroidery to create buttons with conductive thread, while Google's Project Jacquard (Poupyrev et al., 2016) utilises conductive thread in conjunction with a woven structure to create a gesture sensitive fabric. Perner-Wilson et al. (2011) produced a stretch sensor by knitting conductive thread into the looped structure. More challenging materials can be integrated, although these require more attention to manage the material properties. Polymeric Optical Fibres (POF) are an example. POF can be used to carry light, as light can travel down the length of the fibre, but POF are more rigid than conventional yarns. Textiles integration is more difficult as excessive bending can cause unwanted damage (Tan, 2015), hence, POF is better suited to woven fabrics rather than knitted fabric. Finally, the new textiles-based component needs to be critically examined to determine if it can be feasibly integrated into the garment as a whole.

Figure 5. Urban Glow - Garment using woven POF (Tan, 2015)

Preliminary Research: Haptic textiles

The first three phases have been employed in the authors' exploration into textiles-based haptic textiles, using the working principles behind existing vibration motors. First, the mechanism behind vibration motors was examined. Vibration motors create vibration through an unbalanced weight attached to the shaft. The motor movement itself relies on electromagnetism. The concept of using electromagnetism with fabric has been explored by researchers for other functions. Harnett (2018) developed a fabric linear motor, while V2 (2012) created a garment that used knitted fabric speakers. Kobakant (n.d) underwent a similar development process in the creation of Flipdot fabric. Flipdots are beads which can change orientation through electromagnetism, based on the principles behind flip-disc displays. In the previous works, the electromagnet works in conjunction with a permanent magnet. Secondly, after the Initial Ideas and Mechanisms phase, preliminary experiments were conducted on the creation of haptic feedback textiles, based on the previous works. During the experimentation, it was found that there were a number of issues that make this idea difficult to implement in textiles. The fine enamelled wire used in the electromagnet heats up when powered, potentially making it uncomfortable. This can be rectified by using a thicker wire, but the thicker wire creates additional bulk. It was found that the haptic feedback generated was weak when compared to conventional vibration motors. Due to these reasons, the decision was made to not continue with this option.

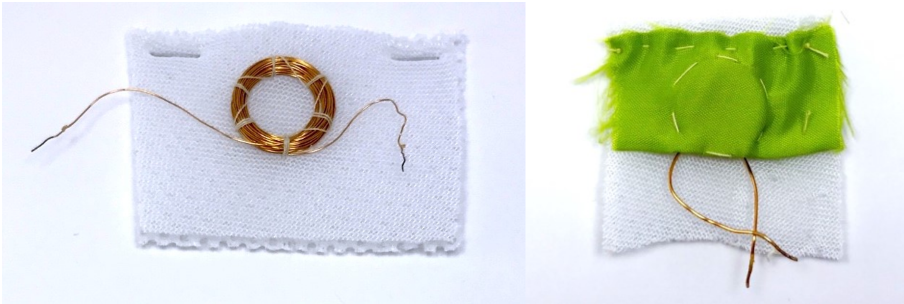

Figure 6. Electromagnet (Left: Without magnet. Right With magnet)

A second option explored as part of the haptic feedback textiles is the use of electrical muscle stimulation (EMS). This is based on the work of Pfeiffer and Rohs (2017), who discuss the use of EMS as haptic feedback. The preliminary research in this area was designed to investigate its feasibility in textiles, as Pfeiffer et al. (2014) used self-adhesive electrodes in their research. The mechanism behind EMS is that electrical impulses are transferred to the body through the electrodes, which, depending on the strength, can activate tactile receptors or cause muscle contraction. Textiles-based electrodes has been extensively researched, as they are can be used in electromyography and electrocardiography, as well as EMS. Textiles-based electrodes have been created using knit, embroidery, weaving and print (Mestrovic et al., 2007, Lenninger et al., 2013, Erdem et al., 2016, Rattfalt et al., 2007), therefore the concept of an electrotactile based haptic textiles seemed feasible. Electrodes can be produced using conductive fabric and yarns, however, during the initial experimentation, it was found that these simple electrodes require a filler, such as water, to reduce the electrical resistance between the electrode and the skin, in order to function. Prior research has successfully created dry electrodes that do not require a filler (Yang et al., 2014, Erdem et al., 2016) but during the preliminary experimentation, the materials available were not capable of producing a dry electrode.

Design Refinement with E-textiles

The design of an E-textiles garment can be considered in two parts, the design that necessitates the electronics' function, and the design for the garment. The first part is primarily relating to the placement of components in order for them to perform a function. Touch sensors need to be placed somewhere that is within reach, just as illuminative elements need to be placed where they can be seen. While necessity may impact on design, the design of the garment may also influence the technology the designer wishes to use. For instance, a knitted stretch sensor that detects the movement on the hand needs to be placed near the hand and wrist. In contrast, for EMG, the electrodes may be placed on the forearm, as the muscles that control the hand's movement are located there.

As well as placement, visibility is also a key consideration. The visibility of electronics exists on a scale. The electronics may be completely concealed, or placed on an inner layer of the garment. This is especially the case for electronics that facilitate the functional part. Often, the more complex the function, the larger the supporting electronics i.e. microcontroller and battery. Simple illuminated garments can be created using LEDs, and a power source but garments that have sensing functions often need a microcontroller to perform their programmed actions. In other cases, the electronics are partially concealed, as a certain amount of visibility may be required for its function. With illuminated garments, the form of the LEDs may be hidden by a layer of sheer fabric to obscure the appearance of the LEDs (Michel and Fraunhofer IZM, 2008, CuteCircuit, n.d). Visibility may be required to indicate functional areas, like with the weave of the Project Jacquard fabric. On the other hand, the electronics may be incorporated into the garment as a decorative element, forming part of the identity of the garment, as seen in the embroidery on The Crying dress.

Prototyping/Toile & Evaluation, and Implementation

The design of the garment is likely to be developed further during the garment prototyping phase. In this phase, methods used in the embodied design process, such as trialling the garment and the electronics on the body, can be used to troubleshoot the human-garment interaction. The designer may choose to use conventional electronics or E-textiles electronics in this phase, depending on the functions required from the garment. Prototyping electronics on a garment can be difficult, as discussed with regards to E-textiles construction kits, but the process provides key insights into the garment’s usability, comfort and feasibility. Recording this information can assist in refining the garment design. Evaluation against the criteria established at the beginning of the project is necessary to ensure that the garment performs how it is intended to. Once the set of criteria has been satisfied, the final design can be implemented.

Conclusion

The inclusion of electronics into garments is a field that has been approached from a number of perspectives. Researchers have tackled the practical elements of attaching electronics onto fabric through the development of E-textiles construction kits, although this has seldomly been within the context of the fashion design process. At the more conceptual end of the scale, E-textiles has also been explored as a means for human-garment interaction, with the design starting with the interaction, and ending with the garment. This paper has sought to address the complex nature of E-textiles in a fashion design process, with the aim of balancing the demands of functionality with expectation of beauty and expressiveness. To this end, the author proposes a hypothetical E-textiles fashion design as a means of addressing the needs of fashion and electronics within the design process. This hypothetical methodology has been developed following a review of design processes undertaken within fashion and E-textiles design, as well as preliminary research conducted by the author. The proposed methodology considers the inclusion of E-textiles not necessarily as the addition of electronic components onto the fabric, but as the integration of working mechanisms into the textile and garment design. In this way, the proposed methodology is designed to be flexible, and aims to encourage further exploration and experimentation in E-textiles, from a design perspective. The methodology encourages a bilateral relationship between function and fashion to ensure that design compromise is not too one-sided. As the methodology is largely based on the FEA model Lamb and Kallal (1992), it is hoped that it will be applicable in the design of functional apparel and fashion design, although further research is required to refine the methodology.

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