Digital Materiality, Embodied Practices and Fashionable Interactions in the Design of Soft Wearable Technologies

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The emergent field of smart textiles is recognized as an interdisciplinary domain drawing from fields including electrical engineering, materials science, textile design, physiology and interaction design as well as involving specialists from application areas such as sports and health science. While each discipline has contributed specific knowledge, an initial focus on technical development has led to an emphasis on function and scientific discourse, ignoring relevant fields like dress and fashion and post-cognitive perspectives that prioritize materiality and embodied experience. As the field continues to develop, different theoretical perspectives are needed to inform new conceptual and methodological approaches to support this expanding, combinatorial field. The notion of embodied interaction, which recognizes the fundamental importance of engaging and re-conceptualizing technology through the experience of the body and its senses, is critical to this effort.

Technology oriented approaches informed by theories of human-computer interaction (HCI) have underpinned the development of interactive textiles. This paper considers the limitations of HCI approaches, and those of normative semiotic theories of fashion in relation to the design of soft wearable technologies. Two recent smart garment design projects that have used embodied interaction approaches are discussed in relation to three theoretical perspectives: firstly from current dress/fashion theory, where notions drawn from new materialism and embodiment theory have led to a reconceptualization of dress as corporeal experience; secondly that of somatics, an approach where knowledge is developed from within the lived experience of the moving body; and thirdly in relation to new material ontologies that address the digital materiality of smart textiles. The theoretical and methodological approaches discussed in the paper and explored through the projects introduce new ideas and methods to inform the design of soft wearable technologies and smart textiles.

Keywords **–** Design, Embodiment, Interaction, Materiality, Smart Textiles, Wearable Technologies.

Relevance to Design Practice **–** The theoretical and methodological approaches introduced in the paper and exemplified in the projects introduce new frameworks and processes to inform the design of soft wearable technologies and smart textiles.

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Introduction

The field of smart textiles and wearable technologies is recognized as an interdisciplinary domain drawing from areas including engineering, material science, physiology, textile design, and human-computer interaction design (HCI). Emerging in the late twentieth century, initial research focused on technical issues and functionality framed within a discourse of science (Ryan, 2014). As technological artifacts worn by human beings—predominantly in health, military, or sporting applications—the design of smart textiles and wearable technologies was framed in terms of ubiquitous computing. Methods of human-computer interaction (HCI) design, where understanding the user, the problem space, and the opportunity space is paramount, have been proposed for the design of soft wearable technologies. However, HCI's initial focus on the design of interfaces for screen and keyboard interaction through the improved usability of hardware and software assumes an implicit ontological position about computing that is antithetical to soft wearable technologies. Dourish and Bell (2011) have pointed out that computing is not just a rational science but is also a philosophical enterprise in the way it represents the world and creates and manipulates models of reality, people, and action. The implicit dualism of hardware and software that is fundamental to the origins of computers as calculating and business machines, parallels dichotomies of body and mind, materiality and abstraction that underpin Western philosophy and cognitive science frameworks.

However, the nexus of technological, physiological, material, and cultural perspectives that influence the design of soft wearable technologies and their particular *digital materiality* suggests a new ontological positioning and associated theoretical framings that move beyond dualistic assumptions. The term *digital*

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materiality recognizes that digital artifacts are not immaterial, they possess a physical dimension that was overlooked in earlier computational discourse which was concerned with virtuality. Central to this shift is the notion of embodied interaction, which recognizes the fundamental importance of engaging and re-conceptualizing technology through the experience of the body and its senses, emphasizing engagement and practice rather than symbolic, disembodied rationality. In addition notions of digital materiality challenge binaries of hardware and software, the physical and the abstract, and lead to a reimagining of new forms of flexible, conformable interface such as e-textiles, as washable, wearable, drape-able computers (Dias, 2013).

The significance of dress and fashion has until very recently been ignored in the discourse of wearable technologies. Susan Ryan (2014) has claimed that "the messiness of dress must be reconciled with the systematic programming of devices that seek affective returns" (p. 229) if the hybridization of dress and device is to become a more critical and transversal practice intersecting these different domains.

HCI and Fashion

Pan and Stolterman (2015) have suggested that HCI design would benefit from an engagement with fashion. However, the concept of fashion they propose is based on notions of popular taste and style, focusing on the aesthetics and consumer appeal of fashion design rather than its relationship to the body. "While the culture of HCI is traditionally grounded in research, looking for scientifically sound solutions, fashion is recognized as being more subjective, aesthetically oriented, and driven by creativity and searching for taste and style that could appeal to people" (p. 52). Tomico and Wilde (2016) have proposed the term human garment interactions (HGI) as a counterpart to Human Computer Interactions (HCI), transferring HCI concerns with "the design of interfaces, the way humans interact with technology, and user experience, into the realm of garments" (p.3). Fashion, as the application of design to clothing is relevant to the design of soft wearable technologies, because fundamentally fashion is about bodies: "Fashion is (…) produced, promoted and worn by bodies. It is the body that fashion speaks to and it is the body that must be addressed in almost all social encounters" (Entwistle, 2000, p. 1).

A key problem that is evident in trying to relate dress and fashion theories and practices to HCI and the design of wearable technologies is the overlaps and ambiguities that are fundamental to relationships between fashion and dress, or "industry and street" (Ryan, 2014, p. 229). Fashion theory has been described as an interdisciplinary field that investigates fashion as "a meaning system within which the manifold cultural and aesthetic portrayals of the clothed body are produced." (Maglie, 2012, p. 236). Normative theories of fashion have tended to focus on fashion as a system (Simmel, 1957) or fashion as symbolism (Barthes, 1983). Fashion is also recognized as an industry that manufactures and sells material commodities:

> [A] socio-cultural force bound up with the dynamics of modernity and postmodernity; an intangible system of signification (…). It is thus made of things and signs, as well as individual and collective agents, which all coalesces through practices of production, consumption, distribution and representation. (Rocamora & Smelik, 2016, p.2)

The notion of fashion as a system of meaning that is subject to semantic analysis continues to be influential, but fails to address the multiple contexts and messiness of fashion and dress. As a method semantic analysis has been applied by researchers to both singular items of clothing and broader trends. But as Barthes himself noted, it is problematic to apply semiotic approaches to concrete items of clothing because such tactics seem "to deny the very material stuff of fashion" (Woodward & Fisher, 2014, p. 3).

While avant-garde fashion designers including Hussein Chalayan, Iris Van Herpen, and Ying Gao have produced remarkable smart garments that explore relationships between bodies, garments and technologies, deeper theoretical analysis of smart fashion has been limited. Susan Ryan's (2014) contribution to *wearable discourse* and the emphasis she gives to reconciling the diverse contexts of dress with the systematic and futuristic framings of digital devices is notable. The recursive dimensions of smart garments, which span both material and digital worlds, open up new perspectives, possibilities and challenges to both technological and fashionable domains.

Associate Professor **Frances Joseph** is currently director of Colab, a collaboratory for interdisciplinary inquiry at Auckland University of Technology (www.colab.aut.ac.nz). In 2007 she secured New Zealand government funding to establish AUT's Textile and Design Lab (TDL) where she subsequently established a multidisciplinary team and a number of projects in the field of smart textiles and wearable technologies (www.tdl.aut.ac.nz).

Miranda Smitheram is an interdisciplinary lecturer, artist, and designer. Miranda's recent doctoral thesis questioned how cloth and surface can be reimagined through a digital materiality. Her creative research and teaching shifts across fashion, textile, and art practices, merging new technologies, traditional techniques, and mixed reality to craft speculative physical-digital design. Miranda's main areas of research are material knowledge, embodiment, experimental motion capture, generative design, 3D surfaces, and digital surface imaging.

Donna Cleveland is a lecturer, researcher, and PhD candidate within Colab, Creative Technologies Research Centre at the Auckland University of Technology in New Zealand. Her research engages with innovative design led strategies, entrepreneurship, and designing for systems change. Her areas of expertise include sustainable fashion and textiles design, social engagement through sustainable design education, textile reuse within a social context and developing more effective systems of fashion textiles waste management. Her interests include functional textiles and wearable technologies. Her passion lies in sustainable design education and the fusion of traditional applications with emerging technologies, such as e-textiles to redefine the future landscape of design.

Caroline Stephen is a designer and researcher working in a space situated between textile design, digital knitting and interactive design methodologies. She has recently completed her Masters in Creative Technology at Auckland University of Technology. Her practice-led research sought to explore methods of designing with smart textiles, utilizing the interactive and temporal behaviors of knitted conductive materials. This practice proposes new processes of designing, opening up a design space for creating interactive textile surfaces. Caroline's work aims to readdress structure, materiality and interactive behavior in textile design.

Hollee Fisher is a textile design researcher with a background in Textile Design (BArtDes) and Creative Technology (MCT, Auckland University of Technology). Her research is conducted in a multidisciplinary manner where the connection between the body, materials and physiology is explored. Specialising in smart/intelligent textiles a core component of her development embraces seamless knitting technology and composite fabrics. A main area of Hollee's research platform explores health applications and potential use within animal care.

In addressing the problem between Human Computer Interaction design and normative theories of fashion in relation to the design of smart wearable technologies, this paper engages with phenomenological perspectives, namely more recent theoretical positions that recognize fashion as both material practice and corporeal experience and new digital theories of materiality and embodiment. These framings are brought to bear on two workshop-based projects conducted at the Auckland University of Technology (AUT). The first, *Soft Wearables: Where Embodied Imagination Meets Digital Materiality* (2015) was facilitated and directed by Dr. Oscar Tomico of the Eindhoven University of Technology (TUE) with a group of postgraduate students from Colab, a Centre for Creative Technologies research and teaching, and the Department of Fashion and Textiles, at AUT. The second project, *Digital Skins* (2016) was facilitated by Miranda Smitheram and Donna Cleveland from Colab and a group of Bachelor of Creative Technologies students within a studio program. The first project focused on the design of a smart fashionable garment, the second on the design of a smart costume. These distinctive contextual framings have provided useful perspectives for expanding design approaches and extending the discourse of embodied interaction in smart wearable technologies.

Bodies of Knowledge

Within the Western tradition, aesthetics—as the study of the world through the senses—has tended to focus on vision and hearing, senses that are concerned with the interpretation of phenomena that are largely external to the body, interpreted through discrete and precisely located sense organs. Therefore, they can be more easily and objectively studied. Embodied senses such as haptic, olfactory, kinesthetic, and proprioceptive perception are phenomena that are experienced more subjectively, on or within the body, with sense receptors distributed internally or across the body. Accordingly, these senses have been more difficult to study and theorize (Diaconu, 2006). This lack of articulation has diminished awareness and value of these ways of experiencing the world, and they have been long regarded as secondary senses.

Clothing, often described as a *second skin*, is part of our corporeal schema. Dress is understood through our experience of wearing it. This haptic and somatic engagement with dress is part of embodied human experience. Clothing and textiles are fundamental to the skin as an interface, augmenting, and extending the body. Smart textiles and soft wearable technologies take this dimension further, providing a dynamic interface between our bodies and the environment, generating data that can feedback into and influence the behavior of the garment and of the wearer and extending out into information spaces that are separate from the body.

The relationship between performance practice, somatics and HCI has been explored by the dancer and academic Thecla Schiphorst (2006, 2009), proposing a new approach to the design of wearable technologies. She recognizes wearable technologies as "an interface into ourselves" and suggests that performance methodologies, based on knowledge "constructed through experimental and embodied practice" (Schiphorst, 2006, p. 172) can be used to model experience and inform the development of gestural movement vocabularies in interaction. Critical to this approach is the proposition that an artifact can create or enact a dynamic bond between participants and their own movement and can become source material for designing interactions. Schiphorst's approach to embodied interaction through somatic awareness and gestural vocabularies has articulated a way of thinking that emphasizes a performative approach to the design of soft wearable technologies.

Digital Materiality and Smart Textiles

The digital realm has long been associated with disembodiment and abstraction. The materiality of digital artifacts, composed as they are of both atoms and bits (Ishii & Ulmer, 1997) involves people in everyday entanglements of the digital and the material. The recent turn towards New Materialism has proposed a vitalism that recognizes matter as "an active force in the making of the world" (Pink, Ardevol, & Lanzeni, 2016, p. 11). This ontological reorientation decenters the human from dichotomies of subject and object, to acknowledge the notion of active, living matter which we are part of. This framing recognizes a sapient or knowing materiality where cognition is bound to the specifics of materiality rather than defined by an opposition to a material world (Miller, 2006). The Maker Movement, as a technology based extension of DIY (Do it yourself) culture that encourages open sourced, networked, peer-led processes and learning through doing, has led to a broader engagement with digital materiality. Access to digital fabrication and communication technologies and a DIWO (Do it with others) philosophy have enabled a collaborative design-and-making culture, encouraging exploration of intersections between traditionally separate and specialized domains through practices such as the construction of wearables.

Technological developments have advanced textile capabilities through unprecedented material innovation. Traditional methods of textile fabrication have been combined with electronics and new materials, to produce smart fabrics with the ability to sense and react to environmental stimuli through mechanical, thermal, chemical, electrical, magnetic or other sources. Küchler (2008) has recognized that "the materiality of fibre and the structure of fabric is playing an increasing role in (re)animating the material world" (p. 102). The abilities of smart textiles introduce new properties beyond those of traditional textiles, as a sapient materiality that has conformability and a corporeal relationship that is more flexible and integrated with the body. These new materials introduce new design opportunities with smart textiles that have the potential for complex, responsive, behaviors; extending the ways we consider and deploy textiles on the body.

The Projects

The two projects discussed in the following section of this paper present different approaches to the design of soft wearable technologies using methods informed by embodied interaction design and notions of sapient materiality. The projects are framed by the contexts of fashion and of costume. Both costume

and fashion are recognized in the literature of dress as cultural constructions of identity. The term costume is often used to describe a mode of dress specific to a time period, nation, or social class while fashion indicates a predominant form or style of dress during a given time. Costume is associated with role and character in a theatrical sense, often with an associated sense of masquerade or disguise by hiding or temporarily obscuring an individual's everyday identity. Fashion is described as a distinctive trend in the style in which a person dresses. Fashion is seen both as an expressive tool for designers to deliver messages about society, and as a way for consumers to communicate identity and individuality. Such normative theories of dress as self-expression or identity reinforce symbolic and communicative dimensions of fashion and costume design. These projects focus instead on dress as behavior, explored through embodied practice, material engagement and performativity as interaction. In the first project the body is used as a tool; in the second as a context of application.

Project One: *Where Embodied Imagination Meets Digital Materiality*

When a person is situated in context, they sense the environment through their body, interact with garments through their body and fulfill goals using their clothed, accessorised and thus augmented body in an intuitive manner. A designer's augmented body filters data, picking up what is relevant to the designer's goals, including what might impede these goals. By using their own bodies in context in this way, designers are able to achieve the necessary intimacy and personal meaning-making required in worn objects. (Tomico & Wilde, 2016, p. 12)

The development of soft wearables using smart felted textiles and embodied interaction design approaches was explored through a two-day workshop at AUT's Colab in October 2015, facilitated and directed by Dr. Oscar Tomico (TUE). The workshop explored the augmentation of the body, and involved a mixed group of postgraduate and undergraduate students from AUT's Creative Technologies and Fashion and Textiles programs. Participants brought a diverse range of garment and electronics design experience and associated technical abilities. The workshop investigated the design of soft wearables through considerations of body/technology relations, movement, materiality, expression, and garment/material interactions. This project utilized facilities and expertise available through AUT's Textile and Design Lab (TDL), with support from Colab PhD student and tutor, Donna Cleveland.

Textiles are the mediating surfaces between our bodies and our environments. As a starting point the group looked at philosophical concepts of textiles as *soft habitats*, structures that offer emotional and physical protection and shelter for the wearer. An initial design exploration in the workshop included a visit to a local coffee shop in order to analyze how participants and the people around them *interacted* within a social context. Observations were made on the way in which people interact with each other as well as with their personal belongings and clothing. The group then furthered the experiment by focusing directly on the body, investigating sensory responses to different outputs such as heat and vibration. This exploration of basic sensing technologies allowed for what Tomico and Wilde (2016) have described a "full immersion in context" (p. 3) where the participants could personally experience these sensory outputs through their own interactions and their own bodies. Emotional and physical responses were documented throughout the explorations in order to better study and reflect on engagement, interactions, and to explore sensing technologies. The group noted how vibration and heat can activate dual physical and emotional responses such as (dis)comfort or (in)security and how these differed between individuals. Video and photographic documentation was gathered throughout these experiments as material to inform the design stage.

The participants then worked with large lengths of fabric and explored interacting with the cloth, wrapping and encasing the body, seeking ways to create spatial dimensions around the human form. One group made up of postgraduate textile designers Caroline Stephens and Hollie Fisher, fashion designer Donna Cleveland and creative technologist Charlotte Alexander, chose to emphasize the concept of clothing as a personal habitus by creating a cloak. They explored design strategies that would allow the garment to be worn in different ways, creating a variety of spatial configurations around the body. The design development and analysis of the cloak, detailed in the rest of this section, is presented as an example of the use of smart felted textiles and embodied interaction design approaches in the development of fashion focused smart garments. The engagement of a multidisciplinary team that included fashion design, textile design, and creative technologies students was critical to the original project outcome.

The group decided to explore vibration, looking at ways of integrating this sensory output into the structure of the cloak, questioning what vibration means when incorporated into a soft protective habitat that could be worn in everyday contexts. A textile system was developed using channels and cords designed to allow the wearer to shape the garment into different configurations on the body. Pressure sensors felted from conductive fibers became, at the same time, textile and technology. Vibration motors were integrated into the garment around the base of the neck and across the shoulders.

The garments we wear impact body and spatial awareness, as they restrict or exaggerate gestures. The team created toiles as prototypes, observing how the form and materiality of the cloak prompted gestures and postures, and how specific gestures and postures in turn affected the structure of the cloak. With the design of the cloak the group looked at ways encouraging wearer gesture as an act of interaction; questioning how interactions such as hunching, pulling, gathering, and tying the garment could afford the wearer the ability to create spatial variations around the body. The act of wrapping or pulling the cloak is both gesture *in* garment and interaction *with* garment. Thus the body acts as a tool for activating the garment. Hunching the body and wrapping clothing tighter around it are spontaneous gestures made in response to cold or stress. These gestures were taken into account in determining the cut and construction of the cloak, and facilitated details such

as a tie/pulling mechanism allowing adjustments of the textile structure to create spaces around the body. With the integration of conductive fibres the wearer's actions such as pulling and securing the cloak activated a tactile output that triggered a vibration response through the incorporation of small vibrating motors. As different gestures and postures performed by the wearer create a textile electronic reaction the cloak becomes a spatial extension as well as technological enhancement and augmentation of/on the body. Embodied interaction was understood to occur on a number of levels, including social, gestural, technological, and garment interaction.

Textile development was central to this process. Felting was explored as a method of crafting sensing textiles in order to integrate electronics seamlessly within a soft structure that considered the dynamics of the human body while providing the comforting and protective qualities of a garment. Felting through the mechanical interlocking of fibers using a needle felting machine (FeltLoom) was the textile technique adopted for this project.

This construction technique involves barbed needles punching through a pre mixed fiber batt entangling the fibers. The scales on natural fibers interlock and shrink together when exposed to a felting process. The majority of the cloak was constructed from felted wool, while electronic sensors were integrated into the garment by carding and mechanically felting wool and conductive stainless steel fibers together. The layering of felted wool fibers allowed for a thicker textile to be created, giving the resulting garment a sculptural and spatial quality when worn. Embracing this technique, felting was also used to create surface decoration as well as a method of construction; once the felted textile had been cut into pattern pieces the garment was constructed and shaped by needle felting the panels together.

The group aimed to encourage the wearer to interact with the garment creating a sense of bodily awareness. The intent was to explore interaction that brings awareness to the body through the design and integration of technology and garment. The designers sought to develop a garment where posture and gesture would activate the smart garment, with the cloak becoming a dynamic tangible interface responding to the body's own reaction to cold and stress by producing vibration akin to a massage on the neck and shoulders.

The workshop explored the design potential of soft wearables through the conceptual framework of sensing and the dynamic body in motion, where the body becomes a tool for garment activation. This led to a project brief that brought attention and design sensitivity to social/body interaction, body/garment interaction, and gestural/smart garment interaction. While both tacit knowledge of making and technical know-how were brought by the students from their various disciplinary backgrounds, the design approach was not dictated by fashion as style or symbol or HCI design methodologies. The cloak that was developed can be described as a garment with reactive behaviors, made from materials that possess the power of change and have the ability to perform or respond, thus augmenting the body. This ability added a communicative capacity, transcending that of traditional

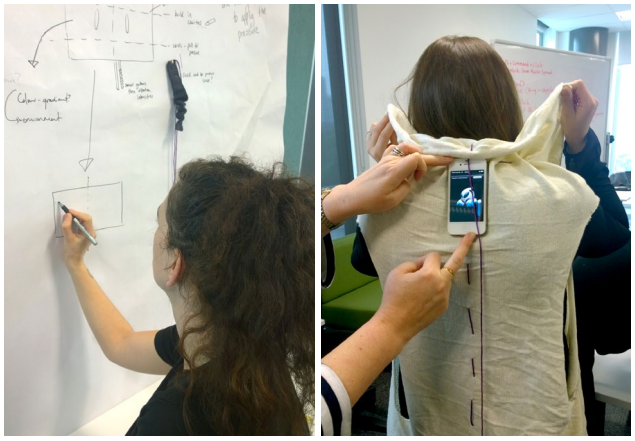

Figure 1. Left: Cloak pattern development. Right: Experimenting with mobile phone vibration.

Figure 2. Carding wool and conductive fibers.

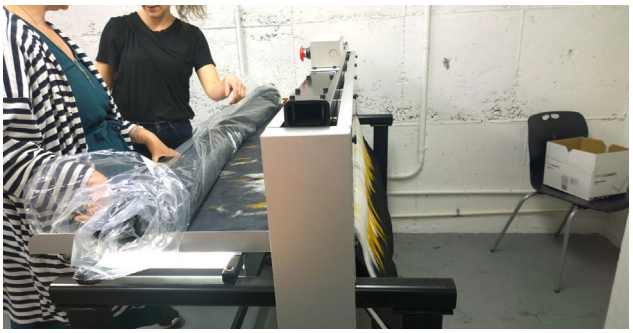

Figure 3. Felting the cloak.

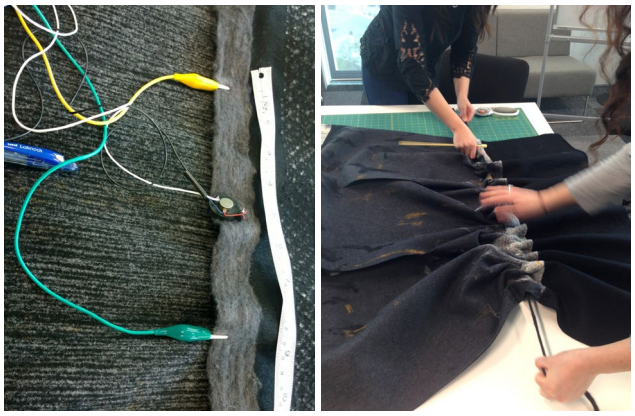

Figure 4. Left: Testing sensor conductivity. Right: Testing the tie/pulling mechanism and sensor activation.

(non-digital) garments with their inherent cultural and historical meanings. Here smart material systems integrated into garments can be understood as carriers of different types of knowledge, capable of impacting on us directly in an open-ended sensory manner. Being technologically responsive and dynamic the cloak and its attachments had the means to communicate via pressure and vibration to enable a change of expression in the garment through body/garment movement as interaction. The engagement between the garment and the animated body produced a tactile expression, a response generated in the garment and through into the body of the wearer.

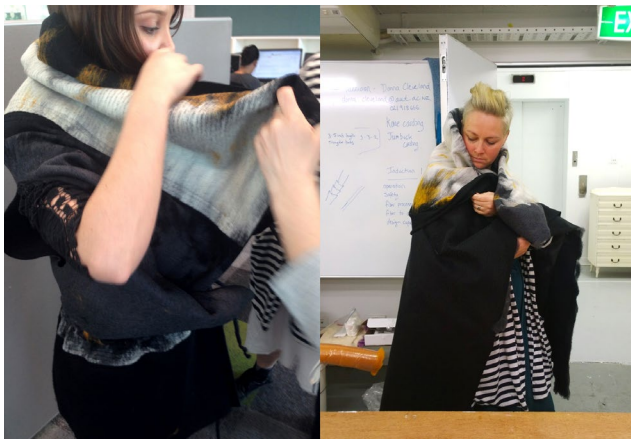

Figure 5. Testing different ways of wearing the cloak.

Project Two: *Digital Skins—Costume and Embodied Interaction*

The *Digital Skins* project involved a group of second and third year students studying in the Bachelor of Creative Technologies degree. This program does not train students in a specific design or fashion discipline, but rather encourages innovation through processes including hacking, making, programming, and collaboration. This foregrounded an approach that emphasized experimentation through doing. As creative technologists, the students' challenge in this project was to explore, design, and create wearables as costumes that extend human and environmental capabilities utilizing interactive, performative and material dimensions.

Led by Colab tutors Miranda Smitheram and Donna Cleveland, the aim of the studio was to extend experimental digital and textile processes of making, informed by post-human theory and embodied interaction design methods to create interactive clothing as embodied augmentation. The term *cyborg* describes human bodies that have been altered and augmented with machines. This studio paper asked students to reconsider earlier Frankenstein-like approaches of joining disparate biological and technological forms, to explore notions of clothing as a sensory interface and new approaches to costume design beyond established methods of characterization through the semiotics of dress. The project aim was to develop new *digital skins* that engaged with contemporary aesthetics, embodiment theory, digital and physical materials and processes of making. In this project the body was the context of the application. Students worked to develop a wearable technology garment concept and enter a fully realized costume for the 2016 *World of Wearable Art Awards* (WOW®). WOW® is a renowned annual costume design competition that attracts hundreds of entries from all over the world.

Traditionally costume design in theatre and film works to define and give insight into a character's development within the framework of a narrative and the visual style of a production's scenic design, informed by the director's vision of the staging. The Wearable Arts context frees the costume designer from the conventions of a formal script and the director's vision, emphasizing instead the originality of a costume design, the way it its made and how it will be performed. At WOW® each selected design is presented in a lavish staged performance. WOW® has been held in New Zealand since 1987 and over this time has developed a huge following and a tendency towards a style of garments that are spectacular and theatrical, presented on dancers who use movement to show off the design and kinetic possibilities of a costume.

The 2016 theme selected for the student projects was 'The Greatest Show on Earth' which sought entries inspired by the golden age of the circus. It is 1884 projected into 2084 and depicts the world of the big top circus in all its glory, its madness and amazement. Students set the scene as a bleak dystopian view of 2084, when the circus comes to town. Framed by Donna Haraway's (1991) concept of the cyborg as "theorized and fabricated hybrids of machine and organism" (p. 150), the circus theme opened up opportunities for considering how the design of the costume could enhance, limit or extend the wearers performance through technological augmentation to create cyborgs or circus freaks of the future, as a condensed image of both imagination and material reality. Key concepts identified and discussed by the students in relation to wearable augmentation included enhancement, morphing, mutation, and adaptation.

Classes were designed as a series of weekly sessions which ran over 12 weeks and included both theoretical content for discussion and practical making workshops where design concepts and iterations were developed. The workshop topics included embodiment and gesture; shape, proportion, silhouette, and exaggeration; hard materials; soft materials; and garment construction. The approach encouraged design of wearables that used gesture and movement to embody and thus communicate character rather than just trigger aesthetic activation such as kinetic or lighting effects. The initial workshop on *Embodiment and Gesture* was pivotal in exploring this approach. Gesture was considered as an activation rather than just a communication, as a source material for designing interaction so that gesture and movement not only conveyed character, but could also trigger or even extend inputs and outputs through pressure sensors, stretch sensors, dimmer switches, etc. In this manner, gesture changed the mechanical behavior of a textile (its resistance or conductivity) and thus the behavior or response of the costume.

The class initially worked in small groups to prototype ideas. Using two key activities, *expansion and contraction* and *action and reaction* students fabricated and modeled a gestural idea related to wearable augmentation. Both activities were

rapidly prototyped and fabricated as a model of a concept. To conclude these activities participants came together as a group and held a *gesture runway* presenting prototypes of artifacts and associated gestures. Following this session, the participants re-grouped to work in small teams or individually on developing a smart costume design.

Figure 6. Left: Prototyping action and reaction. Right: Constrained movement presented in the gesture runway.

One of the projects entitled *Darling*, designed by a student team including Lara Galea, Ingrid Worrall, and Sophie MacIntyre, was selected as a finalist for the public staged presentation, and was also runner up in the WOW® Factor Award 2016 judged by World of Wearable Arts founder, Dame Suzie Moncrieff.

During the design process, all the *Darling* team members worked on making and trying on the costume. This performative relationship between the garment and the designer and this embodied process of making produced a unique form of tactile expression. This was an iterative process, and each time a student from the team tried on the costume, observations of weight, constriction, movement, stance, and posture were noted and responded to by the team. As a character *Darling* was timid, abject, disconcerting, and highly original. Conceptually, the design of *Darling* responded to the students' ideas of post-humanism. Conceived as a circus freak from a future world of genetically modified perfection, *Darling* was a misfit generated through mutation. People initially laughed at Darling's ungainliness, and then felt empathy for her. She was grotesque, an object of derision that reacted self-consciously to the gaze of the spectator so that the fleshy scar-like lesions on her skin pulsated when she felt overwhelmed at being publicly exhibited as a side-show freak. In this context the technology extended the expressivity of the garment and augmented the costume.

The fleshy, skin-like look of the costume was a central concept in the development of Darling, as was her distinctive posture. The costume itself was a body rather than a dress or garment, so that the body of the wearer was the context of the application. The initial movement workshop documentation and first sketches of Darling (with arms and legs—that were subsequently discarded) had a hunched over, dragging, ashamed pose. The base form was shaped out of wire mesh and padded with polyester wadding to achieve the intended exaggerated shape. The group then further explored gestures and movements that fitted with the feel and shape of the costume. As it was heavy, the costume encouraged the wearer to slouch over, curling up felt natural and was an effective gesture, creating a sense of empathy with the viewer. Whenever the person wearing the costume slouched over, it looked like they were hiding, abashed, scared of the world.

Figure 7. Discussing the sensor location and activation pose.

An early idea was to put pressure sensors on the performer's knees, so the performer could pause, bend over and push down on their knees to activate a contracting movement on the surface of the costume, produced using electronics and actuator wire a form of shape memory alloy. This action followed the gestures work-shopped during the character's development. The gesture and pose were effective and it was an effective design solution in terms of placement and accessibility for the performer.

> When she slouches and rests her hands on her knees, the mechanical lesions covering her body pulsate, expressing discomfort towards her exploitation. Her design is inspired by trans-humanist theories and the aim was to create something uncomfortable to look at, but still relatable. (MacIntyre, 2016, unpaged).

The surface of the costume was covered in a digitally printed cotton knit fabric, produced at the AUT *Textile and Design Lab*, that used photographic imagery of details of skin textures from the designers own bodies. This was stitched onto the frame, covering the electronics. The surface was scarred and lumpy. This fleshiness of form and surface was a distinctive, critical dimension of the costume. The flesh made the character/performer appear vulnerable, obscuring her vision and overriding any reading of the costumes technological capability as futuristic or idealistic.

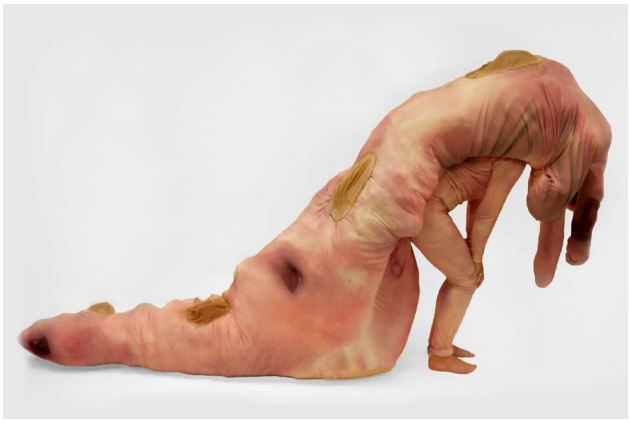

Figure 8. The completed *Darling* costume.

The development of the Darling costume was based on knowledge gained through experiential embodied practice. As a smart costume, the body became the context of application. The materiality of the costume utilized both physical and digital dimensions. This informed a movement vocabulary expressed in part through the performer's body, but more particularly extended through the responsive body of the costume. Gesture and posture became critical source materials for designing interactions based on somatic awareness. The production of the costume involved engagement through iterative processes of work-shopping movement and prototyping with materials, ideation, making, testing through wearing, analysis through observation, and further design development.

Significantly, given the tendency of the majority of WOW® entries to be highly styled and spectacular, *Darling* stood out for her peculiar, reflexive, self-conscious fleshiness, her abject physicality, and powerful corporeal sensibility. The costume didn't present character through the symbolism of dress, but rather the costume evolved through somatic and material experimentation to embody the character. This focus on the augmentation of the costume through interactive technologies was a distinctive feature of the project.

Conclusion

The perspectives and methods derived from scientific paradigms, in particular that of ubiquitous computing, have dominated the discourse of wearable technologies and informed the use of HCI design methods. Recognizing the interdisciplinary nature of wearable technologies and the limitations of dominant, technologically oriented discourse, Ryan (2015) has suggested that the area of wearable technologies needs to become a "transversal practice" that draws from multiple contexts (p. 230). While fashion discourse has tended to separate technological development from the discourse of dress, it is important to bring fashion into the area of soft wearable technologies, because fashion, at its core, is about bodies: "Fashion is (…) produced, promoted, and worn by bodies. It is the body that fashion speaks to and it is the body that must be addressed in almost all social encounters" (Entwistle, 2000, p. 1). In addressing the problematic between Human Computer Interaction design and normative theories of fashion in relation to the design of smart wearable technologies, this paper has engaged with phenomenological traditions and new theoretical perspectives that recognize fashion as both material practice and corporeal experience and new digital theories of materiality and embodiment.

The projects discussed in this paper explore experimental, hybrid approaches to the design and discourse of soft wearable technologies. Drawing from areas of dress theory, somatics, digital materialities, practices of embodied making and embodied interaction, these diverse frameworks (originating from fields of fashion, dance, new media theory, the Maker movement and design) challenge functionalist and techno-futuristic thinking and introduce some new approaches to the development of soft wearable technologies and smart clothing.

While textiles have long been described as a second skin, an interface between body and environment, smart textiles and garments expand and, significantly, activate this interface. Interaction between the body, the garment, the physical environment and other digital devices and spaces opens up new possibilities that can inform both the design process and the design outcome. In two projects discussed in this paper, soft wearable technologies were explored as interfaces on, into and beyond the body using performative methodologies and embodied interaction design processes. This approach emphasized corporeal experience and movement to inform the development of gestural vocabularies in interaction so a dynamic, recursive bond was formed between the garment and the wearer. While both project teams took turns wearing and experimenting with prototype garments so that their understanding of the potential of the interaction was developed through embodied interaction, the underlying corporeal contexts and forms of interaction taken within the two projects were distinct. The first project aimed to augment the body, using innate gesture and posture (as a response to cold), creating tension across the shoulders of the cloak. Thus the body became a tool for activating the sensors and triggering the vibrational response of the garment. The second project used body posture as a form of communication, enabling sensors on the legs to be accessed to trigger an action in the garment (a pulsing of lesions) which amplified the character expressed through the garment. In this costume project the body is recognized as the context of the application.

The exploration of materials and structures through various stages of prototyping was another key aspect of this process. The word fashion is also a verb, meaning to form or make, and the *crafts* of textile design and garment construction have strong tactile and haptic dimensions. Within the DIY Maker movement, where e-textiles have emerged as a strong area of engagement, the historic, material, and domestic associations of craft are posed as a challenge to the immateriality of the digital and the industrial scale of both technology and fashion industries. In the projects, the performative relationship between the garment and the designer, and the embodied process of making have also contributed to the development of unique forms of tactile expression.

However, the goals of the two projects in relation to the body, technology, and clothing are different. This distinction is linked to the different forms of dress (fashion and costume) engaged in each project. In the first project, situated in a fashion context, the technology and garment augment the body, sensing the body's response to changes in temperature through affective gesture. In the second project the clothing—as costume—is augmented to emphasize the expression of character. The performer's gesture (of hunching) is used as a resting pose so the body can better hold the weight of the costume. This also creates a temporal impact allowing the audience to focus on and so intensify the self-consciousness reaction of the character while also allowing the garment response to be triggered unnoticeably by pressing a sensor on the legs. This is a dramatic effect created through the augmentation of the costume as an extension of the character.

In the field of wearable technologies work on the development of comprehensive wearable systems architectures has generally been framed by ubiquitous computing approaches, with the focus on the interaction between the user, the system and the environment, see for example Lukowicz, Kirstein, and Tröster (2004). The development of more nuanced articulation and categorizations of forms of embodied interaction in relation to soft wearable technologies and smart clothing requires a deeper engagement with fields like fashion and dress, which have longstanding focus on the complex relationships between body, garment, and environment. This paper begins to explore these issues through smart fashion as an augmentation of the body using affective gesture, and through smart costume as an augmentation of the garment to create dramatic effect.

The approaches described in this paper emphasize the awareness of the human body and its part in a dynamic digital/material hybrid system, rather than as a distinct and separate subject that creates and uses technologies for purely practical purposes. As the field of wearable technologies continues to grow, different theoretical perspectives are needed to inform new conceptual and methodological approaches to support this expanding, combinatorial field and to inform the production of meaningful artifacts rather than gadgets. The notion of embodied interaction, which recognizes the fundamental importance of engaging and re-conceptualizing technology through the experience of the body and its senses is critical to this new agenda; as is the discourse of dress and fashion. The theoretical frameworks and methods introduced in the paper and exemplified in the projects introduce new ideas and approaches that we hope will contribute to a deeper understanding and fresh approaches to the design of soft wearable technologies and smart clothing.

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