# Design considerations to redefine ‘wearable’ technology

## If it is truly beneficial to wear technology, how can we create a more ‘wearable’ hybrid solution?

Maureen Selina Laverty
Department of Design
Norwegian University of Science and Technology

**ABSTRACT**

This article sets out to challenge the definition of ‘wearable’ technology, by exploring design considerations that give form to a technology that is more suited to being worn on the body. It explores materiality, arguing against rigid polymer housing attached to apparel, in favour of the integration of computational capabilities during the textile manufacturing process. It uses traditional Jacquard knitting as a case study to integrate conductive properties, proposing an alternative aesthetic and physicality. The article draws on Maurice Merleau-Ponty’s phenomenology to consider the body as the primary context for the design of worn technology, from which everything is perceived, experienced and actioned. The technology, its carrier and the body on which it is worn is treated as a holistic embedded system. The article also re-evaluates Hiroshi Ishii’s work on Tangible User Interfaces, to explore dynamic affordances within interactive textiles, considering the possibilities of both passive and active user interactions.

**KEYWORDS:** Wearable technology, materiality, e-textiles, Jacquard, conductive knitting, perceived affordances, dynamic affordances, embodied interaction, phenomenology, tangible user interfaces

## 1. INTRODUCTION

The noun ‘**wearable**’, is used to categorise worn technology as a component of the Internet of Things. It’s definition, has become intertwined and appropriated from the adjective meaning “easy to wear, suitable to wear” (Oxford Dictionaries, 2017). This definition has been diluted with the development of products such as, but not limited to, the *Apple Watch*.

On *Apple’s* website the product is displayed, and the interactions are demonstrated, in an unworn state. The design is focused on transferring the functionality of a hand-held device to a bodily attachment by reducing its real estate. It is formed using the same components, materials, manufacturing processes and interactions as the hand-held *Apple iPhone*.


*Figure 1: The Apple Watch*

I will argue that technology, in this form, misses the intricacies that demand focus when designing

products that are worn. These intricacies are defined by Tomico & Wilde as:

"a particular sensitivity for material details; an eye for fit and comfort on bodies with perhaps diverse and idiosyncratic movement capabilities; openness to a diversity of meanings that may be generated; and consideration of wearers' intimate relations with technology" (Tomico & Wilde, 2015)

### 1.1 Motivation

I have worked as a designer, both in the fashion and medical device industry. I developed anatomy specific medical devices containing technology that was to be worn on the body. The design process, for each device, was always focused on the technology. The technology was almost always comprised of traditional PCBs housed within hard polymer structures. My role was to integrate the housing within a garment. The result was often an uncomfortable, inelegant aesthetic, requiring unintuitive interactions.

From a technology perspective, these devices successfully performed their function. However, they were not "easy to wear" nor "suitable to wear", resulting in a poor user experience. Hence, they were not fully adopted by the users who could benefit most from their function.

In this article, I wish to challenge the definition of 'wearable' technology. My aim is to explore design considerations, in the context of worn technology, that borrow from a range of theories and disciplines including Fashion Design, Phenomenology and Tangible Embodied Interaction. When combined, I hope these ideologies encourage a more 'wearable' hybrid solution.

### 1.2 Method

In parallel to writing this article, I have conducted an investigative design project. They are one research effort. The article has concentrated on a review of academic literature and the project has been used as a complimentary exploration tool. Both have fed into each other, to develop a language that gives form to technology that is more "suitable to wear", applicable to a multitude of use cases.

This research project began in response to a brief to create a soft, low profile controller. It should be suitable to be worn on the body, and should explore materiality and the use of industrial apparel manufacturing methods. The controller was expected to have a familiar user interface and allow typical interactions associated with mobile technology. However, through theoretical insights acquired during the writing of this article, and consequential user testing, the project evolved with an unexpected physicality.

I began my research by evaluating current design practices in the field of **wearable technology**, including my autoethnographic observations. I extended my research into Maurice Merleau-Ponty's philosophical studies in **phenomenology** and Hiroshi Ishii's work on **Tangible User Interfaces (TUI)**. Although neither specifically refer to worn technology, I believe their work contains many relevant theories that can be adapted to create a more 'wearable' computation. I have tested this hypothesis at a rudimentary level, which I will document in my design report, and discuss in this article.

## 2. THEORY

Dr Lucy Dunne, a leading academic in wearable technology, contributes to *Social Aspects of Wearability & Interaction*. Using *Google Glass* as a case study it discusses how aesthetics influence the social acceptance of worn technology, examining:

1. static aesthetic
2. position of technology on the body
3. passive vs active gestural interactions

(Dunne et al., 2014).

To balance this approach, I sought to find publications that shifted the focus from integrating technology to fashion, to **integrating**

**technology and fashion**; driven by the body's form, rather than the form of the technology.

Pauline van Dongen, a fashion designer and Ph.D. candidate at TUE, addresses this integration in her contribution to *Solar fashion: An embodied approach to wearable technology.* This paper uses her *Wearable Solar* project, seen in figure 2, as a case study for the use of the conceptual tools provided by **phenomenology** when designing worn technology (Smelik et al. 2016).

*Figure 2: Pauline van Dongen's 'Solar Shirt'*

Her approach is the antithesis of Dunne et al.'s "static aesthetic**"**. Tomico and Wilde's paper *Soft, Embodied, Situated & Connected*, agrees with van Dongen's embodied approach, but also looks deeper at materiality's role, in integrating technology and apparel, before evaluating passive vs active gestural interactions (Tomico & Wilde, 2015). Although Dunne et al. briefly mention "somatosensory perception", they have omitted materiality from their research.

### 2.1 Phenomenology

Phenomenology is primarily concerned with how we perceive, experience and act in the world around us (Dourish 2001). It's definition and interpretation has been extensively debated. This article will refer only to Maurice Merleau-Ponty 's *Phenomenology of Perception* that places emphasis on the body as our "anchorage", from which everything is perceived, experienced and actioned (Merleau-Ponty, 1962).

The body is a system that perceives, experiences and acts both mentally and physically. Each sense and mechanism is interdependent. This system extends to what is worn on it; "it will in fact be seen that my clothes may become appendages of my body" (Merleau-Ponty, 1962).

Smelik et al. refer to this as an "embodied approach" and concur that:

1. dress is located spatially and temporarily
2. anything worn is an appendage of the body
3. to wear is a lived experience

(Smelik et al. 2016).

### 2.2 Embodied Interaction

In his book, *Where the Action Is*, Paul Dourish created the foundation for **Embodied Interaction**. It draws heavily on phenomenology, to explore an approach to interacting with software systems that takes advantage of our physical skills. He proposed to take computer interaction "off the screen" and into everyday physical objects (Dourish, 2001). Similarly, Ishii & Ullmer's vision, in 1997, was "to move beyond the current dominant model of GUI bound to computers with a flat rectangular display" (Ishii & Ullmer 1997).

In *Tangible Bits: Towards Seamless Interfaces between People, Bit and Atoms*, Ishii & Ullmer ask us to consider designing interactions heightened by the richness of a more tangible physicality (Ishii & Ullmer's, 1997). **Tangible Embodied Interaction** (TEI) places emphasis on "the

- tangibility and materiality of the interface
- physical embodiment of data
- whole-body interaction

- the embedding of the interface and the users' interaction in real spaces and contexts" (Hornecker, 2017).

**2.3 Tangible User Interfaces (TUI)**

In 2012, Ishii and his team revisited this vision, introducing Tangible User Interfaces (TUI) in *Radical Atom: Beyond Tangible Bits, Toward Transformable Materials*. They proposed a future where all digital information has a physical manifestation so that we can interact directly with it:

"Tangible interfaces take advantage of our haptic sense and our peripheral attention to make information directly manipulable and intuitively perceived through our foreground and peripheral senses" (Ishii et al. 2012).

They refer to this vision as **Radical Atoms**; dynamic physical materials that "fulfil the following three requirements:

- **Transform** its shape to reflect underlying computational state and user input,
- **Conform** to constraints imposed by the environment and user input, and
- **Inform** users of its transformational capabilities (**dynamic affordances**)" (Ishii et al. 2012).

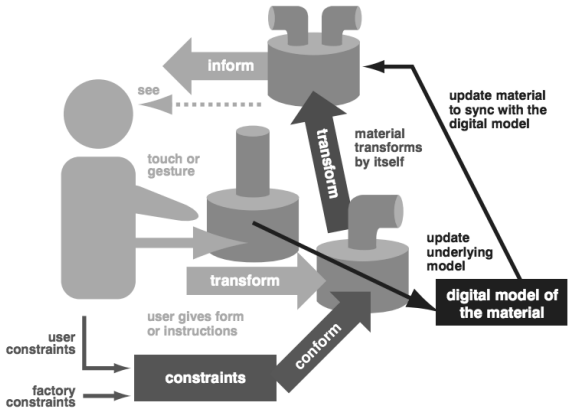


*Figure 3: Ishii et al.'s vision for Interactions with 'Radical Atoms'*

**2.4 Affordances**

Affordances, as defined by the perceptual psychologist J.J. Gibson, is the range of activities a person can perform upon an object in the world (Norman, 2007). Gibson didn't believe their obvious visibility was critical, however Don Norman argued that in design, "the critical thing was their visibility" (Norman, 2007). Norman believes that objects should be suggestive in their interaction, providing clues about how they are meant to be used (Norman, 1988). After some ambiguity surrounding this definition, he clarifies that he meant **perceived affordance**; "for in design, we care much more about what the user perceives than what is actually true" (Norman, 2017).

**2.5 Perception**

This is not strictly a theory but rather a word that repeatedly appeared within the aforementioned theories, in a variety of contexts. Throughout my research, I found it important to keep in mind Norman's observation that what is true is not necessarily what the user perceives.

Dourish explains that "perception begins with what is experienced, rather than beginning with what is expected; the model is to 'see and understand' rather than 'understand and see' ... (phenomenology) is also concerned with action, with understanding, and with how these are all related to each other, as part and parcel of our daily experience as participants in the world" (Dourish, 2001).

Worn technology has the potential to outsource and heighten our senses; what we see and understand. However, Norman cautions that computers do not have emotions which are "central to our behaviour and interpretation of the world". He explains that physical sensing is not the same as psychological perception (Norman, 2007).

Aside from the user's perception, I also wish to challenge the technology designer's perception, of what materials, physicality and aesthetic, can form computational technology.

## 3. MATERIALITY

Material selection, and the understanding of the material's physical properties, is an essential part of design. It is critical to forming aesthetic and functional qualities (Jung & Stolterman 2011). To drape around the body comfortably requires a material with soft and flexible properties. Opposing this, technology requires electrical conductivity to compute, which traditionally consists of hard and rigid components.

In 2009, Coelho et al. wrote that computation is "an entity of information which is overlaid on top of the passive physical world with little regard for how material and computationally-driven behaviours can operate together". With the growth of mobile technology, industrial designers have developed retro-futuristic, rigid, hand-held devices to house technology; refining injection moulding processes to create the smoothest surfaces. As demonstrated later in figure 15, these materials and processes do not translate well to objects worn on the body.

For centuries, textiles have been designed and refined to be worn on the body. They are ubiquitous, immersive and tactile. Technology has become ubiquitous, immersive and interactive. Textiles have the potential to offer tactile interactions and sensory modalities that have not yet been fully explored.

### 3.1 E-Textiles

One method that has been explored in the maker community is hand-crafted **e-textiles**. E-textiles replace wires and some electronic components, with conductive threads and fabrics, transferring circuitry on to soft cloth. In previous projects, and in this research project, I experimented with e-textiles. Due to their tangibility, I found them to be an excellent prototyping tool. However, it presents an obvious gap when translating to industrial manufacturing processes, and clean aesthetics.

Building on the open source work of Dr Lynne Bruning, I developed a pressure sensor using only fabric and industrial apparel construction techniques, demonstrated in figure 4.

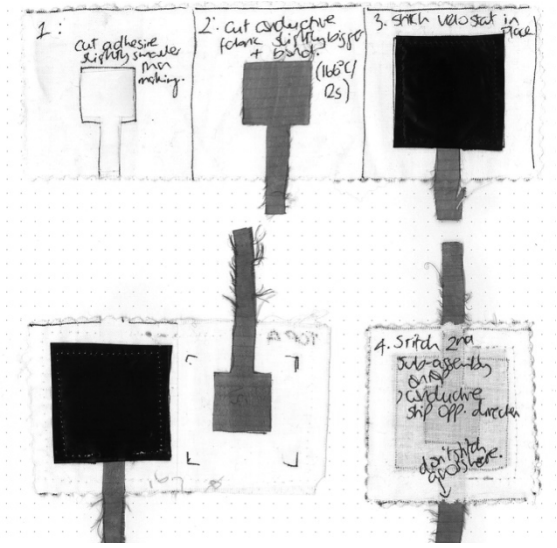


*Figure 4: E-textile pressure*

This fabric pressure sensor gave surprisingly reliable and repeatable results with excellent sensitivity. It's softness, flexibility and low profile makes it ideal to wear on the body. However, it's construction seemed like a band aid solution, fighting the materials to execute the concept. There is a need, to delve one step further back in the manufacturing process, to create a material with the required inbuilt structural, performative, functional and aesthetic qualities.

### 3.2 *Google ATAP's Project Jacquard*

Arguably the most exciting development, in materiality, has been detailed in *Google ATAP's* recent publication *Project Jacquard: Interactive Digital Textiles at Scale*. It proposes an interactive textile, shown in figure 5, that can be manufactured using existing textile weaving technology and equipment (Poupyrev et al. 2016). This article will not discuss these technicalities in depth, but it has been an important inspiration and reference for my accompanying design project.

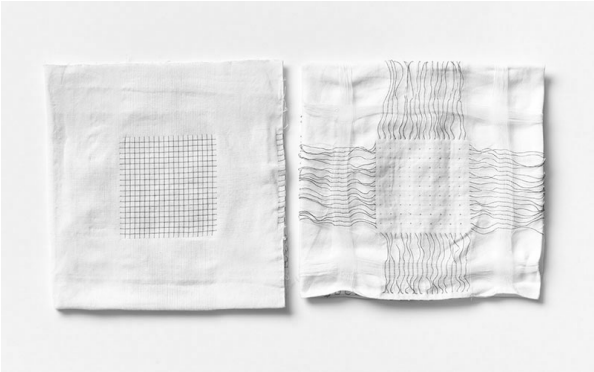

*Figure 5: Google ATAP's Project Jacquard*

*Google ATAP* observed that the structure of woven textiles is similar to the grid structure of capacitive touch screens. They explain that "by replacing some of the yarns in warp and weft direction with conductive yarns, we can weave flexible, textile multitouch panels that have properties of both has … viable for digital sensing and computation to become basic properties of textile materials" (Poupyrev et al. 2016).

The *Project Jacquard* team found that weaving a conductive yarn through the entire fabric was of little benefit. It became necessary to insulate and cut areas where conductivity was not required, similar to what was found in figure 4. They deployed the traditional **Jacquard** weaving technique, which determines when alternate yarns are used, creating a pattern. This allows control to limit the conductivity and interactivity to predefined locations when weaving the fabric.

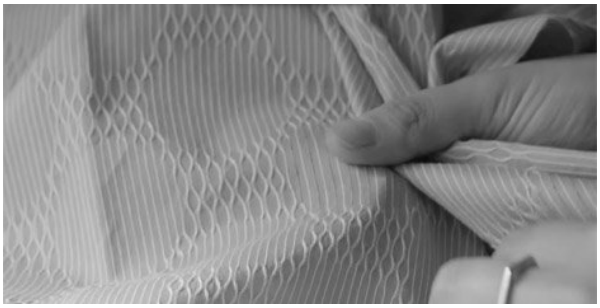

*Figure 6: Woven Jacquard from Google ATAP*

**3.3 Jacquard Knitting**

Located in Norway, I have been inspired by Norway's rich tradition of knitwear. Their hand-knitted *setesdal lusekofte* uses a Fair Isle technique to create a pattern. This can easily be programmed on an industrial scale using the Jacquard method.

*Figure 7: Arne og Carlos' Scandinavian inspired knitted jumpers using Fair Isle patterns*

By using a conductive and non-conductive yarn, I experimented with knitting digital and physical properties to create a composite material, transferring the circuit into a Fair Isle pattern, shown below in figure 8.

*Figure 8: Jacquard knit with conductive yarn*

This craftsmanship of technology provides the opportunity to integrate a non-physical product into an everyday physical object, as envisioned by both Dourish & Ishii. The interplay of digital and physical materials presents an alternative aesthetic and physicality for worn technology.

## 4. WHOLE-BODY INTERACTION

The composite material, developed in *Project Jacquard*, has the potential to respond to actions, a trait primarily assigned to an assembly of materials in a finished product. Tomico & Wilde argue that soft electronics provide an opportunity to engage the wearer's senses in diverse and subtle ways;

"The qualities of interaction made available through these capabilities differ from those that are possible using gadget-style wearables where components and their surrounding architecture are often rigid" (Tomico & Wilde, 2015).

This new materiality invites the possibility of exciting new interactions, however, how can the user know what to do in such a novel situation?

### 4.1 Tactility

Dress is a haptic experience and textiles can carry emotional characteristics. The *Project Jacquard* team's user feedback noted that "fabric invites touch and gesture" (Poupyrev et al. 2016).

The cotton used in my first iteration of the pressure sensor is arguably more inviting than a hard, cold polymer. However, wool is inherently warm and comforting. Merleau-Ponty characterises this sensation as "literally a form of communication" (Merleau-Ponty, 1962). To indulge this sensory experience, I choose a silk and mohair yarn, however, the issue became the temptation to touch it all, not just the interactive elements. I observed that the user needed specific guidance where to touch.

### 4.2 Perceived Affordances

The *Project Jacquard* team tested two scenarios; one where the interactive area was completely invisible, another where "the Jacquard yarns were raised over the surface of the garment providing subtle visual and very distinct tactile feedback for interaction" (Poupyrev et al. 2016).

The power of visual, perceivable affordances is that the user knows what to do. A knitted pattern naturally lends itself to creating affordances through colour and shape. An industrial Jacquard knitting machine also allows the possibility of varying yarn and stitch types to create contrasting 3D raised textures. Figure 9 shows my experiments with knitted affordances.

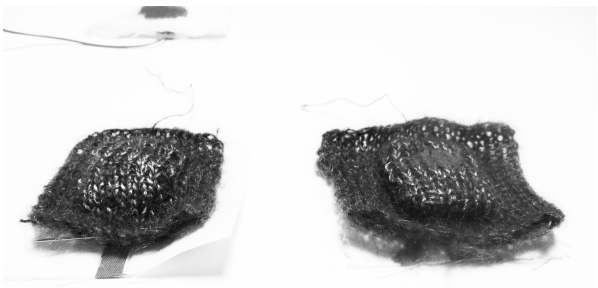

*Figure 9: 3D knitted dynamic affordances with conductive yarn and ESD foam*

These affordances do not alter the product's sensing performance, but user testing revealed that it altered the user's perception of the product. This endorses both Dourish's theory that "perception begins with what is experienced…the model is to 'see and understand'" (Dourish, 2001), and Norman's theory that physical sensing is not the same as psychological perception (Norman, 2007); "we care much more about what the user perceives than what is actually true" (Norman, 2017)

### 4.3 Dynamic Affordances

Ishii et al. have a vision for "human interactions with dynamic physical materials that are computationally transformable and reconfigurable" (Ishii et al. 2012), see figure 3.

Reconfigurable textiles, where a digital input has the potential to control a corresponding output on a textile worn on the body, is an exciting prospect for the future of worn technology. However, for now, I have concentrated on exploring how a textile interface can transform in shape to modify and reflect computational changes in the system, digitally displaying these changes in synchronicity.

As discussed in section 2.3, the material used in Ishii et al.'s concept of *Radical Atoms* must transform, conform and inform. The springiness of soft, raised, knitted textures allows the material to **transform**.

To perform its function, the material must **conform** to the laws of physics, conducting electrical current, providing the appropriate fixed resistances and allowing a variable resistance that can send an analogue signal. Dually these properties must be achieved by conforming to industrial knitting techniques. My hand knitted prototypes, shown in figure 8, are presented as proof of concept, that connections and resistors can be Jacquard knitted using a conductive and insulating yarn. More sophisticated versions can be achieved with the correct industrial knitting equipment.

To **inform** the interfaces must alter in shape; "the user has to be continuously informed about the state the interface is in, and thus the function it can perform" (Ishii et al. 2012). Norman advocates subtle natural signals, for example "mechanical knobs can contain tactile cues, a kind of implicit communication, for their preferred settings" (Norman, 2007).

I experimented with 3D conductive knitting and ESD foam to provide tangible physical feedback to the user, see figure 9. The physical resistance under hand, provided by the foam, mirrors its change in electrical resistance, in synchronicity. This is aligned with Norman's writings on affordances;
"during the carrying out of the action, we want to know how it is progressing. Afterward, we want to know what took place" (Norman, 2007).

It is vital that users must understand what the possible outcome of their action is. Merleau-Ponty writes that two senses can be elicited during the same modulation (Merleau-Ponty, 1962). I choose to digitally display this electrical change visually, so the user understands their action through touch and is informed of the result of their action through sight. I experimented firstly with using the analogue input from the sensor to successfully digitally control the brightness of an LED, change its colour and finally the size of on-screen graphics. Theoretically this can be substituted for any output and elicit any sense.

**4.3 Active vs Passive Interactions**

These dynamic materials compliment Smelik et al.'s proposed "embodied approach" and Tomico and Wilde's approach that deals with a worn object in context, and asks us to consider how we sense and interact through our body, in an intuitive manner, to fulfil the functionality (Tomico and Wilde, 2015).

Our body has both unconscious and conscious sub-systems. The autonomous unity of the body, can cause movements and gestures without the user's awareness (Merleau-Ponty, 1962). Therefore, we must carefully consider if gestures should be active or passive.

In figures, 8 and 9, I am asking the user to consciously make the decision to move their hand to touch the interactive area. However, it could accidently be activated during an unconscious bodily movement. I experimented with a combination of interactive areas that must be touched in combination to activate the system.

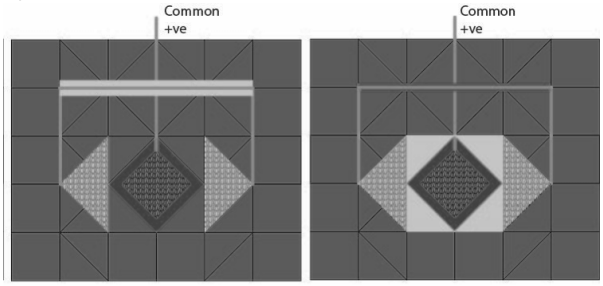


*Figure 10: Place holder for project pic*

The body is a rich repository and body based gestures allow the user to naturally interact without movement limitations. The inherent flexibility of textiles, without computational capabilities, allows them to deform and reform

as the body moves, reacting in synchronicity. When embedded with computational capabilities, whilst remaining flexible, we can use textiles to map the natural movements of the body, with the possibility of enabling a corresponding digital change. Interactive textiles have the potential to exploit the body's natural movements.

Mika Satomi and Hannah Perner-Wilson have documented their work in this area on their website, Kobakant. I have built on their open source work to test different yarn combinations and knit stitches to subtly integrate knitted stretch sensors. When the conductive knitted region is stretched, the resistance between the stitches alters. This change in resistance has the potential to be used to detect unconscious movement, and measure passive interactions.

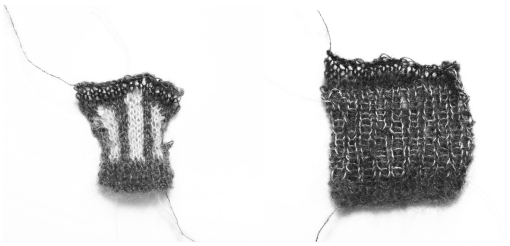

*Figure 11: Along body and across body stretch sensors, knitted with high resistance yarn*

Further research is required to fully explore the interaction possibilities and evaluate the most suitable position on the body for passive and active interactions. *Project Jacquard* adopted the "*swipe left, swipe right* and *hold*" gestures of touch screens but concluded that "the effectiveness of wearable gesture sensors strongly correlate to the context of human activity. Further studies and gesture interaction design are needed to accommodate this new form of wearable input" (Poupyrev et al. 2016).

## 5. DESIGNING FOR THE BODY

It is my experience that technology engineers consider worn technology exclusively in terms of an electronic and software system.

Phenomenologically, I propose that technology which is worn must be considered as a non-permanent augmentation of the body. The body, the technology and the carrier of the technology should be treated as a holistic embedded system.

Don Norman uses the term **symbiotic system**, to describe this hybrid of machine and person, each has the potential to influence the other's behaviour (Norman, 2007). Worn technology must therefore be designed within the context of the body. It should of course also be considered in an unworn state in terms of cleaning and storage, donning and doffing. However, this article will deal exclusively with technology in a worn state.

### 5.1 "Static Aesthetic"

Dunne et al. refer to the "static aesthetic" of wearable technology. I posit that, something that is worn, cannot be considered as a "static aesthetic". The body that wears the technology is dynamic, and the technology should therefore have a dynamic interaction with the body. "Static aesthetic" implies the technology is intrusive and obtrusive in relation to the body.

Dunne et al. have researched the positioning, of technology on the body, using hard polymer, and indeed obtrusive, housing prototypes, shown in figure 12.

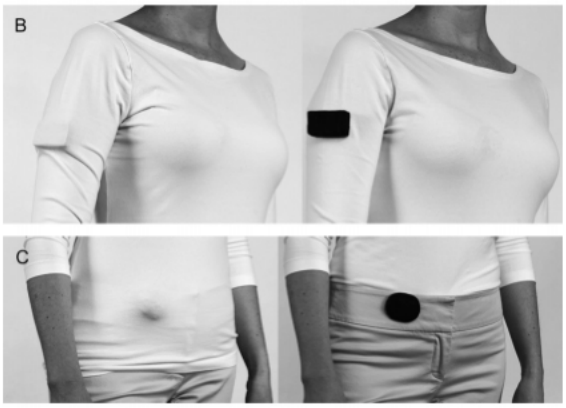


*Figure 12: Dunne et al.'s research into body location of wearable technology*

I argue that these are examples of the poor design of worn technology. They do not consider the curves of the body, the psychology of having a 'bump', the hardness of the material against the skin and/or the mechanical difficulties of attaching a hard material to a soft textile. I also argue that research, into the most suitable positioning of an object on the body, is void if the object was not designed with the body as the primary context. This is aligned with Dourish's view that "physically, our experiences cannot be separated from the reality of our bodily presence" (Dourish, 2001).

**5.2 "Lived Experience"**

"In order to perceive things, we need to live them" (Merleau-Ponty, 1962). When designing worn objects, the experience cannot be simulated, it must be lived (Smelik et al. 2016). Tomico and Wilde agree that we need to redress the balance between representations and felt experiences:

"Bodies are not renderings and behaviour is far more than a thought experiment, no matter how sophisticated the visualization (Tomico and Wilde 2015)".

Ideation on the body in context allows fashion designers to combine functionality, think thorough movement capabilities, user interactions and perceptions of aesthetics. It naturally encourages co-design. The body, and the wearer, presents instant feedback.

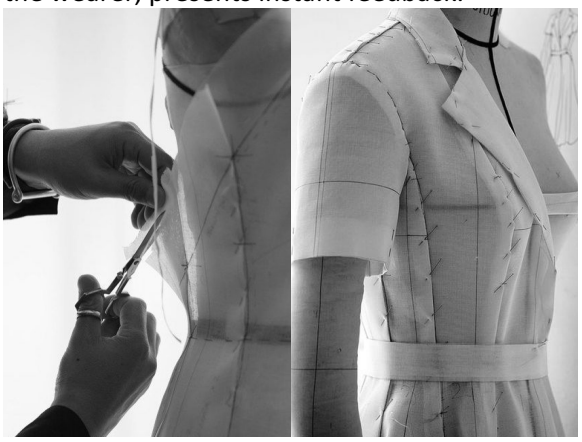

*Figure 13a (left): 'Draped' on mannequin*
*Figure 13b (right): Division of 3D draped panels*

*Figure 13c (left): 'Pattern Cutting' in 2D*
*Figure 13d (right): 'Fittings' on the body*

This method of ideation is called '**draping'**. The material is draped on a body and manipulated, figure 13a. It is divided into 3D panels, figure 13b, which are opened out and laid flat to create 2D panels, called **pattern cutting**, figure 13c. Only then does CAD drafting begin, in parallel with iterative technical and ethnographic **fittings** to refine details, figure 13d.

**5.3 Body as the Primary Context**

Exploring materials on, with and through the body, define the material properties required. It demands a direct engagement with the constraints that come from context, the performing body and functionality. I used this method before knitting a functioning sleeve.

By designing directly on the body, I was guided by the emotional response, and visual and auditory feedback, from the wearer. I could experiment with the aesthetics, form and interaction in context. I also found this a useful reminder that we were designing for people, not CAD renders. Quantitative testing was required to verify the efficacy of the product performance, but it was not the first limiting factor.

## 6. CONCLUSIONS

Worn technology, has the potential to enhance the body's awareness, challenge perception and cognition and aesthetic gesture. Design plays an important role in advancing its relevance. This field is still in its infancy, so designers have an opportunity to define what 'wearable' technology is in terms of materiality and form, and consequently it's interactions and aesthetics. This is essential to realise the full potential of worn technology, by ensuring an effective adoption by users.

The *Apple Watch* has successfully taken computer interaction into everyday physical objects, as proposed by Dourish in 2001. However, it has failed to move beyond the flat rectangular display, as envisioned by Ishii & Ullmer in 1997. Worn technology has been focused on the intangible functionality of the technology, neglecting the rich sensory experience of physical materials as an active invitation to engage with an object.

I have challenged the perception that worn technology must be rigid and smooth like the *Apple Watch*. I have attempted to demonstrate the pertinence of material's role in the design of worn technology. Integrating technology to fashion is not simply about overlaying computational functionalities onto a physical object. By remembering that the moving body is the primary context for the design, and allowing material properties to guide our design process, these functionalities can be integrated during the textile manufacturing process.

The haptic experience of interactive Jacquard textiles, presents infinite possibilities for new aesthetics, physicality, and interactions. Poupyrev et al.'s proposed future research into gesture interaction for this new input, must merge function, form and material, powered by the moving body. Physical and digital interactions are not separate, but physical sensing is not the same as psychological perception. All the above must be considered within a holistic system. To wear is a lived experience, shaped by what we perceive and interpret. If we consider interactive textiles as a TUI, then TEI can provide many valuable tools with which to design exciting new dynamic affordances and whole body interactions for worn technology.

My research benefited from a general approach, focusing on the opportunities rather than the challenges of designing for a specific use case. However, future research must move towards more specific use cases. These new interactions will depend on what we wish to monitor or control, to determine whether actions should be active or passive, conscious or unconscious.

I did not set out to explore the social acceptance of worn technology, however I believe that Dunne et al.'s research in this area should be revisited, with the new materiality of *Project Jacquard* in mind. Dourish believes that both tangible and social computing have a common foundation in the notion of embodiment (Dourish, 2001). By using the tools of embodied interaction to create a better tangible physicality for worn technology, we should inadvertently improve its social acceptance.

Using conductive Jacquard knit, within the physicality of a woollen jumper, may provide an opportunity to introduce new adopters to worn technology, for example the elderly. A familiar materiality and form, will be both felt and perceived as "easy-to-wear, suitable to wear", forging, what Tomico and Wilde described as, a more intimate relationship between the user and technology.

It is necessary for the design of worn products to evolve, but it does not need to be reinvented. Rather, a reflection on inter-disciplinary collaborations and a rethinking of processes will enable truly beneficial new functionalities.

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