TAILORING DIGITAL TOUCH:

An ethnography of designers' touch practices during garment prototyping and the potential for their digitisation

by

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Declaration of Originality:

I, Douglas Atkinson, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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ABSTRACT

At a time of rapid digital transition in garment design industries and education, this thesis ethnographically documents garment designers' use of touch and its role in meaning-making and understanding during garment prototyping. A novel *diffractive ethnographic attention* is utilised to attune to differing aspects of touch and felt experience, revealing the significance of the felt, kinaesthetic awareness of the moving body to garment prototyping. Further demonstrating that designers relate felt histories of material entanglement with their moving bodies to their contemporary experience. Development of felt histories is thus identified as a key means of designers' enskillment, alongside moments of overlooked and informal skills sharing.

A socio-material perspective informed by New Materialism is adopted to foreground the critical role of designers' entanglement with non-human things in structuring their felt experience and deriving meaning from it. Significantly, this thesis demonstrates that sensations are perceived beyond the conventionally defined body *in* and *through* entangled tools and materials and that sensations are socio-materially mutable and can be altered by peers directing designers to touch and feel in particular ways. This problematises current haptic technologies, which simulate touch at physical and virtual boundaries. The ethnographic data is supplemented by two workshop studies facilitating garment designers to engage with prototypical digital touch technologies, enabling speculation on future digital touch tools more relevant to garment prototyping.

The thesis analytically discusses differing theoretical stances on non-human agency in design and making and their implications for digital touch tools. It concludes by proposing a theoretical Framework of Garment Designers’ Felt Enskillment and making recommendations for the design of digital touch interfaces for garment prototyping. The findings of the thesis contribute to the fields of HCI, design and education, deepening academic understandings of designers’ sensory experience and the impact of digital processes, potentially informing future technology development.

IMPACT STATEMENT

This thesis provides data, analytical insight and methodological innovation, which have the potential for impact both within and outside academia.

Data Impacts

This thesis presents detailed ethnographic accounts of garment designers' touch practices, a subject which has previously received little academic attention. Designers' practices working with both digital and traditional prototyping processes are documented to address discussions of skills loss due to the adoption of digital technologies. This thesis demonstrates that touch practices are not only developed through specialist education but also through wider material engagement and informal moments of learning, and as such, may be noteworthy for educational policymakers. The pedagogic implications of this work highlight physical activities which can be implemented within current garment design curricula.

The data may inspire professional garment design practitioners to interrogate their touch practices, contributing to their analysis and discussion through practice and in design literature. More broadly, researchers in diverse fields such as the anthropology of design, crafts and making, creative subjects' pedagogy, interaction design, haptic and touch technology engineering, or sensory studies will be able to use the data in their critique and exploration of haptics and the sensory.

Analytical Impacts

Analytically, this thesis is notable in adopting a perspective informed by New Materialism, attempting to move the field beyond a phenomenological stance that prioritises the human designer's centrality. In particular, this thesis advances arguments for the entanglement of the social and material in the acquisition of touch practices and the structuring of felt sensation itself during garment prototyping.

The Framework of Garment Designers' Felt Enskillment proposed by this thesis contributes a theoretical model describing designers' development of touch practices, accounting for perceptions of never having been taught to touch and the development of individual practices as part of designers' identity formation.

The recommendations for the design of digital touch interfaces for garment design are of interest to haptic technology engineers and interaction designers, digital content designers and students on new specialist digital fashion degree courses seeking to embed meaningful felt experiences in their creations.

Methodological Impacts

Methodologically the thesis proposes a diffractive, rather than tradition and discipline bounded attention to ethnographic fieldwork, entangling approaches derived from sensory ethnography, multimodal ethnography and autoethnography. *Diffractive ethnographic attention* using these lenses offers a method applicable across disciplines, including sensory studies, dance, material culture, and HCI. More broadly, *diffractive ethnographic attention* can be applied to other contexts than touch by changing the approaches to ethnography which are diffracted.

The use of sensor fabric probes to visualise designers' touch and focus them on their engagement with non-human things is novel in an ethnographic, situated context. Along with the thesis's third and final methodological contribution in assisting designers to experience and create their own digital touch prototypes, these methods promote an in-depth understanding of emergent technologies, supporting designers to speculate on future roles they might play in their everyday, situated practices. As such, these methods are applicable when studying a broad range of emerging technologies and their domestication.

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https://in-touch-digital.com

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For readers who want to learn more about these designers, the links below will give an insight into the real person represented in my ethnographic vignettes and fieldnotes.

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CHAPTER 1 – INTRODUCTION, BACKGROUND & CONTEXT

Figure 1.1: Pattern blocks at University X, Site A (see Table 4.1)

1.1 Research Topic

At a time of rapid transition to digital practices in garment design education and industry, narratives of the loss of hands-on processes leading to diminished skills are circulating (Ræbild, 2015; Almond, 2016; Montgomery, Henry and Brotheridge, 2016), yet largely unsupported by research data. As prior research has yet to document the use of touch in garment prototyping processes and the understandings it reveals, it is currently challenging to move beyond speculation on changes which might be occurring due to the introduction of digital tools. This thesis addresses the gap in knowledge and, in doing so, provides an ethnographic account of garment designers' use of touch to inform discussion of the impact of digital processes on touch behaviours and skills acquisition. Additionally, as digitisation of some aspects of garment prototyping is likely inevitable, this thesis seeks to propose possible design considerations for digital touch technologies, which could support current touch-based understandings and meaning-making. Indeed, digitising the garment prototyping process can be beneficial in terms of reduced consumption of materials, reduced shipping costs for sample garments and associated emissions, as well as facilitating global communication between designers and manufacturers around a virtual prototype.

1.2 Aims and Objectives

In light of these possible gains and losses, this thesis aims to better understand garment designers' touch practices at a time of digital transition and to make recommendations for digital touch technology development which might support current touch-based meaning-making and understandings. It does so by addressing three key objectives:

- To document contemporary touch practices used during physical and digital garment prototyping and the associated meanings and understandings designers derive from them.
- To explore how a New Materialist perspective on garment prototyping, prioritising material liveliness and enactments of non-human agency, can inform recommendations for digital touch design tools and interfaces.
- To facilitate garment designers to speculate on how their touch practices might be captured and/or supported by digital touch technologies.

1.3 Research Questions

To address the aim and objectives of the thesis, the following research questions are posed:

RQ1) What touch practices are utilised by garment design students and educator/practitioners during the development of a garment prototype, and what are their socio-material contexts/entanglements?

RQ2) What meanings or understandings do garment designers derive from or communicate through the ethnographically observed touch practices?

RQ3) What speculations on future applications of digital touch technology in garment prototyping are elicited through garment designers' situated interactions with digital touch prototypes, such as touch sensing e-textiles, in a garment design studio context?

RQ4) How do differing agential cuts, representing different understandings of material agency in the ethnographic data, shed light on approaches to the design of digital touch technologies for garment prototyping?

1.4 Context and Scope of the Research

This section outlines the scope of the thesis, defining specialist terminology in a Glossary of Garment Prototyping Terms (1.4.1), then defining key concepts such as the understanding of touch informing the thesis and the nature of 'garment prototyping' (1.4.2). This section then contextualises the thesis in the contemporary landscape of garment design education, specifically in London (the location of the ethnographic sites), and reflexively situates me as a member of the culture I study. It also discusses the increased use of digital processes, both in education and industry, in the following sections: Garment Design, Prototyping and Digital Technology (1.4.3), Sensory Attunement (1.4.4) and Garment Design Education and the Realities of Employment (1.4.5).

1.4.1 Glossary of Garment Prototyping Terms

The following definitions are given for specialist terminology and tools, or terms which have a particular meaning when used in the context of garment prototyping:

Arduino – a programming language and system of physical computing components which allow users to prototype basic electronic circuits and associated code. Certain Arduino hardware such as the LilyPad Arduino (Buechley *et al.*, 2008) is designed specifically for use with conductive threads in e-textile projects.

Avatar – a digital representation of a human body. For the designers I observed, avatars varied from abstracted bodies in virtual environments to realistic representations of bodies used for fitting garments in 3D design software.

Clo3D – the 3D garment design software of choice for the designers featured in this thesis, likely due to its comparatively low cost and user-friendly interface. Clo3D allows designers to draft 2D garment patterns, assemble and 'fit' them in 3D on customisable avatars. The results can be rendered and animated to produce more lifelike digital representations.

Fitting – testing a garment prototype on a live human being, generally a performer, or model.

Pattern Cutting – a broad term generally referring to the drafting of a paper or digital pattern representing the shaped panels of a material, which are joined to create a garment. This can occur before or after creating a garment form, as a means to both generate and document (to make replicable) novel forms. Expanded definitions of pattern cutting also include aspects of drape and prototyping to inform more unusual and complex garment patterns.

Tailor's Dummy – also variously referred to as a dummy, dress form, mannequin and stand, the tailor's dummy is a model of a human body (generally life-size, but occasionally half or quarter scale) on which garment prototypes can be constructed and fitted. An essential garment design tool.

Toile – A prototype garment, either in calico, or a cheap fabric similar to the intended final fabric of the garment. Also known in American English as a Muslin. Both terms are derived from words for cheap unbleached cotton calico. While a toile is considered a mostly complete prototype, e.g., a garment shell without final finishing, a prototype of a part garment, or a finishing technique e.g., a sleeve, or a seam finish is generally referred to as a **sample**.

1.4.2 Scope and Key Definitions

The following terms, used throughout the thesis, are defined below to indicate the scope of the study.

Garments and Garment Design

Initially, this research began as a specific exploration of touch in fashion design prototyping processes; however, the designers I observed problematised the traditional distinction between the design of fashion garments and costumes. Despite teaching or studying fashion-focused university courses, their practices and range of experience encompassed garments for dance and theatrical performance, as well as digital augmentation of the body. For this reason, the thesis discusses ‘garment design’ as a broader category of enquiry than bounded definitions of costume or fashion.

Garment Prototyping

In this thesis, I focus on garment prototyping, which occurs through manipulating materials to understand their potential and develop a three-dimensional garment form, toile, or sample. This can take place before, during and after design sketching as a means to iterate a design and is believed to be a crucial step in understanding more complex designs, those using unusual materials, or both, for learners and in industry. This is sometimes also referred to as ‘experimental pattern cutting,’ e.g., Sgro (2018: P25)

In addition to being described as experimental pattern cutting, aspects of prototyping are also often discussed as drape, material experimentation or toile making. Sgro notes that such processes are conventional in designer fashion, a context in which Almond (2010) argues they contribute to market level differentiation due to the material costs and time they require.

‘These costs signal towards intimate skilled practices that involve handling cloth and spatial knowledge in cutting, through which the practitioner experiments with finding

a creative solution that underpins the structural integrity and aesthetic of the garment.' Sgro (2018: P29)

It is these intimate encounters which students are generally expected to engage in to learn design prototyping skills and to which educators draw their attention. Similar processes to Sgro's 'dynamic cutting': experimentation with form and re-situating material experiments on the body are often taught as an exercise for students to familiarise themselves with three-dimensional shape development (e.g., Hardingham, 2016; Montgomery, Henry and Brotheridge, 2016), or to progress their design development. It was certainly an everyday activity in the bachelor's student cohort, which included two of the designers I ethnographically observed. The rationale for continuing to foreground experimental prototyping in garment design education is that it enables learners to understand how complex shapes constructed in different fabrics will behave and apply this understanding to future designs.

Kinetic Melodies (Sheets-Johnstone, 2003) – in this thesis, a key theorist I refer to when discussing felt kinaesthetic experience is dance and movement scholar Maxine Sheets-Johnstone, who considers the relationship of feeling the moving body to processes of enskillment and habituation. Sheets-Johnstone develops Luria's (1973) observation that movement is temporal and spatial. At first spatiotemporal kinetic sequences must be learned through attention to each action and feeling, e.g., attending to the feeling of moving a pencil in an arc dictated by a pattern drafting ruler (see Chapter 7). Once familiarised through the repetition of the spatiotemporal sequence (e.g., years of drafting armholes with particular tools), the kinaesthetic experience of an initial familiar movement can trigger, or initiate, a following spatiotemporal kinetic sequence which is recalled from kinaesthetic memory. This initial movement is volitional, but directed attention is not required afterwards. Kinetic melodies are ‘experienced kinetic events’ (Sheets-Johnstone, 2003, P72) learned and familiar, part of a felt history and inscribed in kinaesthetic memory. Yet each time they play out, they are tailored to the task we apply them to. We can become aware of kinetic melodies should we choose to focus on them or allow them to play out without conscious focus but are able to move between the two. Kinetic memories of certain ‘invariant features’ of a spatiotemporal sequence and its situated adaptation are ‘inscribed in the body’. They are recursively formed in and through the playing out of constantly adapted kinetic melodies.

Sheets-Johnstone situates the recursive formation and adaptation of kinetic melodies in opposition to Merleau-Ponty’s ‘habit body’ (Merleau-Ponty, 2002), which she argues implies the development of fixed internalised understandings of movement, replayed similarly in each new context. This is a conceptually similar viewpoint to traditional models of craft enskillment based on repeated habits rather than continual adaptation to entangled contexts.

Similarly, Paterson (2021) notes that Merleau-Ponty’s ‘motor intentionality’ breaks down when an intention to move in a familiar way with a familiar thing must be adapted to a new context. However, he argues that Merleau-Ponty was not necessarily drawing on such fixed understandings of habit and that in Donald Landes’ translation of Phenomenology of Perception, there is room for adaptation of ‘general motricity’. Having received a ‘motor consecration’, or alternately an initial instantiation of a kinetic melody structured by a particular thing, it is then possible to adapt bodily habits when presented with a similar ‘motor space’ or replay a kinetic melody in a context close to its initial instantiation. This presents a remarkably similar reading to Sheets-Johnstone. Due to the contentious interpretations of Merleau-Ponty’s position, I refer to Sheets-Johnstone’s conceptual model in this thesis.

Multimodality (Kress, 2010; Jewitt, Bezemer and O’Halloran, 2016) – an approach which considers communication and meaning-making to occur through other means than language alone. Multimodality assumes that meanings are communicated through multiple representative *modes* such as speech, gesture, touch and eye contact in combination. A *multimodal* analysis attends to the various modes used during the communicative activity under study. These modes are socially shaped as resources, and thus their chosen usage reflects social norms and interests of the communicating parties. While I adopt this approach to investigating communication both around and incorporating touch, multimodality has specific theoretical and methodological concerns that are not fully compatible with this thesis’s central New Materialist theoretical stance. These are discussed in Chapter 4.

Practice – a term used by the majority of the designers I observed, referring to their activities of design and making and the continuous process of learning, developing, applying and refining new skills and understandings through their designed garments (and broader creative output). The designers' use of the term practice often demonstrated the significance of garment design as part of their lives and identities.

Tacit Knowledge (Polanyi, 2009) – a form of knowing which cannot be communicated or knowing more than we can tell. Originally theorised by Polanyi in the early 1960s tacit knowledge has since become canonical in art and design disciplines to argue for the presence of skilled understandings in creative processes and the difficulty of articulating these understandings in traditional academic (linguistic) publications. This construction of non-linguistic understandings as impossible to articulate is contra to multimodal understandings of communication and is therefore problematised by this thesis.

Touch – touch in this thesis is conceived as both cutaneous and kinaesthetic and experienced through the tactile-kinaesthetic body (Sheets-Johnstone, 2003). Sheets-Johnstone argues that felt experience is fundamentally kinetic and spatial, grounded in movement and holistic, rather than composed of discrete sensations (for a fuller discussion, see 2.8). Similarly, sensory ethnography (Pink, 2015) proposes that touch is fundamentally linked to multisensory emplaced experience. This expanded definition, holistically including felt experience of the body in space and movement, is similar to the definition offered by Paterson (2007, 2021), who argues it forms a background openness or orientation to the world, which provides a basis from which to understand or anticipate sensations and actions. He develops this concept from phenomenological ideas of the natural stance, or natural attitude of Merleau-Ponty's

(2002) ‘lived body’ and its’ ‘motor intentionality’, discussed further in 2.8. However, unlike Paterson (2007), I do not separate cutaneous and tactile sensations.

Touch Practices – refers to designers’ use of touch specific to the context of their garment making practice (see **Practice** above). This term includes gestural behaviours and the associated felt experience and purposes, meanings and understandings that designers relate to them.

Digital Touch Technologies – this term is used to describe technologies that can digitally capture, transmit, create, or replay touch. Its scope is broader than that of ‘haptic’ technologies, which are generally discussed as replicating cutaneous sensations at specific points on the body rather than re-creating a holistic and emplaced felt experience, which may include kinaesthetic and proprioceptive sensation. Digital touch technologies are primarily an emerging field of technology research, with few current examples providing more than vibrotactile and force feedback in consumer devices. For this reason, they are discussed speculatively and in relation to low fidelity prototypes such as basic touch sensing e-textiles (see Chapters 4 and 6 for more information on the development and discussion of prototypes).

In the following sections, the context of the thesis is discussed in greater detail.

1.4.3 Garment Design, Prototyping and Digital Technologies

The garment design context is particularly pertinent for contemporary research as it is a disciplinary area which has been relatively slow to adopt digital processes. It is only in the last five to ten years that everyday computing hardware has caught up with the processing requirements of complex fabric physics modelling, and 3D garment prototyping software has reached a level of refinement, making it genuinely useful and user-friendly. Concurrently, interest in wearable technologies has boomed thanks to the visibility and commercial success of smartwatches and fitness trackers over the past decade. While the use of physical computing systems in costumes and clothing produced by technology labs can be traced back to experiments in the 1990s and arguably even earlier, the introduction of commercially available physical computing systems such as Arduino in the mid-2000s enabled amateurs and maker communities to begin experimenting in earnest with garment integrated electronics. This has led to a rapid digital transition in the education of new garment designers, fuelling concerns within education and industry about a rapid change in touch practices. Moving from a focus on ‘intimate encounters’: material experimentation and sustained interaction with physical materials, to a greater emphasis on interaction with design and development software through screens and computer input devices. In this narrative, garment prototyping activities are constructed as being endangered by the introduction of digital processes and therefore form the core focus of this thesis.

While the use of visual software tools such as the Adobe Creative Cloud Apps Illustrator, In-Design and Photoshop (Adobe, 2022) is common in garment design development, replacing hand drawing, some aspects of prototyping through making are now being digitised; both in industry and educational contexts. For example, it is common to offer students inductions to 3D software such as Browzwear (Browzwear Solutions Pte Ltd., 2021), Clo3D (CLO Virtual Fashion LLC, 2018) or Optitex (Optitex, 2021), which allow garments to be prototyped virtually on a 3D avatar, yet whose fabric physics rendering is numerically based and problematic to relate to the incredible diversity of physical materials. It is also common to introduce students to other 3D software such as Rhinoceros (Rhino) 3D (Robert McNeel & Associates, 2022), which is traditionally used to design solid products, and 3D Virtual Reality sketching tools such as Zbrush (Pixologic, 2018) and Tilt Brush (Google, no date), along with 3D body and object scanners. While these technologies offer the potential to develop new practices (Atkinson, 2017), this shift, along with higher student numbers, has reduced the time garment design pedagogy dedicates to an 'education of attention' (Grasseni, 2004; Ingold, 2013; Gowlland, 2015) to touch by more experienced, skilled makers. This traditionally included observing the touch practices of skilled makers and imitating their processes while making *with* them. Feedback from the more skilled maker also helps attune learners to sensory cues. For example, when learning to tailor a jacket by hand (a process involving a considerable amount of hand manipulation and stitching to shape the canvas in the chest and shoulders), a garment making technician would describe and visually demonstrate where to stitch, the movements used in stitching and the shape and size of stitches on their own sample garment. Yet beyond this, they would also direct learners' attention to the feeling of the canvas, wadding and outer fabric as they are sandwiched together and shaped into body contoured curves through the hand-stitching process, the feeling of capturing particular layers with the needle, and so on.

1.4.4 Sensory Attunement

A pressing question for garment design pedagogy is whether reducing the emphasis on education of attention leads to reduced attunement to, and understanding of, material qualities and their influence on making outcomes that can be inferred through touch? Swindells and Almond argue that '*Sourcing the feel and drape of the fabric is extremely important as it indicates the possibilities and limitations of the design'* (2016: P53) and further propose that an understanding of this material behaviour in an applied context is a crucial competence of fashion designers and artists alike, while Petreca, (2017: P192) proposes that *'physical engagement with textiles is part of [garment] designers' know how.'* A diminished understanding of the qualities of materials and their connotations for design may reduce new learners' understanding of potential designs which can be executed with a particular material (as argued by Montgomery, Henry and Brotheridge, 2016). This is significant as it may hinder design and manufacturing innovation in the garment industries, make new and recent graduates less employable, or lead to a skills gap.

The importance of a sensory attunement to material qualities is highlighted as a critical competence among makers by scholars of craft, making and material culture (e.g., Pye, 1995; Adamson, 2007; Sennett, 2009; Ingold, 2013). As Ingold (2013: P29) observes: *'The experienced practitioner's knowledge of the properties of materials, like that of the alchemist, is not simply projected onto them but grows out* *of a lifetime of intimate gestural and sensory engagement in a particular craft or trade.'* This was historically developed through apprenticeship models and physical familiarisation with materials, guided by a skilled maker in inferring properties deemed to be significant.

While studies have explored the communication of tactile material properties via digital swatches using non-haptic technologies (Atkinson *et al.*, 2013, 2016; Orzechowski, 2016; Petreca *et al.*, 2016), these have proved limited in their perceived usefulness by designers and makers (Petreca *et al.*, 2013, 2016). The increased reliance on digital materials for communication and understanding is another concern for garment design pedagogy as it further removes new learners from felt experience.

1.4.5 Garment Design Education and the Realities of Employment

The research for this thesis was conducted in the context of central London design universities and practitioners' studios in the Greater London area. Along with providing manageable geographic boundaries to the research, this also resulted in an ethnographic site with ideologies of education, employment and practice, which were assumed to be particular, yet in reality, were broadly representative of garment design education and practice throughout the UK and beyond.

1.4.5.i Is it ‘a London thing’?

Nicewonger (2011, 2015, 2016) observes that during his studies of pedagogic encounters at Antwerp Academy, there was little focus on the mass market fashion industry or the industry at all. Their mission was (and still is) to develop avant-garde designers based on the international success of ‘The Antwerp Six’[1]. Key pillars of this approach include the development and articulation of a personal aesthetic and a rejection of prevailing fashion trends in the search for novel and unique garment designs. In UK universities, in London and beyond, this is similarly foregrounded. The adoption of a more creative rather than technical approach can also be linked to the commercial and media success of graduates from the masters’ degrees at Central Saint Martins and the Royal College of Art, consistently rated as the world’s best fashion courses. This has led to a trickle-down of prioritising experimental approaches in other, previously more industry-focused universities, though this is not a recent phenomenon. One ethnographic participant noted the foregrounding of creativity over technical skill as being ‘a London thing’. She experienced a similar approach even in the 1980s at an outer London university. This sat in marked contrast to her prior technical education at a college in the north of England. However, in my experience, this approach has expanded beyond London to other UK universities.

[1] The Antwerp Six refers to a group of the most famous and commercially successful graduates of Antwerp’s Royal Academy of Fine Arts’ Fashion degree course, all of whom graduated between 1980 and 1981. They began to receive critical acclaim for their conceptual and experimental approach to fashion in the 1990s when the collective term was coined.

Faerm proposes that the creation of ‘complex narratives’ (2015: P190-191) around fashion is a crucial skill for designers to differentiate their work in a saturated marketplace and create socially beneficial products. Both the idea of situating garments within complex social narratives and the drive to make a difference through design are also noted by Nicewonger (2011) as key tenets of Antwerp Academy trained designers. In addition, Ashdown (2013) observes the popularity of projects with a social benefit at Cornell University. The prevalence of similar ideologies the world over indicates that while London may have a particular history and cultural positioning in garment design, a London based education or practice is no longer unique.

1.4.5.ii Experimental Prototyping

My training between 2001 and 2009 at undergraduate and postgraduate level, at two universities in outer and central London, respectively; industry experience in London-based high-end designer fashion and small designer start-ups; teaching experience across the UK from 2011 to the present day; and ethnographic observations at two London universities sit firmly within this model of fashion pedagogy. As Nicewonger argues, I have been socialised to the practices, values, and ways of seeing and *feeling* that narratives around experimental rather than mass-market fashion engender. In short, I have an insider status in the culture I study and bring a particular relationship to experimental design and making. Indeed, my interest in exploring the significance of touch in garment prototyping can be traced to my being a product of a more Bauhaus influenced pedagogic environment (a UK BTEC Foundation Diploma in Art and Design and a highly hands-on bachelor’s degree) which prioritised learning through *experimental prototyping*, as well as developing design skills.

While the diminishing focus on making is lamented by academics and educators such as Montgomery, Henry and Brotheridge (2016), many universities using an experimental model continue to value garment-making processes to gain a personal understanding of the design possibilities particular materialisation techniques might afford.

‘Students … may not use construction skills on a daily basis when they reach their ultimate career path – yet we maintain that they will benefit from knowing them for portfolio building, and for understanding the relationship between skilled patternmaking/construction and a successful clothing design.’ (Ashdown, 2013: P116)

This educational environment and the design development of complex garments, to be produced in low volumes for high-end customers, are the contemporary contexts most likely to allow the designer to engage with touch and tactility when developing a garment design. Yet they sit in contrast to the increasing detachment of design and making at less rarefied levels of the fashion industry, led by the massive offshoring of garment manufacturing from the newly service focused economies of Europe and North America from the 1970s onwards (as discussed by Moon, 2009, 2011). For many, the reality of a contemporary role in fashion design is either working with the Adobe Creative Cloud Apps to visualise design ideations or create specifications for overseas suppliers and checking samples against them (Pycock and Bowers, 1996; Manlow, 2005; Moon, 2009, 2011). While for graduates working in more technical roles, their experience will be one of creating garment patterns to be sampled elsewhere.

Yet the ideology of experimental fashion education persists in the majority of universities, perhaps to attract students who dream of a more creative career in high-end designer fashion. This perpetuation of the ideology of the student as ‘creative genius’ is also highlighted by McQuillan, Rissanen and Roberts (2013). Sadly, these jobs account for a minuscule fraction of the global fashion workforce, and the prestige of high-end designer brands allows them to fill staff roles with eager interns. The majority of paid positions for these brands are so oversubscribed as to be ‘one in, one out’.

1.4.5.iii Employment Opportunities

Entering professional garment design roles becomes even less attainable for graduates, with many UK universities expanding their student cohorts as part of the ‘massification’ (Hornsby and Osman, 2014) of university education. Mainly driven in recent years by the need to recruit far more fee-paying students to fill the financial voids left by the withdrawal of funding for institutions which sit outside the UK Government’s prioritisation of STEM (Science, Technology, Engineering and Maths) subjects.

This has led to a situation in which many fashion graduates struggle to find, or alternatively leave, conventional employment and set up as independent practitioners. Working outside the mass market industry and thus maintaining and utilising the practices developed during an experimental fashion education. This reflects the personal practice of two of my ethnographic participants (see Chapters 5 to 8).

A smaller number turn to an ‘expanded practice’ (Hoette and Stevenson, 2019) in which they create heavily conceptual or experiential artefacts more akin to fine art (Atkinson, 2017). These are the designers closest to the inter and trans-disciplinary model championed by Faerm (2015). Many designers who work in this space do not come from conventional garment design backgrounds, such as one of my ethnographic participants whose undergraduate studies were in fashion design but who went on to study interaction design and critical, speculative practices (see Chapters 5 to 8).

If the distinction between the majority of fashion industry roles and the individually focused experimental approach to garment design education is so great that a garment design education (at least in fashion) does not prepare learners for the realities of future employment, why have individualist and hands-on pedagogies remained the norm? Is touch experience still helpful or relevant?

I finally began to engage with digital processes through my master’s studies on a specialist ‘digital fashion’ course. Faerm (2015) and Postlethwaite (2020) argue for engagement with digital technologies through inter and trans-disciplinarity in future fashion education instead of a trade school focus on one product. This, they propose, will enable designers to work with future making processes and diverse design teams on products which cannot yet be predicted. In this sense, inter and trans-disciplinary design education is quite different to the creative education model I have described, which prioritises the making of garments using largely traditional approaches to materialise them but removed from the commercial imperative of the trade school. It also prioritises the training of a designer as a sole creative rather than a team worker. Lee *et al.* (2021) note that this model is common in contemporary fashion pedagogy while stressing the importance of developing collaboration skills in fashion design graduates, even if they plan to enter the mainstream industry.

1.4.5.iv Educator Histories, Ideologies and Technological Scepticism

Another career path (one with which I am intimately familiar) is turning from practice to education. Faerm (2015) and Lisewski (2018) note the convention of hiring successful fashion practitioners as educators, despite their lack of any pedagogical training. Garment design and making education historically derives from trade education, based on the transfer of practical, physical skills from expert to novice in an apprenticeship model. From this origin, the concept of the skilled practitioner as a teacher has endured despite radical changes in both the fashion industry and the garment design education system. In particular, the increase in class sizes making it impossible to deliver situated, one-to-one learning with practitioners.

Preferentially employing garment design educators with PhDs is a recent shift, made possible through increasing Doctoral scholarship in Arts and Design disciplines and the growing acceptance of Practice-Based PhDs. It also reflects the increasing prioritisation of theoretical understandings alongside, or over, technical skills. Yet a PhD is also no guarantee of pedagogic training, particularly for practice-based disciplines.

Recruitment of practitioners creates a cycle that maintains the pedagogic practices of garment design education, which have, in many cases, remained essentially unchanged since the 1980s and 1990s. The period when technical skills were subsumed by the development of design competencies and experimental approaches as a response to the offshoring of garment manufacturing. Indeed, Nicewonger (2011) notes that many of the educators at Antwerp Academy were graduates from the same programme they now taught. As Faerm (2015) argues, this often leads to the re-use of pedagogic techniques from the educator's undergraduate studies that may no longer be contextually appropriate for the student cohort or the changing industry they hope to enter. This is particularly true of digital skills training, with educators being left behind as the industry progresses. It can also manifest as resistance to digital processes, as Ashdown notes:

'When a technology is unfamiliar, it is easier to focus on what can be lost in the translation from manual methods, instead of how to maintain quality and reap the benefits of the CAD process.' (2013: P114)

Therefore, it is highly likely that narratives of the significance of hands-on, touch activities are circulated from practitioners trained prior to the recent transition to digital garment design and prototyping methods. I recognise the significance of touch and hands-on making in my motivation to conduct this research. Yet, I am also broadly in favour of integrating digital processes into garment prototyping and realistic about the unfeasibility of garment designers being able to avoid using them as they become more commonplace.

As touch practices and stances on engagement with technology are likely circulated between professional and educational contexts by educator/practitioners, an ethnographic understanding of touch at various levels of enskillment, from undergraduate students to educator/practitioners, was pursued by this thesis to expose the movement of understandings between an older generation of established practitioners and new learners. Particularly concerning the prioritisation of the material or the digital. Also, allowing an exploration of the induction of new learners into non-verbal practices, which Osmond (2021) proposes are not formally taught. Yet, I argue they are likely developed through engagements with more experienced designers.

While the observations and discussions with designers did not reveal a linear path of developing touch practices through educational progress, the data highlighted significant moments of enskillment and sharing of touch-related understandings. These were not linked to educational level and occurred even between educator/practitioners and other skilled makers. Similarly, many were related to professional experience. It is on these moments and their links to designers' lived histories of feeling that this thesis focuses.

In relation to the previously described context, the following sections outline the theoretical stance of the thesis and the methodological approach used to investigate it.

1.5 Theoretical Stance of the Research

Current literature focuses on generalised embodied experience (e.g., Ræbild, 2015) or gives detailed models of touch behaviour with textile materials removed from their eventual context of use (Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016). Additionally, much prior research has adopted a phenomenological stance, ontologically prioritising the experiencing human subject, thus leading to accounts that do not closely attend to the roles of non-human materials and tools in the garment design and prototyping process, despite many authors acknowledging their liveliness.

This study offers a reading of the ethnographic data informed by New Materialism and highlights the roles of non-humans and their potential agencies enacted in garment prototyping. Thus, the onto-epistemology of this thesis is closely aligned with Agential Realist theory (Barad, 2007), arguing for the inseparability of matter, meaning, the human and non-human, and therefore their equal prioritisation in the research encounter. Thereby exploring how designers' engagements with non-humans trouble the ontological separation of a human subject from their tools, materials and emplaced context. For further detail, see Chapter 3.

As argued by Barad, the epistemological grounding of this thesis is inseparable from its foregrounding of the entangled nature of matter and associated flattening of ontological priority afforded to human designers. This resulted in a methodological approach which attempts to bring the qualitative ethnographic tradition, which by its nature relies on human subjective interpretation, into productive dialogue with an attention to sensory perceptions of the non-human and an exploration of the ways things and entangled social meanings shape felt perception. This is problematised in more detail in Chapter 3. As such the thesis attempts to take steps beyond an ontologically human-centred, interpretivist viewpoint. In relation to ethnography, the knowledge claims of this thesis are underscored by an approach acknowledging meanings and understandings as the product of intersubjective processes between myself (the investigator), the designers, and crucially also, the material and emplaced context of the ethnographic study. I propose that all these factors are entangled in the creation of meaning. In this sense taking a Baradian viewpoint that the researcher is fundamentally entangled and co-constitutive of the phenomena they observe. Thus, the thesis adopts a socio-material perspective informed by Barad’s Agential Realism on the creation of meanings and understandings.

1.6 Methodology

The research questions are addressed through a collection of ethnographic practices. Sensibilities derived from the methodological and analytical approaches of 'multimodal ethnography' and 'sensory ethnography' are used as lenses to differently attend to a multi-sited ethnography in the studios of six student and educator/practitioner garment designers. The lenses respectively attend to the structuring of meaning-making through touch and the subjective and emplaced sensory experience of participants and the researcher. Additionally, autoethnographic sensory accounts of garment making were documented from my perspective as the researcher to provide a first-person sensory account of the designers' observed touch practices, given that felt experience is individually subjective and impossible to share. Moving among and across these ethnographic approaches in the field, allowing them to intermingle and influence one another, rather than taking a singular epistemological approach to observation, revealed greater nuance in the observed touch practices. I term this *diffractive ethnographic attention* as it allows ways of observing to mingle and reshape, producing new hybrid attentions to the field rather than choosing a fixed theoretical and methodological viewpoint which is deemed the best fit to represent the observed culture (as proposed by Van Maanen, 1988). The New Materialist theoretical notion of diffraction is discussed further in Chapter 3.

Designers participating in the ethnographic study represent three stages of garment design education: two bachelor's students, two master's students and two educator/practitioners. The rationale for this range was to investigate the development and circulation of touch practices and associated understandings between educational levels and ethnographic sites. At each educational level, one designer was observed whose practice used digital tools, or techniques in garment prototyping, along with one designer working in a traditional manner. This distinction allows the thesis to engage with the purported changes that the use of digital processes may bring about in garment designers' touch practices.

The total time spent with the designers was spread over periods ranging from a week to several months. Along with written fieldnotes, this generated 25.5 hours of video data (approximately 257 minutes per participant). The observations followed their development of a particular garment prototype, though designers often worked between several prototypes simultaneously.

The ethnographic data is used to answer Research Questions 1 and 2, documenting touch practices used by the participating designers and the meanings or understandings they derive from them.

Two additional workshops were conducted to contextualise the study—first, Workshop 1 a week-long, project-based workshop with postgraduate fashion design students. Participating students were tasked with autoethnographically documenting their touch practices while prototyping garments and designing digital touch tools they believed would support them. Second, Workshop 2 was a short, concluding workshop with garment design educator/practitioners and researchers, exploring future tools for garment design and manufacture. In this workshop, participants were introduced to pressure and location-sensing e-textiles in an emplaced studio context to allow them to experience their touch practices being digitally mapped and visualised and help them speculate on how digital touch technologies might be introduced in a future garment prototyping process.

The workshop data is used to answer Research Question 3 by analysing the speculations on digital touch that the workshop activities elicited.

Data was iteratively analysed throughout the ethnographic fieldwork process to develop thick descriptions which created sensitising concepts and inspired the cyclic development of further questions to guide the analysis. The data was then thematically analysed following Braun and Clarke’s (2006) guidelines. Emergent themes were mapped to create the thematic structure, which is used to report the data in the empirical chapters (Chapters 5 to 8). Finally, the methodological approach of diffraction is once again employed to diffractively read three key theories relating to the agency of designers and materials through the empirical data to generate new insights on the potential to digitise touch in the garment prototyping process. The diffractive analysis of the empirical data is used to answer Research Question 4. An in-depth discussion of the methodology is set out in Chapter 4.

1.7 Findings and Contributions of the Thesis

This thesis demonstrates that while prototyping with digital technologies diverted designers from hands-on felt experience with materials, this was still accompanied by physical making using forms of touch common to designers working in traditional ways. Past experiences of material engagement informing designers' felt histories were identified as more significant than their educational level in developing skilled touch practices. Acquisition and circulation of touch practices were similarly demonstrated to not occur in a linear progression through educational levels but relate to specific moments of learning from other practitioners throughout designers' lives. Additionally, the spatial and epistemic separation of digital prototyping from studio practice was indicated as a potential reason for digital technologies detracting from material engagement.

This thesis proposes a framework of garment designers' felt enskillment to outline how the kinetics and behaviours of touch are shared, enacted, and experienced, then adapted by designers in the process of defining their touch practices as individual and unique. This accounts for the often overlooked, rather than tacit, nature of such moments of felt enskillment. They are brief and quickly integrated by designers into their evolving repertoires of kinetic melodies – felt, and later recalled, kinetic sequences of acting and being in the world.

This thesis develops descriptions of textile selection activities as animated by the hands and scaffolded by passive bodies (e.g., Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016), demonstrating that designers animate materials and feel their touch with their full bodies. Further, the thesis demonstrates the importance of the felt experience of movement along with sensations of touching materials and things. For this reason, the thesis identifies Sheets-Johnstone's discussion of 'kinetic melodies' as a significant analytical concept.

The thesis theoretically contributes to understandings of touch during design and making by highlighting the entanglement of the sensorium into tools and materials, troubling the concept of the bounded human body and senses. The observation that designers feel *in* and *through* tools and materials problematises current haptic technologies that enact boundaries by creating touch feedback at the surfaces of things. Additionally, the thesis has shown that perceived sensations are socio-materially mutable and peers directing designers to touch in particular ways and feel for certain aesthetic qualities can alter the sensation experienced.

Methodologically this thesis makes three significant contributions. First, it proposes a diffractive, rather than theory or discipline-specific attention to ethnographic fieldwork, which better lends itself to inductive development of theory and understandings about touch and felt experience. Second, the thesis contributes to the development of materially informed research methods through the use of sensor fabric probes to visualise participants' touch engagement with a material thing. The third methodological contribution of the thesis is in facilitating designers to speculate on applications of a novel technology through the creation or introduction of relevant prototypes in their everyday situated context. Digital touch technology applications highlighted the perception that digital touch technologies would be most suited to an educational context and confirmed the fear that the recording and replay of touch would lead to the creation of generic garments.

Based on these findings, the thesis contributes to the development of digital touch interfaces for garment prototyping by recommending they incorporate the designers' entire bodies in a non-task directed, social environment and allow customisation of the liveliness of the interface itself to provide creative inspiration and accommodate individual sensory perception and preference.

1.8 Outline and Structure of the thesis

The thesis is structured as follows:

Chapter 2 – Literature Review

In this chapter, relevant literature concerning the pedagogy of garment prototyping, including garment design and making textbooks, is reviewed to explore how designers' touch practices might be developed. This includes the consideration of digital garment design pedagogy and the role of emplacement. Next, situated ethnographic and autoethnographic studies of garment prototyping are reviewed, exploring how they account for touch, the body and associated meaning-making. This is followed by a review of literature on materials experience and touch, which provides helpful models for contextualising the roles of touch practices which engage with materials, and the understandings derived from them. To explore the current state of the art in digitising touch practices during garment prototyping, prior experimental research on digital touch interfaces for garment design, prototyping, or other relevant hands-on making skills are reviewed. The chapter concludes with a discussion of key concepts emerging from the literature and the limitations of the reviewed texts.

Chapter 3 – Theoretical Framework: Why and How New Materialism Matters

This chapter presents and discusses the New Materialist philosophical framing of the thesis, arguing for the benefits of bringing an ethnographic and sensory approach to research into dialogue with these theories. In working across this theoretical and methodological divide the thesis adopts a vital New Materialist stance incorporating agency as an emergent factor in entanglements between human and non-human things. As the nature of agency in related theoretical texts is much debated, three agential cuts, which differently construct material agency, are identified to structure the discussion of the thesis data in Chapter 9. These are represented by foregrounding the theoretical concepts of hylomorphism, in which a design is a pre-conceived mental construct applied to inert matter through the agency of the designer; Pedagogies of Matter, in which agencies of material and forms it may take are revealed through touch interactions between material and designer, in the evolving creation of a designed form, and Transducers, in which liveliness in matter is brought to bear in a configuration of human and material by a third agentive party (or tool) touching both.

Chapter 4 – Methodology and Research Design

This chapter provides a detailed justification of the thesis's chosen methods based on the limitations of previous studies. Arguing for the relevance of a multi-sited ethnographic approach that diffractively attends to the observed encounters through lenses informed by multimodal ethnography, sensory ethnography, and autoethnography to foreground significant aspects of designers' touch practices differently. The epistemological conflicts of each approach are acknowledged, and the possibility of working across them is discussed. In addition, the chapter discusses the rationale and methods of two workshop studies employed by this thesis to more directly engage participants with speculation on the future use of digital touch technologies in garment prototyping. The site and participant selection processes are discussed, and ethical considerations of the research are outlined. Finally, data collection methods and the process of thematically analysing the data are discussed.

Chapter 5 – Setting the Scene: Situating Garment Prototyping in the Studio

This chapter begins to report the empirical data, providing a backdrop for the touch contexts and landscape of skilled touch practices detailed in Chapters 6 to 8, first by introducing the designers and their practices, then by describing the garment design studio and its role as a multimodal resource and emplaced context in the socio-material construction of designers' touch practices and identities. Digital divides in the studio environment are noted and discussed. The individuality of design approaches is indicated as a source of productive tension for the designers, leading to a perception of corner-cutting or 'doing it wrong' but also as a means of constructing an identity as an inquiring, innovative and experimental practitioner.

Chapter 6 – Touch Contexts: Felt Histories, Presents and Futures in Garment Prototyping

This chapter discusses the role of designers' felt histories in developing touch practices and hands-on design and making competencies more broadly, noting that familiarity with materials and aptitude for communicating about their properties and applications did not necessarily equate to seniority or educational level but instead to longer histories of both directed and un-directed material engagement. The chapter also flags the significance of kinaesthetic experience in felt histories, which will be developed in Chapter 7. Designers' application of felt histories in creating empathy with imagined wearers and situating their designs in alternate sensory worlds is discussed. I argue that felt histories are deployed to understand alternate presents as a means to situate new designs, while genuine future speculation is beyond trend-based models and is rarely valued in fashion design. Finally, this chapter discusses designers' speculations and sociotechnical imaginaries of future digital touch technologies for garment prototyping, as recounted during the ethnographic observations and revealed by Workshops 1 and 2.

Chapter 7 – The Landscape of Skilled Touch in Garment Prototyping: Manipulating Tools and Controlling Materials

This chapter analyses the commonly observed touch practices shared by the participant designers during pattern drafting, pinning, folding, laying fabric, and cutting. Touch practices used in physical and digital processes are contrasted and discussed as processes which develop and replay kinaesthetically informed 'kinetic melodies' after Maxine Sheets-Johnstone. The touch practices recounted in this chapter are primarily skilled means of manipulating tools and materials. Crucially this chapter documents instances of feeling *through* tools and argues that this can create an extended and mutable body and sensorium, troubling the ontological prioritisation of the human subject and its distinction from the non-human material world.

Chapter 8 – The Landscape of Skilled Touch in Garment Prototyping: Sharing and Communicating Touch Practices

Having detailed the shared touch practices common to the designers, this chapter reports more individually specific touch practices that designers used to understand material properties and communicate how to experience them. In this case, the touch practices were often un-mediated by tools. The chapter begins with an example of multimodal communication between a designer and a more experienced maker (despite designers' frequent assertions that they were never taught how to touch), proposing possible explanations for such learning encounters being overlooked by designers. The observed touch practices are contrasted with materials experience frameworks proposed by Haug (2019) and Petreca, Baurley and Bianchi-Berthouze. The significance of moving materials and moving bodies in understanding the physics of a material and how it may influence a garment design or pattern is highlighted, then related to the possibilities and limitations of digital fabric physics. Finally, the mutability of perceived sensation through socio-material construction and mimicry of other designers' behaviour is demonstrated. Arguing that felt experience cannot be considered an outcome of material properties alone but also of designers' socially shaped movements and kinetic entanglement with them.

Chapter 9 – Discussion: The Felt Enskillment Framework

This chapter summarises the empirical findings of the research, reported in Chapters 5 to 8, to contextualise a discussion of possible approaches to digitising or digitally supporting them. Referring to the data and significant theoretical concepts, a framework of designers' felt enskillment is proposed. This accounts for the process through which designers are shown the kinetics of how to touch and invited to feel the resulting sensations, instantiate, and adapt the demonstrated touch practice and, in doing so, come to overlook the initial demonstration as a moment of learning.

Chapter 10 –Discussion: Diffractive Analysis and Digital Touch Support for Garment Prototyping

The chapter revisits and discusses the data through agential cuts (Barad, 2007), which foreground the key theoretical concepts of hylomorphism (Ingold, 2013), transducers and correspondence (Ibid.) and pedagogies of matter (Hickey-Moody and Page, 2016). These agential cuts are enacted to problematise the phenomena of the observed touch practices through diverse perspectives on material agency. Thereby attempting to counter traditional approaches to technology design which enforce particular ontologies and epistemologies of the 'user' as the locus of agency, re-creating real-world experiences for specified tasks. An entangled reading of the common themes of all three agential cuts is proposed to foreground aspects of digital touch design which transcend each theoretical viewpoint. In addition, solutions to incorporating and embracing differences in individual design approaches and sensory experience are also proposed. The problematic nature of current digital touch technologies as enacting boundaries and surfaces is noted as contradictory to the entangled and non-localised felt experiences discussed in the previous chapters.

Chapter 11 – Conclusions and Future Work

This closing chapter critically reflects on the findings and contributions of the thesis, their potential relevance to garment design pedagogy, the design of digital touch interfaces, and to researchers in a broad range of fields, identifying significant areas for future research. Finally, it concludes by contextualising digital touch in changes to the way garments are designed and experienced, which have been accelerated by the Covid-19 pandemic, demonstrating the timeliness and relevance of the research in the context of emerging interest in digital clothing.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This chapter explores how current literature positions touch and felt experience during garment design and making and if and how touch is articulated as having a role in the garment prototyping process? Full details of the literature search criteria and process can be found in Appendix 1.

Surprisingly, given the primary role of material things and engagements during the development of a garment, literature relevant to garment making, textiles, fashion and costume more broadly, with a focus on touch and felt experience, is sparse. This reflects another issue dealt with in this thesis, namely the difficulty in accessing and articulating felt experience through language, currently being problematised by methods such as sensory ethnography (Pink, 2015); the inclusion of art and design methods in social science studies (Jewitt *et al.*, 2019, 2020; Mitchell *et al.*, 2019); and the sensory, or bodily turns in HCI, particularly Somaesthetic Interaction Design (Höök *et al.*, 2016; Tomico and Wilde, 2016a; Höök *et al.*, 2017; Tomico *et al.*, 2017; Wilde, Vallgårda and Tomico, 2017; Castan and Tomico, 2018; Höök, 2018).

This literature review is thematically presented, highlighting key areas of significance for the thesis; garment design pedagogy (section 2.2), garment design textbooks (2.3), analysis of touch in garment design practice (2.4), insights into touch and feeling from ethnographies and autoethnographies of garment design (2.5). While this review touches on the methodologies of the reviewed texts, particularly the limitations of current studies, ethnographic and autoethnographic methods are discussed in further depth in 4.2. The presentation of the literature concludes with studies of material experience (2.6) and digital touch research for garment prototyping (2.7). This is followed by two sections discussing emerging themes of the literature. First, is the focus on touch actions and movements (2.8). Second, a discussion of the construction of touch and felt experience as tacit within the literature (2.9). The chapter concludes by summarising the significant themes and gaps in the existing literature that the thesis will address (2.10).

2.2 Touch and Feeling in Studies of Garment Design Pedagogy

Literature on garment design and garment making pedagogy potentially influences or documents the formation of garment designers' touch practices. Exploring if and how tactile and kinaesthetic learning are promoted in garment design pedagogy can shed light on designers' contemporary touch practices and the meanings and understandings with which they are associated. Or alternatively, expose the lack of research into the role of touch in garment designers' education and development. For the most part, the existing literature points toward the latter.

Pedagogic texts largely fail to offer advice to other educators. Teaching Fashion Studies (Kent, 2018) is unusual in providing learning goals and assessment criteria for the projects it discusses. However, despite the editor acknowledging the inherently tactile nature of fashion garments and proposing that the chapters which focus on fashion design and making practice discuss kinaesthetic learning styles, they do not mention *how* tactile and kinaesthetic learning might be measured or assessed.

Further studies of garment design pedagogy mainly argue for more creatively engaging, student-directed, project-based work. Ashdown (2013) and Gully (2009) also propose that the student-directed pedagogic model allows students to follow their interests and understand the relevance to industry of the (touch) skills they learn. Regarding an exercise simulating a factory assembly line using the progressive bundle system[2], Ashdown states:

'Students will gain facility handling fabric, will learn what it feels like to develop a manual skill through repetition, and will understand the bundle system of manufacture first-hand.' (Ashdown, 2013: P116). However, this could be argued to be a contextualised form of learning by rote (after the traditional apprenticeship model).

In literature which discusses studies of creative approaches to garment design pedagogy, e.g., Hardingham (2016) and Martindale and Mckinney (2018), touch is rarely mentioned or explored in detail. In contrast, Montgomery, Henry and Brotheridge (2016) report a project which they claim '*explores the influence of tactile knowledge in fashion pattern cutting*'. Yet the authors present the role of felt

[2] The Progressive Bundle System, Bundle System, or PBS is the manufacturing model historically used to mass produce clothing. Machinists are responsible for only one aspect of the garment assembly process, e.g., sewing side seams, sleeve heads, or adding elastic, which they repeat throughout the day. The bundle (initially a bundle of unsewn fabric pattern pieces, which is progressively assembled) is passed from one machinist to the next, for the following assembly operation to be completed, and so on down the production line until the garment is complete.

experience within this task as implicit, failing to state *how* their study explores tactile knowledge. This appears to be a case of tactile learning equating with any hands-on activity. The authors make several unsupported claims, such as '*there may be creative benefits if pattern cutting teaching incorporates more tactile methods'* (P153) and extoll the affective potentials of touch rather than *demonstrating* its influence. While they repeatedly state the importance of touch in an increasingly digitised industry context, they do not discuss what tactility or touch provides students or how tactile knowledge might be accessed and developed. As such, the contributions of this paper to extending an understanding of the role of touch in garment design pedagogy are limited.

Touch can include directed feeling and the felt experience of emplacement in the environment the designer inhabits. Thus, when exploring touch, the role of the felt environment is also significant, as a particular discipline-specific environment has the potential to shape touch practices. Seitamaa-Hakkarainen and Hakkarainen (2016) and Salolainen, Leppisaari and Niinimäki (2018) discuss the role of the studio as a critical learning resource due to its material similarity to a professional context and 'studio pedagogy', which is considered to represent pedagogy grounded in material making. Beyond this, emplacement is little explored in pedagogic environments. This thesis seeks to address the gap in the literature through a sustained focus on non-humans and emplaced context in both students' and educator/practitioners' studio environments.

Literature on garment design pedagogy primarily considers touch an implicit aspect of education through novel creative approaches to hands-on garment prototyping and student-directed learning. In doing so, the role of touch in the respective pedagogic contexts is never thoroughly investigated. Knowledge claims are made concerning the value of physical making for the development of 3D and spatial understandings. However, these are mostly unsupported by in-depth research. This thesis contributes to the study of garment design pedagogy by investigating learners' experience of touch through detailed ethnographic research.

2.2.1 The Role of the Digital in Garment Design Pedagogy

This section reviews the literature on digital processes in garment design pedagogy to discover if and how they consider touch or felt experience. Discussion of digital technologies is often linked to the demise or loss of touch and hands-on material experience that facilitates an understanding of making in relation to traditional garment design processes (Ræbild, 2015; Almond, 2016; Montgomery, Henry and Brotheridge, 2016).

3D garment development software is increasingly included in university curricula and is the subject of several fashion pedagogy studies. Sun and Parsons (2017) discuss the application of garment designers' 'tacit' knowledge when developing garments in 3D CAD software for solid object design (Rhinoceros 3D), noting it was a primarily visual experience relying on general spatial understandings. Yet the authors observed that designers relied on' haptic memory' from traditional practice when designing for areas of the body with more dramatic curves and shape changes (P2).

Though the authors do not define haptic memory, I interpret this to mean that designers relied on sensory and kinaesthetic knowledge of formation processes which create ‘dramatic’ shapes in physical garment prototyping and attempted to re-create similar shaping processes in 3D software.

Baytar (2018) notes that despite 3D software enabling students to develop visualisation and problem-solving skills successfully, they did not believe that digital fabric behaviours were accurate enough to make fitting decisions. This concurs with Baytar and Ashdown (2015), Porterfield and Lamar (2017), and Lee and Park (2017), who report that participants struggled to recognise visual indications of ill-fitting garments in 3D software. This indicates that modes which screen-based software cannot replicate (such as touch) aid designers in making judgements about the fit of garment prototypes. However, Porterfield and Lamar (2021) propose that designers may become as skilled at visually interpreting a digital prototype as a physical toile through continued use and familiarisation with 3D software. Porterfield and Lamar also note designers’ perceived lack of support for tactility in fashion design software. Their study participants considered 3D prototyping software to be an addition to their existing tools and skills rather than a replacement for physical processes. This highlights a socio-technical gap (Rode, 2011) between what is socially desired to be supported and the technologies which are currently possible to develop. Gu and Liu (2018) propose that developments in digital human modelling (creation of avatars) and VR may address the socio-technical gap between current 3D garment prototyping software and desired functionalities, particularly for online learning. They propose that instruction in 3D garment development software such as

Clo3D allows students to associate 2D design with 3D prototypes, minimises material requirements, and enables students and teachers (or teams) to view and edit designs synchronously, collaborating in real-time.

The collaborative aspect of digital technologies is further emphasised in Porterfield and Lamar's (2021) study on the impact of virtual prototyping on collaborative costume fitting processes in which design and making roles are separated and in the emerging literature on VR for garment design pedagogy. Yang and Lee (2021) review the effectiveness of VR collaborative environments (VRCE) for garment design teams' communication, noting that their use is currently unexplored in a garment design education context. They consider garment design a problem-solving process and note that existing VRCEs have mainly been used for collaborative 'spatial problem solving' in similar design disciplines. They define categories of VRCE Apps, noting that existing offerings lack specific functionalities for garment design and prototyping and that 3D sculpting Apps offer a more intuitive prototyping solution for designers who are not used to creating three-dimensional CAD models. They argue that virtual sketching helps connect a two-dimensional design sketch to problem-solving in a three-dimensional garment.

Concurring with Jewitt *et al.* (2021) in their identification of disembodied virtual hands in VRCE interfaces, Yang and Lee (2021) propose that gesture and 'visuospatial information' such as posture and direction represented through designers' avatars aids communication. Creating lifelike interactions that they argue are perceived through designers' senses and body movements, likely referring to the association between an avatar and kinaesthetic sensation. Yang and Lee argue that this leads to a deeper conceptual understanding of the design discussion without recourse to linguistic description. The centrality of co-presence in these contexts argues for the need for digital touch technologies, which Paterson (2007) proposes can collapse distance and create a sense of connection between users.

To summarise, literature on digital garment design pedagogy indicates that kinaesthetic experience may be highly significant for learners.

The literature proposes technologies such as VR sketching and virtual garment prototyping as critical tools for collaboration, with multimodal bodily cues such as posture and gaze in collaborative environments significant to designers' communication. When discussing the use of 3D garment design software, the literature notes learners' difficulty assessing garment fit from untouchable screen-based representations. This indicates a disconnect between the capabilities of current visual digital tools and designers' desires for them. This thesis extends the literature by investigating (student and professional) designers' use of digital technology in their situated practices during non-collaborative garment prototyping activities.

2.3 Touch and Feeling in Garment Design and Prototyping Textbooks

Other than through observation and experience (either informally or in educational contexts), the most common way for garment designers to be introduced to design, making, and pattern cutting practices is via textbooks. These textbooks could be considered forms of Grasseni's (2004) 'focussing media' which develop both discipline-specific skilled vision and more than visual sensitivities. Ræbild (2015) also notes their significance in a review of 'practice-based' fashion literature. In this section, I briefly acknowledge the ways garment design textbooks feature touch. For this review, I selected a sample of the most canonical and commonly referenced textbooks in garment design education in the UK (Fischer, 2009, 2015; Nakamichi, 2010, 2011, 2012, 2016; Aldrich, 2011b, 2011a, 2013, 2015; Jenkyn-Jones, 2011; Dieffenbacher, 2013; Kiisel, 2013; Sorger and Udale, 2017; Fischer and Gobin, 2017; Lo, 2021; Sievewright and Sorger, 2021). Despite a lack of specific attention to touch in the reviewed textbooks, the touch-related, cross-cutting theme of visuotactile language is discussed in the following sections:

2.3.1 Visuotactile Language

The transduction of understandings and meanings from one (felt) mode to another (linguistic, mathematical and/or visual) allows them to be more readily communicated but often involves the suppression of the felt (Paterson, 2007). A particular and specialist language of touch-related terms emerges across garment prototyping textbooks. Many are used to indicate visuotactile judgements based on acquired knowledge of sensation (either specific to garment development or more generally), but these are inferred visually rather than through touch. These terms primarily relate to the mechanical qualities of the fabric and whether they will inform the design process, often referring to the fabric grain[3] (e.g. Kiisel, 2013; Lo, 2021).

The way a garment looks and visual assessment of a toile is related to fabric behaviours and seemingly tactile terms: *stretch, supple, crisp, balance, cling, stable*. Further frequently used terms include *tightness, pulling, relax, ease, hang, give, weight, shear,* and *volume*. Yet these terms are often linked to whether a garment *looks* tight, whether a fabric *looks* heavy or clinging etc. How to assess these qualities by feel is not explored. The most indicative example of this is Aldrich (2013), a book primarily dedicated to understanding fabric properties but that says nothing about assessing fabric by feel, calling handle 'an elusive quality' (P44) and even going as far as to describe thickness and drape as visually assessable qualities. Finally, Aldrich introduces the term 'visual stretch' (P48), referring to whether a fabric looks unappealing when under tension.

If, as Paterson (2007) argues, touch confirms and verifies visual understandings, it is surprising that such understandings are discussed in purely visual terms. Modal associations between touch and vision must be learned, and most people learn these from birth. These visual and tactile/kinetic associations are argued to

[3] The grain of woven fabric refers to the direction of the yarns which run parallel and at 90 degrees to the selvedge (the finished edge of the woven fabric). When cut following the selvedge, or at 90 degrees to it, a fabric is considered to be on the 'straight grain' – when stretched in this direction the fabric will have very little give. If stretched at 45 degrees, on the 'bias', fabrics can have far more give and very different behaviours depending on the weave structure.

developmentally ‘calibrate’ vision. In particular, they combine to provide spatial information (P41). If so, although designers can infer fabric distortion visually, understanding a fabric’s response to formation, either through three-dimensional movement (folding and draping) or when distorted by a three-dimensional form (fitting), requires felt understandings.

For this reason, it could be argued that concepts such as Sgro’s (2018) ‘spatial creativity’ (discussed in 2.6.3) rely on associations between visual and felt perception. So how do garment designers learn these associations? If textbooks such as Aldrich (2013) encourage designers to overlook touch, I argue that rather than digitisation leading to reduced understandings of the tactile, contemporary garment prototyping epistemologies may be to blame.

2.4 Touch, Feeling and Thinking in Garment Design Practice

The following section reviews discussions of specific types of ‘thinking’ relevant to garment prototyping to discover how they relate to touch and felt experience.

Dieffenbacher (2013) uses the term ‘fashion thinking’ as the title of a textbook exploring creative garment design, proposing that fashion thinking occurs in three stages of garment development activity: idea generation, concept research and design translation. As an academic concept, fashion thinking was further discussed in a 2014 conference of the same name and later a 2016 special issue of the Journal *Fashion Practice*. In the editorial, Petersen, Mackinney-Valentin and Melchior (2016) review the prior literature on fashion thinking, acknowledging that the use of the term had yet to stabilise. However, they note that the texts focus on taste, trends and temporality without mentioning touch-based understandings.

A highly relevant text from the special issue which explores touch is 'Sculptural Thinking in Fashion' by Swindells and Almond (2016). This is a philosophical reflection on three-dimensional thinking in fashion design, which aims to understand parallels between fashion and sculpture practices. This is particularly pertinent due to sculpture's tangible association with materiality through multisensory associations of sight, touch, and spatial movement (Paterson, 2007). The authors define sculptural thinking as: *'the accruement of knowledge gained from the handling of materials, … a conflated intelligence of haptic and cultural competences'* (Swindells and Almond, 2016: P50). They propose that the disciplines of both fashion and sculpture share a requirement of the practitioner to think *in the round,* simultaneously thinking, handling and working materials (P50). This idea is similar to the concept of live problem-solving in craft disciplines proposed by Marchand (2016) and Malafouris' (2014) 'Creative Thinging' (see Chapter 3). Swindells and Almond adopt the stance that spatial concepts are acquired through language, socialisation and development of 'tactile intelligences', arguing that the contrasting of one's self and experience with the world through touch is the way an artist or designer finds *'creative currency'* (2016: P52).

Swindells and Almond propose that in acknowledging the body's boundaries, it can be left behind *'to perceive, adopt and understand the form, shape and materiality of* *something else'* (P52). This concept is extended to explore developing sensory (encompassing touch and affect) empathy through mimicry and relationally 'inhabiting' (rather than entangling with) both the human form in space and non-human tools and materials. The sense of inhabiting occurs through feeling and movement, with the authors arguing, *'In fashion design a kinaesthetic sensibility is the controlling force dictating the designer's vision.'* (P53). This approach accounts for felt experiences relating to kinaesthesia and proprioception but fails to engage with felt material properties fully. Swindells and Almond's (2016) concept of 'inhabiting' non-humans is discussed in Chapters 7 and 8 in relation to the perceived boundaries of the sensing body.

This seemingly proposes a troubling of the boundaries of human and non-human common to New Materialist philosophical stances (for more detail, see Chapter 3) and Karen Barad's treatise on touch as a means of experiencing and interrogating otherness (Barad, 2012), rather than the ontological prioritisation of the human found in phenomenology. However, the authors later discuss the inhabiting of a non-human as a way to relationally construct the perceiving subject through existing as both subject and object, after Merleau-Ponty (2002). In this sense, the subject and object remain defined even when brought into relation. Paterson (2007, 2021) observes that Merleau-Ponty prioritises 'I can' over 'I think' (after Husserl) as a marker of consciousness; however 'I can' retains a key ontological focus on the human, rather than considering the critical role of entanglement between equally important things, e.g., '*the scissors, fabric, emplaced context and I* can'. A specific sensory experience is impossible to create without rendering these things present in the phenomena of touch during garment prototyping, so should any be prioritised? Merleau-Ponty (2002) further considers that consciousness is extended into the world, assuming that to be conscious confers ontological significance. I argue that things without consciousness are equally critical to a perceived, felt experience.

In summary, key texts on touch and fashion thinking again highlight the importance of the kinaesthetic experience to create bodily empathy with the wearer and explore garment material forms. This thesis explores both surface touch and kinaesthetic experience during garment prototyping and specifically accounts for what understandings (or thinkings) garment designers gain through touch.

2.5 Touch and Feeling in Ethnographies and Autoethnographies of Garment Design

This section focuses on the accounts of touch and feel in ethnographic and autoethnographic literature on garment design and prototyping. For a discussion of ethnographic and autoethnographic methods, see Chapter 4. The literature is presented under the following sub-headings: Ethnographies in Educational Contexts (2.5.1), Ethnographies in Professional Design Contexts (2.5.2) and Autoethnographies of Personal Practice (2.5.3). The literature is introduced in each section, and then texts that may help understand or contextualise garment designers' touch practices are discussed in depth. Though the ethnographies described in this section shed light on the situated, day-to-day lives of garment design students and professionals (including some aspects of touch and feeling), none place a specific analytical focus on touch, a significant contribution of this thesis.

2.5.1 Ethnographies in Educational Contexts

Ethnographic, situated studies of garment design in educational contexts explore the development of shared practices and identities among fashion design students at an internationally renowned higher education Academy (Nicewonger, 2011, 2015, 2016); explore students' multimodal composition of garments and mixed-media design development as texts (Rowell, 2020); and investigate educator practitioner's practice-based knowledge at a private fashion university in London (Lisewiski, 2017). In these educational ethnographies, communities of practice theory (Lave and Wenger, 1991; Wenger, 1999) is commonly used to analyse the observed environment and interactions (Lisewski, 2017; Nicewonger, 2011). While this helps highlight social dynamics within practitioner communities, the focus on human relations de-emphasises the role of non-human, material things. Communities of practice theory also has a strong focus on aspects of gatekeeping and attainment of status within practitioner communities, which is contra to the findings of this thesis on the significance of individual practices, corner-cutting and 'doing it wrong' as means of identity construction (see Chapter 5). Nicewonger and Rowell's studies are discussed in further detail below.

Nicewonger's ethnographic studies of fashion design students' socialisation into particular practices and judgements of what is accepted as avant-garde fashion design (or, as he terms it, 'morally acceptable') give little attention to touch but are enlightening in several ways. The studies sustain an ethnographic focus on fashion design learners as they explore the formation of a designer's identity in a community of practice. Nicewonger's premise is that social interaction – of which touch is a part – shapes communication, which in turn shapes the translation of design ideas into their realised outcome. Despite Nicewonger acknowledging the influence of non-humans, such as materials and tools, his work continues to place a strong emphasis on *human* communication.

While focusing on visual design, Nicewonger mentions prototypes, arguing they are unfixed, negotiable and a means for designs to develop (2011.: P28-29). Worldbuilding as a creative concept is proposed by Nicewonger (2011, 2016) as a core competence developed by the fashion design students he observed at Antwerp Academy of Fine Arts. He particularly refers to the anticipatory creation of future bodies (a terminology from Antwerp's instructors) and imagined scenarios on which contemporary social issues can be mapped and alluded to through design. Nicewonger's discussion of the temporal orientation of garment design processes is helpful to this thesis in framing the sensitisation of fashion designers to the generation of future scenarios. Nicewonger notes that students at the Antwerp Academy are encouraged to design scenarios in which 'future bodies' inhabit alternate worlds. In exploring an unfixed and emergent area of technology like digital touch, the affinity of fashion designers with future speculation is of particular interest. This is discussed in further detail in Chapter 6.

Rowell (2020) focuses on ethnographically documenting the composition processes of three undergraduate fashion design students, conceptually situating the research in writing studies. As such, the framing of garments and media such as mood boards as texts – static articles representing a culmination of designers' activities, or 'literate activities' which lead to their creation, represents a particular disciplinary viewpoint. In this context, Rowell proposes that composing processes are any factors leading to the development of a visual design or a physical garment, including broad networks of non-human, contextual and situated influences, after Latour (2005). Within these network-embedded composing processes, Rowell is particularly interested in composition that takes place not only on paper or on-screen, but that blends digital and tactile processes. For this reason, the study's initial focus was designers' mood boards, which can be both digital and tactile. However, despite terming them tactile, Rowell is clearly distinguishing between physical, material, and digital processes. This appears to follow much of the garment design pedagogy literature in considering the physical to equate with the felt without focussing empirical investigation on the sensory experience.

Rowell proposes micro and macro-iterations of a design, respectively referring to repeated small actions such as pinning a garment or stitching an embroidery, which accumulate to make a larger design iteration, or creating an entirely new macro iteration of a design, for example, re-draping or re-cutting a garment panel (Rowell, 2020: P114). While Rowell discusses these categories of design iteration with reference to gesture, she does not explore the touch experiences they afford the designer. A contribution of this thesis through the attention to small micro and macro touches in the Framework of Garment Designers' Felt Enskillment. (see Chapter 9).

2.5.2 Ethnographies in Professional Design Contexts

Studies of professional design contexts have explored corporate practices and brand image development in the head offices of a company with off-shored production (Pycock and Bowers, 1996; Manlow, 2005); the role of interns and international migrant labour in similar corporate structures with the inclusion of a local sample room (Moon, 2009, 2011); informal skills acquisition among garment makers in Trinidad (Prentice, 2008, 2012); the prototyping and sample development process as a collaborative activity, both in costume design (Osmond, 2021) and fashion design (Ræbild, 2014, 2015; Kristensen and Ræbild, 2016), including studies placing a heavy emphasis on multimodal discourse analysis, with little discussion of materiality (Fasulo and Monzoni, 2009).

Several ethnographies in professional design contexts take a phenomenographic approach (Ræbild, 2015; Lisewski, 2018). Though common in higher education art and design research (Lisewski, 2018: P16), phenomenography attempts to linguistically describe a range of research subjects' varying experiences of a topic. This is problematic for research exploring touch, as felt experience requires a first-person perspective to truly understand what is being experienced, rather than, or in addition to, a researcher's interpretation of a described experience. The inability to fully communicate a felt experience (particularly using language) makes it impossible to understand a range of experiences of touch. It has also been argued that phenomenography's focus on 'outcome spaces' in which perceptions can be located removes the study subjects from the broader contextual historical, political, and social contexts similarly to ethnomethodology.

Ræbild's (2015) ethnographic study of Danish fashion designers' studio practice is particularly significant for this thesis. Ræbild focuses on the roles of the body, time, and the fashion collection, using fashion thinking (after Dieffenbacher, 2013) to frame garment design as a problem-solving process (Ræbild, 2015: P62). This is despite her acknowledgement of authors such as Sinha (2002), who argue that a problem-solving focus may lead to *'lesser focus on prototype development and visible making processes*' (Ræbild, 2015: P25) or Hallnäs (2009), who argues that fashion designers introduce difference, rather than solve problems.

Though Ræbild's investigation of touch is rarely explicit, it forms part of her focus on the body. She uses an expanded definition of the haptic senses after Paterson (2007), incorporating proprioception, kinaesthesia, cutaneous (pressure, temperature and pain), and tactile (specifically pressure) forms of touch. This is similar to the understanding of touch adopted in this thesis.

Ræbild develops five categories of actions she observed 'by which designers do design', all with a form of bodily focus (Ræbild, 2015: P123). Each category relates to various observed methods that were largely not spoken about by participants but documented visually. This implies that interview and verbal methods alone will not adequately account for touch practices and supports a multimodal approach to researching touch in garment prototyping. It also supports the proposition that people often find it difficult to talk about their felt experiences. These categories of design actions are elaborated in her thesis through multiple examples from the ethnographic data:

- Design by **3-dimensional drawing** – Drawing on the body or toile; Indicative ‘drawing.’
- Design by **Dimension shift** – Moving between 2D and 3D; Seeing a design in the mirror and feeling it on the body
- Design by **User proxy** – Testing on other bodies; Improvising on a dummy or body – in Ræbild’s construction, this relies on verbal descriptive feedback from the wearer and is therefore often language-based
- Design by **Own body** – Using the designer’s own body for design testing; Using the designer’s own body for design innovation (probing touch)
- Design by **Handling** – Handling fabrics/materials; Handling clothes on hangers; Improvising by handling together as a design team

Ræbild proposes the ‘body lens’ metaphor as a means by which designers ‘refocus’ and move between these different roles of their body and embodied attention in the garment design process. I use these categories, along with the ‘design by own body’ concept of ‘probing touch’, in Chapters 7 and 8 to discuss the touch practices I ethnographically observe and their associated meanings and understandings.

Ræbild provides no specific discussion of *what* is felt and how this informs the design process, other than a comparison to a remembered felt experience of wearing other garments. Thus, I would argue that felt experience in Ræbild's study is not fully explored. However, it is notable that Ræbild proposes the combination of vision and touch – discussed as 'seeing and knowing' (where feeling is implied as a means to know) as a significant theme in the data. This is exemplified in her discussions of wearing (feeling) garment prototypes and observing (seeing) them in a mirror.

In addition to Ræbild's analytical framing of designers' activities which employ the body (and touch), the text is also significant for this thesis as Ræbild critiques the educational context of many studies on creative processes in fashion. She notes that student work is often analysed in retrospect rather than observed in process, resulting in a lack of observation of bodily interactions in the data (P31). This is an important gap in current scholarship that Ræbild suggests merits further research, and which this thesis addresses.

Osmond (2021) notes that communicating, thinking, and gaining understandings through gesture and touch occur throughout garment design and making but focuses on costume fitting as a temporal frame rather than design and prototyping. Osmond describes the process of non-verbally communicating and collaborating around a performer's body during a garment fitting as 'embodied conversation', proposing its uniqueness to costume design. Despite signalling the importance of non-humans in conversations *'between bodies and other material and spatial actors in the design* *process'* (P278), Osmond focuses on communication between humans. This is a similar stance to Fasulo and Monzoni, (2009) and Ræbild's focus on design teams' communication around prototypes. However, it is important to note that although students may communicate around their work in educational contexts, they are still primarily tasked with developing individual skills and will receive individual grades (as problematised by Lee *et al.,* 2021). The process of a garment designer's enskillment in touch practices and their lifelong development and adaptation is as often solitary as not. Therefore, the concept of embodied conversations may be less applicable to the context of the designers I study.

2.5.3 Autoethnographies of Personal Practice

Autoethnographic studies which are relevant to this thesis focus on personal garment design practices (McQuillan, Rissanen and Roberts, 2013; Lindqvist, 2015; J. S. Lee, 2016; Y. Lee, 2016; Valle-Noronha, 2017; Sampson, 2018b; Sgro, 2018, 2020; Kim, 2019). While some attempt to make a personal process legible to a broad audience (e.g., Lindqvist, 2015), the majority seek to contextualise a personal practice philosophically (e.g., Y. Lee, 2016; Sampson, 2018a, 2018b). However, within these texts, few provide accounts of touch and felt experience, while some discuss feeling as emotion rather than sensation (e.g., Varcoe, 2016; Valle-Noronha, 2017).

The most relevant autoethnographies to this thesis are Kim (2018), Y.Lee (2016) and Sampson (2018a, 2018b). Kim (2018) discusses the role of tacit knowledge (defined as making experience stored in the body, and particularly the hands) when attempting to translate a calligraphic concept into a garment. Kim mentions a growing awareness of tactile sensations during her study, with some discussion of felt experience (e.g., '*the tension of fabric between my holding fingers*' P445; *I keep touching and stroking the fabric surface, as if reading Braille, to check the front side and the lengthwise grain of the fabric'* P452), but not how this informed the design process. Y. Lee (2016) and Sampson (2018b) focus on discussing the conceptual blurring of boundaries of self and other through physical, hands-on garment making, with Y. Lee discussing a personal practice consisting of hand-making garments without sewing machines. She uses a weaving process instead of conventional seaming, and seaming is extended as a philosophical metaphor throughout her study. Sampson discusses 'cleaving' together and apart of materials, tools and makers. Both studies engage with touch but generally attribute philosophical meanings to it, extending the multimodal proposition that made items carry the semiotic traces of their maker's intent (Kress, 2010; Jewitt, Bezemer and O'Halloran, 2016), in this case, arguing that the maker and garment themselves become entangled in a durational manner. However, unlike the empirical data presented in this thesis, neither study explores how touch and material agencies it enacts practically influence a garment prototyping process.

2.6 Touch and Feeling in Studies of Material Experience

In this section, materials experience and selection studies are reviewed and discussed. These studies focus on the perception of materials by both designers and consumers, exploring the associations, perceptions of value and sometimes the emotions they elicit. Their focus is on materials experience detached from a final 'use context'. However, the process of material experience has been theoretically framed by Giaccardi and Karana (2015) as encompassing sensorial and performative levels, including use and making. Other authors have explored embodied materials experience within the context of textiles selection rather than the use of materials during prototyping (Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016; Petreca *et al*., 2016) but have also explored the potential to digitally support textile selection activities (Petreca *et al*., 2019).

Of primary interest to this thesis are the frameworks for material experience proposed by Haug (2019) and Petreca, Baurley and Bianchi-Berthouze (2015). Both are reviewed in more detail in the following sections (2.6.1 and 2.6.2). In addition, Sgro's attempt to integrate a materials experience perspective with an applied garment design context is discussed (2.6.3).

2.6.1 Haug's Twelve Materials Knowledge Acquisition Types

Haug's (2019) material knowledge acquisition types offer a helpful framework I refer to when discussing the nature of understandings developed through designers' touch practices reported in Chapter 8. Haug provides an overview of materials selection and materials experience literature, arguing that materials are selected to represent particular meanings in a design through their affordances, implying that designs are largely preconceived ideas for which an appropriate material is sought. This is representative of the stance of much materials selection/experience literature. This thesis attempts to understand how material knowledge acquisition types might relate to emergent, materially mediated design development rather than applying pre-conceived design ideas. Haug's matrix of materials knowledge acquisition types is shown in Figure 2.1 below.

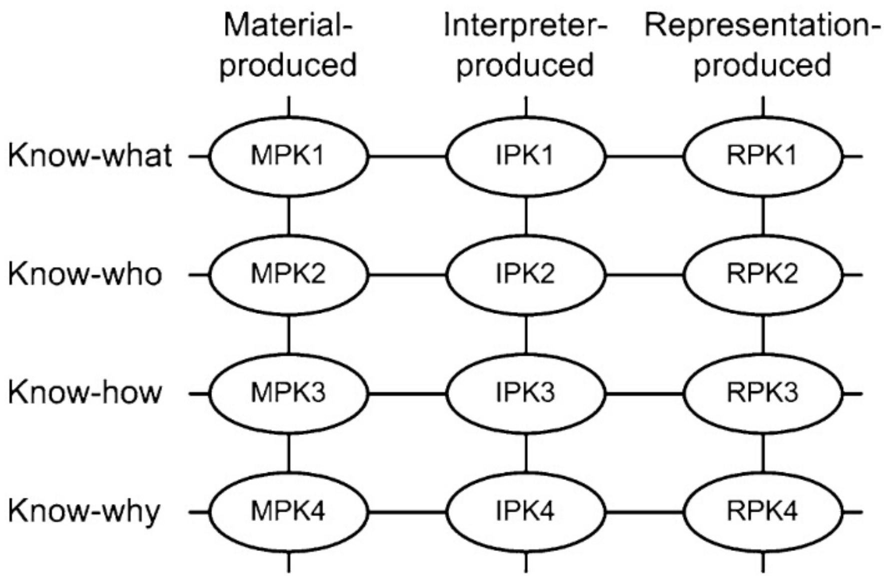

Figure 2.1: Haug (2019: P414) A framework of materials knowledge acquisition types

Haug argues that understandings related to each type of knowledge can vary in how tacit or explicit they may be, further arguing that designers often triangulate between several knowledge acquisition types to build a more complete understanding of materials.

2.6.2 Petreca's Three S' Framework of Tactile Experience in Textile Selection

Across several publications, Petreca and colleagues focus on the ways garment designers touch textiles in the context of 'textile selection' (Atkinson *et al.*, 2013, 2016; Petreca *et al.*, 2013, 2014, 2016; Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016, 2017). This context accounts for the potential changes in pre-determined design ideas derived from material experience when handling textile samples. Yet despite noting that designers attributed liveliness and agency to textile samples (Petreca, Baurley and Bianchi-Berthouze, 2015: P984), this is still contextualised as inspiration rather than an applied, live adaptation of design-in-process based on felt material characteristics during prototyping.

Petreca and colleagues' studies were structured using experimental protocols or the elicitation interview method. Although they provide numerous helpful insights for this thesis (discussed further below), the research was removed from the immediate emplaced context of design activities, particularly prototyping. Only two studies conducted at consecutive textile trade fairs (discussed in Petreca *et al.,* 2014, 2016; Petreca, 2016) provided real-world context, and none accounted for a context of use.

In an important text for this thesis, Petreca, Baurley and Bianchi-Berthouze (2015) propose three tactile phases of the textile selection process: Situating, Simulating and Stimulating. In these phases, three types of touch are classified: Active Hand, Active Tool-Hand and Passive Body:

- Situating is proposed as the initial touch encounter in which designers seek to understand the properties of the textile and how it feels. This understanding comes about 'with the hand' using 'active hand', a concept similar to Ræbild's (2015) 'probing' touch, in which touch is exploratory. Petreca, Baurley and

Bianchi-Berthouze note the types of textile manipulation this relates to, which they link to the textile’s behaviours:

‘Designers performed diverse touch behaviour according to the property they were investigating, e.g., hold by the corner to see how it falls (drape), squeeze and/or drop to feel weight … shake or stroke to feel temperature (warm, cool, fresh, and so on), pull to feel its resistance (weak or strong), touch around the edges to understand size’ (P984)

The authors further propose that situating can take place ‘on me’ (Ræbild’s 2015, design by own body) to understand designers’ felt, bodily reaction to the textile. Here ‘active hand’ or ‘active tool-hand’ (which, rather than probing, shapes the textile for a felt experience, e.g., producing drapes and folds) shape the textile onto a feeling body. Petreca, Baurley and Bianchi-Berthouze argue that full-body engagement is crucial for producing new felt experiences and supporting understandings of what a textile could be made into yet reduce their classification of touch behaviour when experiencing textiles to ‘active hands’ and ‘passive bodies’, proposing bodies as passive scaffolds and recipients. I argue that this negates the possibility of other body parts initiating movements and structuring felt experiences.

Petreca, Baurley and Bianchi-Berthouze note that ‘Situating on me’ always took place *afte*r understanding the textile’s properties was established. Having situated the textile, the authors propose that designers then use touch to 'Simulate' and 'Stimulate', as described below:

- Simulating is discussed as using textiles to enact a garment design concept, for example, placement of a pleat, or pocket, location on the body. In this phase, all three types of touch are used. A movement between attentional focus on the hand structuring the felt experience and the body receiving it is noted during this phase.

- Stimulating is proposed as a process by which the designer's associations with the textile are revealed, mainly through visual (mental images) and verbal metaphors to express hard to convey felt experiences. In this phase, both hands are often actively used in a range of experimental ways to engage with the liveliness of the textile, described as moving to create stimulation after Noë (2004). In doing so, designers create touch gestures and movements related to the metaphors being explored. In this way, the metaphor is reinforced or developed while the designer experiences the qualities of the movement and felt sensation.

I use these phases and touch types to discuss the observed touch practices in the empirical chapters of the thesis, particularly Chapters 7 and 8. Though Petreca (2016) revises her proposed Three S' Tactile Framework to integrate it with the 'Quad Core Textile Selection Model' and eventual sCrIPT Toolkit presented in her PhD thesis, there is significant overlap with the original Three S' model. The 'quad core' model phases are defined as Collect, Interrogate, Project and Transform. The latter three are equated by Petreca to the Three S' framework Situate, Simulate and Stimulate phases, respectively. The Collect phase is also suggested as a form of Stimulating but is primarily concerned with sourcing rather than using and manipulating textiles. For this reason, I reference the earlier originating text in this thesis.

Significantly, Ræbild's 'Tactility and Metaphor' design method card (Ræbild, 2015: P253) supports Petreca, Baurley and Bianchi-Berthouze's (2015) findings on the use of metaphors to describe and share tactile sensations, or preferences, also situating metaphor use in the context of textile selection where an applied context may be imagined. Metaphor use is central to the embodied cognition approaches to design outlined by Lindgaard and Wesselius (2017), particularly their framing of design as attempting to apply and refine a metaphor, or structural pattern, as opposed to a pre-determined, fully formed design (P89). Overall, tactile metaphors appear to be commonly observed when communicating about felt experiences.

Petreca's focus on language, not only in the use of metaphors but also in the verbal 'elicitation interview' method used to attempt to access the phenomenal experience of another person, is potentially limiting. The concept of metaphors expressed through movement is identified as potentially of interest by Petreca, Baurley and Bianchi-Berthouze. However, it is not explored, highlighting the contribution of the inclusion of a multimodal perspective in this thesis.

2.6.3 Sgro's Material Creativity in Garment Design

While Sgro's (2018, 2020) research can be considered autoethnographic, she situates it in the context of materials experience, noting that while a focus on the body in pattern cutting is not uncommon (McQuillan, Rissanen and Roberts, 2013; Lindqvist, 2015), a materials experience approach to pattern cutting is little explored. In a reflection on her practice, Sgro (2020) links material engagement (which she defines as the experience of materials when handled by practitioners) and the affordances it reveals with the creative development of garments in a small designer-maker fashion studio. The concept of 'material creativity' is developed from Sgro's PhD thesis (2018), in which she proposes that a garment designer *'experiences material creativity and spatial creativity when designing and making garments through individual engagement with materials and cutting methods using 2D and 3D imagination'* (P33). Identifying spatial creativity derived from three-dimensional movements and forming processes with materials is notable as it proposes that garment development in three dimensions may be significantly influenced by kinaesthetic experience.

Material creativity in Sgro's work is more specifically described as '*attunement to experience of working with and analysing material affordances, or finding 'potential within the fabric'* (2020: P233). Arguably this is similar in scope to Ræbild's 'probing' and Petreca, Baurley and Bianchi-Berthouze's 'situating'. However, Sgro does not elaborate on *what* this potential informed or *how* it changed her designs. Sgro lists many touch activities that she proposes to reveal thinking through making. She categorises these as 'micro movements between my hands and materials that involve[s] my full perceptive awareness and aesthetic judgment*'* (2018: P245). However, despite the extensive list of touches, the *felt* experience and links between what is perceived and Sgro's aesthetic judgement are not discussed or revealed through the accompanying visuals. Similarly to Petreca, Baurley and Bianchi Berthouze, Sgro (2018) identifies metaphor as a means to attune to tacit understandings of touch. Yet, in this case, metaphor is used to focus and develop a personal thought process relating to felt experience rather than to communicate about touch and feel.

Sgro's re-framing of pattern cutting as a form of materials experience is significant for this thesis as a reflection of the materially mediated nature of pattern cutting. Yet, Sgro does not fully elaborate on how this informs garment prototyping. Material and spatial creativity could be considered similar to more detailed accounts of developing form through engagement with materials, such as those proposed by Malafouris and Ingold. See Chapter 3 for further details.

2.7 Digital Touch Research for Garment Design

This section reviews literature which proposes novel digital touch technologies to support garment prototyping or touch activities in relevant adjacent disciplines. As this thesis makes recommendations for the development of digital touch tools and interfaces relevant to garment development, it is essential to understand the current state of the art in this area and explore the limitations of prior research. This review is divided into studies proposing New (Touch) Interactions (2.7.1) and those which propose digital solutions Supporting Existing Practices (2.7.2). McCullough's 'Abstracting Craft' (1996) is referenced throughout this thesis and provides a rare example of an attempt to theoretically account for the process of digitising craft disciplines, considering both support for established practices and the creation of new ones through processes of abstraction from material manipulation. Written at a time of early digitisation of visual design, many of McCullough's arguments seem somewhat utopian, proposing a speculative re-coupling of creativity and production re-uniting the mental and manual. Despite roughly fifteen years of technological development, the promises of digitisation discussed by McCullough are yet to be realised in the garment industries.

Commercially available digital tools for garment development, such as industry standards Gerber Accumark PDS (Gerber Technology, 2021) and Lectra Modaris (Lectra, 2021), along with others noted by Berthouzoz *et al.* (2013), are currently limited to the visual modality and targeted to commercial product development, rather than the early phases of creative design ideation and experimentation. Though most such software packages have 3D rendering options to virtually prototype garments, these are still based on the mathematical and geometric process of pattern cutting.

2.7.1 New (Touch) Interactions

Textile visualisation for 3D visual software has a long history of development (Berthouzoz *et al.*, 2013), including foundational textile physics modelling research by Magnenat-Thalmann and colleagues (Volino, Courchesne and Magnenat-

Thalmann, 1995; Volino and Magnenat-Thalmann, 2000), who extended their studies into communicating tactile qualities of textiles via force feedback devices (Magnenat-Thalmann *et al.*, 2007; Magnenat-Thalmann and Bonanni, 2008). However, these were extremely cumbersome and likely offered little realism in terms of tactile sensation. In a rare example of a tangible interface for garment development, Wibowo *et al.* (2012) explore the possibility of using a physical tailor's dummy as a base for the development of 3D garment shapes. Dines and Biddulph (2019) extend this study using contemporary 3D drawing applications such as Google Tilt Brush (Google, no date) or Pixologic Zbrush (Pixologic, 2018) with a tailor's dummy and explore the efficacy of a variety of VR and AR technologies to mediate the encounter. They argue that tangible interfaces or 'haptic metrology' (in this case, the haptic relation to the tailor's dummy) for garment digitisation and design move beyond the current state of the art in 'no touch' interfaces and allow more seamless integration of physical and digital practices.

Importantly these studies do not work with existing practices; instead, they create new ones using specifically adapted (Wibowo *et al.*, 2012) or standard VR interface tools (Dines and Biddulph, 2019). While this may engage novice garment makers (Wibowo *et al.'s* target audience), it does not engage with or communicate traditional physical making skills. Inui, Mesuda and Horiba (2013) report a Kinect-based gestural interface for manipulating virtual cloth with hand gestures rather than tools. However, the authors focus on cloth modelling and collision detection rather than use in context.

Most of the interactions described above rely on gesture and movement, in line with the focus of much of the previously discussed literature on kinaesthetic experience. However, the tools used to interact with these systems limit their degree of realism, and the studies do not explore the possible impact of introducing novel interface tools. The introduction of novel types of digital touch may be seen as a way in which the digital is detracting from designers' traditional touch practices. This thesis seeks to document garment designers' existing touch practices and understand how to support them with digital touch technologies to address this issue. Additionally, questioning whether new touch practices may actually be helpful in this context?

2.7.2 Supporting Existing Practices

As this thesis focuses on documenting designers' touch practices and exploring the potential to digitally support them, this section reviews studies that aim to *support existing* practices with digital tools.

To capture and preserve touch practices during hand-making activities as a resource for learning and skills transfer, Nakagaki and Kakehi (2012) use a sewing needle and conductive textile to track the location and angle of the needle as it enters and exits the textile. This is recorded in real-time for sharing or archiving of embroidery activity so that the user can gain feedback. Similarly, (Schoemann and Nitsche, 2017) use a needle and conductive textile as a musical interface, aiming to support the development of rhythmic practices in hand sewing. However, it is unknown whether movement and velocity information or needle angle would still be of value as a learning tool when not accompanied by the guidance of an expert. Hiyama *et al.*

(2011) argue that visual images or verbal guidance alone are not enough to learn an artisan skill, particularly in terms of the artisan's movements (their study focused on traditional Japanese paper making) and propose a system of experience capture and replay using EMG sensors, stereoscopic video, and binaural sound. When the experience was replayed, vibration motors in corresponding positions to the EMG sensors were activated based on the recorded muscle activation levels. Their study indicated that for nine novice papermakers, the use of a wearable stereoscopic display and vibration feedback increased their ability to replicate the movements of a master artisan. An additional semi-expert participant noted being able to observe differences between their style and that of the artisan whose process was captured. This raises the question of whether individual approaches within particular craft techniques can be developed through technology-based learning.

Additionally, a real-time simulation may not be adequate as a learning tool. Gowlland (2015) notes that when being trained in a craft skill (studio pottery) by a master artisan, the master draws the learner's attention to both temporality and materiality, speeding up and slowing down processes to draw the learner's attention, rather than to the rhythm they would follow when working alone. In addition, McCullough argues that control over the speed of a craft process is key to designer/makers' active participation.

It is interesting to note that the studies reported in this section are not concerned with capturing the sensations experienced by the artisans, including highly pertinent tactile features such as material textures and pressure. While Schoemann and

Nitsche (2017) capture the artisan's reflections and insights on their making processes, their purpose was not to inform a creative interface for design or artefact development. Instead, the studies proposed interfaces for learning movements and bodily actions. Where tactile feedback was included, it was used to draw attention to the muscles employed rather than a particular sensation. Therefore, movement could be considered the focus of most of the interfaces described above rather than the sensations they produce.

Petreca, Baurley and Bianchi-Berthouze observe that existing touchscreen and tactile array devices do not support *'free sensorimotor experience' … 'natural body movement and touch behaviour'* (2015: P986) or support full-body experience instead they only deliver sensation to the fingers. Again, their focus is on touch movements rather than sensations. Petreca *et al.* (2016) and Petreca *et al.* (2019) further explore the potential of digital tools to allow designers to reflect on their touch experiences. The 2016 study used 5 x 5 cm sensors that could be inserted into fabric pockets to visualise the fingertip's pressure on the fabric. Designers considered this valuable in visualising how they touched textiles, both in comparison to other designers and to reveal more about their own, often overlooked behaviours, heightening and developing their tactile awareness during an encounter they considered multisensory. This study has obvious limitations given the limited tactile interaction afforded by the small sensor surface. This could not support the authors' observations that felt experience encompasses movement and kinaesthetic elements or their proposal that full-body engagement with a textile or digital interface was desirable (Petreca, Baurley and Bianchi-Berthouze, 2015). Participating designers in Petreca *et al.* (2016) expressed a desire to see textiles in diverse, applied contexts, particularly on the body, which the authors propose is a means to access tacit proprioceptive understandings. This supports the argument against studies of material experience removed from a design or product context.

Petreca *et al*. (2019) report two further touch sensing textile designs, the 'Haptic Sleeve' and the 'Hyper Textile', which address some limitations discussed above. These include exploring whether a viewer could understand how a fabric feels by observing someone else manipulating it and addressing the limitations of small-scale touch sensing textile interfaces with a large-scale interactive textile installation.

Petreca (2017), Petreca *et al.* (2019), and Schoemann and Nitsche (2017) argue that to integrate skilled design and making practices with tangible interfaces, it is necessary to move beyond the utilitarian replication of an experience into something more playful. Both in response to current technical limitations and to engage designers' creativity. Yet while this approach undoubtedly supports creativity, it may modulate rather than support and preserve existing felt understandings. Indeed, Smitheram (2016) considers the 'hand of the digital' through a practice-based digital design project. She approaches this as discovering the affordances or agencies enacted during digital processes, similarly to handling a material to discover its potential. Nimkulrat (2019) takes a similar approach when exploring means to translate her textile knotting practice into 3D and VR environments for 3D printed outcomes, learning the digital as a new material in a similar process to that of developing a skilled digital practice suggested by McCullough. The action and movement focus of the studies reviewed in this section does not capture the felt experience of materials, which would allow designers to discover their potential. Therefore, they support only one aspect of the touch experience with materials. This highlights a gap in current literature, indicating the need for studies such as this thesis, which link movement to felt sensation when touching materials, particularly when interacting with technology prototypes. To address the focus of much of the reviewed literature on touch actions and movements, kinaesthetic experience and enskillment are discussed in the following section.

2.8 Kinaesthesia: Feeling Beyond the Tactile

Across the reviewed literature, a focus on movement and touch actions is common, indicating the significance of kinaesthetic experience to garment prototyping processes. As such, it is necessary for this thesis to adopt a definition and theoretical understanding of kinaesthetic experience.

Surface touch is often categorised as tactile or cutaneous. For example, Paterson (2007) proposes that both terms relate to the skin as a sense organ. Yet tactile sensation refers explicitly to the experience of pressure on the skin rather than temperature or pain. While this accounts for the sense of something moving against the skin, it does not account for how we sense body movement. As one of the ‘internal’ or somatic senses that are considered forms of touch and feeling, kinaesthesia is not perceived by specific organs or receptors, perhaps contributing to the difficulty of isolating and describing kinaesthetic experiences. As such, the description of kinaesthetic experience is often reduced to the recounting of actions, as noted in the literature. Despite early constructions of kinaesthesia as ‘muscular sense’ (Paterson 2021), it is a complex combination of feedback from sensory receptors in the muscles and skin. Though the term is contentious for some theorists (see 7.2), it is a *sensorimotor* experience.

Much of the literature in this review focuses on surface touch (the sensory) *or* kinaesthetic experience (the motoric) and rarely both. Attempting to account for both aspects of felt experience holistically is a significant contribution of this thesis. While Paterson (2007) proposes that proprioception includes kinaesthetic, cutaneous and vestibular sensations, these are taken holistically to account for the state of the static body rather than a body in action. For example, during animate garment prototyping activities, which will produce kinaesthetic sensations. Therefore, it is essential to distinguish kinaesthesia from proprioception and the vestibular sense related to balance.

2.9 Touch as Tacit

In this section, I problematise a significant theme of the literature: the construction of touch practices and felt experience as tacit. I argue that understanding touch as tacit is problematic and limiting for research into felt experience. In this thesis, I seek to move beyond such accounts. I discuss this in the following sections: Recourse to the ‘Tacit’: a tendency to dismiss touch as impossible to communicate through language and thus not explore it in detail (2.9.1) and Contested Understandings of the Tacit: the varied understandings of the term tacit which make its use problematic (2.9.2).

2.9.1 Recourse to the Tacit

Almond (2016) recounts an incident at a garment pattern cutting conference that is unfortunately reflective of much of the literature on garment design pedagogy and practice:

‘The delegate questioned the validity of the research and other papers delivered at the conference, claiming the majority of presentations only served to describe interesting ideas and discussions of new methods and techniques in pattern cutting.’ (Almond, 2016: P171)

Almond’s response to the above question emphasises the embodied and tacit nature of understandings gained through practice and touch. He argues that because these understandings are tacit, they cannot be communicated or reported. Yet, in an era where communication, knowing and telling are acknowledged as multimodal and more than merely linguistic, arguably, we can move beyond Polanyi’s (2009) concept of tacit knowledge as what we know but cannot tell. I argue that this naming of processes not easily verbalised has led to diminished scholarly attention to them and a harmful dismissal of the ‘tacit’ as impossible to explore. Indeed, Polanyi’s examples of instances of tacit knowing often relate to subconscious reactions rather than non-linguistic understandings.

Finn (2010) similarly argues the limitations of Polanyi's construction of tacit knowledge, and as I share this reading of Polanyi, I support the sceptical delegate Almond reports. I propose that greater academic depth in explorations of garment making and touch is not only possible but vital to either flesh out or counter unsupported narratives around the tactile. This thesis argues that a sustained empirical focus is required to reveal and *tell* this knowledge and makes the case that it is possible to do so.

2.9.2 Contested Understandings of the Tacit

Describing understandings as tacit raises the question of what this term means. Polanyi's (2009) 'proximal term' of tacit knowing includes movements and gestures, which Polanyi argues are only understood in the context of the task they accomplish (the distal term of tacit knowing). Yet if we do not recognise these movements as representative of skilled understandings when out of context, how do designers share them? Polanyi labels this the semantic aspect of tacit knowing, in which we attach meaning derived from the distal term to otherwise meaningless touch sensation. He argues that we overlook the particulars of an act of sensing to attend to their collective meaning. Yet if this is so, how do designers and makers understand and communicate the significance of nuances of touch?

Lisewski's (2018) ethnographic study of educator/practitioners' 'practice-based knowledge' is helpful in its discussion of tacit knowledge, highlighting and discussing the lack of a consensus definition. Lisewski proposes that his data demonstrates that educator/practitioners know that they have tacit knowledge, referring to unconscious and non-rational understandings (P145); however, none of the reported vignettes discusses touch. Lisewski focuses on Polanyi and Prosch's (1975) concept of 'indwelling', which bears many similarities to Swindells and Almond's (2016) discussion of relationally inhabiting non-humans. Further arguing that Polanyi discusses *knowing* as a process through which understandings are implicit in our actions and responses to the material world, rather than static *knowledge* to be stored and recalled (P50). However, this semantic distinction is contradicted by Lisewski's use of the terms and his quotes of Polanyi to support his arguments. The idea of tacit knowledge as 'knowing in action' corresponds with (Schon, 1991) and readings of tacit knowledge as only accessible through practice. If tacit knowledge is only accessible through practice, then I question how practitioners can communicate such understandings beyond the context of prototyping together. Yet understandings are clearly not always gained through apprenticeship or re-discovered by each new generation of designers and makers.

Kim (2019: P444) cites the Cambridge Dictionary definition of tacit knowledge as knowledge which is not taught but derived from personal experience and emphasises the need for practice through repetition of movements and techniques. Osmond (2021) similarly defines tacit knowledge as 'beyond language' and only possible to express through making *practice*, drawing on her reflective practice and tacit knowledge in her analysis. This focus on practice seemingly negates the possibility for non-verbal communication to share understandings out of context. Sgro shares the framing of 'practical knowledge that can be known but not expressed in words' (2018: P31). At times, she appears to conflate tacit understandings with habits that have become routine but, in many cases, can be expressed through language, e.g., the notion of acceptable garment forms based on normative bodies and traditional garment typologies (P120). In other instances, Sgro's 'tacit' judgments relate to personal aesthetic understanding. A feeling of 'rightness' in the design is similar to the use of the term 'feeling' by Lindgaard and Wesselius (2017).

Haug's proposed framework of materials knowledge acquisition also discusses tacit and explicit knowledge. However, the paper does not define these terms. It can be inferred from the surrounding language used that Haug considers explicit knowledge to be that which can be described and tacit knowledge that which is understood. This appears to correspond with the idea of tacit knowledge being non-linguistic and, therefore, uncommunicable. Taking a similar stance on the role of language, Ræbild (2014, 2015) proposes that because her participants could not verbally discuss and did not recall in interviews, some of the felt and bodily design methods that she identifies, these methods must be tacit. This is similar to Petreca's (2016) usage when discussing her participants' unspoken or unknown textile selection methods.

Regarding the possibility of communicating tacit knowledge through other modes than language, Sgro states that *'tacit knowing formed through material engagement is typically hard to articulate… it is easier to show than to put into words'* (Sgro, 2020: P238). Expanding upon this point, Petreca (2017) notes: *'conversations about, and with materials … are also heavily reliant on tacit knowledge, that is the use of physical things goes beyond verbal communication, as we can show someone how a* *fabric drapes, but the manner in which we feel and appraise tactile properties is automatic and unrecognised.'* (P193). This articulation offers an expanded understanding of tacit knowledge as possible to communicate through non-linguistic means.

Lisewski (2018: P50) identifies an important distinction between stances on the understanding of tacit knowledge in readings of Polanyi. Lisewski proposes one stance argues tacit knowledge is not reducible to explicit knowledge. Thus, it cannot be communicated but is a form of 'knowing how' accompanying an explicit 'knowing that'. The other stance argues that tacit knowledge is not expressible through language. Lisewski (2018) attempts to navigate this issue by referring to 'sensible knowledge' after Strati as multisensory and aesthetically informed understandings.

Following Sgro and Petreca, in this thesis, I argue that *showing* how to manipulate and touch is a mode of 'telling' and making an understanding explicit rather than tacit.

2.10 Conclusion

The literature discussed in this chapter highlights the shared acknowledgement of the significance of touch and felt experience in garment design and making. Yet it also demonstrates the current lack of specific investigation into the *nature* of these experiences and their exact role in a design development process. Overall, the literature points toward the significance of movement and kinaesthetic sense during garment prototyping but gives little insight into the perceived sensations designers experience. There is also a strong focus on affective touch experience and a reliance on the ill-defined term tacit. As this review has shown, these have taken precedence over in-depth empirical studies of sensation.

The literature exposes a gap in research on felt experience, specifically the emplaced, lived experience of touch during garment designers' daily activities. This highlights the novelty of the contribution of this thesis in exploring the touch landscape of garment design prototyping in the emplaced context of designers' studios. Also, the literature identifies the lack of studies exploring designers' practices across both educational and professional contexts, a further contribution of this thesis.

While the literature demonstrates concerns that the removal of hands-on experience with materials may prove detrimental to designer'' competencies, it also shows that the touch practices of designers working with digital technologies have yet to be documented. Therefore, a more critical exploration of garment designers' touch across a range of digital and physical practices is a timely contribution of the thesis. Further, this empirical study will provide a more rigorous grounding from which to propose how the observed touch practices might be supported with digital touch technology.

Finally, the literature demonstrates a common theoretical grounding: prioritising the experiencing human subject, despite frequently acknowledging the liveliness and influence of non-humans. This indicates an opportunity for this thesis to more fully account for the roles of non-human materials, tools, and emplaced context using a New Materialist influenced philosophical frame. In the following chapter, I outline the work of significant Posthuman and New Materialist authors and propose their most relevant theoretical concepts for understanding touch and felt experience in garment prototyping.

CHAPTER 3 – THEORETICAL FRAMEWORK: WHY AND HOW NEW MATERIALISM MATTERS

3.1 Introduction

Van Maanen (1988) recommends that before conducting ethnographic research, the ethnographer familiarises themselves with theoretical stances which may inform their interpretation of the culture to be studied. While this approach appears to advocate the selection of a single epistemological and interpretive viewpoint, in this thesis, New Materialism and diverse theories from Barad (2007), Hickey-Moody and Page (2016) and Ingold (2013) inform this theoretical background, allowing me to explore viewpoints on non-human agency, design, and learning which could be applied to my ethnographic analysis.

This chapter sets out and discusses these varied theoretical stances on material agency. The New Materialist influenced theoretical stance adopted for the study of touch practices in this thesis allows a *more balanced* focus on humans (designers, makers) and their engagements with non-human things (fabrics, scissors, pins, sewing machines) during the process of prototyping a garment. In doing so it attends to the constitutive entanglement of the social and the material. It also frames sensing beyond traditionally understood body boundaries differently to phenomenological accounts, allowing for the perception of the body and felt sensation to be experienced more mutably from moment to moment and in a wider diffuse range of material things.

This chapter first introduces and outlines key concepts in Posthumanism and New Materialism (3.2), next problematising the adoption of a New Materialist theoretical stance in conversation with the ethnographic methods of this thesis (3.3) arguing why a combination of theory and method which for some may seem contradictory, brings a novel approach to the study of touch. In 3.4 I discuss the construction of touch and feeling in Phenomenology (3.4.1) and New Materialism (3.4.2). In 3.5 I propose a means of working across the two approaches. Next, I discuss questions of non-human agency which are foregrounded by a New Materialist informed theoretical frame and are pertinent to the analysis of the ethnographic data (3.6). These analytical perspectives include Agencies or Affordances of Made Things (3.6.1), Hylomorphism: Agency in Design (3.6.2), Transducers: Intuiting and Engaging with Agency (or Animacy) (3.6.3) and Pedagogy of Matter: Non-Human Agency in Meaning-Making / Learning (3.6.4). In 3.7 I conclude by recapping the key theoretical concepts I adopt in this thesis and the framework in which they are operationalised.

3.2 Key Concepts in Posthumanism and New Materialism

To situate the discussion in this chapter I first introduce and define key theoretical concepts for this thesis.

Vibrance, Animacy or Flow of Matter

New Materialism' prioritises the agentive nature of all matter, considering humans as matter, with no greater ontological priority than any other matter, including that which is conventionally perceived as inanimate. From this stance, all matter is considered animate, 'vibrant' (Bennett, 2010), and understood as entangled in a constant unfixed state of ‘becoming’ (Barad, 2007), or flow (Ingold, 2013). These understandings are grounded in the concept of one uniform matter after Spinoza.

Things

While the terms used to describe agentive non-human entities vary among scholars, in this thesis I refer to them as things. Things are generally constructed as unfixed and unbounded entities whose animacy is accessible by other things (including humans) and so can be shaped through agencies enacted in their entanglement (Malafouris, 2013), whereas actants are prefigured with forms of agency (Latour, 2005) and objects are inaccessible, finished, and fixed (Ingold, 2013). The thing is a gathering (or inviting), not a locking out, hence Malafouris’ (2014, 2020) use of the term ‘thinging’ or creative thinging, as a form of thinking with things. Ingold and Malafouris’ notion of things appears to concur with the affective and pedagogic nature of matter proposed by Hickey-Moody (2009; Hickey-Moody and Page, 2016).

Phenomena (Barad, 2007)

The smallest units of Barad’s Agential Realist theory. A phenomenon is an intra-action within uniform matter (as opposed to an inter-action of discrete units of matter) of a thing and the ‘measuring agencies’ such as touch, or my ethnographic observation, which seek to perceive it. Neither phenomena, things, nor measuring agencies pre-exist the intra-action. Therefore, the way we understand and the thing we understand are inseparable. A highly appropriate conceptualisation of touch that relies on the act of touching to create both meanings and a sense of toucher and touched. Due to this inseparability of matter and meaning Barad considers it impossible to separate ontology and epistemology, coining the term ‘onto-epistemology’ and proposing that ethics is also inherently bound up in this relationship. A stance which is sometimes disputed (Rekret, 2016)

Agential Cuts (Barad, 2007)

Agential cuts enact what is bounded within, or excluded from, a phenomenon at the moment of intra-action. They can be considered different ways of conceptualising a phenomenon, particularly concerning the agencies performed within it. Agential cuts can cut things together and apart to create different, diffractive readings of the phenomenon.

Diffraction (Haraway, 1996; Barad, 2007, 2014) – The term diffraction is derived from the diffraction of waveforms in physics. Waves are disrupted and create new patterns when encountering obstacles or other waves. At a quantum level, this process is also observed in matter. For this reason, it is a significant concept relating to the entanglement of matter and meaning in Barad’s Agential Realism. Diffraction is methodologically applied in feminist theory as a mode of thought which attends to difference. Therefore, a diffractive analysis is a disruptive process of reading *through* and *intermingling* a variety of differing perspectives on the phenomena being studied, as opposed to interpreting it through a singular theoretical lens. The intention is that when diffracted together, new and unexpected understandings emerge from existing positions and perspectives which are traditionally unaccounted for may emerge. It sits in opposition to reflection: the mirroring of an existing position.

In this thesis, diffraction is a key methodological approach applied both to my attention to ethnographic sites and to the data analysis, through exploration and intermingling of different theories of agency in the design and making process (see 3.6 and Chapter 4).

3.3 Problematising New Materialism in Dialogue with Ethnography

This thesis adopts a theoretical perspective seemingly at odds with its methods: Posthumanism is a broad category, under the banner of which sit diverse thinkers whose common ontological commitment is a de-centring from the prioritisation of human perspectives and experience in philosophical thought, along with an expansion and blurring of the understanding of what it is to be human. New Materialism is one such theoretical perspective. In contrast, ethnography, by its very nature is structured by a human observer. In many interpretations, this kind of first-person human-centred research is inherently phenomenological as it recounts human (sensory) experience. This is particularly true for sensory ethnography or a study of touch. For this reason, the alignment of New Materialism and ethnography is problematic. Additionally, New Materialism seeks to flatten ontologies which prioritise particular people and things over each other and so re-balance anthropocentric perspectives. It is reasonable to ask how this might be achieved when using methods which document human perspectives through a single human interpreter.

Two broad schools of thought exist within Posthumanism and adjacent theories (Bennett, 2016; Wilson, 2018). These are broadly categorised as ‘Vital Materialism’ –

New Materialism and ‘the world with us’ (e.g., Barad, 2007) or ‘Eliminative Materialism’–- ‘the world without us’ (e.g., Bogost, 2012; Morton, 2013; Harman, 2016), where ‘us’ refers to human subjects. The inherent limitation of eliminative accounts is that they are impossible to research or truly conceptualise. To be human makes it impossible to ‘think like a brick’ (Bennett, 2016), no matter how hard we try to abandon our preconceived ideas and hierarchies. Indeed Bogost (2012), while offering creative methods to attempt to empathise with the experiences of things, still notes that these are limited and we will never truly attain an ‘alien phenomenology’. Therefore, this thesis takes a vital materialist approach. Vital approaches advocate for *flatter* ontologies and for researchers as an entangled part of the material world to attend to the more than human, while acknowledging that humans as a research apparatus (Barad, 2007), or part of one, inherently structure what is observed and deemed significant to some degree. In this way, the researcher’s positionality must be acknowledged in a similar way to more interventionist forms of ethnography, such as Sensory Ethnography (Pink, 2015). Yet while in ethnography it is conventional to acknowledge the influence of the researcher on other humans and their structuring of a research encounter, in a New Materialist informed research encounter all material things rendered present during the act of observation must be considered as structuring the encounter. In doing so the socio-material entanglements – connections between the traditionally separated spheres of the social (human) and the material world which mutually structure and constitute one another – can be explored.

Contra to the vital materialist stance of this thesis, understandings of Posthumanism which construct it as completely incompatible with humans as interpreters of experience can derive from 'eliminative' (Bennett, 2016) stances mentioned above. In doing so they deny research in which humans attempt to explore differing perspectives on their material entanglement, moving themselves away from the analytical focus of encounters, as not sufficiently fulfilling the aim of decentring from the human. In relation to this tension, ethnographic studies with a New Materialist focus, along with New Materialist fashion studies often explore animals and the non-human (Parker, 2018; Vänskä, 2018; Smitheram and Joseph, 2019, 2020), or the role of the digital (Joseph, 2017; Smelik, 2018, 2020) as their primary focus. This approach avoids the possible contradiction of focussing on human experience, yet these studies still rely on the human interpreter representing the more than human.

Previous New Materialist studies in a garment design and prototyping context have focused on the researcher's reflections on finished garments and studio visits, without acknowledging the problematic nature of this theoretical and methodological contrast. Indeed without considering the ontological prioritisation of the creations of particular famous designers, whose work is held in museum archives (Toussaint and Smelik, 2017; Smelik, 2018, 2020). In the context of this thesis, the reintroduction of the significance of matter and the non-human is key to exposing what is under-researched and unarticulated in the context of garment prototyping. The deflection of attention away from the 'superstar designer', or master artisan inherent in this stance is also timely.

Sampson (2018b) and Y. Lee's (2016) autoethnographic methodologies incorporate touch sensation to investigate the experience of making and wearing garments, noting the entanglement of the wearer and the worn. In particular, the traces left in a garment by its creator and vice versa. A posthuman reading of Pye's (1995) 'workmanship of risk'. Y. Lee (2016) uses the analogy of seaming, while (Sampson, 2018b) considers the maker (herself) as a third party to this relation, exploring the entanglement, or cleaving together and apart, of maker, tools and garment through the lens of phenomenology and body schema after Merleau-Ponty (2002). Despite presenting new materialist readings of her practice, Sampson's (2018b) location of her work in the phenomenological tradition again presents a possible contradiction in the ontological positioning of consciousness and the human. In particular the use of the phenomenologically perceived body schema. Despite the theoretical relevance of the text, Sampson's focus is on the personal garment-wearer-maker relationship (also explored in sensory fashion studies such as Chong Kwan, 2016, 2020 and Robinson, 2018, 2019) rather than the understandings and meaning-making that inform and come about during the development of a garment.

In attempting to bridge ethnographic practice and posthuman theory Giaccardi *et al.*, (2016) propose the use of automated data capture from the perspective of a non-human thing, to attempt to understand its life beyond human, phenomenological attention. In such studies, they argue that non-human temporalities are critical in differently conceptualising the life of a thing and moving away from interactionism. Yet the use of thing-centred methods is still a human interpretive endeavour and acknowledged as such. If New Materialist research is reliant on human interpreters already, then I propose that while acknowledging this problematic contradiction, it can be applied to human perceptual experience as a means of exploring which non-human things structure it and how they do so. The difficulty in studying touch is that it is generally considered a moment of interaction (or intra-action), rather than durational. A thing ethnography of touch may reveal when something is touched and how often, but long-term temporal data, beyond human phenomenological timeframes, would say little about the experience.

3.4 Touch and Feeling in Phenomenology and New Materialism

I argue that at an ontological level, there is greater interplay and messiness between humanist and posthuman stances than may be expected. In relation to this thesis, both invite reflection on the more than human nature of the senses, though from differing stances.

3.4.1 The Body, Touch and Sensing in Phenomenology

While phenomenological accounts do allow for the roles of things and emplaced environment in human conscious experience, the sensorium and individual senses are prefigured and, in many cases ascribed demarcated boundaries. McGregor (2020) proposes that *'Traditionally, phenomenology is concerned with the moments when the (bounded, singular) human conscious examines the (external, stable, waiting) phenomenon, and brackets out all that is not "essential" to the phenomenon, so something "essential" about the world can be "revealed."'* P508. This indicates an understanding of the posthuman and the humanist traditions as oppositional due to contrasting ideas of what is bounded and stable (bodies, material and that which we perceive), or unfixed and relationally constituted. In addition, phenomenology is constructed as primarily focussing attention on perceptions, in opposition to the material things that might inform them, which are foregrounded by New Materialism. In this frame, I argue there is an opportunity for Phenomenology and New Materialism to come into dialogue, in that it is important to attend to the material world, as well as our perceptions of it. In a New Materialist reading fundamentally the two are inseparable. For this reason, considering touch and felt sensation as experienced by humans, in conjunction with attending to the material contexts which structure it, but may sit outside a perceptual field, bridges the interests of the two positions. In addition, understanding the touching body and that being touched as not being prefigured, but instead emerging relationally only when touch is attended to, invites consideration of touch as more than a product of particular body parts and sensory receptors coming in contact with fixed external objects with defined qualities.

In proposing a dialogue between phenomenology and New Materialism, McGregor does not discuss the work of Merleau-Ponty (2002). Merleau-Ponty's discussions of feeling beyond the body acknowledge the body as a collection of possibilities for experiencing the world, rather than a thing: depending on fields in which we perceive, extended bodies through things we wear and manipulate, and the influence of lacunae (things which we are aware of, but which have not influenced our perception) on sensing. Nonetheless, Merleau-Ponty primarily focuses on what makes the world *present to humans.* Additionally, he frames bodily extension and extended sensing as bound up in the body schema, a fixed and prefigured sense of the bounded human body, adopted from Head and Holmes (Paterson, 2021). It is through a personally defined schema, an unconscious understanding of the body's perceived limits and spatial placement, that Merleau-Ponty argues we can understand possible actions and movements (motor intentionality), and attend to, and make use of, bodily *extensions* which our sensorium can be expanded to inhabit. For example, Merleau-Ponty's well-known example of a blind person sensing through a cane. This construction serves to pre-figure the sense of self so that it can be considered in relation to the other, creating a subject and object, despite the perception that we may be experiencing felt sensation an object which participates in the act of sensing.

3.4.2 The Body, Touch and Sensing in New Materialism

In New Materialist accounts of touch, the body, tools, and senses all emerge in the moment and are unfixed (relationally performed in the moments of specific intra-actions). There is no pre-figured body with no learned schema or boundaries, or defined sense of touch, thus allowing the experience of both to be mutable. In Barad's (2012) treatise on touch, they argue that through touch we can consider ourselves and the non-human, material world to be overlapping and indistinct. We inherently *are* the other and vice versa. This allows entanglements to be considered among all the things enacted in the phenomena of touch, not only those with physical meeting points. Through these diffuse entanglements, we can experience sensation in unbounded, mutable bodies which do not need to conform to an established schema. Feeling can be reconfigured between different moments of observation.

A question emerging from arguments against fixed understandings of body boundaries, is how kinaesthesia emerges if not through the cognitive definition of an established body schema? I argue that in a posthuman sensorium, sensing matter registers the flows and movements within it. This can account for the influence of a lively medium (e.g. air, water) as well as the human body moving within it and the things it moves with (Ingold, 2013), in collectively enacting momentary agencies which create and structure kinaesthetic experience. These may shift and change from one moment of observation to the next, as sensation and the body boundary inhabit different parts of a material entanglement.

Here the metaphor of entanglement serves to highlight another issue of considering bodies as discrete entities, which can be extended or augmented. An extension of the body into an other implies the coming together of two threads. They can be entwined but will always be relatively simple to separate. An entanglement of threads is a more complex form and less easily deconstructed. This thesis proposes this as a useful metaphor for the possibility of sensing in and through the non-human world. In addition, the irregular structure of an entanglement reflects the mutability of the sensorium at any moment of observation. If we approach tangled threads from one perspective, or another the perceived character of the entanglement will change in a way that it would not in a regularly woven fabric or a twined cord.

While Sensory Ethnography (Pink, 2015) is informed by Ingold’s understanding of the senses as holistic, attending to the entanglement between the senses in an emplaced context. It does not take this further step into considering sensory experience as entangled with, and potentially moving into the wider material world. This thesis demonstrates why such a framing is relevant in Chapter 8.

3.5 Working Across New Materialism and Ethnography

While acknowledging the challenges and tensions generated by combining New Materialist theory and ethnographic method to explore the senses, I propose that these are productive, as a New Materialist perspective brings attention to the role and perception of the other in the oft remarked upon reciprocal nature of touch, during which we touch and are being touched by other things in our wider emplaced context. While the acknowledgement of this duality (or multiplicity) of felt experience is common, touch sensation beyond the body is largely discussed as an *extension* of human consciousness (Merleau-Ponty, 2002), I suggest it should instead be considered an entanglement among matter which is also important to the felt experience. Rather than assuming that the body is extended into a pair of scissors to produce a felt experience of cutting fabric, I argue that the scissors, designer and the fabric they cut, along with their environment all extend into and entangle with one another to produce the felt experience of cutting fabric. Without these material aspects being enacted in the phenomenon of cutting fabric, the felt experience would not be the same.

In this way, the attention to all the material things present during a felt experience invites the consideration of a posthuman sensorium in which we are entangled with and sense in and through non-human things, which are relationally enacted in the phenomenon of touching. The social and the material co-constitute felt experience. Thus, we are entangled with the material world and only perceive discrete elements as present when they are enacted through an observing apparatus. This allows us to contemplate that there may be no ‘end’ to our sensorium, that we may experience feeling not only via things in direct contact with our body but also through the wider material environment. We can consider not only extended forms of feeling but feeling as a condition of socio-material configurations, a key analytical framing for this thesis (see Chapter 8). What we feel may be shaped by factors such as peer direction and behavioural conventions, touch taboos, etc. In a New Materialist reading, these ‘material-discursive forces’ (Barad, 2007) are constitutive not only of how we think about what we feel but the very sensation itself which we perceive in the moment. Always acknowledging that this moment of sensing is a temporary construction and never truly replicable, as material and social conditions are constantly in flux.

Moment-by-moment attention to emplaced and contextual factors can be read as complementary to ethnographic attention to context, however, the interpretation is from a human viewpoint. While ethnography seeks to account for the wider context of the people an ethnographer observes, it is rare to find an ethnography which gives such significant attention to the non-human. Through the shift in onto-epistemological emphasis toward attending to the non-human in balance with designers, this thesis attends further to the material world. While still a human interpretive act, it is an aim of this thesis to nudge such interpretations away from a central focus on a human designer, to explore their entanglement with tools and materials as crucial to and constitutive of their felt experience. That is, to attend more closely to the non-human things structuring, mediating and facilitating our sensing, acknowledging that sensing does not end at the boundary of the skin and is more than an extension of the human.

3.6 Questions of Agency

New Materialism not only informs the onto-epistemological stance of this thesis but also contributes key analytical concepts and approaches which are applied to the interpretation of the ethnographic data. These primarily relate to the exploration of different perspectives on agency in a design and making process, moving the analysis beyond a single interpretive stance.

The question of agency matters for this thesis, as it relates to the influence of the non-human on sensory experience, and the understanding commonly reported by garment designers of non-human things such as materials and tools having influence and actions or forms they ‘want’ to take (e.g., Petreca, Baurley and Bianchi-Berthouze, 2015; Sampson, 2018b). Attributing agency to things allows them to take on greater analytical significance in the documentation and discussion of garment designers’ touch practices. It allows things to be conceptualised as more than simply informants of human experience, carriers of human actions and human will, to be seen as having critical influences in structuring human actions and perceptions. Yet garment designers do not conveniently ascribe to one theoretical framing of their engagements with materials and things, often contradicting their assertions or behaviours.

To theorise the observed activities of touch during garment prototyping in a way that remains faithful to designers' understandings of their experiences with non-humans, it is essential first to understand the nuances of New Materialist thinkers' positions on non-human agency so that framings can be applied mutably, as appears to be the case for designers themselves. This 'diffractive analysis' is methodologically described in Chapter 4 and presented in Chapter 10.

In this thesis, I define agency as an emergent, emplaced, contextual ability to change or reconfigure. It is the intra-action of doing and being (Barad, 2007). I argue that within the phenomena of garment prototyping, designers, things, and materials, both raw and man-made, can enact these capacities relationally with another human, thing, or material in an emplaced context. Even a highly experienced garment maker can never fully predict the impact of the behaviours of a material they manipulate, though they can make more educated predictions.

Within New Materialism the ways agency is conceptualised vary. Whether individual things have agency, exert animate forces, whether it is an emergent property of the intra-action of humans and things, or whether it can even be attributed to anything is much debated.

Ingold (2013: P96) critiques Latour and the idea of non-humans possessing agency as *a 'causal attribution of action to an 'agency', of which that action is the effect'*. Ingold argues that ANT supposes that all actors in a network exist independently of their relations and are prefigured (Ingold, 2008; Fowler and Harris, 2015). Whereas, for Ingold, entities are in a constant process of definition by their relations. For example, their correspondence with matter flows in the act of making (Ingold, 2013). Fowler and Harris (2015) critique Ingold's stance as an interpretation of ANT, with many other readings aligning Ingold more closely to ANT than he chooses to.

For Malafouris (2013), agency is an emergent property of the engagements of humans and non-humans; thus, it is non-localised and not situated within humans or materials but in their coming together. The non-localised nature of agency is also present in Barad's theories as forces of intra-action within matter instead of between discrete *interacting* units. Rather than unfolding through a coming together, any perception of localisation and agency is brought about through temporary 'agential cuts' within unfixed matter. Agential cuts temporarily perform and structure the matter within observed phenomena, demonstrating a possibility for the combination or separation of matter into distinct units and presenting a possible reading of their agencies in the observed configuration. All of which are inextricably linked to the act of observing or researching phenomena. Therefore, agencies of things (and things themselves) are inherent to their context, only existing at the point of observation.

Yet if agency is non-localised, how can designers conceptualise specific things such as materials as possessing it (or something like it)? Malafouris also uses concepts such as affordances of materials in conjunction with discussions of 'distributed' or 'non-localised' agency. Malafouris (2014) proposes that although a designer or maker may intuit agency through creative thinging, agency is not the property of the maker but the entangled process of making. Agency is not possessed; it is enacted. The question is not of who or what has agency but of when agency occurs (Malafouris, 2013). Interestingly this is also the approach of Sampson (2018b, 2018a) when discussing worn things. But are simultaneous attributions of agency and affordances to non-humans reconcilable? As discussed in the following section, I propose that they represent a continuum of perceived ability to influence. Further, that the concept of affordance is often used to limit the agency of certain non-human things.

In the following sections, I discuss whether manufactured materials ‘possess’ agency as opposed to raw materials (3.6.1), the question of agency in design processes (3.6.2), transducers and engaging with agency (3.6.3), agency and the nature of touch communication (3.6.4) and non-human agency in pedagogies of matter.

3.6.1 Agencies or Affordances of Made Things

Agency is not evenly attributed to things, even by those who argue that they possess it. In anthropological literature concerning making, attention to examples of knapping flint (Ingold, 2013; Malafouris, 2013), throwing pottery (Malafouris, 2008, 2013, 2020; Gowlland, 2015), or glassblowing (Atkinson, 2013; O’Connor, 2017) can be commonly observed, as practices which engage with highly unstable *raw materials*. Here the reference to raw, rather than processed, or made materials exposes an epistemological priority in existing research, demonstrating that different types of matter are afforded greater or lesser academic significance even in supposedly flatter ontologies. Further, they are considered to possess more agency or demonstrate stronger human will in their formation. McCullough (1996) argues that in exploring form giving during craft processes very little is now truly made by hand and this consideration is perhaps no longer relevant, rather the control of a machine or digital tool should be of equal academic interest. Yet McCullough constructs this argument from a hylomorphic stance in which little agency is afforded to the material being shaped, or the tool. This imbalance in current research exposes the need for studies of engagement with processed or made materials, shaped by agentive tools, that foreground their potential to enact agencies in the live processes of design and making, a key contribution of this thesis.

Some scholars, particularly those of multimodality, argue that fabric as a man-made material will, according to semiotic understandings, bear the traces of the semiotic work of its maker, (Kress, 2010). For example, their intentions and aesthetics when making it and traces of the context in which it was made are imbued in fabric and inform its eventual use, rather than recognising its potential agency enacted when coming together with humans or things. Yet the affordances of a roll of fabric (or any sheet material) are vast and are not always designed or considered. In this thesis, I argue that the degree to which the design of a particular garment can be imbued in a textile is limited and that design forms are emergent through a designer’s felt engagement with the material. Given the prevalence of textiles in our material environment, a textile is just as likely to become upholstery, architecture, an industrial filter, etc. Even within the domain of garments, while heavy wool might suggest outerwear or light silk might suggest lingerie or eveningwear, these are categories of garments. While they may further suggest finishing techniques, the design details cannot be specified by an affordance. These materials may be regarded as a point along a matter flow (Ingold, 2013) or a Chaine d'Operatoire (Gowlland, 2015), which still invites further manipulation and transformation through their materiality.

If their possible use cases cannot be considered during the creation of a made material, then they cannot be said to have been pre-determined by the semiotic work of their designer or maker. It is also fair to say that unconventional materials are a means of generating design novelty in contemporary fashion and costume. Further to this, the appropriation of non-traditional materials (beyond textiles, leathers etc.) in making garments can be seen as another example of working against or beyond what might be considered the traditional affordances of a material. McCullough considers affordances of a material to productively constrain design experimentation, yet this is often actively challenged.

I argue that agency emerges when a designer and a material come together with specific tools in specific material conditions. This entails an array of potential variables that the limited idea of 'designed in' affordances does not account for. This potentiality allows processed and made materials to be equally agentive to raw materials. Malafouris (2013) proposes 'enactive signification' as part of his Material Engagement Theory framework, arguing that material forms are not representative signs of a pre-existing idea but are instead generated through the engagement of the mind with material, constituting novel forms of material culture as they emerge. Similarly, McCullough argues that material affordances give rise to design conventions through the range of possible artefacts they dictate. Yet this does not address the issue of making with a made thing (such as fabric), which in this reading would still signify something once it is made and have specific *created* affordances. Indeed, Malafouris concentrates his research primarily on making with raw materials.

Ingold (2013) argues that materials 'leak', that is to say, they are exchanged across the boundary surfaces that differentiate them from their surrounding mediums. This, he believes, is key to exploring the question (and validity) of material agency. If things are seen as objects–- finished and fixed 'externalist' (Malafouris, 2013) representations of human design in the classic Material Culture conceptualisation–- they cannot interact with their environment. Malafouris and Ingold link understandings of agency to subjectivity, arguing that when understood in this way, agency is often dismissed as impossible for things to possess. Ingold (2013) believes that the body, existing as potentials in a field of forces and energies, is driven by these forces and the exchange with the environment (air, food, etc.), rather than an agency which others would ascribe. Thus, for Ingold, agency negates things from engaging with one another. Yet, in most other readings, the agency enacted in their coming together allows things to act on and with one another. In this thesis, I choose the latter reading rather than rejecting agency.

3.6.2 Hylomorphism: Agency in Design

The concept of hylomorphism, from the Greek *hyle* (matter) and *morphe* (form), is developed by Ingold (2013) after Deleuze and Guattari and Aristotle. Hylomorphism proposes that a fully formed design idea, held in the mind of the designer/maker, is imposed unchanged upon homogenous matter. Malafouris' (2013) concepts of 'internalist' (focused on the mental process) and 'externalist' (focused on the made outcome) creativity further define the two halves of the hylomorphic split. This approach to materialising a pre-conceived design is common to traditional design pedagogy. This separation of idea and matter, mind and made, enacts Cartesian dualism (the decoupling of the mental and the physical). In opposition to hylomorphism, Malafouris (2014) proposes that the mind is extended in a *hylonoetic* field encompassing matter.

Ingold (2013) notes that no matter whether a maker has a form in mind, it is not the form that creates the work. This happens through engagement with materials in flow and the forces which meet during this process, so these are what we must study so that we can understand making. Similarly, Malafouris argues that it is not the study of the outcome of a making process which is of interest, but the processes during it. Touch as a mediator of these engagements will be crucial, though Ingold overlooks this as a possible research area. This thesis contributes to the academic understanding of the role of meaning-making through touch during making processes.

Malafouris observes the difference between the feeling of having agency and the judgement of agency, or the perception that one has caused an outcome. He argues that only humans experience either of these perceptions (though in the case of intelligent non-humans, this is debatable) and that these perceptions are the origins of the hylomorphic idea of enacting a design on matter. The human perception of causing an outcome allows a hylomorphic understanding of design to emerge.

Ingold and Malafouris directly relate hylomorphic understanding of a making process to the stance of material culture studies – imposing culture on a material which then represents the received cultural (mental and ideological) tradition. Ingold also notes a French-language text by Simondon (2005) in which he concludes that hylomorphism equates to the perspective of someone who only observes the inputs and outputs of a process and not the process itself, akin to Malafouris' (2013) 'externalist' representations of creativity. This certainly seems an apt description of much Material Culture scholarship, which seeks to infer meaning from artefacts perceived as finished and stable.

The concept of hylomorphism is employed in this thesis as a valuable framing to enact agential cuts supposing that the agency that leads to a design outcome resides in the designer or is emergent in an anti-hylomorphic stance from the designer's engagement with materials and things. Specifically, hylomorphism is used to structure the discussion in Chapter 10.

3.6.3 Transducers: Intuiting and Engaging with Agency (or Animacy)

Ingold theorises transducers as tools or things which allow correspondence between humans (hands) and materials. They translate bodily movement into material flow and are always present at the point of the 'emergence of things' (Ingold 2013: P102);

thus, they are indispensable to the making process. In Ingold's theoretical understanding, you can interact with a transducer without a material, but without a transducer, you cannot correspond with a material to shape it. Transducers serve to combine your movements, resulting from your sentience, with the flows of animate life (P108).

In this conceptual framing, transducers allow a designer or maker to comprehend, conceptually engage with and *work with* the liveliness, or in a reading slightly contra to Ingold, the emergent agency of a material. This is significant as it indicates the relational and non-localised nature of agency in a garment prototyping encounter. Yet it also makes a third-party thing a prerequisite to forming materials.

Sampson (2018b: P350) takes the concept of the transducer and applies it to fashion and the manifestation of personal style and internal ideas of the self through clothing. However, she does not explore transducers used in the making of garments, such as scissors, sewing machines, tracing wheels, and many more. Engaging with the concept of transducers as things which allow a garment designer to intuit and discover the agencies of materials and means of creating forms with them allows this thesis to foreground the role of touch encounters with transducing tools such as those listed above. These everyday things are often overlooked as mundane and not academically significant, while analytical focus attends to the designer or the made thing. For this reason, foregrounding transducers will form another agential cut made in Chapter 10 to present an alternative analysis of the data.

Ingold (2013) introduces a further concept within material engagements, that of 'anticipatory foresight', which may be read as a judgement of agency in the moment attributed to the maker. He proposes that foresight required by a material-making process is different from pre-determinist thinking required by design. It is not pre-visualising a design but a forward-looking stance anticipating the responses of the lively material after Sennett's 'prehension' (Sennett, 2009: P175). In this mode, the maker acts as a go-between among themselves and various materials and tools (one or more of which may presumably be read as a transducer) '*following and reconciling the intentions of alternately pliable and recalcitrant materials'* (Ingold, 2013: P70). This kind of in-the-moment negotiating and understanding in response to felt sensation can also be compared to the process of gaining understanding and discovering changes in affective capacity through material engagement in Hickey-Moody's material (Hickey-Moody, 2009; Hickey-Moody and Page, 2016), or affective pedagogies (Hickey-Moody, 2018) and embodied and material pedagogy (Page, 2018).

3.6.4 Pedagogy of Matter: Non-Human Agency in Meaning-Making / Learning

Meanings and understandings can be developed through touch with non-human things; therefore, it follows that touch encounters with them can be considered pedagogic. Many authors discuss the power of arts practices to enable learning in ways which are not language-dependent and conceive the body and the non-human in new ways, entangled with and agentive in the learning process.

A key concept for this thesis is the notion of a posthuman pedagogy (Hickey-Moody, 2009, 2016a; Bennett, 2016), pedagogy of matter (Hickey-Moody and Page, 2016), materials as teachers (Hood and Kraehe, 2017), or living literacies (Pahl and Rowsell, 2020).

Pedagogies of matter are proposed as gaining understandings and changing the affective capacity of a human through their un-directed, exploratory interaction with material in its broadest sense. Learning and contextually re-learning together with people and materials, rather than from formal instruction. Page (2018) later expands the definition of material pedagogy to more centrally include embodiment, noting that bodies are fundamental to our ways of knowing while fundamentally material and entangled with matter. Hickey-Moody and Page (2016) argue for a non-localised understanding of material agency, which can be foregrounded through material interactions with the body and unexpected responses. They see matter as resistant (to both hylomorphic processes and received modes of thinking or being).

‘*'Matter can be inherently resistant, ... matter can often teach us through showing us otherwise. Bodies resist instruction, ideologies and political boundaries, and in doing so they show the limits of political, educational and popular discourses and policies. Matter resists manipulation; it inspires and demands attention, and through engagement with matter, new modes of practice transpire.'* (Hickey-Moody and Page, 2016: P16).

While Hickey-Moody and Page generally discuss pedagogies of matter through examples of creative practices, making and experiencing art, Pahl and Rowsell (2020) take a broader view, arguing that living literacies are inherent in all aspects of emplaced, lived experience. In both cases, as Pahl and Rowsell (2020) propose the emphasis on real and lived aspects of these experiences constructs learning and enskillment as social practices in opposition to abstracted, structured and formalised ideas of learning. Rowsell (2020, 2021) further argues that stories are central to living and material literacies, situating them in learners' lived experiences. Rowsell and Pahl (2020) acknowledge the historical link to language in literacies research (which this thesis seeks to extend), and the term pedagogies of matter emphasises the pedagogic nature of such encounters more strongly than the names proposed by other authors. In addition, the arts practice focus of pedagogies of matter lends itself well to this thesis' area of study. Therefore, pedagogies of matter is the primary term adopted by this thesis.

Pedagogies of matter are described as being both felt and situated. They can be considered to be the ways understandings and learning come about through Ingold's (2013) art of enquiry, Malafouris' creative thinging (Malafouris, 2014, 2020), Ræbild's (2015) probing touch or Petreca, Baurley and Bianchi-Berthouze's (2015) situating phase of textile selection. All leading to the development of Haug's (2019) material-produced knowledge.

‘Pedagogy of matter is not about describing sensation or memories, but is about the learning and teaching these entanglements constitute’ (Page, 2012, cited in Hickey-Moody and Page, 2016). This process is often mediated by touch.

‘It is the action between that matters; therefore, just as we know and learn matter pedagogically, we also know and learn matter just by being.’ (Hickey-Moody and Page, 2016: P16)

Though this could be considered the way we continually learn through our sensory engagement with our environment or categorised as embodied or extended cognition, I propose that it is a useful concept for this thesis when applied to the focused, intentional, but freeform exploration of materials. Thus, it foregrounds what is excluded from a hylomorphic agential cut concerning unfolding learning and discovery with materials and is a valuable additional lens that can be applied to the diffractive analysis of the data in Chapter 10.

Norris’ (2012) concept of ‘touch/response-feel’ offers a potential mechanism through which pedagogies of matter might occur. Norris takes the dual nature of touch (that the kinaesthetic act of touching leads to sensation and feedback) as a given but argues that touch and feel are not simply two sides of the same experience. Norris argues that touch is something the social actor does, and feel is something that happens as a reaction to that touch, rather than simply the resulting sensation (Norris, 2012: P7-8). In other words, touch-response/feel involves structuring a touch experience and feeling into the resultant sensation. In this way touch-response/feel is similar to Petreca, Baurley and Bianchi-Berthouze's (2015) Simulate and Stimulate phases of textile selection but makes no distinction between active hands and passive bodies. Norris further proposes that touch/response-feel is learned through recognising feedback from felt engagement with the world or managing materials to create desired outcomes. While her argument often focuses on feedback from other humans, she also acknowledges feedback from non-humans.

Norris primarily investigates how a horse-riding instructor communicates how to touch the horse to guide it along with the expected response to feel for. Yet she also considers touch/response-feel with non-sentient things, giving the example of cooking as a mediated form of touch/response-feel, which can be linked to Ingold's (2013) concept of engaging with the liveliness of matter through transducers. Norris argues that this is a sequential process. Thus it is spatiotemporal and kinetic, as proposed by Sheets-Johnstone's (2003) understanding of felt experience. In the case of touch/response-feel, the experience before and after the touch is the primary temporal frame that forms an important part of teaching touch/response-feel. In response, the size and strength of the touch being taught can be inferred and adapted. The bodily positioning of the teacher, direction and dimension of their movements convey the anticipated felt response in conjunction with spoken directions. The desired touch and feeling are multimodally performed.

As Norris' example of teaching touch-response/feel relies on a multimodal aggregate (a combination of communication in different modes) to draw attention to a felt experience, she invites other researchers to explore the concept. She asks whether it is possible to teach touch-response/feel through language alone? This suggests the need for multimodal attention to the ethnographic data, attending to communication occurring in multiple modes as well as language (e.g., through gaze, gesture and visual communication) when exploring designers' communication around how to touch and expected or desired sensations (as discussed in Chapter 8).

3.7 Conclusion: Key Theoretical Concepts and Framework

I argue that the concepts discussed in the prior section are particularly helpful in theorising the role of touch in meaning-making and developing understandings from felt engagements with non-human things during garment prototyping. They are operationalised in the following analytical framework:

This thesis takes a vital new materialist stance, arguing that agency is enacted in the coming together of things in motion. A vital materialist approach allows this thesis to consider the significance of touch encounters with non-human things from an ontologically more balanced perspective, including humans while moving beyond human-centric accounts of touch common to prior studies. It also considers a posthuman sensorium, allowing for feeling in a wider entangled context than simply an 'extension' of the body.

Researching touch creates the phenomena (Barad, 2007) of observed touch practices, which are materially specific arrangements within animate matter flows

(Ingold, 2013), documented during the ethnographic and workshop encounters which inform this thesis (see Chapter 4 for further discussion of the thesis Methodology). In discussing the data derived from these encounters, differing agential cuts (Barad, 2007) are used to explore and re-conceive the agencies at play within the phenomena, the boundaries of the body and the location of sensation. The concept of transducers bringing humans into correspondence with materials through touch to mix their animate forces could be considered one such agential cut. In Chapter 10, agential cuts drawing on the concepts of hylomorphism, pedagogies of matter, and transducers and correspondence are used to explore specific material configurations that often do not include an apparent transducing tool, yet a human and non-human(s) intra-act in the touch practice phenomena. These agential cuts are diffracted through the data and one another to discover new perspectives on the phenomena of touch during garment prototyping, which may inform the creation of digital touch technologies. Additionally, the concept of Touch-Response/Feel is drawn upon to inform the proposed Framework of Garment Designers' Felt Enskillment in Chapter 9 (see Figures 9.1 and 9.2). Having theoretically framed the research, the following chapter describes the research design and methodology in more detail.

CHAPTER 4 – METHODOLOGY AND RESEARCH DESIGN

Figure 4.1: University X, Site A (see Table 4.1) – Tailor’s Dummies in storage

4.1 Introduction

The chapter begins by presenting an overview of the research design, relating the chosen methods to the research questions they address (4.1.1). Next, the rationale for using each aspect of the research design is presented in 4.2 in relation to themes that emerged from the review of related literature (see Chapter 2). The first of these themes is Addressing Lack of Materials Experience Studies Conducted in Designers' Situated Environments (4.2.1), which addresses the use of multi-sited ethnography (4.2.1.i), multimodal ethnography (4.2.1.ii), sensory ethnography (4.2.1.iii), the possible epistemological conflicts between these approaches to ethnography (4.2.1.iv), and strategies to work across such conflicts. The second theme derived from gaps in the existing literature is Addressing Focus on Gesture and Action over Sensation (4.2.2), which presents the use of *diffractive ethnographic attention* to the fieldwork site to investigate the complexity of touch and felt experience. Next, the methodological rationale for the New Materialist theoretical stance of the study is introduced in Extending the Phenomenological Theoretical Grounding of Prior Studies (4.2.3). In section 4.3, the identification of sites and participants is discussed, beginning with Ethnographic Site and Participant Selection (4.3.1), then detailing the participant selection for Workshop 1 (4.3.2) and Workshop 2 (4.3.3). The ethical considerations of the research and safeguarding procedures are discussed in 4.4. The methods of data collection are described in 4.5 for the core ethnographic fieldwork (4.5.1), Workshop 1 (4.5.2) and Workshop 2 (4.5.3). The use of touch sensing fabric probes in Workshop 2 is described in 4.5.4. In 4.6, the collected Data Materials are summarised, and in 4.7, the Data Analysis methods are described. To conclude, the key arguments for the chosen research design are summarised (4.8).

4.1.1 Methodological Overview

Briefly, the research design adopted by this thesis is as follows. A core multi-sited ethnographic study followed six garment designers in their respective studio spaces through the process of prototyping a garment. The designers represented a range of engagement with traditional and digital processes and three educational levels: bachelor's students, master's students, and educator/practitioners. This allowed the ethnography to engage with a cross-section of levels of enskillment and levels of digitisation in garment prototyping practice. To more fully attend to touch practices, the ethnography utilised *diffractive ethnographic attention.* This approach attends to the data and the ethnographic site using lenses derived from multimodal ethnography, sensory ethnography, and autoethnography, which are used both singly and intermingled or diffracted *through* one another to create new modes of attention.

Additionally, two workshop studies were conducted prior to and at the close of the ethnographic fieldwork. Workshop 1 facilitated twelve postgraduate fashion students to autoethnographically document the use of touch in their garment prototyping practice, then facilitated them to create prototype digital touch tools to support their practice. Throughout this workshop, group discussions on the role of touch and the digital in garment prototyping processes were captured. Workshop 2 engaged four educator/researchers conducting a project investigating future garment manufacturing technologies and the two educator/practitioners who took part in the ethnographic study to explore their speculations on the application of digital touch technologies in the garment industries or education. An initial discussion was captured on the Zoom platform. Follow-up interviews supported by handling a prototypical digital touch technology (pressure and location-sensing fabric sensor probes) were conducted in situ in the educator/practitioners' studios.

The video data and fieldnotes captured during all three studies were initially developed into thick description to develop further lines of questioning and guide the analysis. Next, data were thematically analysed, and the themes were visually mapped to highlight their entanglement and establish a structure for the ethnographic narrative. Finally, the concept of diffraction was again employed to reflect on the empirical data by reading three agential cuts (see Chapter 3) representing different stances on non-human agency through the data and each other, developing new perspectives (see Chapter 9).

The key research questions of the thesis are reiterated below with reference to the methods used to capture the data addressing them:

(RQ1) What touch practices are utilised by garment design students and educator/practitioners during the development of a garment prototype, and what are their socio-material contexts/entanglements?

RQ2) What meanings or understandings do garment designers derive from or communicate through the ethnographically observed touch practices?

Research Questions 1 and 2 are addressed through the core multi-sited ethnographic encounters, observing six garment designers with differing experience levels and relationships to digital technology (see 4.3.1 for further details) as they prototyped a garment.

RQ3) What speculations on future applications of digital touch technology in garment prototyping are elicited through garment designers' situated interactions with digital touch prototypes, such as touch sensing e-textiles, in a garment design studio context?

Research Question 3 is addressed by the two structured workshop studies (see section 4.5 for further details), which more specifically attend to speculations on future applications of digital touch technologies for garment prototyping. These included creating digital touch prototypes (Workshop 1) and interacting with ready-made digital touch prototypes (Workshop 2). Observation of designers' practices during the workshops also informed Research Questions 1 and 2.

RQ4) How do differing agential cuts, representing different understandings of material agency in the ethnographic data, shed light on approaches to the design of digital touch technologies for garment prototyping?

Research Question 4 is addressed through the analytical use of diffractive analysis in which three agential cuts representing different stances on non-human agency are read through the data (4.7). These different stances on agency are linked to considerations when designing digital touch interfaces and tools. An entangled reading of the compatible insights from each agential cut is then proposed, giving recommendations for digitising garment designers' observed touch practices.

4.2 Background and Rationale for Study Design

The Literature Review (Chapter 2) identified the following limitations in previous studies of garment prototyping. In the following sections, each is discussed in detail to argue the rationale for the chosen research study design:

- 4.2.1 Lack of materials experience studies conducted in designers' situated environments
- 4.2.2 Focus on gesture and action over sensation
- 4.2.3 Phenomenological theoretical grounding

An ethnographic approach was chosen to address the issue of emplaced context in materials experience, a significant gap in the research literature (e.g., Petreca, Baurley and Bianchi-Berthouze, 2015). Diffractive ethnographic attention, including sensory ethnographic practices and autoethnography, was developed to address the focus on doing over feeling in prior studies (e.g., Ræbild, 2015). The diffraction of more sensory ways of inhabiting the research site and feeling *with* participating designers afforded by sensory ethnography, and the structured observation of communication through touch afforded by multimodality, allowed a balance of attention to both doing (i.e., action and gesture) and feeling (i.e., the experienced sensation). This was necessary due to the lack of emphasis on feeling and sensation within the literature, which instead focused on the role of movement in felt experience. The New Materialist stance of the thesis was adopted to extend the phenomenological perspective of prior studies.

4.2.1 Addressing Lack of Materials Experience Studies Conducted in Designers' Situated Environments

I chose an ethnographic approach due to its attention to the broader context that may be entangled with touch practices but seek to extend this attention to specifically address the non-human, material world. This sets the thesis apart from ethnomethodological studies that focus on specific actions and phenomenography, which focuses primarily on the range of experiences of a particular phenomenon by a specific group. Though phenomenographic studies were found in the related literature (Bailey, 2002; Ræbild, 2015), the touch practices of garment designers are not easily (or usefully) narrowed to a range of experiences. This thesis explores the many diverse touch practices involved in garment prototyping, rather than only the range of felt experiences when cutting fabric. It focuses on the individually specific experiences of each garment designer (as felt experience by its very nature cannot currently be compared across a range or shared) and the meanings, purposes and reasonings designers attach to these felt experiences during a garment prototyping process.

Ræbild's use of phenomenographic methods is ontologically similar to Petreca's phenomenological approach rooted in Merleau-Ponty (2002). Although phenomenography appears to separate the phenomena and the experiencing subject to a greater degree than Merleau-Ponty. Subject-object dualisms and the ontological prioritisation of the subject are problematic in relation to the New Materialist stance of this study.

4.2.1.i Multi-Sited Approach

Anthropologist George Marcus (1999, 2005) proposed that multi-sited ethnography is suggested to study people in motion and in cultural spaces that are increasingly fragmented yet connected by shared processes, identities, or cultural understandings across different locations and times. In a multi-sited model, these connections become the ethnographic site, with LeCompte (2002) suggesting that the idea of a physical site defining the boundaries of a case study is no longer applicable. This is particularly necessary for an era of increasing international travel and migration, where digital technologies facilitate social and cultural connections. It is also an appropriate means to explore globally distributed industries such as fashion, whose shared cultural practices must be maintained among designers, suppliers and manufacturers, separated by thousands of miles. The cultural meanings, things worked with by, and identities of designers themselves must also remain broadly connected across these spaces. It is these common meanings, things and identities (Pierides, 2010) which are established and stabilised through garment design education.

Perides (2010) argues that such ‘partial connections’ between sites should be taken seriously in any ethnographic analysis as they both establish and are established by the research focus. Indeed, Marcus (1999) argues for the study of ‘non-obvious sites’ which have little contact and exchange and whose connections may not at first be apparent. The concept of ‘partial connections’ also links with Harraway’s (1988) ‘situated and partial knowledges’: bodily and emplaced ways of understanding. All cultural connections between personal understandings of touch will inevitably be partial due to the individually specific nature of felt experience. Touch is also situated in that it is environmentally specific (changing due to heat, humidity and the conditions of the body and the touched thing).

A multi-sited approach has been previously utilised to explore notions of embodiment mediated by digital technology usage in creative education practices, including fashion (Jewitt, 2017; Jewitt, Price and Xambo Sedo, 2017). In this study, the ethnographic ‘site’ was the digitised body, but the focus was not specific to touch. In the case of this thesis, the site is considered to be the garment prototyping process rather than immersion in one physical place. As such, I am researching a site and culture I am familiar with. While critics of multi-sited ethnography suggest that spending less time in each site means that the multi-site ethnographer may miss the nuances and depth which constitute an ethnographic account, proponents of this approach argue that it is well suited to the ethnographic study of a culture familiar to the ethnographer (Marcus, 1999). They further argue that the familiar researcher will rapidly engage with sites where they may not spend a lengthy period of weeks, months, or years.

4.2.1.ii Multimodal Ethnography

Multimodal ethnography is a framework combining the structuring concepts of social semiotic theory that relate to meaning-making or communication in social contexts with the situated observational encounters of ethnography. It supports an ethnographic encounter focused on processes of meaning-making while also understanding their social context. Ethnography, in this case, provides thick description – contextual description used alongside a more detailed multimodal description of specific processes.

In conducting a multimodal ethnography, traditional ethnographic methods of situated observation of participants, collecting video data, alongside note taking and interviews, are employed. The reflexivity of an ethnographic researcher is a critical methodological concept and tool of the ethnographer (Jewitt, Bezemer and O'Halloran, 2016: P120).

Craft ethnographies can sometimes overlook or mystify the understandings gained through or in relation to the making process (Atkinson, 2013), or can categorise such knowledge as 'tacit' after Polanyi (2009) and thus only inferable through its outcomes (O'Connor, 2017). In this thesis, the focus on mechanisms of meaning-making within multimodal ethnography allows for contemporary touch practices in garment prototyping to be observed in structured detail and for the perceived purposes of and understandings or meanings derived from these touch practices to be addressed. This includes their social context in relation to institutions and pedagogic practices

(Nicewonger, 2011) but maintains a focus on the meaning-making or communicative acts which occur through touch. While this is inevitably structured through social and power relations, these are acknowledged where appropriate but do not form the core of the study.

4.2.1.iii Sensory Ethnography

Sensory ethnography is an approach pioneered by Pink (2015) which prioritises the emplaced sensory experience of participants or co-ethnographers. The use of the term co-ethnographer is pertinent as sensory ethnography attempts to access the situated sensory experience of participants through engaging in activities with them. This is constructed in opposition to assuming the role of a detached observer striving for objectivity and to reduce the influence of their presence on the research encounter. For this reason, sensory ethnography is noted by Dicks (2014) as having a markedly different epistemological focus from more traditional ethnographic methods, such as those which inform multimodal ethnography.

Pink’s (2015) methods include re-enactments of practices, during which participant co-ethnographers are invited to demonstrate how they carry out certain activities (with a focus on sensory experience), and ‘sensory tours’ in which the co-ethnographer guides the researcher around the space they inhabit, describing their emplaced sensory impressions of it. Thus, accessing how both activities and space are sensorially constructed for the co-ethnographer. These are filmed as part of a co-constructed process, with the co-ethnographer guiding the video’s focus. The video is then regarded as a co-created document which, rather than being subject to transcription and interpretation, serves as a prompt to recall the emplaced, sensory experience it depicts. In addition, the ethnographer collects more traditional contextual data and fieldnotes.

Sensory ethnography methods formed additional components of my primary research encounters with participants in the situated context of their studio environment. During the period of ethnographic observation, participants were invited to guide me on sensory tours, demonstrate practices which they engage in regularly or propose to be significant, directing me in how they were carried out and how to film them. This also included instances of teaching me their practices, giving me a first-person sensory insight into their activities, along with their third-person descriptions. These activities were interspersed between periods of more traditional etic observation and act as an emic counterpoint in the data, showcasing what was perceived as significant by participants.

4.2.1.iv Possible Epistemological Conflicts

Dicks (2014) comprehensively reviews and contrasts the methodological and epistemological differences between ethnomethodology, sensory ethnography, and multimodal social semiotics. She proposes that sensory ethnography explores experience and the perception of meaning, while multimodality explores processes of communicating meaning. However, Jewitt and Leder Mackley (2018) note that these methods can be combined across academic territories that are differently constructed by their proponents yet share many commonalities. Touch is an enactive

sense (it requires action, such as movement or contact, to receive perceptual stimuli), through which experience is perceived and communicated.
As multimodality is concerned with meaning-making across multiple modes, it is distinct from sensory ethnography in its study of separate but interrelating modes (both within and across the senses) rather than a holistic sensory experience. In this thesis, I argue that both approaches are helpful, as multimodal ethnography allows structured investigation of separate but interrelating sensory experiences, while sensory ethnography allows touch practices to be explored as a holistic component of the emplaced experience. Diffracting between these epistemological stances can potentially frame sensory interactions and cross-modal effects between senses, which may not be accessible through a single analytical lens.

Also significant for this thesis is a tension between the perceived role of the researcher and the degree of their intervention into participants' lifeworlds which is accepted in multimodal and sensory ethnography. While in multimodal ethnography, the researcher's influence is acknowledged as a methodological concern, in sensory ethnography, the researcher is recognised as co-creating the data. I argue that both approaches can be incorporated in a situated encounter if the researcher's reflexivity is recognised and considered during data analysis. Indeed, I believe it is beneficial to compare emic and etic perspectives on touch.

The theoretical backgrounds of both multimodal and sensory ethnography sit in opposition to New Materialism and Agential Realism. They are either derived from phenomenology and therefore prioritise human embodied experience or, in the case of multimodality, grounded in the structuring process of semiotics and attempt to divide matter flows and entanglements. Yet both can be re-focused to productively foreground the non-human. However, the separation of senses and material modes in multimodality cannot be overcome without nullifying its structuring qualities.

4.2.1.v Working Across Epistemological Conflicts

Dicks (2014) acknowledges that multimodal ethnography and sensory ethnography differently use video to collect data, both in terms of styles of video data captured and the objectives of the data capture. Sensory ethnography and multimodal ethnography use roving cameras, following significant events chosen by the participant co-ethnographer or the researcher. Both allow for the capture of contextual detail. In this thesis, I variously use both roving and static camera shots as appropriate to the activity studied and differing between fixed camera for general observation and roving camera directed towards activities by the participant (for example, during ‘doing with’ activities or sensory tours). In this way, I aim to imitate the ‘education of attention’ model (Grasseni, 2004; Ingold, 2013; Gowlland, 2015), learning to look where participants deem significant to their practice.

Due to the epistemological differences between the methods chosen, I do not integrate them. I aim to work with these differences rather than diminish their distinction or nullify the benefits of using them as lenses on the research encounters. Instead, multimodal ethnography and sensory ethnography are employed diffractively (see 4.2.2), maintaining their contrasts, but exploring their intra-actions to deepen and re-frame the analysis of the situated encounter, as theoretically proposed by Dicks (2014). Additionally, the diffraction of these two approaches allows for a fruitful movement between focus on the specific and the general in constructing an insider account of participants' felt lifeworlds. My autoethnographic re-enactment of significant activities enabled a further diffractive lens which facilitated a movement between first-person and third-person perspectives on touch.

4.2.2 Addressing focus on gesture and action over sensation

To explore the complexity of touch, I developed a strategy to incorporate three-fold modes of attention to the ethnographic encounter: *diffractive ethnographic attention*. First, a multimodally informed attention explores the detail of the acts of touch-based meaning-making. Second, a sensory ethnography informed focus specifically explores feeling within a broader emplaced context. Third, the use of autoethnography in this study also allows an in-depth perspective on sensation, which is individually subjective and difficult to communicate. While engaging in co-feeling activities with a sensory ethnography focus, my attention as a researcher was split between attending to questions of sensation and the events unfolding. When conducting autoethnographic re-enactments of the observed touch practices, I could better focus on the sensations I experienced. Moving through and among these three modes of attention within the ethnographic encounters also attempted to limit criticisms of the detachment of multimodal ethnography from what is observed, the interference in naturalistic observation that participatory sensory ethnography methods may cause and the subjectivity of reporting individual autoethnographic experience. Attending to the observational encounters in the diffractive space where the three approaches were entangled allowed for the foregrounding of the most helpful qualities of each approach while allowing new ways of seeing and feeling the ethnographic site to emerge through the entanglement of the methodological approaches.

4.2.3 Extending phenomenological theoretical grounding of prior studies

Though this thesis is an ethnography, it diffractively adopts the viewpoints of several ethnographic approaches in attending to the participant encounters to better understand the phenomena of touch practices and associated meaning-making. It works to de-centre from the ontological prioritisation of the human, taking a more balanced interest in the roles of humans, non-human things, and their intra-actions in the phenomena of touch practices during garment prototyping. In this ontological de-centring, the perspective of this thesis is aligned with New Materialism and Agential Realist theory (Barad, 2007).

The New Materialist understanding of matter as entangled also allows the thesis to investigate how designers' engagements with non-humans trouble the ontological separation of a human subject from their tools, materials, and emplaced context, including the extension of the sensorium and the socio-material mutability of perceived sensation (see Chapters 7 and 8).

This thesis can be considered an educational study, which Pierides (2010) observes often leads to the construction of students as lower status members of a culture and performs colonial practices and representations of power. In the case of this thesis, taking a New Materialist inflection to the study of the studio environment, both within and outside educational settings, and exploring the non-humans involved in an ethnographic encounter attempts to trouble such constructions. By not making prior assumptions about whether an educator or material things direct learning, this thesis takes a step to destabilise conventional understandings of power. Particularly those relating to the designer's power and hylomorphic understandings of design as enacting ideas on the material world. I ontologically flatten the analysis and limit the power and value judgments inherent in exploring practices at varying educational and professional levels.

4.3 Identifying Sites and Participants

4.3.1 Ethnographic Site and Participant Selection

Discussions with teaching staff in the Fashion departments of several universities informed my initial concepts of a distributed site in transition, both spatially and through changes in associated practices. The transition from physical, apprenticeship-based learning to the acquisition of digital skills and from a studio-based practice with a fixed workspace to a multi-sited and spatially unfixed mode of working. These changes in the nature of garment design learning were both cited as concerns due to their impact on the process of garment development and associated emplaced and sensory experiences.

While both garment design education and practice are in flux, the distributed nature of garment design, manufacture and specialist finishing skills as a 'site' is a long-standing feature of the garment industries, even pre-dating the movement of garment manufacturing to low-wage economies. Despite this, for learners, the concept of the studio is largely unchallenged as a stable entity. Touch practices are inculcated through garment design education and apprenticeship to prepare learners for the cultural customs of the studio – the stabilised global norms described above (4.2.1.i).

Based on these initial discussions, a network of related physical sites was identified across which shared designer identities, engagements with non-human things and understandings of touch in garment prototyping may circulate. These sites were linked to six purposively sampled participants representing a spectrum of experience, including undergraduate students, postgraduate students, and higher education fashion course leaders (educator/practitioners) who retained a practice independent of their teaching (see Table 4.1, page 163). This is a common practice in fashion education observed by Faerm (2015) and equated with a master-apprentice relationship for mass education.

Figure 4.2: University X, Site A (see Table 4.1) – Ground floor Machines Room (an open-access sewing space)

Physical locations included the studios of two higher education institutions, in which the undergraduate and postgraduate students worked, and the professional studios of the two educator/practitioners.

These sites give an opportunity to study how touch practices are developed in novice garment designers, further refined and utilised in a professional context, and then cyclically re-introduced into the educational context to maintain or disrupt a studio community of practice. This network of sites includes the potential to understand whether touch practices are apprenticed through a contemporary fashion education or whether understandings are gained through other means such as material interaction? Pierides (2010) proposes multi-sited ethnography as a means to investigate ‘contemporary educational events and processes that are not spatially fixed to a classroom and relate to the broader social and employment landscape. Thus, multi-sited ethnography lends itself well to this context.

An additional component of the purposive sampling frame was to represent a spectrum of engagement with digital processes, ranging from those who used little, or no digital technology other than mobile phones or laptops, to those working with wearable technology, 3D design, and virtual or augmented reality (VR or AR) garments. Participants at each educational level were chosen so that one represented a more digital approach to garment design development and one a less digital approach (see Figure 4.3).

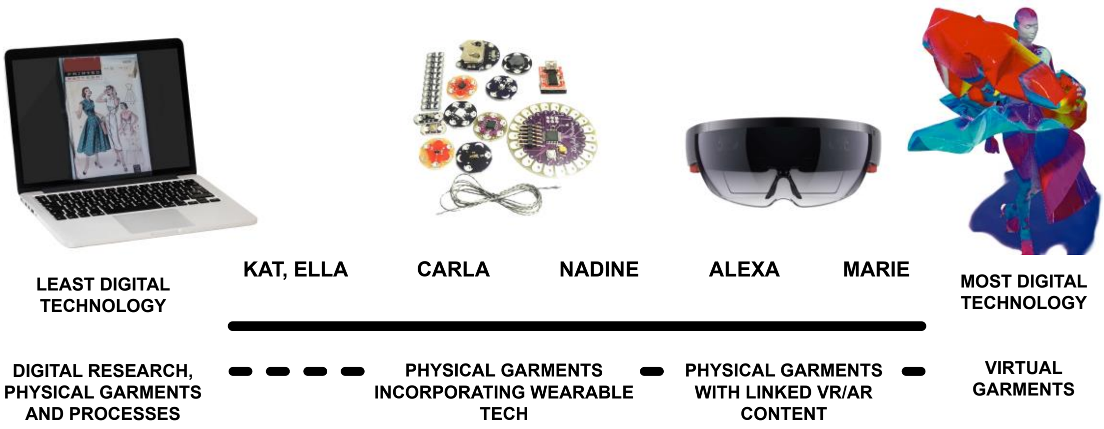

Figure 4.3: Degree of participant engagement with digital technologies and digitisation of garment outcomes

Potential participants were identified based on the nature of their practices by gatekeeping colleagues and I at the two art and design universities that formed the physical sites of the ethnography. The final participants were then chosen to account for a range of touch practices and represent a diverse engagement with materials (e.g., jersey, fluid, and stable woven fabrics), different garment types (e.g., outerwear, jersey, eveningwear) and differing training and prior industry experience (see Table 4.1 on the following page). The participants identified as female and represented four nationalities and educational backgrounds. Two had worked internationally after or in between their studies. The core ethnographic participants: Alexa, Ella, Marie, Carla, Kat, and Nadine, chose not to be anonymised, as the thesis reflects their highly personal practices and, in many cases, documents the culmination of significant work for the designers. They were also able to build greater rapport with me during the longitudinal research process and trust in how they would be portrayed. More information about each designer and their practice can be found via the links in the Acknowledgements section (see page 9). Each participating designer is introduced more fully in Chapter 5. In addition, my positionality in relation to the designers' experiences and felt histories is further discussed in 6.2.1, particularly highlighting shared histories and problematising the asymmetry of myself as a cisgender male researcher exploring felt experiences of primarily female-identifying designers.

Table 4.1: Ethnographic sites, participants and the focus of their observed practices

	Body/Material Focus	**Digital Focus**
Undergraduate (Site A – University Studios)	Kat – Design from body/material Interactions No prior industry experience – Varied Fabrics	Nadine–- Wearable tech for space colonisation Studio internship during degree – Varied Fabrics
Postgraduate (Sites B & C – University Studios)	Carla – Adaptable garments for changing bodies UG Costume degree, costume making experience for ballet and Broadway, and personal eveningwear practice – Varied Fabrics	Marie – Digital garments and AR content based on wearers' digital avatars and identities UG Fashion degree Studio internship after degree – Stable Woven Fabrics
Educator/Practitioner (Sites D & E – External Professional Studios)	Ella–- Tango garments Pre-degree Technical qualification, UG Fashion degree and personal eveningwear/dancewear practice – Stretch and Fluid Fabrics	Alexa–- Costume for VR experiences Tailoring Apprenticeship leading to UG degree, PG degree in Interaction Design, and personal interdisciplinary art/fashion practice – Stable Woven Fabrics

4.3.2 Workshop 1 Participant Selection

Twelve postgraduate fashion design students self-selected to take part in Workshop 1. The workshop was part of a non-assessed week in which the entire student cohort was allocated to work with various academic researchers to gain new insights into their practice. All students were invited to participate with a description of the workshop activities and their focus on touch and digital technology. This was circulated via internal email by the gatekeeping Senior Tutor responsible for the curriculum unit during which the workshop took place. The workshop was conducted in the participants' open-plan studio space, allowing the study to reflect their usual emplaced environment and giving participants access to the specialist machinery they used to develop garment prototypes.

Nine participants identified as female and three male, representing eight different nationalities. This was broadly representative of the gender balance and diversity of the wider course cohort. Nine had prior experience in the fashion industry, while the remainder had progressed directly from bachelor's level studies. Participants, their previous experience, and the focus of their practices are listed in Table 4.2.

4.3.3 Workshop 2 Participant Selection

Participants in Workshop 2 were purposively selected for their experience as educators and in industry, along with their interest in future garment design and manufacturing technologies. They included the two educator/practitioners who took part in the ethnographic study and four educator/researchers who were members of a project exploring future fashion and textile manufacturing. One member of the research project team was the Senior Tutor acting as the gatekeeper for participants in Workshop 1. All had several years' experience in design or manufacturing roles in the fashion industry. Participants identified as female or non-binary and represented two nationalities and educational backgrounds. However, three had worked internationally in the fashion industry. Of the six participants, four maintained a creative practice alongside their academic roles.

Other than Alexa and Ella, most workshop participants chose to remain anonymous. Although all had fascinating histories and practices, my relationship with them was briefer. It could not build the same level of trust and familiarity with the project, which would give them confidence in being identified. Pseudonyms are indicated with an asterisk*. In cases where identity and representation were a significant personal concern for participants, we engaged in a dialogue allowing them to select their pseudonyms. Participant selected pseudonyms are indicated with a double asterisk**.

The in-situ activities of Workshop 2 took place in two studios belonging to the educator/practitioners, again providing a familiar context and the equipment, tools and materials common to a garment design studio.

Table 4.2: Workshop 1 participants' experience and practice focus

Participant Name	Previous Industry Experience (Y/N)	Practice Focus
Annette*	Y	Womenswear, 3D Digital Design, 3D print, CNC Cutting, Moulded and Formed Materials
Georgia*	Y	Womenswear, Industrialising/Digitising Craft Processes and Expanded Theoretical Practice
Illaria*	Y	Menswear, Tailoring
Caitlin*	Y	Accessories, Traditional Leatherwork and Leather Moulding
Una*	Y	Menswear, Knitwear and Crochet
Matteo*	Y	Womenswear, Bio-Textiles
James*	Y	Menswear, Tailoring
Liyang*	N	Menswear, Ergonomic Sportswear
Chloe*	N	Womenswear, Knitwear
Eugenia*	Y	Menswear, Costume Inspired Tailoring and Outerwear
Difei*	N	Menswear, Knitwear
Ji-hyun*	Y	Womenswear, Eveningwear and Tailoring

Table 4.3: Workshop 2 participants

Participant	Ethnographic Participant (Y/N)	Interview Participant (Y/N)	Educational Role & Practice / Research
Alexa	Y	Y	Accessories Course Leader & Expanded Practice Exploring VR/Performance
Ella	Y	Y	Fashion Production Course Leader & Tango Dress Designer/Maker
Helen*	N	Y	Senior Fashion Tutor & Design Research Project Lead
Noxi**	N	Y	Fashion Tutor & Design Researcher
Holly*	N	N	Design Researcher
Amber*	N	N	Accessories Tutor & Milliner

4.4 Ethics

Local ethics approval for the research was issued on 17/09/19. UCL data protection reference: Z6364106/2018/03/93 social research.

Participants were offered anonymity in reporting the data by default. At the close of the data collection period, participants were pseudonymised; however as previously mentioned, the core ethnographic participants chose not to be anonymised. In this case, additional written permission was sought. Similarly, additional written permission was sought when it was impossible to visually anonymise participants in the reported data (e.g., the visual transcript of Alexa and Mabel weighing fabrics in 8.2). Non-identifying participant data was uploaded daily from cameras and video recording devices whose memory was then wiped. Data is stored on a password-protected, encrypted hard drive and will be erased ten years from the completion of the PhD.

The nature of the research, right to anonymity and data handling procedures were explained to all potential participants. Project information sheets were provided detailing the steps taken to safeguard their anonymity, along with contact information in the event of their wish to withdraw their data or lodge a complaint. The fact that participants would not be financially compensated for participation was clearly stated.

All student participants were previously unfamiliar to me and were selected from course cohorts I had no prior relationship with as an educator. The voluntary nature of participation was emphasised, including the right to withdrawal, and gatekeeping course leaders for student participants were consulted throughout the research to ensure the nature of their students’ participation was fully understood and did not impact concurrent teaching. Both participants and gatekeepers signed ethics consent forms.

Though working on unfamiliar campuses and courses, I was well-versed in the regulations, practices and norms of the institutions which comprised the ethnographic sites, having been employed in other roles at both for several years. I am also familiar with professional practices in a fashion studio environment, and my positioning as an ethnographer reflected this. This also allowed me to gain particular types of insight. I was a peer to the educator/practitioners, initially contacting them through professional connections and other peers in fashion education. I introduced myself as both an academic and a learner to the student participants, emphasising that I had no direct influence or power over their success and my general distance from their courses, yet maintaining my status as a relative expert. In this way, students were able to ask about my practice and, in return, share their thoughts on their own, creating a productive research dialogue between us. Conversations during the ethnographic observation were directed to their benefit and interest, as well as my academic insight.

Following designers' prototyping process enabled discussions comparing my touch practices with their own and often a sharing of life, employment, and education histories. Their thoughts on particular occurrences were often prefixed with questions about my own experience or approach to design and making processes, to which they could compare their own. As the educator/practitioners were accomplished designers in their own right, they too were interested in noting differences in our approaches rather than attempting to agree and mimic my behaviours. I was not the only one intrigued by the often-hidden processes behind the creation of a garment.

As Workshop 2 took place during the Covid-19 pandemic, the in-situ phase was conducted when limited, indoor social interactions were legally permitted. They took place in the two educator/practitioner's studios at their discretion. As the workshop included touch sensing fabric probes, to mitigate concerns over touch and shared objects or surfaces, participants were offered the option to change the outer calico shell of the probes, and hand sanitiser was provided. Social distancing was observed between the participants and I, though they often chose to interact more closely among themselves.

4.5 Data Collection

4.5.1 Ethnographic and Autoethnographic Data Collection

As highlighted in 4.2, when collecting ethnographic data it was neither wholly possible nor desirable to distance myself from the influence of my experience in the field of garment design and prototyping (I outline this experience in greater depth as my personal felt history in 6.2.1).

I followed students' practice on campus. Their design development, touch practices and processes were discussed when they visited the university studios. Students commonly worked on campus on days when they were scheduled to see tutors or technicians. This provided longitudinal snapshots of their design development process rather than a sustained intensive period of observation.
Educator/practitioners were engaged intensively over shorter periods of consistent observation. Due to their other commitments, their practice was generally condensed

into days off, evenings or weekends when their academic workload was relatively low.

The duration of observation periods varied from under two weeks to several months, but in each participant's case, it followed as much as possible of the activity of developing a garment, from initial research to physical experimentation and creation of a prototype. In two cases, the lockdowns and university closures implemented due to the Covid-19 pandemic curtailed my observation of the entire process. However, the data captured up to that point proved rich enough to still allow in-depth analysis

When approaching the ethnographic fieldwork with a multimodally influenced attention, I noted the non-human things available to the designers in their studio spaces as resources for meaning-making. I considered how these things and their particular felt qualities were employed by the designers, and the choices they made of one felt resource, or bodily interaction with it, over another, including the movement between felt resources. Thereby exploring the multimodal concepts of motivated signs and modal affordances (though I reject the deterministic notion of affordance in made or processed things – see Chapter 3).

In observing and noting the semiotic resources, motivated signs, modes and their proposed (modal) affordances utilised by participants, sensitising concepts were developed for further investigation in interviews and sensory ethnography activities. For example, the significant meaning-making roles of materials of different stiffness, such as paper or fabric (see Chapter 7).

Through a multimodally influenced attention, I also explored touch as a distinct mode, which could be brought together with other modes to make meaning rather than a part of a holistic felt experience, as in sensory ethnography. This helped focus attention on the relationship between touch and other senses or carriers of meaning (modes) such as drawing or spoken language. For example, exploring how touch, gesture, facial expression, and linguistic prompts are specifically employed within a broader situated, felt experience to demonstrate how to touch fabric to elicit a particular understanding (see Chapter 8).

When approaching the ethnographic sites with an attention informed by sensory ethnography, I remained open to the interconnected nature of my senses and how they created a combined sensory atmosphere unique to the emplaced context. To explore this, I invited participants to guide me on sensory tours (Pink, 2015) of their studios. I also engaged in activities of directed co-feeling with participants.

I chose to autoethnographically re-enact touches related to emerging sensitising concepts as I iteratively analysed the data. When autoethnographically re-enacting forms of touch I had observed, I primarily attempted to do this in participants' studios with them present so that we could touch together as suggested by sensory ethnography: co-creating sensory experiences. I recorded my observations and actions using static video or in the form of fieldnotes and occasionally as audio recordings when my hands were engaged in complex activities.

When it was impossible to re-enact a form of touch in-situ, my re-enactments took place in my personal studio space. A shared unit with four other garment, accessory, and jewellery designers, containing similar equipment to the studio spaces at my ethnographic sites.

4.5.2 Workshop 1

The preliminary workshop study, referred to as 'Workshop 1', took place over the course of one week and comprised three activities, interspersed with group discussions and individual interviews, which were video recorded:

- Participant Autoethnographies

The workshop began by inviting participants to reflect on their touch practices when prototyping a garment. As prompts, they were asked to focus on their gestures or movements, the sensations they experienced and parts of the body they were using to touch. Considering these aspects of their experience, they were asked (if possible) to note the purpose of their behaviour and what they might understand from it? During this time, participants took turns wearing an Autographer lifelogging camera for thirty minutes to capture their actions visually. See Figures 4.4 and 4.5 for visual data captured by the Autographer camera. This provided an additional viewpoint on their actions, and the captured data was used as a prompt for recollection and discussion at the end of the day.

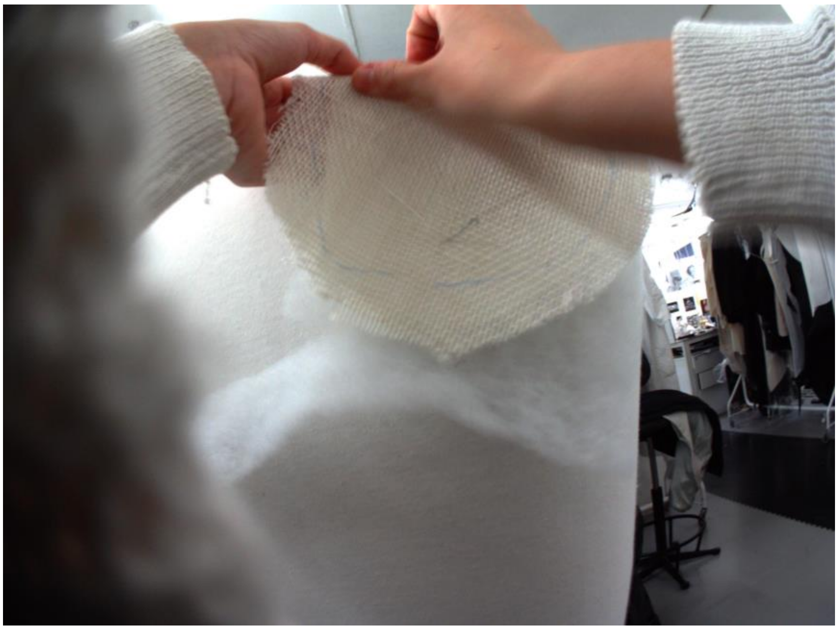

Figure 4.4: Lifelogging camera image from Workshop 1

Figure 4.5: Lifelogging camera image from Workshop 1

- Touch Sensor Making

The following day participants were given a basic introduction to Arduino, sew-able (Buechley *et al*. 2008) and wired prototyping boards, along with a range of touch sensors that could be utilised in physical computing. These included: piezoelectric pressure sensors, piezoelectric flex sensors, heat sensors, accelerometers, stretch sensors, capacitive sensors, and 3D gesture sensors (Skywriter breakout boards). To help them relate this session to garment design practice and soft materials, participants were also introduced to examples of conductive cords, yarns and textile materials and their potential to create sensors. Next, they were guided through the process of making a fabric version of a basic pressure or flex sensor using tutorials from kobakant.at (Perner-Wilson and Satomi, 2021d and 2021c, respectively). Finally, they were asked to consider overnight how the sensors they had been introduced to might help them capture the insights they had gained into their touch practices during the autoethnography task on the previous day.

- Digital Touch Tool Design

On the morning of day three, participants were asked to reflect on their experiences during the prior days of the study to help them answer a design challenge: to create a prototype digital touch interface that would support or inform their garment development practice. Participants were asked to work in groups of three for the design task and spend the next two and a half days developing their concepts. As participants were novices to using Arduino, an expert in physical computing was available to them for the duration of the task (in addition to myself) to troubleshoot their prototyping and assist with writing code. On the afternoon of day five, the groups were asked to present their final concepts, then collectively discuss their experience of the task and reflect on any significant themes. The design concepts and early-stage prototypes which provoked the most pertinent discussions around digitally supporting garment prototyping are reported in Chapter 6.

4.5.3 Workshop 2

To conclude the research and more explicitly address speculations on the future application of digital touch technologies in garment design education, professional life and manufacturing, a workshop was held after the period of ethnographic observation. To familiarise participants with the possibilities of touch digitisation, touch sensing fabric probes were introduced to visualise their touch practices.

Workshop 2 took place during the Covid-19 pandemic and was modified to encompass two phases. The first a preliminary group discussion convened and captured using the Zoom video conferencing platform, exploring participants' imaginaries of the role digital touch technologies might play in the future of garment design education and industry. This was introduced with a presentation giving an overview of current digital touch technologies for context.

Figure 4.6: A participant familiarises themselves with a sensor fabric probe and its visual feedback

The second phase consisted of follow up interviews with selected participants from the prior discussion, allowing them to interact with the sensor fabric probes in a professional garment design studio context. One educator/practitioner was interviewed alone and one in a group with two educator/researchers from the preliminary discussion. Interviews were video recorded to capture participants' touch behaviours and physical responses to the sensor fabric probes, as well as their comments.

Figure 4.7: Experiments with touching through, and touching the underside of a sensor fabric probe, with pressure and location visualised

Figure 4.8: Draping garment pleats with a large-scale sensor fabric probe

4.5.4 Sensor Fabric Probes

I used sensor fabric probes in Workshop 2 to give participants a tangible, touchable reference point from which they could speculate on possible applications of digital touch technologies in garment design education and industry. The touch sensing fabrics introduced workshop participants to the concept of digitising touch, allowing them to comment on the benefits, applications, and limitations of current technologies and consider how these might integrate into their practice. The visualised sensor data provided a non-human perspective on the situated encounters and helped participants to explore which aspects of touch practices during garment design development are possible to capture digitally? Thus, informing an understanding of how these might be detected and replicated in future iterations of touch interfaces to support garment prototyping.

An initial goal of this thesis was to create an everyday fashion studio object (e.g., a tailor's dummy, sewing machine, scissors etc.) which was touch-sensitive and could record data on its usage as a non-human co-ethnographer (Giaccardi, Speed, Cila, *et al.*, 2016; Chang *et al.*, 2017). Data from Workshop 1 revealed that participant perceptions varied widely as to which object would be most universal to all fashion practitioners and which would be most insightful to capture data from for their practice; for this reason, and based on data from Workshop 1 proposing the utility of a location and pressure sensing surface (Prototype 3 – see 6.4.1) I chose to develop touch sensing fabrics, as fabric is possibly the most universal non-human thing utilised in garment prototyping. While small touch sensors mounted under different fabrics were employed in structured studies of touch behaviours relating to material qualities by Petreca (Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016; Petreca *et al.*, 2016, 2019) and their expressive usage on a larger scale was explored by Petreca *et al.*, (2019) their use in a situated context, to collect data, and prompt discussion on physical garment design development activities has yet to be explored.

Fabric sensors were developed to visualise the location and pressure of contact in real-time, which could be captured on video during their emplaced usage. While longitudinal data recording is considered an essential aspect of 'thing ethnography' (Giaccardi, Speed, Cila, *et al.*, 2016), the focus of this study is on meaning-making through touch and feeling during a garment prototyping process. It provides a specific timeframe for focusing on the entanglement of things and humans. Though longitudinal data capture may have revealed more about the overall temporality of designers' engagement with a thing, it was not deemed critical for a study of touch.

As such, the final implementation of the touch sensing fabrics constituted an approach similar to a probe (Gaver, Dunne and Pacenti, 1999; Boehner, Gaver and Boucher, 2014) which was introduced into the ethnographic encounter to generate reflection, discussion, and explore how a digitally connected, sensing non-human thing might integrate with, extend, or inform participant's touch practices.

For further detail on the design and development of the sensor fabric probes, see Appendix 3: Sensor Fabric Probe Development.

The sensor fabric probes were initially presented to participants laid flat on their pattern cutting tables, with the visualisation playing on an adjacent laptop. Participants were encouraged to handle the fabric sensor probes freely and to 'destruction test' the probes in various contexts to which they could be applied or that might help participants consider the digitisation of touch. In practice, this led to participants pleating and draping with the probes, using them as pressure sensors when ironing, or on the foot pedal of an industrial sewing machine.

While they touched the fabric probes, participants were invited to share their thoughts on seeing their touch mapped and visualised. These comments and the concurrent on-screen visualisations were captured in the video data from the workshop.

4.6 Data Materials

During the ethnographic encounters, I captured video data with an alternately roving, participant-directed (after sensory ethnography), self (researcher) directed camera viewpoint (after multimodal ethnography) and a static, contextual viewpoint (after non-interventionist ethnography, such as some multimodal approaches). Sometimes, I simultaneously used these different perspectives to focus on the detail of touch practices while recording the emplaced context. I produced written ethnographic fieldnotes to supplement this data and took still images of the observed activities and emplaced environments.

In total, 25.5 hours of video data were captured during the ethnographic study, with an average of approximately 257 minutes per participant, over 26 periods of observation.

Additionally, data from Workshop 1 comprised visual documentation of the digital touch prototypes created by student teams (see Chapter 6), video recordings of their development, and group discussions around the workshop tasks. The data collected by the Autographer lifelogging camera during participants' autoethnographic documentation of their touch practices were also collected. Using this method of data capture, the first-person perspective images (see Figures 4.4 and 4.5) often provided limited views, which did not adequately capture the designer's focus. For this reason, wearable cameras and first-person viewpoints were not used in the main ethnographic study or Workshop 2.

Data from Workshop 2 comprised a recording of the Zoom discussion and both static and roving camera footage of the in-situ interview component of the workshop, along with ethnographic fieldnotes.

4.7 Data Analysis

The data was iteratively developed from sensitising concepts into ethnographic prose featuring thick description through diffractive attention to the observed encounters, alternating and mingling sensitivities to the encounter derived from multimodal ethnography, sensory ethnography and autoethnography. Thereby enabling a fuller exploration of touch in the observed encounters. Each of these ways of seeing and understanding offers different but complementary insights. They were read through one another to discover new viewpoints on the observed touch practices, their communication, and the reasoning for their use. This approach could be likened to an epistemological equivalent of Ræbild's (2015) proposed 'body lens' through which the body refocuses and moves between different roles in a design process. In the context of this thesis, I discuss the approach as a '*diffractive ethnographic attention*'.

After developing thick description through the research fieldnotes, the data from both workshops and the ethnographic encounters were inductively coded following Braun and Clarke's (2006) guidelines. First, the workshop and ethnographic data were coded individually, then as a collective data corpus to generate a mix of both emergent, data-driven thematic codes and theory-driven thematic codes relating to key concepts from prior literature. Microsoft Excel tables (see Appendix 2 for an example table) were populated with extracts from the data relating to each code and used to develop sensitising concepts, which were then taken back to the ethnographic sites to be further explored for their fit with the lived context of the study. The tables enabled a further systematic review and familiarisation with the data, highlighting which themes were relevant and which could be removed or combined. The themes highlighted in red in Figure 4.9 were excluded due to a lack of instances appearing in the ethnographic data (Touch Description, Touch and Emotion/Affect, and Tactile Metaphors), their common occurrence, but lack of specifically related touch practices (Physical/Digital Crossings and Material Crossings), or their accounting for limited touch practices with primarily screen-based or printed visual media (Agency of Creative References – as categorised separately form material agency).

Ethnographic vignettes were then developed in relation to the thematic coding to create a coherent ethnographic narrative depicting the observed touch practices and associated meanings and understandings. The creation of narrative and re-introduction of the contextual and entangled nature of the coded data through thick description allowed a further opportunity for reflection. At this stage, mapping of the themes was conducted after Braun and Clarke’s (2006) recommendations, further demonstrating the ‘messiness’ (Law, 2004) of the data and highlighting situated socio-material entanglements (see Figure 4.9).

The mapping illustrated links between themes, such as the connection between familiar and shared touch practices and tool use, in contrast to more individual and specific touches used to infer material behaviours and communicate how to touch (linked to the Demonstrating and Adopting theme in Figure 4.9). The artificial separation of themes, both from each other and their context is a significant criticism of traditional coding processes by scholars who use diffractive analysis methods (Doyle and Fenwick, 2018) and seek to maintain entanglements in their data. The connective mapping aimed to address this issue in my understanding of the data.

Having structured the data into a coherent ethnographic narrative, a diffractive approach was used again to analyse and discuss the data (see Chapter 9) through three differing agential cuts, representing different stances on non-human agency derived from the literature (see Chapter 3 for further details). Diffracting these contrasting readings within the ethnographic data enabled a more nuanced understanding of multiple ways touch practices might be digitised and the limitations of current technology solutions without proposing singular solutions. It also accounted for the sometimes-contradictory viewpoints on non-human agency expressed by the designers.

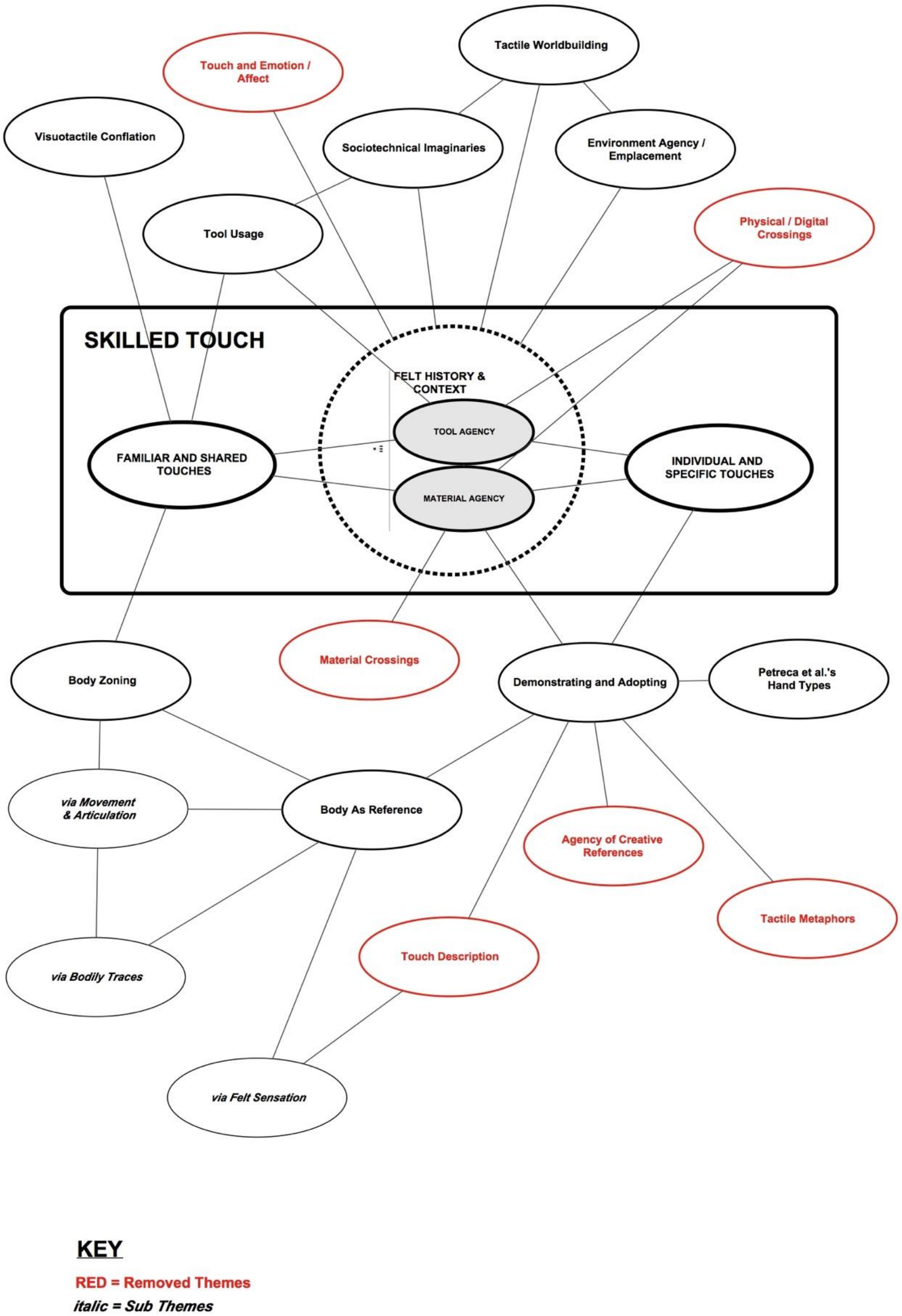

Figure 4.9: Analytical mapping of initial themes, demonstrating their entangled nature and the core focus on skilled touch, which forms the structure of the empirical chapters reporting the ethnographic data

4.8 Conclusion

The use of diffractive ethnographic attention during a multi-sited ethnography of garment designers' touch practices has been introduced and defined, arguing for the benefits of diffracting the epistemological approaches of multimodal ethnography, sensory ethnography and autoethnographic accounts of touch practices. In the diffraction, their distinctions are preserved rather than nullified. In the process of intra-relation, new forms of ethnographic attention not bounded by a fixed epistemological commitment are possible. Despite perhaps offering limited depth in the pure, bounded application of each epistemological approach due to the reduced attention to a single focus, shifting among ways of seeing, *feeling* and being emplaced in the ethnographic sites successfully foregrounded the nuances of felt experience which would not be possible to infer through a single lens on the ethnographic encounter.

Additionally, two workshops conducted to explore imaginaries of potential digital touch technologies to assist garment prototyping are discussed. Student participant'' development of digital touch technology prototypes and the emplaced use of ready-made touch sensor fabric probes with garment design educator/practitioners and researchers have been described, creating complementary approaches to introducing digital touch technologies to garment designers with various histories of education and professional experience.

Finally, the processes of thematic and diffractive analysis of the data have been described, highlighting the analytical process of diffracting between agential cuts that relate to technology and non-human agency, enabling a movement away from pre-defined technology narratives. Indeed, due to technical limitations, it may be impossible to essentialise the richness of felt experience through current technology options, which also enact and reinforce social expectations that the route to digitising touch has already been decided. Therefore, the diffractive analysis moves away from a singular technology-oriented stance and allows an account of what is desirable and beneficial to develop in digital touch technologies, not just what is possible or expected within academic disciplines.

Having outlined the methodology of the thesis, the following chapters empirically report the findings of both the workshop studies (Chapter 6) and the core ethnographic encounters (Chapters 5 to 8).

CHAPTER 5 – SETTING THE SCENE: SITUATING GARMENT PROTOTYPING IN THE STUDIO

Figure 5.1: View into an open-access studio at University X, Site A (see Table 4.1)

5.1 Introduction

This chapter situates the garment designer's studio as a site where resources come together and entangle to make meaning during the design development process. The chapter draws on data from the ethnographic fieldwork and discussions held during Workshop 1. During the workshop, twelve students on a fashion design master's degree attempted to document the role of touch in their practice and propose designs for digital tools to support their working processes (for further details of the workshop design and participants, see Chapter 4). This chapter points to the importance of non-human things, material references and emplaced context to the landscape of skilled touch in garment prototyping, which is explored in further depth in Chapters 6, 7 and 8. It further identifies the epistemic construction of the studio as a means by which certain technologies are accepted or excluded from designers' practice.

First, the chapter introduces the designers who participated in the ethnographic observation, outlining their backgrounds and practices (5.1.1 to 5.1.6). The chapter then introduces the concept of the design studio as an emplaced material environment (5.2), discussing digital divides (5.2.1) and locating touch (5.2.2) in the studio. Next, the chapter discusses the individuality of approaches to the garment design process (5.3) and their perception as a means to speed up and shortcut labour-intensive processes (5.3.1) as well as a means of identity construction for designers who wish to be innovative (5.3.2). The chapter concludes in 5.4, recapping the main arguments and contributions.

Before introducing the studio spaces in which they are emplaced, I introduce the designers who participated in the ethnographic study, becoming my co-ethnographers. Each has a unique practice with related skills and imaginaries.

5.1.1 Meet the Designers: Kat

Kat is in the third year of her BA in Womenswear Design at University X. A digital sceptic; she prefers to do as much design development as possible physically and be led by engagement with materials. She is resistant to drawing and committing a design to paper before creating three-dimensional forms responding to material qualities, preferring only to ‘fix’ a design once she has resolved it through making. This sometimes leads to tensions with her tutors, but on the whole, she finds it productive to challenge expectations. Though she has worked in fashion retail before and during her studies, Kat has never interned at a garment design business, instead needing to work to support herself through her studies. This also led to her working with cheap, or free, found materials, expanding the conventional palette of fabrics used by designers. She spends as much time in the university studios as possible, sometimes from 9 am to 8 pm or later, though a lot of this time is spent socially discussing design work or future aspirations with peers. Kat aspires to work for small contemporary designers and has strong opinions on what garment design should involve. She feels that a prestigious master’s degree would help her gain media exposure and achieve her ambitions, but she doesn’t see this as realistic due to the cost. Her nightmare is to be perceived as stylistically similar to existing brands or employed only to draw rather than prototype garments.

5.1.2 Nadine

Nadine is a classmate of Kat's, though they rarely interact due to the size of the course cohort. However, they often work in the same open-access studios. Nadine is there less often, having a mini studio set up at home on the outskirts of London. Unlike Kat, Nadine has undertaken several internships with garment designers. One before starting her degree and one as a year out before entering her third year. Nadine is passionate about wearable technology; attending many industry events and conferences. She has tried to prototype digital functions in all her final year projects using the Arduino physical computing system. Nadine is realistic about working and taking on other internships after she graduates, preferring this to further study.

5.1.3 Carla

Carla is studying for a master's degree with a focus on sustainability and innovation in the fashion industry at University X. She has an undergraduate degree in costume design, and for the ten years before returning to university, she worked in various costume 'shops' [studios] in New York, often clothing dancers, and actors. In addition, she has a bespoke bridalwear business which she tries to run on sustainable principles. Carla often remarks that she thinks her background in costume gives her a different approach to most fashion designers, particularly considering the body and fitting. Though she is interested in technology, particularly how it can be used to connect people or reveal the history of a garment, the project I observe her working on is developed without using digital tools. After graduating, Carla imagines a future role as a consultant to the garment industry, advising on sustainability.

5.1.4 Marie

Marie is studying a fashion design master's degree at University Y. She has previously interned at several fashion businesses, from small high-end designers to a major high street brand. She is technically enrolled as a menswear student but currently designs for men and women. Her designs explore online, and gaming identities in contrast to the people they represent, accounting for the blurred gender boundaries. Much of Marie's inspiration comes from video gaming and digital representation of the body, leading to a particular focus on avatars. In particular, ideas around wearing avatars or blending them with real-world garments using augmented reality, as well as physical design cues. In our discussions, she often references MMORPG (Massively Multiplayer Online Role-Playing Game) worlds with their associated character building, Guilds, and tribes. In line with her interest in the digital, Marie primarily works with a 3D garment design development software called Clo3D. She is relatively new to the software, having only started to use it during her MA. It allows designers to create virtual garment prototypes and fit them on digital avatars, replacing physical sampling and fitting. However, Marie is also keen to materialise her designs where possible.

5.1.5 Ella

Ella is a Course Leader for a master's degree at University X, specialising in the technical and production aspects of garment development. She has run her own business for over twenty years alongside teaching roles. Though initially working with fashion garments, Ella now also creates dresses to be worn by Tango dancers. The Tango dresses must fulfil specific performance requirements and fit well to the moving body of a dancer. Though sometimes externally more straightforward, the Tango dresses are constructed on a complex base bodice to secure them. The design of the internal structure has been perfected by Ella over several years and does not change beyond fitting to individual bodies. As a keen dancer herself, Ella has drawn on her own experience to create these garments. I often reflect that my time with Ella teaches me as much about Tango as garment design. Though not working with digital technologies for the garments I observed her designing, Ella is interested in exploring 3D garment design and pattern cutting software in future.

5.1.6 Alexa

Alexa is Course Leader for a bachelor's degree at University Z (another specialist design and media university in London) that focuses on innovative approaches to accessory design. She is a graduate of University Y, though not their fashion design course. Despite a pre-degree tailoring internship, studying an undergraduate fashion degree, and subsequently working in the industry as a designer, her master's degree was in speculative and critical interaction design. The move away from an industry-led approach to garment making to an expanded fashion practice (as described by Hoette and Stevenson, 2019) is key to Alexa's understanding of her work. She is a member of a three-person design collective that often works in wider collaborative networks on projects employing digital technologies. The Collective use garments and other worn objects as a medium to critically explore social issues. Their current project involves creating the identities of digital characters for a VR performance, along with physical costumes for dancers who will be motion captured and transposed into the VR world. During my time with Alexa, this grew to include costumes for audience members visiting the performance, bridging their experience of the physical and digital worlds. Though she is enthusiastic about digital technology, Alexa does not believe in its uncritical application.

5.2 What is a Garment Designer’s Studio?

To those unfamiliar with garment making and, more broadly, with creative industries, the studio may seem like a mysterious black box from which designs emerge but about which little is known. Occasionally a refined, tidy and aesthetically pleasing studio will be presented as part of a fashion brand, ballet, or theatre company’s marketing, demonstrating the activities of their skilled artisans and giving a staged glimpse ‘behind the scenes’. Yet the realities are often different. Less glamorous and more chaotic. Is it like a workshop? An office? A little of both?

The studios included in this study are the spaces of individual practitioners which incorporate in-house sampling or deal with design development activities like pattern development, in other words, spaces that retain an engagement with materials and their three-dimensional manipulation. It excludes design offices (common in mass-market fashion companies) because, in these, the focus is solely on the visual iteration of a design, with sampling, prototyping and production conducted off-site; usually outsourced overseas (Pycock and Bowers, 1996; Moon, 2009, 2011). An example of the distinction between these two types of site can be seen in Ræbild's (2015) ethnographic documentation of examples of each type of studio. Ræbild notes that designers still handled garments and materials in a 'design office' studio. However, they did not prototype them as part of their design development. Osmond describes costume designers' workspaces as 'physically immersive, materially oriented' (2021: P278). In a costume context, as garments are not produced as multiples, the prototyping and final production remain in-house.

In this thesis, a garment design studio is defined as a site in which a designer collects and curates multimodal resources and the tools to form and manipulate materials into a garment prototype. In this case concurring with McCullough's assertion that collections of tools (both digital and physical) define practices (1996: P61). Though the designer leads this curation, unlikely, unforeseen, and rhizomic links develop among these non-human things and often become key triggers for imaginative developments in the design process. These links extend beyond the geographical boundary of the studio, and Ræbild notes that for her participants, the design process was not bound by location. Yet, for practicality and ethical engagement with participants, the data reported in this thesis is also bounded by the studio environment, except for a chance meeting with one of the designers in a fabric shop.

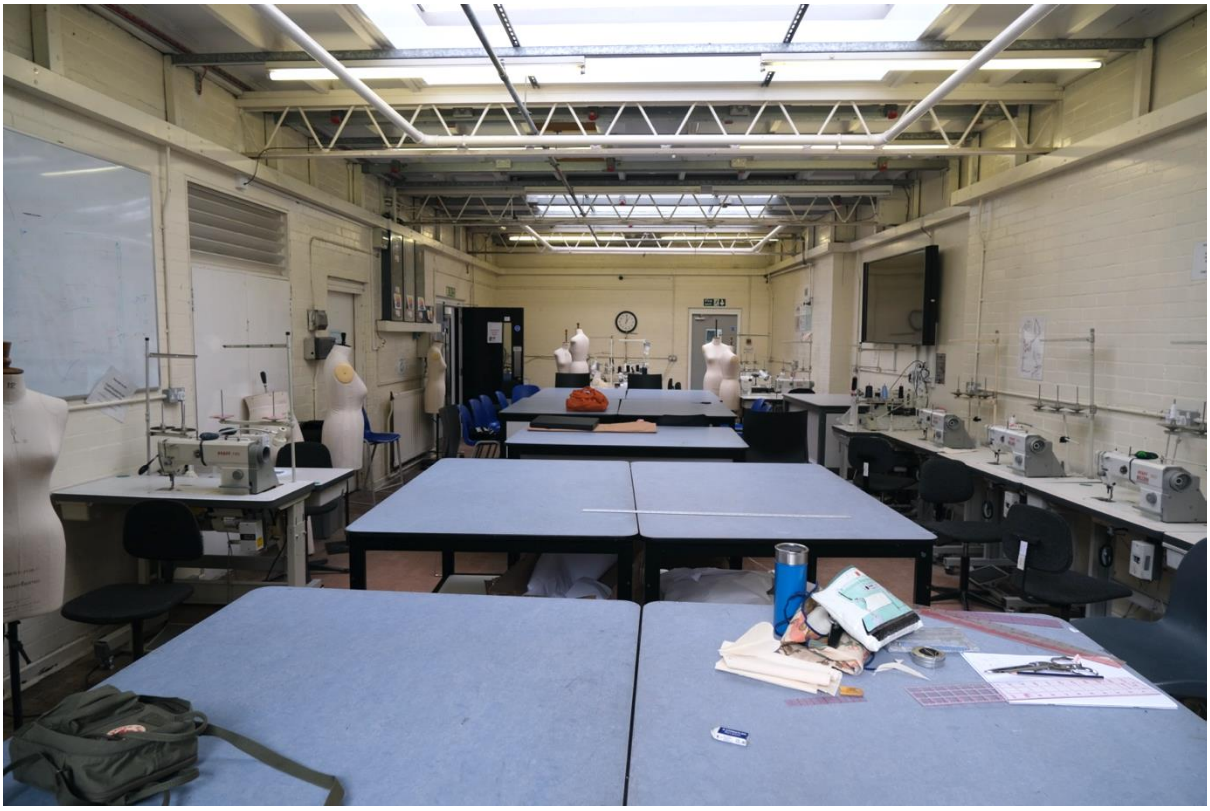

Figure 5.2: An open-access studio at University X, Site B (see Table 4.1). Central banks of pattern tables, surrounded by industrial sewing machines, tailor’s dummies, and steam presses

The configuration of fashion studios varies, particularly between education (documented by Nicewonger 2011, 2015, 2016; Lisewiski, 2018; Rowell, 2020), industry (documented by Moon, 2009, 2011 and Ræbild, 2015) and individual practitioners’ studios (as contrasted to educational studios in this thesis). However, studios do have commonalities. They are likely to contain a large high table for drafting patterns and cutting fabric, tailor’s dummies, sewing machines of various descriptions (sometimes for specific materials like leather or fine fabrics such as chiffon), irons and ironing boards and storage for materials, haberdashery, trimmings, and tools. Computers are also increasingly ubiquitous in a studio, particularly in commercial contexts, as noted by Ræbild.

Figure 5.3: Marie's assigned space and adjacent pattern table at University Y, with stored materials, reference images, and past and current projects on display

Figure 5.4: Alexa's studio

Figure 5.5: Ella's studio

Figure 5.6: Alexa’s Collaborator Mabel’s Studio

Studios are materially and sensorially rich. I am accustomed to and have spent decades in studios. But to the uninitiated, even without a sense of the sounds, smells, temperature and tactility of the spaces, the sensory experience can be surprising. When sharing the study photographs of studios with a fellow ethnographer, they were described as 'sensory overload'. I have instead come to see them as Library-like. Even in the most chaotic of the studio spaces in this study, there is an internal logic dictated by the designer who curates it; they could all quickly identify material references to support their communication of a concept or advance their thinking around a design. This supports McCullough's identification of studios, or workshops, as '*the perfect access structure to its various contents for its resident.'* (1996: P151). Yet, as I will discuss, beyond this human ordering, materials themselves can trigger previously unconsidered connections.

Seitamaa-Hakkarainen & Hakkarainen (2016) discuss the textile design studio as a collaborative socio-material learning environment, proposing that it is as much a site as a method of instruction. The similarity to a professional environment and the presence of material resources being key to the learning experience. Murphy (2015) also considers design studios to be spaces of multimodal resources to communicate with, considering these resources primarily to support communication and collaboration *between* designers. As the spaces I recount in this thesis were almost all occupied by individual designers, this foregrounding of interpersonal communication (also noted by Ræbild) must be reconsidered. While the studio resources supported their communication with me, an outsider, they held other meanings and purposes for the designers themselves in developing their garments.

The studios visited in this study include visual images, made material, printed, sketched, photocopied, and written notes, with rhizomatic links to digital data, reference images, films, and social media accounts, all of which can be inspired by material references. Other studies rarely remark upon the nature of this resource base and its connections, but I argue that it is a critical sensory resource. An exception is Ræbild, who constructs studio resources in relation to temporality, as discussed in Chapter 6.

5.2.1 Digital Divides in the Studio

There was no sense of discontinuity for the designers between showing me a drawn design, a sample garment in calico, a selection of materials, photographs on their phone (taken by them or in a social media feed) or a film on their laptop. In this sense, the material is interwoven with the digital. However, the VR, motion capture and physical computing technologies that some of the participating designers work with sat both physically and epistemically outside the studio. For Alexa, for example, this meant working with specialist collaborators, developing garment and accessory making separately in response to avatar design, VR, and motion capture work. Occasional studio visits and joint meetings-cum-workshops allowed the collaborators to experience and engage with each other's studio environments and resources.

The split between the analogue and digital materials and practices of the studio was most evident in Nadine's work, marked by the lack of overlapping skillsets between garment makers and coders. Nadine worked between the studios and tutors assigned to her course (a non-specialised BA in womenswear design) and the university's 'Digital Lab' located on another campus, where she could access specialist support for building circuits and programming Arduino physical computing hardware. As a result, on a day-to-day basis, her main source of feedback was on the design and construction of traditional garments without the addition of wearable tech. These were the competencies that the course taught, and her tutors thought Nadine needed to master before adding the additional complexities of coding and integrating hardware. While this ensured Nadine focused on the main learning outcomes of the course, it created a division between the digital and traditional aspects of her practice which proved contentious in differing opinions of whether the two should be holistically integrated. In Nadine's imaginary of the potential of wearable technology, this distinction was not present. My fieldwork captured Nadine's frustration at being presented with this divide, for example, needing to book timeslots to visit the Digital Lab and the impact on her workflow, which had to be planned or adapted accordingly. In addition, working with the slower temporality of sourcing specialist mail-order Arduino components, e-textiles, or smart materials, that could not be purchased in a hardware or fabric shop. This temporality introduced a sense of disconnection for Nadine. Her studio collection of resources was often temporally and spatially separated. In recent practice-based research theorising wearable technology development, this epistemic separation of technology and garment is challenged by adopting theoretical lenses such as post-phenomenology (Van Dongen, 2019; Van Dongen *et al.*, 2019), which addresses technology as material. However, this has yet to impact the majority of educational studios.

Marie's work with 3D design software was better integrated into her studio environment. Quite literally, in the form of numerous printed images of her digital design work adorning the studio, making material links to intangible data. Although this software required a new skillset with a steep learning curve, the fact that it operated in the realm of visual design to develop a garment enabled it to be more confidently incorporated into the studio than code or soldering. As a master's student, Marie was considered by her tutors to have appropriate garment design and making skills. Therefore, extending her practice to bring new skills to her studio resources was accepted.

Nonetheless, Marie struggled to engage with technologies which did not directly relate to design, such as VR and motion tracking. While exploring the possibility of dressing a moving avatar in her designs and showcasing them in an AR or VR space, she had to book time with specialists from other university departments and struggled to find the expertise she needed. Despite a willingness to engage with new digital technologies, again, not all technologies were accepted into the resource base of the fashion studio.

Annette*, a designer who took part in Workshop 1 (for further details, see Chapter 4), sometimes started her process by working digitally, making 3D forms with zBrush (a 3D VR drawing App) and then considering how to translate them into a garment pattern and physical prototype manually, rather than using a 3D garment development software. She cited a frustrating experience with Marvellous Designer (a similar software to Clo3D, but geared toward garment design for 3D characters rather than physical clothing development). Her opinions are captured in the fieldnote below. The analogy of sculpting and discussion of freedom and intuition as oppositional to mathematical approaches summarises the perceived divide between traditional creative competencies and those required by digital tools and software. Annette*'s comments also support Yang and Lee's (2021) proposal that virtual sculpting processes may be more intuitive for designers unused to creating 3D CAD models.

FIELDNOTE – Workshop 1 Discussion: Virtual Sculpting and Software Frustrations

> "You have to first think of the pattern and then drape it onto a virtual model. Whereas I'm now using zBrush a lot because you can sculpt very freely and then later think about how to translate it into a pattern, and I think this is a nicer and more intuitive way to approach silhouette making. I experienced a bit of frustration with a lot of 3D modelling softwares; they are very mathematical!"

Qualitative, experiential, and sensory understandings and meaning-making inform most garment design processes (except the more mathematical approaches to pattern cutting). These are worlds apart from the quantitative and structured approaches to meaning-making and understanding that underly digital technologies. This highlights an epistemic separation between the studio and the laboratory, which had visible ramifications for the designers I observed, their peers and tutors.

Technologies which did not offer a visual mode of engagement familiar to design educators were marginalised. This raises the question of whether other sensory feedback common to a garment design practice (for example, touch) may make technologies more accessible to designers?

McCullough (1996) considers that tools should go unnoticed, becoming transparent so that they do not introduce additional cognitive load in a craft process. Digital garment prototyping software appears to have reached an acceptable level of transparency, visually and functionally re-creating a familiar medium (fabric) and an associated tool set comprising metaphoric functions and actions of garment prototyping, with reasonable (though not perfect) accuracy. However, the technical requirements of connecting platforms and porting assets from one digital environment to another (e.g., Clo3D to VR gaming engines) still include movement between the encoded contextual structures which frame different digital design and making spaces. This often requires a return to the abstract symbolic structures of code. Ironically, physical computing gives very little physical or sensory feedback during its development. Though a circuit can be created through physical prototyping, its functions are also reliant on code. A language which must be mastered, rather than a medium which can be intuited and manipulated with (digital) tools.

Due to their lack of grounding in tangible processes, or lack of fidelity in representing them, digital tools can unintentionally introduce randomness in a design process when they do not behave as expected. While McCullough argues that this breaks immersion in a digital simulacrum of a craft medium (e.g., digital fabric) and its contextual structures (e.g., stitching, pins and a model to drape on), this can be a productive space for creative garment development (Thiel, 2017), harnessing unintended consequences of technology usage as a design inspiration. However, it can also reinforce the epistemic divide between garment design and coding or engineering, proving off-putting for garment designers who traditionally prioritise slick product outcomes and do not have the in-depth skills to troubleshoot what may be perceived as glitches. These aspects of epistemological otherness appear to prevent educators from both sides of this divide from understanding how interdisciplinary engagement can be facilitated. It is rare to find hybrid practitioners or educators who can span this divide yet working in this space is of increasing interest to students who have been immersed in digital technology use throughout their lives. This research supports the argument that understanding how to facilitate and maximise the benefits of interdisciplinary dialogues will be a core skill in garment design educators of the future, as suggested by Faerm (2015) and Postlethwaite (2020).

5.2.2 Touch in the Studio Environment

Having contextualised the studio environment, this and the following sections spatially and temporally situate touch encounters within the studio. They also introduce some of the smaller non-human things (primarily tools) that contribute to the material experience of the studio. The richness of the designers' material environments, whether in a fixed space or created and transported with the designer themselves, is a commonality observed across all the designers. Resources for felt experience, particularly materials, technique samples, and previous prototypes (or toiles) that serve as creative references, are generally ‘ready to hand’ in the studio. I use the term ‘ready to hand’ after Heidegger’s (1962) *Zuhanden*, a relational construction of non-human things in terms of their associations and ability to become usefully entangled with designers. I often observed designers handling material references, serendipitously finding or remembering a material or thing which they then sought out, handled, and manipulated (see Figure 5.7). Thus, the material things with which designers think are not contemplated and intellectualised but simply entangled with the designers’ body through felt experience, categorised by Ræbild (2015) as probing or using a highly visual metaphor ‘seeing with the hands’ (Ræbild, 2014).

While things being ready to hand indicates the human curation of material things in the studio, their unlikely associations in the design and prototyping process demonstrate un-orchestrated, more than human connections. Material things are never arranged or structured completely arbitrarily, or completely uniformly, by either human, or non-human forces, but in the case of both human and non-human distribution of things, different things are afforded different priority by humans. It is through material connections to the un-prioritised (the forgotten, or the overlooked) that material entanglements and agencies are revealed. In this case, the connectivity of significant, curated things, to those overlooked in the wider studio, or the wider world.

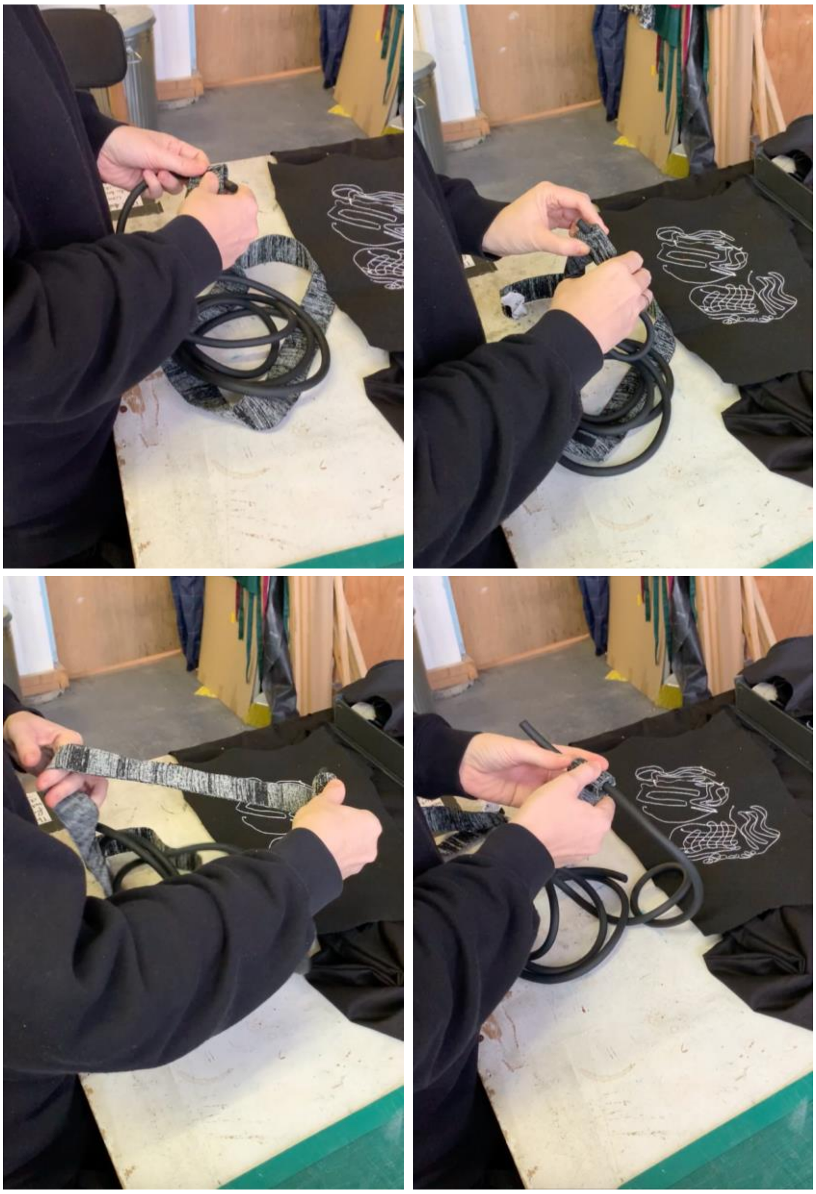

Figure 5.7: While on a phone call, Alexa finds a sample of knitted elastic and a length of rubber cord. She experiments with stretching and coiling them around one another. This reminds her of a previous design idea and leads to her comparing the coiled materials to a sketch which they might help materialise

Ella, Alexa, and her collaborators used materials and things ready to hand in their studio to support our discussions. While without a permanent space, Kat managed to secure (against the college rules) a regular area of her open access studio in which to leave materials and boards of imagery. In contrast, Marie's studio space at University Y (notable as she was the only student to have an official, permanent space assigned to her – a difference in university policies) was densely populated with reference images and materials. During all of our discussions, sample materials, such as braided straw (an inspiration for the straw coat and crown – see Chapter 8, Figure 8.4), toiles, finished garments from previous projects, and even collaborative projects with other designers were put to work to illustrate Marie's thoughts, designs and narratives non-verbally.

Sensations were demonstrated by sharing a material reference to handle and asking, 'do you feel that?' rather than verbally described by the participants. See Chapter 8 for a more detailed discussion of such processes. Though Kat and Ella described sensations, they still did not verbalise what to feel *for*. This contradicts Ræbild (2015) and Petreca, Baurley and Bianchi-Berthouze's (2015) findings that tactile qualities were generally expressed through metaphor. I suggest that this may reflect the framing and method of Ræbild and Petreca's studies which focused on participants' describing felt sensations verbally in conjunction with video analysis of touch gestures in the context of textile selection for a design.

Petreca, Baurley and Bianchi-Berthouze's approach is underpinned by or brings forth a hylomorphic understanding of design as a pre-conceived idea for which a material is selected. However, the 'Stimulate' phase of material experience does allow for the refinement of design ideas based on participant experience of material properties. While Petreca notes that designers consider materials to be lively and therefore, perhaps agentive (Petreca, Baurley and Bianchi-Berthouze, 2015; Petreca, 2016), an exploration or foregrounding of the way designers and materials collectively enact agencies is not incorporated into her studies.

Figure 5.8: Marie's workspace, including boards, several tailor’s dummies, reference imagery as well as previous work and experiments in materials and accessory making

The students without a permanent studio space developed different approaches to managing resources their practice required. These ranged from Kat’s decision to take over an area and demark it with her inspiration boards and stored fabrics under the pattern table (which, along with her strategy of coming in early and leaving late, ensure that the space remains hers) to working out of a suitcase, travelling across

London carrying as many resources as it was possible to take with them. The latter was Carla and Nadine’s approach.

VIGNETTE: An Itinerant Studio

I feel a sense of order in Carla’s space and tools, as evidenced by her almost ritual process of unpacking them in the morning to define her workspace. A floral fabric tool roll and a large zip case with a duck egg blue vintage sewing machine printed on it are positioned around her on the pattern table. These are accessible but demark the boundaries of her space, with a clear area in the centre for fabric. It is an orderly approach, making necessary tools easy to find. Perhaps necessitated and assisted by unpacking and re-packing on a regular basis?

I ask Carla what she thinks are the essential items she needs to work with. “OK, these shears for sure”, she replies and places a large pair of metal fabric scissors on the table between us. They have a fabric name tag sewn around one of the handles. Then, smiling, she begins to collect things from around her space: the pencil and a rubber. Next, she pulls the plastic zip case towards her, takes out a large zip lock sandwich bag of rolls of thread and sets it aside. She opens a tan leather wallet with a felt insert pierced by a range of different size needles. Short threads still hang from some of them. From this, she withdraws a small, flat, yellow leather item with a round section of glinting metal mesh. It is like the fingertip of a leather glove, with a reinforced disc on the pad of the digit. “That thimble for sure. My favourite thimble,” Carla explains. She continues to rummage through the case, removing and setting aside a round metal tin and searching through a layer of fusing offcuts that she pushes to one side of the case. She pulls out the smallest of her rulers (one I never see her use). “These little rulers are great.” It is the dimensions of a school stationery ruler but differently marked. It is a miniature version of a second ruler around 50cm long and 10 cm wide, made of transparent plastic with graph paper-like, red markings on its entire length and breadth. A round box of pins, plastic this time, is discarded next to her left hand along with some black ribbon it has tangled in. She takes out another pair of large metal scissors and sets them aside, then adds a smaller pair to her chosen items. “Snips”, she calls them. Looking through the bottom of the case, she concludes “Yeah, so I would say those are the things that are irreplaceable.” All of Carla’s essential items are found in a more exhaustive list proposed by Lo (2021, P42-43).

At this point, a larger ruler with an unusual, curved shape is not included in the group. “So, what about the bigger rulers?” I ask. “Say this one over here?” I point towards it. “Oh yeah, definitely that one too!” This ruler proved to be a significant talking point with Carla and will be discussed further in Chapter 7.

Commenting on working in an open-access space with no storage, Carla tells me that she has to plan more carefully and comes to the university studio less often because of it. “Like one time I came here and forgot my rulers” Carla smiles sardonically and rolls her eyes. “So, I ended up buying one in the shop.” Carla gestures with her pencil in the direction of the campus shop, which sells art and garment making supplies. “Give us a locker. That would be nice. That’s my call to arms. Lockers for all! If I could just come for a couple of hours and leave stuff. Because once I leave the apartment, I’m out for the day, so I have to carry all of this stuff to all of the meetings that I'm going to next. Sometimes I'll bring a stack of projects, but I won't if I have to go somewhere else. So, it definitely changes what I'm working on."

This encounter highlights the designer's need to spatially organise materials and tools to ensure that the resources are accessible and made present in a temporary studio. An equivalent to the mental cataloguing of a fixed studio's resources. It also makes the limiting nature of itinerant working apparent.

Figure 5.9: Carla's irreplaceable garment making tools, calico and cases containing other resources

Later, thinking back on previous interactions, I realise that Carla's reference images are all digitised, a convenient way to make them portable, but diminishing their collective presence in her studio space. Carla's is a space which is physically reduced to tools and materials yet linked to intangible references and inspirations.

The inability to build and curate their own space with materials, tools and inspirations was a source of frustration. The designers often expressed dismay that they did not have material resources with them that they could easily locate at home or that the resources they sought at that particular moment were split between places. Thus, interrupting their flow of thought during material or design development or forcing them to work on something different from their planned task.

Though the studio's essential components (its tools and resources) may be portable and, to some extent, digitised, physical placemaking supported both traditional and digital garment design development practices. However, material resources can sometimes leave the studio in productive ways. On one occasion, I met Marie while she was fabric shopping. She was looking for a particular type of felt for the under-collar of a jacket and had brought a card with her representing possible fabric and trim choices. A5 in size and slightly dog-eared at the edges, the card had a selection of buttons taped to it and small fabric swatches haphazardly hanging from the bottom. A variety of tan-coloured checked wools and matching linings. It was densely covered in accompanying notes which seemed to fill the remaining space. Though specific to one design idea, this card represented a microcosm of the material resources available to Marie in her studio space and helped support design decision making in much the same way. The material presence of fabrics and buttons was, in this case, preferable to a digital image.

A studio is unlike an office in the expectation of its availability when inspiration strikes. Many of the designers worked long or unusual hours. For Ella and Alexa, this was necessitated by working around their teaching jobs, but for the students, it was an opportunity to maximise their immersion in the material environment of the studio, with creative references, tools and materials ready to hand to enable play and experimentation. Ella and Alexa both expressed regret that they could not spend more time in their studios for just such reasons. Kat went as far as to express dismay that her university studios were not open twenty-four hours. Both she and Marie stayed late into the evening in their studios. However, the studio also represented a social environment for the students, who often engaged in discussions of their work, providing informal peer feedback. In this way, the development of designers' identities and practices is not only facilitated by educators but also exposure to peer's moral judgements about garment design (in the sense of what is acceptable and accepted in garment design, after Nicewonger, 2011), forming a consensus among a community of practice. Yet, in this case, circumventing the judgements of more powerful or skilled practitioners, contra to Lave and Wenger (1991) and Wenger (1999). This feedback would often prompt new experimentation and re-engagement in a design process, temporally acting as a pause that drove renewed activity.

5.3 Individual Design Approaches

The previous section described the participants' studios and the material and spatial aspects of their practice spaces; in this section, I attempt to describe the complex process of garment design development and the many variations I observed. Though textbooks and industrial garment design and production adhere to a linear process moving between different specialist roles (James, Roberts and Kuznia, 2016): from drawn designs to pattern cutting, fitting and adaptation and then a final sample. In the reality of garment design education and small studios, this is rarely as prescriptive or linear, a contrast born out in this ethnography and supported by Dieffenbacher (2013), who observes that the variety of individual approaches has not been researched. For reference, Sgro (2018: P16) illustrates the conventional linear model to represent her *habitual* design process (Figure 5.10 below).

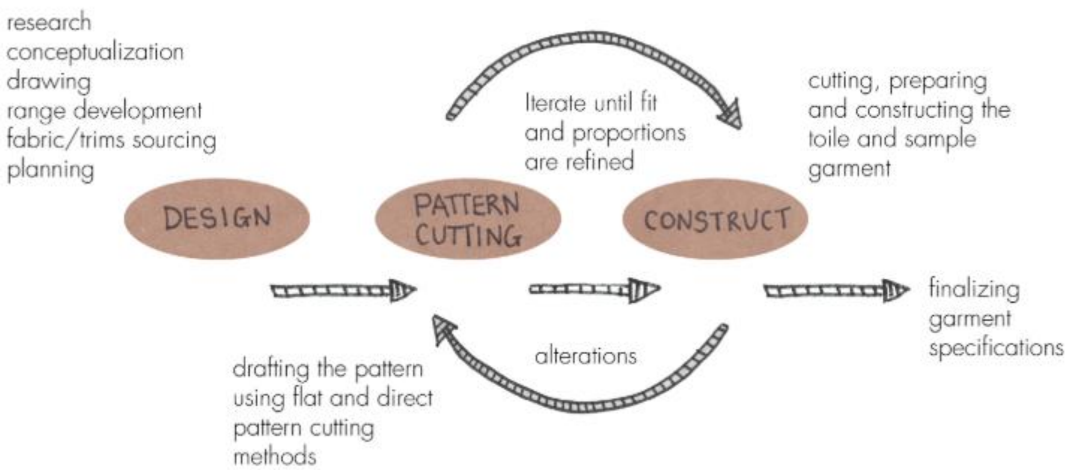

Figure 5.10: Sgro's (2018: P16) habitual design and sample making process

The six designers I observed in this ethnography considered they had an individual approach to design and used non-traditional garment design development practices rather than standard or representative ways of working. Ella described her "idiosyncratic process" and hoped it was still useful to analyse. Alexa commented that she didn't always know what exactly she was doing and spoke of the "undirected lulls in her process". Carla described the garment I observed her making for herself as "an opportunity to experiment with process". At one point, telling me, "I hope this is a shirt at some point! It has been a journey… it's an exploration." She laughs. "But the first one that I've done like this, so I just didn't even know how it would come together." This arguably supports the undirected nature of handling noted by Ræbild (2015) as a more general feature of design development through prototyping.

Marie also described her developing understanding of working between digital and physical processes as an experiment and learning process. Nadine, who expressed a strong interest in learning from her internship placements and course tutors, still described a love of 'breaking the rules' she had learned when working independently from home.

5.3.1 Speed and Shortcuts

Significant variations in individual approaches also emerged during Workshop 1, when student designers were tasked with documenting the role of touch in their garment development process (See 4.5 for a full description of the Workshop methods). When the participating designers discussed the design process and the role of touch, this often inspired impassioned debate. These variations in approach to a garment prototyping process were a recurrent theme throughout the data reported in this thesis.

VIGNETTE – Workshop 1 Discussion: Different design processes

The group of participating design students are sat around a pattern cutting table, discussing their process when developing a garment. James* says he follows a conventional route of linear progression from a drawing to the creation of a garment pattern to 3D making. Georgia* describes this as “very linear. It has like a very specific cadence and steps that you follow” in relation to the way design and making processes are traditionally taught. Similarly, Liyang* initially argues for this model of design, proposing “we kind of have a design first and try to find a material and create the shape, so the touch and the quality of the fabric, it’s only support for the shape we would like to create” many of the group instantly disagree, particularly Georgia* and Matteo*. Illaria* states, “I personally never do sketches because I don’t want the outcome to be shaped by the first sketches. I prefer the other way around, from the material understand where it could go.” Annette* and Una* agree they start with “sampling and draping, working directly in 3D”, which they then translate into garment patterns. Liyang* iterates her design between physical making and 2D pattern development. “because pattern cutting is mixed with every stage until it is precise.”

While this discussion highlights the diversity of design approaches, it simultaneously emphasises the importance of materiality and material engagement through touch in shaping them. It also highlights the role of material experience in working against perceived norms of garment design. Despite the intensity of their debate, all the student designers eventually agreed that even if starting with a design idea, working with a specific material changes the design. This is an established narrative in garment design but appears contradictory to the more linear process of visually establishing a design before materialising it, represented in pedagogy and literature.

All the designers who took part in the ethnography expressed a desire to speed up labour-intensive processes, which led them to feel that they weren't 'doing it right'. This feeling and use of 'shortcuts' was a significant unifying aspect across their different practices. Some of these shortcuts, for example, paper folding (see 7.3.1) and even creating a garment without a paper pattern in Carla's case, relate to specific practices mediated or understood through touch, which I explore in more detail in the following chapters.

Where many of the processes diverged from a traditional workflow, the designers noted that they were creating shortcuts. It took the participants considerable time to create a garment, with much time spent developing the paper pattern (for those who used them), and each garment underwent multiple iterations. For example, Ella spent the majority of two days (and some additional time I did not observe) refining and re-iterating the pattern for a single pleated detail on the hip of a dress. I observed her making five iterations. Alexa spent two intensive afternoons working with her collaborator Mabel to develop a half-scale pattern and toile for one garment. The students generally spaced their development processes over more extended periods. Some took as long as several months to iterate a garment to completion, as they interspersed prototyping it with other projects. The ethnographic process brought the temporality of garment design, including my own practice, newly to the fore.

5.3.2 Innovation

Design and pattern cutting literature present a particular workflow (critiqued by Dieffenbacher, 2013), suggesting tools and approaches rarely adhered to in professional practice. The notion of opposition to these approaches was a means that the designers used to contextualise their practice as innovative (see FIELDNOTE – Alexa's fight with stereotypes, on the following page). A quality which is particularly exulted in fashion (and to a lesser degree costume), as with most creative disciplines. Indeed, education in garment design will often create productive tension by presenting contradictory messages to learners, asking them to at once be as creative as possible while adhering to structures and habits designed to induct them into a simplified and idealised world of garment design (as observed by Nicewonger, 2011). In professional design contexts, messages around workflow and technique can still be conflicting (see VIGNETTE: Carla – Differing Practices as a Resource, later in this chapter, and VIGNETTE: The various 'correct' ways to pin, in Chapter 7), perhaps due to the varied process of enskillment to become a garment designer.

Disciplinary categorisations and stereotypes proved to be another point of productive tension around the designers' identities. Ella frequently referred to a distinction between her ‘fashion’ designs and her Tango designs. To her, a fashion design could be less practical and more creative; it would merit finishing in laborious and technically skilful ways which would not be appreciated by a viewing audience or appropriate for a garment which must withstand the rigours of moving with, and responding to, a dancer’s body. As a former theatre and ballet costume maker, Carla also observed the differences between fashion and costume. In line with her interest in sustainability, she saw opportunities for fashion design to learn from the adaptability and durability of costumes. Alexa had a complex personal position in relation to garment making disciplines, situating herself in opposition to both fashion and costume as a way to develop a novel practice linked to games, characters and interactions.

FIELDNOTE – Alexa’s fight with stereotypes

> Though she is clothing the performers for a specific event, Alexa comments, “I’ve always had a fight with myself calling it costume. Because I don’t think they are costumes, they’re not referencing anything that has been done before, or hopefully not. I mean to some degree, they always will, of course. But not like ‘costume costume’ does. But also… well, they are there to sell a story, I’m still having this conversation with myself, but I actually think of them as characters, like in a game. I think it’s maybe the updated version of costume, I guess? It’s really difficult. I’m not feeling that negative about the term costume any longer. But I did at one point very much!” I ask Alexa whether this is because the associations with costume seem limiting? She replies, “That’s also why I feel most distant to the term ‘fashion designer’, or fashion because I’m not designing fashion and actually, I had a theorist in my [Fashion] BA. In one of

our lectures, she told us, “you cannot be a fashion designer because fashion is only when it’s adopted”! I was like, that’s actually true; I kind of believe in that! The course was fashion, and I had a big fight” Alexa grins at me, raises her finger dramatically and moves to her laptop to look up her past work. “It was great because actually, you need the system in place to be fighting something, and that’s what I keep on telling myself today. People need to fight in order to feel like they have achieved something. On my BA, we had to work with some digital students from another city, and that was the best project! Basically, I made garments pattern cut to be shaped like letters. I developed an installation with them where people could go in, and they would be filmed and see themselves having to put their body into the shape of the letter, so they would understand the cut. That was sort of a game already. And then, for my final BA, I decided not to do a collection and just have objects. Garments as objects. And nearly didn’t graduate because of that!” Alexa laughs sheepishly but with a definite sense of pride.

The diversity of individual design approaches is a source of productive tension when situated in opposition to stereotypes of garment design, e.g., fashion as superficial and temporary, costume as backwards-looking and referential. But also in opposition to traditional understandings of order and the separation of the visual and the material in design and making processes. These understandings helped inform and sustain designer’' perception of their creative identities. Where this opposition relates to ‘hands-on’ working with tools and materials, this has implications for their use of touch.

A sense of opposition to perceived touch norms was not linked to the designer's level of experience and acculturation to garment design practices. Instead, it was linked to identity and efficiency: viewed as either more practical or a unique competence. This implies that although garment design learners may develop particular touch practices, the repertoire of touch practices is expanded and adapted through responses to personal material experience in combination with directed acquisition of touch practices such as those described in Chapter 8.

While garment designers are educated in particular processes and temporalities for design development, designers deviate from received procedures and norms, including established touch practices, when attempting to be innovative and introducing shortcuts. This leads to each designer employing a diverse range of touch practices which can be both widely recognisable and highly individual. This distinction is further expanded upon when reporting the touch landscape observed during the ethnographic study in Chapters 7 and 8. The core touch practices reported in Chapter 7 are relatively common across designers. The types of touch reported in Chapter 8, used to communicate about touch practices or infer and manage material properties, are more individual and diverse.

The designers with greater material experience were able to bring a more expansive repertoire of touch practices, developed through felt engagement with materials and things, to bear during the garment design process. See Chapter 6.1, Felt Histories. The choice from an expanded repertoire can also lead to greater confidence in a designer's choice to use established techniques or work in their own way, as evidenced in the vignette below. Thus, the accumulation of a broad touch repertoire can be viewed as part of the enskillment of a garment designer.

VIGNETTE: Carla – Differing Practices as a Resource

> "Every time I worked in a different shop, they were like 'no, no, no, you're doing that totally wrong!' And it took a little while before I took that personally, and I was like, no, everyone just does it differently, and they think their way is the only way. So, I remember going into a [costume work]shop." Carla laughs. "And they asked me to do something, and I asked what way to do it? And the Manager was like, 'Oh, I'm going to have to teach you how to do it!'" Carla huffs and flounces dramatically. "And I said, 'No, I know four ways. Which of the four ways do you want me to do it?' It's not that I don't know; it's that I know more!" Carla laughs.
>
> I later ask Carla if she usually drafts patterns net (without seam allowance) or includes them? She grins. "So, I've worked in enough costume shops that this is *the only* way to do it, and you *never* do it this way!" She taps the pattern table with her finger to emphasise the strictness of both opinions. "So, depending on what First Hand[4] I was working with, it totally changed, like what are the proper procedures for doing things. Now I kind of change from project to project, I guess."

[4] In costume workshops a First Hand is an assistant to a pattern cutter who advises on garment construction and acts as an intermediary between the pattern cutter and machinists. The role can also encompass other duties in relation to materials sourcing, costume alteration and maintenance.

This discussion highlights Carla's experience with different practices and techniques as a socio-materially shaped resource from which she can draw, either to integrate with different designers or to choose the most appropriate touch technique for her own work. This resource can also allow her to critically challenge proposed or normative techniques where she sees this as appropriate, 'changing from project to project'.

5.4 Conclusion

This chapter has introduced the designers who took part in the ethnographic study and conceptually defined the studio environment as a rich collection of tools and (sensory) design resources. Unlikely, rhizomatic linkages between these resources or their novel material configuration often inspire the design process. It also points to the ways that epistemologies of garment design and digital technology prevent their holistic integration in the studio construct.

The material and spatial nature of touch in the studio are discussed, supporting Ræbild's identification of the significance of casual touch and demonstrating the value of material studio resources being 'ready to hand' to inform a design process. For example, Alexa's casual handling of material samples while engaged in a phone call. The role of placemaking is also revealed as integral to the conceptual organisation of the studio, regardless of whether it is spatially fixed or mobile. Finally, the individuality of approaches to the design process and the use of touch during garment prototyping have been highlighted. Not only through introducing the designers and their diverse practices but also through the debates during Workshop 1 around linear design processes. The significance of both speeding up processes and ideas of innovation in opposition to disciplinary categorisation and procedural norms are identified as motivations for using an individual or non-standard (touch) process. These factors are significant in indicating the role of socio-material entanglements in designers' identity construction and highlighting the range and diversity of designers' touch practices when prototyping a garment. Both provide context for the documentation and discussion of garment designers' touch practices in the following chapters.

This chapter contributes an identification of the epistemic barriers between certain digital technologies and the understanding of what are considered to be garment prototyping activities. Proposing that while visual technologies are accepted, material and 'DIY' prototype making technologies such as Arduino are still ideologically and physically excluded from a garment design studio, particularly in educational contexts. This is demonstrated by the acceptance of 3D design software in Marie's studio practice in comparison to the separation of Nadine's garment prototyping and Arduino prototyping. This demonstrates that digital technologies have still had a limited impact on garment designers' touch practices in the studio, although they may compete for a designer's attention. The descriptions of the studio in this chapter lay the ground for the discussion of incidences of touch bringing humans and material things into correspondence and entanglement so that they might influence one another. These will be further explored in Chapters 6 to 9.

CHAPTER 6 – TOUCH CONTEXTS: FELT HISTORIES, PRESENTS AND FUTURES IN GARMENT PROTOTYPING

6.1 Introduction

This chapter contextualises the sensory worlds of the designers I observed and discusses the role of felt histories, feeling and worldbuilding and sociotechnical imaginaries revealed by these worlds (Jasanoff and Kim, 2015; Jewitt, Leder Mackley and Price, 2019; Jewitt *et al.*, 2020; Mager and Katzenbach, 2021). These represent a timeline of past touch experience, its present role in understanding and informing the felt experience of current designs, and the imagination of future garment design processes. Future imaginaries include speculative manufacturing technologies and educational tools proposed in relation to understandings of touch derived from felt history and contemporary narratives of technology. The relationship of designers' past, present and imagined future touch experience to existing academic constructions of fashion and temporality is discussed, arguing for the chosen viewpoint. The experiences and speculations derived from these eras of felt experience can contribute, either singly or in combination, to further contextualise the touch practices observed in the emplaced environment of the studio and reported in Chapters 7 and 8.

The data reporting felt histories and feeling and worldbuilding is drawn from the primary ethnographic encounters. The data reporting sociotechnical imaginaries is also triangulated with data from Workshops 1 and 2, during which participants respectively prototyped their own digital touch technologies and interacted with pre-made touch sensor fabric probes. Both workshops were explicitly future-oriented and speculative compared to the contemporary activities observed during the ethnographic encounters. For further details on the workshops and ethnographic methods, see Chapter 4.

This chapter begins with a discussion of Felt Histories (6.2). Moving beyond traditional ideas of enskillment (e.g., Pye, 1995; Adamson, 2007; Sennett, 2009) as a repetition and refinement of a particular practice, felt histories more broadly contextualise a designer's felt and bodily experiences. As Paterson proposes, these histories create broad, felt contexts for designers to situate their current felt experiences.

'everyday weighing, counting and measuring as praxis, which involves visual-tactile-kinesic modalities, creates somatic spatial contexts.' … 'the creation of contexts is a dynamic, kinaesthetic framework that includes the motile body, but also what can be incorporated into that body, for example instruments, tools, or spatial measuring equipment'. (Paterson, 2007: P74)

Felt histories build touch resources whose relationship to garment prototyping may not be immediately apparent but sensitise designers to the possibility of sensations and responses they may gain from a material. This includes the kinaesthetic experience of manipulating materials and the associative history of what arose from these movements, for example, creating three-dimensional shapes in different mediums.

In section 6.3, Feeling and Worldbuilding are discussed as the means by which felt histories are brought to bear on the garment prototyping process through empathy with the felt experience of the wearer in the particular context of an imagined world. In this way, felt histories are manifest in the consideration and development of current designs. Finally, in 6.4, the sociotechnical imaginaries of designers are thematically discussed in relation to Efficiency and Value (6.4.1), Supplementing or Replacing Skills (6.4.2), Learning and Understanding (6.4.3) and Crude Tools and Unfulfilled Promise (6.4.4). Sociotechnical imaginaries anticipate the role of touch and felt sensation in imagined future garment design scenarios, reflecting current social narratives on technology, skill and labour, or artisanship.

6.2 Felt Histories

Throughout our ethnographic encounters, the designers shared reflections on their felt histories, which proved crucial in my understanding of their practice. Designers' histories shed light on the origins of their understanding of material possibilities and behaviours. These histories enabled them to develop tactile sensitivities and practices (described further in Chapter 7) and resources they employed to understand materials and communicate their knowledge of touch practices (described in-depth in Chapter 8).

6.2.1 My Felt History

Before discussing the designers' felt histories, as an ethnographer, I highlight my own felt history and reflect on the influence it has on my positionality as a researcher. I have, at different stages of my life, had similar experiences to all of my participants (see introduction 1.4), having studied a bachelor's (with a specialism in womenswear) and master's degree in fashion, then taught fashion and textile courses at master's level, while maintaining a making practice. I did this in London, so share the possible cultural specificity of the location. Yet within and beyond these superficial similarities, I have acquired a history of particular felt experiences through garment prototyping.

Before my bachelor's studies, I had little experience of making functional garments. Only sewing basic items at school or gluing and connecting textiles using jump rings to form a garment shape. However, I already had a history of drawing and mark making in different media, along with forming different materials. As a child, I frequently made things from household materials, much like many children raised watching Blue Peter in the 1980s and Art Attack in the 1990s[5]. Studying an Art Foundation Course, I was exposed to a range of creative practices in more depth, eventually focusing on fine art photography, film, and installation art (another highly material and spatial discipline). Moving from these experiences to sewing on an industrial machine was a steep learning curve, during which I had to attend to the feeling of subtleties of foot pressure and fabric distortion. This was fraught with

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[5] Blue Peter is a long-running afternoon children's TV show on the BBC which featured tutorials on how to make a wide variety of items from leftover household items: shoeboxes, plastic bottles, cardboard tubes etc. Art Attack was a similar programme on ITV, with a stronger focus on visual art.

failures when trying to sew simple seams on calico, then progressively more complex samples of vents, pockets, flies and collars.

While working to develop these skills I used a limited range of fabrics, collecting small samples of more unusual feeling materials from fabric shops in London’s West End. The first time I was allowed to create a garment using one of these fabrics I was unprepared for the behaviours it exhibited when I attempted to sew it, or for the specialist approaches I would have to use when finishing it. However, my bachelor’s studies instilled in me the importance of attention to detail during physical making. We sewed almost continuously and were expected to unpick and re-make anything that did not meet our tutor’s standards. Memorably, this included pin hems which were millimetres too wide. We learned hand tailoring techniques and construction appropriate for high-value catwalk and couture fashion. Skills few of us would use but provided a strong material grounding for our practice. Similarly to the students Nicewonger (2011) observed at Antwerp Academy, we were asked to focus on creativity, rather than commercial, or wearable reality. There was no focus on digital technologies, despite graphic design software like Adobe Illustrator becoming increasingly ubiquitous by the time I graduated.

Though my early education focussed on making, it was through internships that I learned how to practically apply many of the skills I was taught. I interned in several small studios of designers showing at London Fashion Week, working on their women’s Ready to Wear collections, and once for a larger luxury brand, eventually taking on a paid role. In these studios, prototyping took place in-house and many labour-intensive processes were used to differentiate the garments being created from cheaper High Street offerings, reflecting the ideologies of my bachelor's course. Examples included the creation of unique fabrics from scratch, once ruffling then applying strip after strip of closely spaced lace to a backing fabric, creating a dense surface texture.

Based on these experiences I developed specialist expertise in pattern cutting, sewing structured women's eveningwear and jersey garments. For a while, I used this expertise in temporary roles at high-end London designers or freelancing for small start-up studios (all of which retained physical in-house prototype development). Eventually, I returned to university to study for a specialist master's degree focusing on digital fashion which introduced me to new prototyping challenges and materialities. I was able to test very early versions of Clo3D and Optitex software, which at the time could not simulate fabric as accurately and had a fraction of the functionality or user-friendliness of their current iterations. This lack of utility and the perceived inaccuracy of the 3D models left me critical of the application of 3D garment prototyping software (though I continued to follow its development over the years, eventually re-engaging with it when it had developed further), so I began to explore the use of the newly launched LilyPad Arduino system. This presented other material challenges, such as understanding the differences in conductivity of various e-textile materials, and the need to keep traces in circuits relatively short, while at the same time distributing electronic circuits and systems across the body. At the time most tutors (with the notable exception of my

Course Leader) saw wearable tech as something to be hidden and only desirable to present its functionality, rather than its materiality.

Leaving university with a digital skillset led me to a research role exploring the communication of sensory qualities of interactive digital textiles. I taught master's level courses and students specialising in digital processes, largely in supervisory roles, rather than directing practical making and prototyping.

With this felt history, my body, as the apparatus (Barad, 2007) through which I conduct sensory and ethnographic research, has been subject to many of the same sensory experiences as the bodies of the designers I observed. However, I differ from the participating designers in one significant respect. As a cisgender male, my body as an apparatus performs particular privileges of power, assumptions of access and ways of knowing which in many ethnographic contexts might be problematic. Yet, while gender is often related to power in social dynamics, given the smaller number of male-identifying people working in the fashion and costume industries, many positions of power and authority are held by women. In every fashion studio and university I have worked, my managers, superiors, and the majority of my tutors, colleagues and students have been female. For this reason, my experiences of power asymmetry during my education and internships may not have significantly differed from those of female-identifying designers. My normalising of social environments where women formed the majority may have been productive for the research encounter, as it may not have introduced the same awkwardness for me as an uninitiated male researcher.

Nonetheless, my sensory experience itself is shaped by my body. Therefore, the materiality of my body is fundamentally entangled with, and constitutive of my research data. Differences in physiology, gait, ranges of motion and the social acceptability of certain forms of touch mean that felt experience is gendered. This also impacts the way forms of touch might be shared and demonstrated between people with different gender identities. In this thesis, while this may have manifested in a designer's reluctance to use touch to direct and shape my body when engaging in particular touch practices, this did not appear to change how the designers communicated with me. Perhaps as the research took place in the context of a relatively 'low touch' culture (the UK). Demonstration and mimicry appeared to be the preferred means of communication around touch (as discussed further in Chapter 8).

6.2.2 The Designers' Felt Histories

Among the designers I observed, seniority and educational level did not always equate with familiarity with materials, which was more closely linked with a longer history of both directed and un-directed material engagement. This is significant as it indicates that neither conventional training in garment design and making nor accrued life experience alone can account for the nuanced sensory understandings garment designers require. It also implies that higher education in garment design may not provide foundational competencies and brings into question its value compared to vocational learning. The designers' felt histories varied. As a result, they had different breadths and sets of resources to draw on, which shaped the multimodal articulation of their understandings of touch and felt experiences.

Designers' narratives around touch history often included personal recollections, from having an 'outdoorsy childhood' and always making things, having a background in dance, studying sculpture at school, to being taught how to draw curves by their father. In the following fieldnote, Kat recounts her childhood material experiences.

FIELDNOTE: Kat's History of Making

> Kat often talks about working *from* materials, and I ask if she has always worked this way or if it is a habit developed over the course of her studies? She replies, "So from as long as I can remember, I had a very outdoorsy childhood, I was always very creative, and I used to go to my Dad's workshop and build things out of wood. I got a tool kit for my twelfth birthday, and I liked to do sculptures. I got a mannequin as a present, and I remember just getting metres of fabric because my Mum used to make things for horses, like rugs and stuff." Kat makes a rubbing gesture. "So, from a young age, there was always a machine and a fabric, and I'd go with her to the fabric shop. I'd pick things up and just drape things on the mannequin all the time, really naively." Kat shakes her head. "I just really liked touching all these fabrics."

As demonstrated by the fieldnote above, these narratives generally included material and kinaesthetic experiences and could also be considered material histories. This indicates that McCullough's (1996) concept of familiarisation with a medium (digital or physical) to inform understandings of how it can be formed, is reliant on movement.

‘As we push material around, we encounter structure. We find that we may work only in certain ways, and only at certain rates. We say that the medium has a feel, and we sense this quality in action.’ (1996: P194).

I further argue that this movement brings the animacy of materials into relation with other active and moving entities, causing relational material agencies (the feel and workability of a material) to be enacted and committed to a designer’s felt history. I discuss this further in Chapter 8.

The narratives of felt histories further suggest that experiences which shape them are not only felt and gestural but also emplaced and contextual. The frame of reference they account for is built over a lifetime of being in the world and actively engaging with material things. Hickey-Moody and Page (2016) and Hickey-Moody (2018) propose that this enfolding of sensory history with current practice is a key aspect of pedagogies of matter in arts practices. Further suggesting that enskillment cannot be detached from lived, material experience in an educational context. Whether directed or undirected, the exposure to felt experiences relies on the body, actions, and movements, rather than, or in conjunction with, linguistic communication. Knowing what to feel for is impossible without a history of feeling comparable things and materials to draw from and relate to. Thus, the role of feeling during garment design development is often to index and reference, building, or linking to a mental catalogue of similar experiences. While the role of an archive of embodied experienced is recognised by Ræbild (2015), after De Long and Park (2008), she focuses on the felt history of wearing garments, or the relationship of the material qualities of a new design to past, finished creations. In other words, she views garments as artefacts rather than unfolding processes. Histories of feeling *while* making and more general material engagement have yet to be fully considered in accounts of the role of felt histories in garment design development.

If the role of history and context is significant, attempts at digitising touch that take a psychophysics approach and focus on the replication of sensation and movement without context are unlikely to be beneficial in supporting garment designers. Re-playing a sensation without prior contextual experience to equate it to will be meaningless, as will familiarising oneself with a feeling without understanding its situated context.

In the following vignette, Ella highlights the significance of longitudinal exposure to materials and tools over the course of a lifetime in comparison to the relatively short three-year timeframe of a bachelor's degree. She also talks about the applied history of learning to make garments she actually wore. This felt and functional experience of wear is often removed from a garment design education, as students (particularly on fashion courses) are encouraged to create for aspirational bodies and particular sized fit models or performers. Wearing their designs is surprisingly uncommon, despite being noted as a core method of gaining felt experience of a garment design in Ræbild's study of professional designers.

VIGNETTE: Time for Handling & Ella's 'Sewing Miles'

"I think that's the issue with 3D [garment design software]." Ella looks into the distance and bounces the fabric in her hand as she thinks. "Because you can't feel it! And unless you really understand your fabrics, you can't… I think we've got to give these fabrics to students to say, 'look, this is the difference between a silk velvet, here's a viscose velvet, and there's a cotton velvet,' and get them to really handle it and make them understand. I started sewing on a sewing machine when I was eleven, and I've never stopped. But I think students don't do that now. Mums don't have sewing machines at home anymore. You don't make a dress to go out on a Saturday night. All those years when it was too expensive to buy it, so you had to make a dress, and you go out in it! You might only wear it once. It was our fast fashion. So, you had those 'sewing miles'.

This narrative reveals the change in felt histories brought about by socioeconomic circumstances, the availability of cheap fast fashion, and also the durational nature of acquiring tactile sensitivity. Ella continued to say that she felt there "just wasn't time" in a three-year bachelor's degree for students to gain the understanding she had developed before going to university!

Unusually for a bachelor's student, Kat's tactile history featured 'hands-on' making activities, including garment making, sewing and fabric shopping with her mother from a young age. Other designers reflected on their histories of material engagement and autodidactic processes of learning by doing, including their histories of sewing. Carla recounted her experience of learning to use an industrial sewing machine during one of her first jobs, producing a large number of costumes for a parade. The pressure of a real-world outcome and the repetition of making similar garments allowed her to get used to a new type of sewing machine quickly, building ‘muscle memory’.

Dance figured in the personal histories of Kat, Carla, and Ella. Carla related dance lessons as a child to her having a developed sense of kinaesthetic memory, indicating the significance of an expanded understanding of touch when considering felt histories, incorporating felt kinaesthetic experience and surface touch. Ella’s familiarity with Tango as a dancer also demonstrated an awareness of the feeling of the (clothed) body in motion and its dynamic relationship to garments. These felt histories link to the ideas of dance and movement scholar Maxine Sheets-Johnstone (2003), who provides the model of kinaesthetic memory and ‘kinetic melodies’ to account for the role of kinaesthesia in felt histories.

While opportunities for free exploration and un-directed familiarisation with materials or making processes were a significant part of the designers’ tactile enskillment, they also spoke of acquiring touch habits and understandings through internship training. This was considered a reciprocal arrangement through which designers could gain skills in exchange for their labour (much like a traditional apprenticeship). However, some designers recounted instances where they felt this relationship was unbalanced. The opportunity for learning was not fully realised due to the tasks they were given or the inexperience of the designer they interned for.

In the following vignette, Nadine recounts a positive experience of being inducted by skilled designers and makers into their touch practices and felt understandings.

VIGNETTE: Nadine's Tactile Internships

Nadine is chatting with me as she sews samples on an industrial sewing machine. The room is noisy, with the hum of several machines being used by other students and a radio station playing classic pop music in the background. Nadine now has an industrial sewing machine at home too. "I did quite a lot of practice as soon as I got it. Nadine flexes her leg as if pressing down on the foot pedal "because I know from first and second year, whenever I used the foot, it was just like whoosh!" Nadine presses her foot down again and, with a horrified look, gestures a piece of fabric rapidly moving away from her. "I was quite scared of it for a few weeks, and then afterwards, I was like, OK, this is not too bad after you get used to the rhythm of it. I guess also [I practiced] at my internships because we had to use them quite a lot."

"Did anyone at your internships show you how to handle or work with fabrics as well?" I ask. "So, at my first internship, she showed me how to work with chiffon and jersey because I had no idea! She'd tell me to use different needles and to go quite slowly on the machine. I was doing a lot of leather as well, so she showed me how to use the blade." Nadine gestures using a rotary cutting blade, moving her arm back and forth. In mimicking gestures used to handle materials and work with specialist tools, Nadine demonstrates the kinaesthetic memory of particular touch and movement practices which she has absorbed into her body through personal use and adaptation to new contexts, all under the direction of more experienced designers. She later mimes threading an industrial sewing machine. A complex mid-air zigzag, which I also use, but would be unlikely to be read as ‘threading a sewing machine’ by the uninitiated.

In particular, the more experienced designers drew attention to what to feel *for*, inducting Nadine into sensitive practices of holding and manipulating fabrics when feeling them. The pressure to ‘get it right’ for the applied context of commercial garments forced Nadine to absorb the advice quickly and create her own techniques and resources to recollect sensations.

“The pattern cutting team were telling me how to handle a lot of different things. So, things like cutting out chiffon fabrics and hand stitching hems and seams, or the little shaping stitches in tailoring.” Nadine makes a rapid stitching gesture. “I worked with a lot of fabrics, but cutting chiffon was a nightmare. Even with paper to stabilise it and keep it at a 90-degree angle! Even in the toiling stage, you have to do that, which is something I learnt because I did it wrong.” “Do you think you learn more from trial and error or from other people?” I ask. “I think maybe half and half? Personally, for me, I learn through doing. So, I think I learned a lot more at my internships, especially when I was learning to use all these really delicate fabrics! I was learning about the different weights and the different feels of fabric. Like, what’s the difference between double organza and single organza, or triple organza or taffeta.” Nadine makes rubbing gestures as she lists the fabric types. “I had to learn very quickly because the seamstresses would come and say, ‘Nadine, I want single organza.’ And I’d be like, ‘What? I don’t even know what that means!’ I had a little book in the end, so I could remember how they feel. I’d take little snippets of the offcuts and put them in the book. So now I can tell the difference.” Nadine makes a rubbing gesture with both hands, weighing them up and down. “With your swatch book, did you learn what you could do with all the different fabrics?” I ask. “I kind of learnt them along the way because the people that worked with them a lot would be like ‘No Nadine, the reason why this taffeta is different to this zibeline is because of the weave and because this is stretchier, or thinner, or when you pull it this way it’s stiff.’ So, they showed me different ways I could recognise it.”

The sum of these experiences gave Nadine a ‘feel’ for the touch practices of professional designers and contextualised them in relation to their purpose. In this way, established touch practices are informally circulated in the garment making industry. A detailed example is given in Chapter 8 of a similar process I observed.

These examples demonstrate how designers’ felt histories inform their current touch practices when understanding and manipulating materials and tools. Felt histories also inform practices of worldbuilding which situate and provide context for contemporary designs, anticipating the felt experience of the wearer in an emplaced fictional context. These are discussed in more depth in the following section.

6.3 Feeling and Worldbuilding

The concept of worldbuilding can be identified in many garment design practices. Based on designers' felt histories, worldbuilding processes bring these histories to bear in developing current designs. Some authors note this process as a form of user-centred design (Dieffenbacher, 2013; Ræbild, 2015), yet I would argue that designers rarely focus on traditional ideas of 'usability' or 'needs'. Instead, they seek to convey desired aesthetic qualities (both felt and visual) which represent a creative concept (Jenkyn-Jones, 2011). This must be functional for the user but does not necessarily consider their needs. Gully (2009: P41) proposes that if design is to be considered a form of problem-solving (Marchand, 2016), fashion designers simultaneously construct and solve problems. As such, the process of establishing a context in alternate worlds and scenarios can be interpreted as constructing problem spaces to address. These alternate worlds could provide the 'grammars of design' which allow designers to productively constrain their explorations in an abstract design space, prior to prototyping (McCullough, 1996). Hällnas (2009) further argues that fashion designers do not solve problems but introduce difference 'to express people'. Again, this definition of designers' practice focuses on creating alternatives. Alterity, in this case, is explored through stories (Rowsell, 2021) of wearers and contexts.

While 'worldbuilding' is not explicitly used as a terminology by the designers or institutions I engaged with, at both universities and across the three courses at bachelor's and 'master's levels, the construction of a world in which to situate a design or collection was ubiquitous, if more or less explicit. The primary difference was that while Nicewonger discusses the alternate worlds built by Antwerp students as means to *'unmoor social concerns from the constraints of the present'* (2011: P191), allowing designers to highlight them and engage in mild critique or questioning, the worldbuilding processes I observed generally served to do the opposite and ground otherwise extreme or unusual designs in felt reality.

In particular, the bachelor's level student cohort that I observed was encouraged to think about the potential wearer of their designs. They create 'Who Boards' to describe their likes and dislikes, habits, and the (sensory) world they inhabit. This is intended to help them design garments that are not abstract creative exercises but grounded in some aspects of reality by empathy with the wearer's imagined experiential, feeling body. In practice, this construction of a character to represent the wearer may not result in a likely or familiar persona. Still, it will focus the designer on their felt experience in the designed garments.

I describe the constructed worlds as 'alternative presents' unless a future orientation drives the narrative of the scenario. Through creating stories of different contexts, they can be materially realised. Rowsell (2021) emphasises the significance of stories (which in the case of this thesis can be read as constructions of alternate worlds) in bringing about material outcomes, arguing: *'stories are flesh on the bones of matter, stories can move matter into being'* P163. Additionally, proposing that stories can give insight into intuitive understandings about making or conceptually anchor the making process (Rowsell, 2020). In this way, garment designs become through stories which situate matter in comparative felt histories.

A primary way the student designers built alternative worlds was through mood boards (Cassidy, 2011), of which the bachelor's student's 'Who Boards' are an example. These serve as a visual representation of both the visual, emotive and sensory aspects of an alternate world. If, as Cassidy proposes, mood boards are a form of qualitative research, then they can be considered to be multimodal representations of autoethnographic experience, merged with the designer's chosen aesthetics into a story of an alternate 'day in the life' of a wearer. Thus, mood board images are parsed for visuotactile interpretations, similarly to the visuotactile judgements common in fashion literature (see Chapter 2). In this way, ideas of feeling in a constructed world are manifest in another mode.

All of the students employed mood boards except Carla, who, it should be noted, had the most industry experience before returning to study and who worked on a personal side project during my time with her. On the other hand, the educator/practitioners recognised mood boards as a communicative medium but did not create collaged boards. Instead, they relied on digital archives of images or video (e.g., Instagram or locally saved image files) to similarly situate their designs. This was also Carla's chosen process.

Differently from the construction of imagined alternate worlds, Ella's bodily understanding of the world her garments would inhabit is based on her own lived, felt and observed experience as a Tango dancer. Ella inhabits the same tactile world as her clients, negating the need to build a novel world as context. Understandings based on experience, such as the correct placement of a vent to allow a dancer to kick freely and the issues of holding a partner wearing an asymmetric, off-the-shoulder dress (different frictions and grips on the bare skin and fabric), provide the empathic context for the felt experience of her wearer. In this case, Ella’s felt history could be considered to inform a more practical and user-centred approach in line with Ræbild.

The only specifically future-oriented world I observed (in accordance with Nicewonger) was constructed by Nadine. This world served the same functions as the alternate presents constructed by the other designers in grounding Nadine’s garment designs in the aesthetics of a felt reality. Inspired by a recent exhibition at London’s Design Museum, Nadine designed a collection of garments incorporating wearable technology to provide functionality in protective, comfortable and useful garments for an imagined Botanist working to terraform Mars in 2077. The becoming of her material garment design was heavily influenced by storytelling around the life of the imagined Botanist.

VIGNETTE: Nadine – Feeling Future Scenarios

> Nadine and I are discussing her design references and inspirations. She points out an image of astronauts sleeping in zero gravity, restrained within a padded sleeping bag with their arms floating free. “Ah’ so that's where your sleeping bag idea came from," I observe. "Yeah, with the arm thing that you ca” zip up." Nadine mimes unzipping zips down her arms then extends her arms out in front of her and mimes them floating, bobbing up and down in zero gravity. She uses her own body to attempt to empathise

with astronauts' felt experience, as depicted visually, and see how a garment would need to open to allow freedom of movement in this scenario.

“I have this scenario ’here she's [Nadine’s wearer] living on Mars in a rover for four days a week, so she needs a sleeping bag and functional work clothes for the rover. Then on the weekends, she goes out, and she plays space tennis in low gravity, so her outfits have to transform. The atmosphere is a lot thinner than it is on Earth, so there will be elements of weightlessness, [for the Martian surface] you're going to need something weighted and heavy an” padded." Nadine mimes moving with heavy limbs. Here she speculates on the felt experience of protective and functional clothing, necessitated by the world she has built for her collection to inhabit. In this way, the fictional scenario drives a unique design outcome which can be made more detailed and specific (and therefore more compelling and believable) by empathy with her wearer.

"With other projects, have you always had a character and a scenario you designed for? Or is this new for this project?” I ask. "It's all kind of new. I think it started definitely this term. Our tutors have been pushing us to develop our 'Who Board' more and think of who we're aiming towards. I think it's definitely livened up what I'm doing! I'm trying to think of what she's doing every day and making it functional, rather than last term with the useless technology[6] and making it more utilitarian, kind of army-like

[6] Nadine's previous project explored comic and useless applications of wearable technology, as a comment on the current trend to develop wearable tech items of questionable value. One example

protective wear." "It's very speculative", I comment. “Did your tutors ask you to consider this being worn by someone now? Or are they happy for you to think about clothing a character in the future?” “They were saying I need to keep to kind of now. Because it’s meant to be set in 2077, so I think that in fifty years’ time, it will be a bit different, but we won't be completely different people, really, so I still have to keep it a little bit grounded.” In this way, Nadine’s tutors instil the importance of her empathising with a character inhabiting her imagined world as a critical aspect of worldbuilding.

"You have a lot of performance fabrics for functionality, but have you thought about what they might feel like to wear? Have you tried them on? What would it be like to play tennis or go clubbing in them?“ I ask. "You might be sweaty!" Nadine laughs. "Actually, yeah, some of them I have." At this point, Nadine rubs one of the small fabric swatches attached to her line up between her thumb and forefinger. It is such a small piece that this is the only way you can handle it. "Because there's going to be lots of padding in them, and the lining's going to be a lot softer inside." Nadine reaches out to rub another small fabric sample. "And these are breathable materials, used for showerproof coats and stuff usually. But I'm going to use really nice linings! And this one's going to have a heater in it as well to keep you warm. It’s minus sixty on the surface of Mars!" Nadine laughs. "I think it's going to be heated in particular places",

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included shoulder mounted fans to make the wearer’s hair billow in the breeze and screens situated on the body in positions impossible for the wearer to read.

Nadine indicates her outer arms. "I still have to look at some science books to see where the best places are on the body, to keep the body warm and the muscles.”

Figure 6.1: Nadine’s collaged designs with sketched additions on tracing paper

6.4 Sociotechnical Imaginaries

Imaginaries are individually held visions and the associated symbolism and feelings which people attach to a phenomenon. A social imaginary refers to a collectively held set of beliefs perpetuated through society or particular social groups but which do not reside in one person’s consciousness alone. These can help create shared meanings and senses of belonging. As such, they contribute to the consciousness and identity of groups such as student and professional garment designers. Crucially they also inform their ideas of the likely futures of that social group. Sociotechnical imaginaries more specifically focus on the way technological developments contribute to these shared future visions. They are described as:

'*collectively held and performed visions of desirable futures...animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology'* (Jasanoff 2015: 25).

Fashion theory focuses on trends and novelty through the lens of temporality, for example, Eckert and Stacey's (2001) proposition that a designer's core competency is an understanding of a temporal *'acceptable space of garments'* (adopted and extended by Ræbild, 2015). A novel aesthetic, yet not too forward or backwards-looking, rooted in a visual archive of garment memories - a seen rather than felt history, which Ræbild extends to an embodied history of wear. This is a classic example of the trend-based construction of temporality, related to fashion cycles, as separate from garment design development more broadly. The idea of an acceptable space can also be found in Nicewonger's (2011) concept of developing 'moral' judgements of what is considered avant-garde fashion.

Yet the material stuff of fashion is fundamentally experienced in the now, creating an often remarked upon paradox in relation to fashion *trends*. This has meant that garment designers' mid to far-future speculations on their practices' possible evolution are largely un-theorised. The construction of the future as 'a season away', or the outcome of a design process currently underway, limits the possibility of engagement with change in garment design. Locating the future of fashion or costume in the unfolding of trends in the immediate future negates the potential to speculate on further future evolutions of design and manufacturing processes, which will be more closely tied to sociotechnical imaginaries. Arguably this construction of temporality in fashion could be a limiting factor in pushing the boundaries of technology adoption and usage, particularly that of digital touch.

The concept of the sociotechnical imaginary has previously been utilised to explore emergent understandings of digital touch communication technologies (Jewitt *et al.*, 2020; Jewitt, Leder Mackley and Price, 2021) and proved key to identifying recommendations for their future development. While a worldbuilding process may shed light on the individual imaginaries which designers use to situate and develop their garments creatively, an understanding of their sociotechnical imaginaries of technology is critical in ascertaining which aspects of their practice they believe could be digitally supported, along with what degree they believe technology is capable of this? In this sense, designers' sociotechnical imaginaries of touch represent collectively imagined touch futures. Throughout the ethnographic encounters, these sociotechnical imaginaries were brought into circulation unprompted. The designers shared strong opinions on the possibilities of digital technologies for garment design and the question of whether they would use them. This section also triangulates data from the two more explicitly future-oriented workshops (see 4.5).

Designers' sociotechnical imaginaries are reported by key themes which they exemplified. These were Efficiency and Value (6.4.1), Supplementing and Replacing

Skills (6.4.2), Learning and Understanding (6.4.3) and Crude Tools and Unrealised Promise (6.4.4).

6.4.1 Efficiency and Value

In designers' collective imaginations of technology, it was often constructed as a means to increase efficiency. This reflects a broader societal belief with its origins in labour saving and streamlining of various physical making processes afforded by industrialisation and digitisation. Yet within this imaginary, the question of whether increased efficiency led to positive, negative, or ambivalent outcomes was much debated, and designers' perceptions often changed depending on the technology and applied context. Efficiency monitoring was frequently linked to understanding the value either of a garment or the effort expended in its creation. Sometimes prioritising the human designer or maker, and sometimes supporting the use of technology.

An example of sociotechnical imaginaries relating to efficiency and value is Ella's understanding of digital processes to save time and money and streamline her established design development practices. Crucially she did not anticipate that design software could supplement skills she did not already possess. Working on bespoke dresses for international clients, fitting the dresses was often a complex process to negotiate, and Ella was excited about the potential of fitting on digital avatars. At a late stage in the development of the dress I observed her creating, Ella was dismayed that in her recent fitting, the client decided to opt for a simplified design. This rendered a lot of her prototyping work unnecessary. In this case, the understanding that she would be easily able to save design iterations in a digital development process was another practical advantage, in addition to the ease of outsourcing production with digital pattern files. This was perhaps one of the most realistic imaginaries of technology and may have informed Ella's later satisfaction with digital tools introduced to her practice (see Chapter 11.6).

Discussions around Prototype 3 created in Workshop 1 (see 4.5) took sociotechnical imaginaries of efficiency to a sometimes dystopian extreme. Prototype 3 was envisioned as a pressure and mid-air gesture sensing surface (proposed to use a capacitive grid and fabric pressure sensors) to map desk-based activities in a participant's defined studio space, such as pattern drafting and cutting, fabric cutting, and hand sewing. This was imagined as a tool to quantify touch and assign value to the amount of human contact a garment had received as it was produced, referencing both time and motion studies in manufacturing (as discussed by Paterson, 2021) and the labour-intensive value creation through hand-making in Haute Couture and bespoke tailoring. The more technical 'Taylorist' or 'Fordist' ideas of measurement raised by Prototype 3 relate to its creators' commercial garment industry experience and one participant's desire to explore new forms of value in clothing.

Beyond just valuing skilled input, this prototype inspired discussions of surveillance and monitoring of garment 'makers' touch, eventually leading to speculations on measuring the calorific value of the energy expended to produce an item of clothing.

Conversely, the prototype also inspired discussions of the value of a machine's touch and whether it could, or should, ever be valued as highly as human touch?

Similarly, in Workshop 2, the most significant sociotechnical imaginary of touch recording technologies in a garment development context was monitoring and potentially disciplining garment machinists and cutters. This ranged from ensuring compliance with workplace ergonomics, disciplining body posture and touch gestures to ensuring garment 'machinists' wellbeing. This led Noxi** to speculate that such monitoring could become a requirement for corporate and personal insurance.

Alexa proposed monitoring to ensure a lack of touch. Measuring how often machinists handled a garment, potentially getting it dirty, greasy, or distorting it. This aligns strongly with sociotechnical imaginaries of digital touch to create 'low touch' futures, reducing or replacing human touch and focussing on the idea of machine-made items as being 'perfect' and pristine. An imagination of technology aptly described by Pye's (1995) 'workmanship of certainty', a form of risk-free making in contrast to the idea of fallible human effort (applied through touch) as a means of attributing value to a made item.

In Workshop 2, due to the perceived lack of professional creative and prototyping applications for digital touch technologies, two participants also suggested they might have more impact through creating value during the consumer phase of a garment's life. Examples included giving shoppers more information when choosing a fabric or garment, particularly to encourage the owner of a garment to care for or value it for longer. In this context, digital touch would provide feedback about garment handling and damage so that it could be repaired or provide interactivity to foster a long-term rather than a disposable relationship with the garment.

Concerning valuing garments, speculations which included the mapping of how much a garment was touched during design and manufacture had both positive and negative connotations - from a positive perspective, demonstrating which garments had received a greater amount of human touch and therefore affording them more value. This was similar to the valuing metric of human input proposed in relation to Prototype 3 in Workshop 1. From a negative perspective, recording garment machinists' touch was proposed as a metric of how hard they were working, if they were following a proscribed industrial process (e.g., Paterson, 2021), or if they were spending too long touching each garment. All forms of industrial monitoring. This was a significant theme of participants' speculations on industrial applications for digital touch.

Representing contrasting sociotechnical imaginaries in Workshop 1, Prototype 1 is a yarn tension sensor for knitting and crochet, using a conductive rubber cord, or stretch textiles as a variable resistor to measure tension and play different audio clips as feedback to the user, allowing them to adapt their technique accordingly (see Figures 6.2 and 6.3).

Figure 6.2: Handling a sample of crocheted conductive stretch textile which acted as a variable resistor – Prototype 1

Figure 6.3: Knit samples incorporating conductive rubber cord to test the possibility of sensing yarn tension – Prototype 1

Prototype 1's use of sound as a gentle reminder (similar to Schoemann and Nitsche, 2017) relates to ideas of flow and immersion in making processes and the conceptualisation of holistic sensory experience being integral to craft. This view is often expressed in opposition to industrial manufacturing as a core value of craft.

This prototype was a personal tool, rather than an industrial tool, supporting a very different experience to the functional and quantified Taylorist or Fordist view of garment making, providing personal feedback and enskillment rather than recording and optimising a process for efficiency. Prototype 1 could also be considered to help its user learn and supplement felt skills relating to sociotechnical imaginaries of technology to make life easier or replace human input, which are explored in more detail in the following section.

6.4.2 Supplementing or Replacing Skills

Designers' sociotechnical imaginaries of labour-saving technology frequently condense or question the possibility of reducing long-term processes of movement and feeling into a single moment and gesture. These relate to hopes and expectations of automation, which are largely received from domestic technologies and general day-to-day software, enabling us to perform actions 'at the touch of a button'. McCullough proposes that in this case software tools become mechanisms which alter particular parameters within an established model (e.g., a garment pattern), eliminating the need to re-creating the model each time and therefore allowing quicker exploration of alternatives. In garment design and manufacturing, few processes have yet been automated to this level, and so (with some exceptions, see below), many of the sociotechnical imaginaries in this section are highly speculative. In relation to the potential to easily perform complex tasks, or tasks designers could not, narratives of designers and makers becoming obsolete emerged. Yet these were often contested, reflecting the uneven impact of technology adoption in different industries and contexts, which informed participants' sociotechnical imaginaries.

On several occasions, Marie comments that Clo3D could support, supplement, or make up for particular skills she doesn't yet have and which she would traditionally develop through felt skills and actions. Her enthusiasm for Clo3D's Auto Grade feature (which replaces a felt process of physical pattern grading and re-drafting with the click of a mouse) is a prime example.

FIELDNOTE: Auto Grading with Marie

> "One of the things that I think is just genius is because in fittings, there's one person for everyone, and that might not be the guy I want to have. So, with every pattern," Marie points to her laptop, "I can just give the avatar the measurements I want, and then I do 'Auto grading', and it just fits it perfectly." Marie gestures an impression of a body shape in front of herself. "But still, if it were a piece that you want to have a little bit oversized, it doesn't work." She shrugs. "Then you need to do it yourself, manually grading it in Clo. But I've been using that a lot. So, this pattern at first was quite small, so when I took it into Clo, I just gave the measurements I wanted and just cleaned it up. I don't even know how to grade in real life, and it's the measurements I wanted in a click!" Marie clicks her fingers. "So that's good for basic blocks." "And does it seem to fit people in real life when you transfer it across?" I ask. "Yeah." Marie nods. "And you can then do auto grading to four different body types. I wouldn't do it for a final piece when it's detailed and stuff, but definitely for the first, basic thing. And I love it; it's so good. So good! And then you can print it out and just cut it!" Marie laughs. "Genius! So, it provides you with things even though you don't have the skillset for it in the physical."

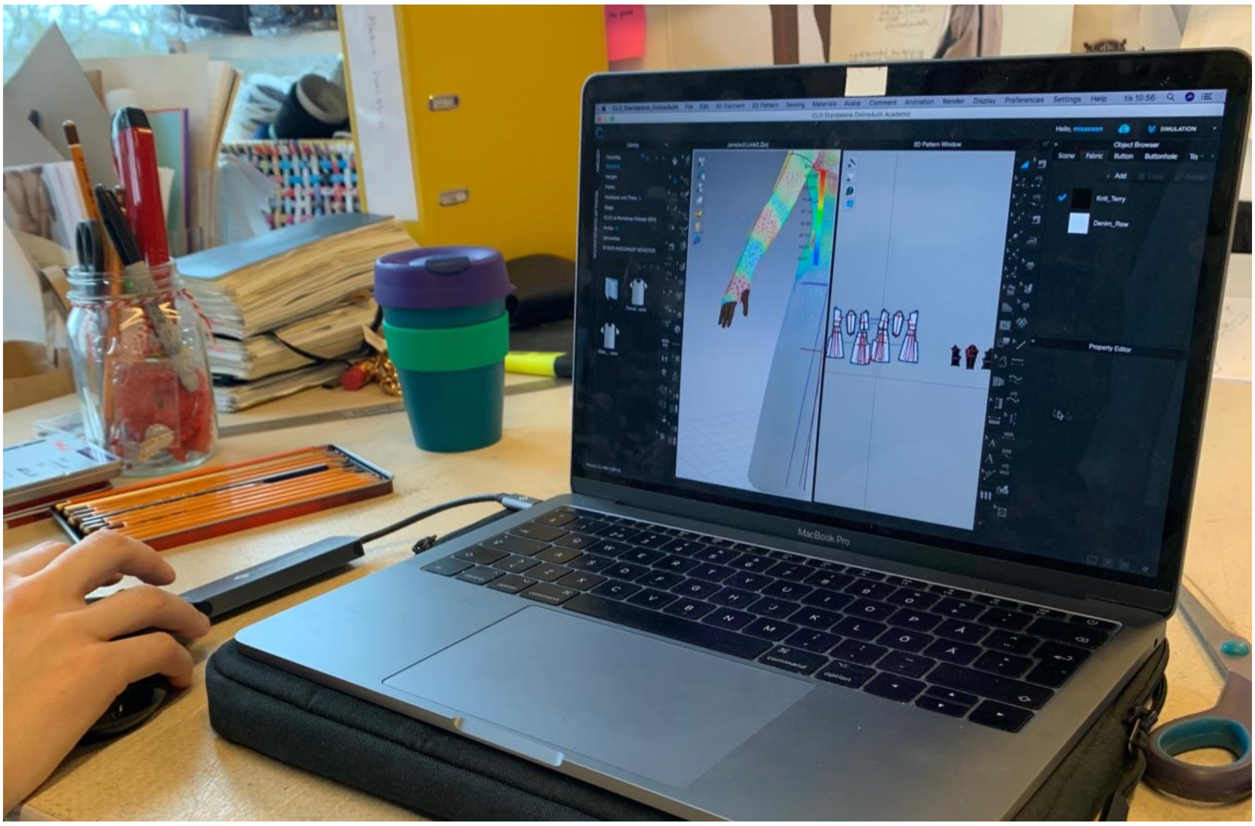

Figure 6.4: A Clo3D heat map indicating the fit of a garment, which Marie adapts with the Auto Grade feature

The fieldnote above exemplifies sociotechnical imaginaries of technology as a means to make life easier and replace human skills and labour (including narratives around replacing human touch in repetitive, tedious tasks), yet this was tempered with an awareness throughout our discussions that to effectively use Clo3D Marie needed to develop another set of skills to relate her digital processes to previously felt, dynamic and spatial experiences. The previously mentioned sense of corner-cutting was replaced by an idea of definite benefits to 3D design software that Marie must first master by drawing on her felt history in comparison to unfolding digital experiences.

Participants in Workshop 1 expressed largely optimistic and utopian ideas about the possibility of automating or replacing touch. These included the expectation that manufacturing and menial forms of touch could be automated but that jobs would be secure. As Matteo* proposed, “there are so many jobs we couldn’t imagine twenty years ago; there will always be something new”. This extended to the privileged belief that the ’designer's role (as opposed to the garment labourer) would also be secure.

Participants in Workshop 2 shared a common assertion that current tools were highly versatile and worked well to produce a wide variety of garment designs and types. The participants often discussed their hope that humans were unlikely to be replaced in a digitised garment design and prototyping process. This understanding of jobs being secure as technology progressed or impossible to replace clashed strongly with Kat’s perception of the global manufacturing industry. In our discussions, she highlighted narratives of technology depriving workers of their livelihoods, raising the issue of replacing or erasing existing manual skills. Kat commented on the issue of predominantly female workforces in Asian and African factories, while craft is now considered a middle-class leisure pastime in the Global North. She highlighted the dichotomy between the need for women to earn a living and gain independence but their lack of rights and safety. She couldn’t see how automated machines could replace garment workers without de-stabilising society. This narrative focuses on the perceived issues with automating and digitising even touch practices seen as undesirable.

The designers in Workshop 2 further questioned whether the process of developing skills is possible to shortcut or replace with digital processes. The process of repetition in learning and the means by which touch was inscribed in the body was mentioned by Helen* when recounting a summer job she had with a designer while studying. Her role was to chalk garment patterns onto fabric and cut them, actions which left her with calluses from regularly working with tailor's shears. "I learnt so much about flattening fabric out on the table and pinning it and how to chalk something out without distorting the fabric. It was amazing! I hated it, but it taught me so much! I'm just thinking if you're a highly-skilled maker, the temporal aspect of that [experience], is it actually possible to hand on to anybody, or do you just need to put the time in? But there might be a kind of [digital] indication, something that demonstrates manual dexterity and the degree of skill to a novice." This concurs with McCullough's argument that becoming a skilled digital craftsperson still requires a process of familiarisation with the (digital) medium and tools being worked.

When considering recording and re-playing touch, participants in Workshop 2 believed that this would lead to the creation of generic products and potentially serve to limit the breadth of designs it would be possible to produce. Helen* argued that this was already an issue with the limited understanding of making held by garment design graduates and similarly a problem with current robotic and automated garment-making technologies designed for generic tasks. Independently echoing the sentiments of Ræbild (2015), Almond (2016), and Montgomery, Henry and Brotheridge (2016). The idea of de-skilling designers through the introduction of digital touch can be seen as a significant sociotechnical imaginary in the garment design field. This led to a discussion of datasets and questioning whose touch should be recorded. Noxi** asked whether it would be possible to identify the ‘best’ tailor from a dataset of twenty ’tailors' touch practices and whether perceived competence was relevant in an industrial system that prioritises efficiency? The question of how large a dataset of human touch practices would be needed to help robotic sewing systems optimise their use of touch was also raised. Given the individuality of designers’ processes discussed in Chapter 5, the fact that every designer or machinist recorded would likely have their own approach was problematised. Could a dataset ever represent one touch practice, and what would be created from a touch average?

6.4.3 Learning and Understanding

The association of digital technology with information is fundamental to our current social experience. Although we may not have received a technology-led education, we are still likely to search for information and new understandings digitally. In the case of garment prototyping, the centrality of touch to prototyping processes led to associations of digital touch with instruction in and development of touch practices, mapping and visualising touch and movement during prototyping actions or visualising sensations such as pressure. This kind of technological support was proposed to develop the skills of less experienced designers.

While comments in Workshop 1 focused on tools for personal or industrial feedback, all participants in Workshop 2 proposed that digital touch sensing and recording would be valuable in an educational or research context. Three participants asserted that it would be more helpful in this field than in a professional studio or manufacturing unit. They argued that having developed sensory competencies, it would no longer be useful for professionals to have feedback on their touch. However, this may relate to their links to garment design education.

There were numerous suggestions for ways touch sensing and feedback could be used to provide feedback to learners as they began to develop garment prototyping skills. Noxi** suggested a traffic light system of simple visual feedback on an industrial sewing machine to indicate whether the user was exerting too much pressure on the foot pedal. Thereby enabling the user to achieve a balance of speed and precision. This is arguably similar to the audio feedback from Workshop 1, Prototype 1, but proposed in a formal educational context rather than the autodidactic and personal role proposed for Prototype 1.

6.4.3.i Understanding Grain Lines

Handling a fabric to ensure the alignment of the fabric grain when laying and cutting was suggested in Workshop 2 as a competence of more skilled garment makers. This was proposed to be a visuotactile competence, similarly to its construction in garment design textbooks (Kiisel, 2013; Lo, 2021). “It’s visual, looking at the grain line, but it’s also feeling out the stretch, understanding the selvedge.” Helen* proposes. Also, arguing that understanding the weight of fabric could help when laying fabrics for cutting, either individually or for small-scale production. To address this, a fabric which could sense whether its grain was aligned, or distorted by handling, was proposed so that students could learn to align the grain and receive feedback on whether they were successful.

6.4.3.ii Understanding Pressing

Ironing, or pressing, was identified as a poorly understood skill crucial to the successful preparation of garments during prototyping and making. Again, a pressure sensor was proposed to give feedback to learners to ensure they didn't over-press a fabric. The perceived significance of pressing is reflected in the fieldnote below.

FIELDNOTE:–Workshop 2 - The Subtle Art of Pressing

> "Pressing is another whole thing. Another set of rules. There's so many students who just don't understand ironing!" Helen* exclaims. "My sewing tutor always used to say; 'a good press is half the sewing." Noxi** agrees. "Maybe it is in the pressing [that touch sensors would be useful]? Because it's so nuanced." Helen* proposes. "Because that's how you can properly destroy the grain of a fabric as well." Noxi** replies to Helen*'s agreement. "Completely, if you mishandle it! I don't think I'm that good at ironing, to be honest; I wish I was better at it. It's such a subtle process." "Especially if you're steaming things, there's *real* knowledge. You steam better when you know what you're doing!" Noxi** agrees. "Quite often, you find out the true shape of something when you press it," Helen* adds.

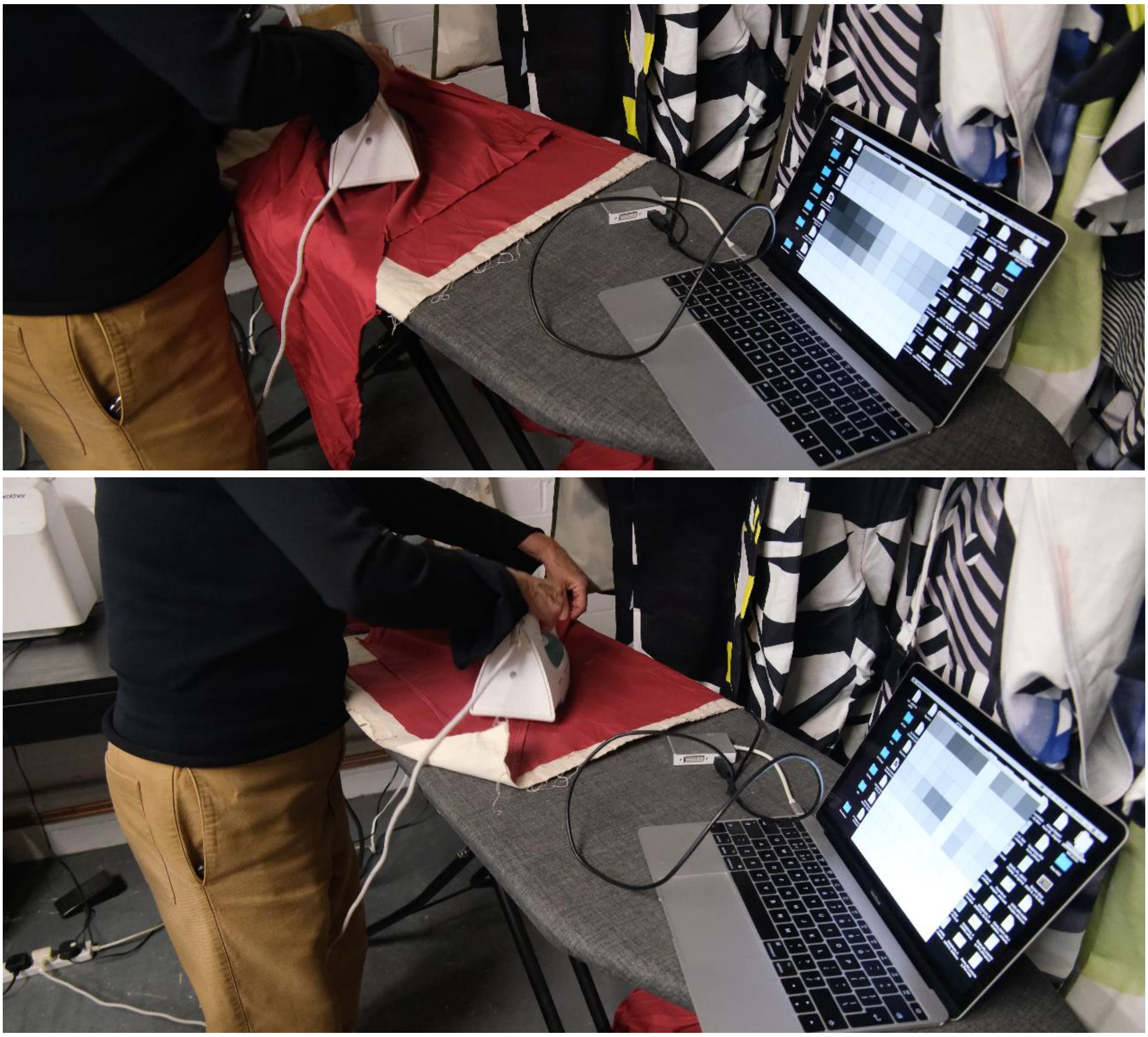

Figure 6.5: Helen* explores subtleties of pressure when pressing fabrics, both on flat panels and on a curved seam (top image)

6.4.3.iii Understanding Fit

Garment fit is a key theme for Ella in Workshop 2, particularly for bodies in motion, such as the dancers she works with. Though Ella acknowledges that software such as Clo3D can create pressure maps on virtual garments, she is interested in ways this information can be more closely linked to physical garments, especially as this may allow students to feel for themselves what particular degrees of tightness and restriction are like on their own bodies.

FIELDNOTE – Workshop 2: Linking digital touch visualisations to personal experience

> "A physical pressure map is very useful for fitting so that you can see where a garment is pulling against the body. For dancers, if you could have a full-motion version of the OptiTex and Clo3D pressure maps so you could see pressure as they move, that would be great. You could also use it as a way to save money, so before you cut a really expensive fabric, you know if it's going to fit. Or to figure out if you have enough of a scarce fabric? Could you reduce the seam allowance if you know you won't have to adjust the garment? Then you can get more out of the fabric. I think it's really interesting as a teaching tool. Maybe it could help students to talk about ideas of how something feels? Or maybe if they could try something on and feel how it fits them, and get feedback at the same time? Then they could associate it with other garments they are designing. You could even make up a set of basic blocks [into toile garments] with sensors, and students could test size and fit. It could help them understand the right block pattern to use for their design. They could figure out the limitations of movement in a particular garment if they had the pressure and strain feedback visualised."
>
> This proposed technology application reiterates the significance of felt histories in designers' development processes.

Alexa also considered that understanding nuances of garment pressure and distortion on the body would be a useful application of digital touch technologies, but for extremely high-performance garments where nuances undetectable by the human sense of touch would be critical. For example, high-performance sportswear and clothing for extreme conditions.

6.4.3.iv Creating New Tools (and Touches)

In one of the only examples of an application for digital touch which was perceived as beneficial for both learner and established garment designers, Alexa proposes that a touch sensing fabric might act as an input device to a 3D design software. The following fieldnote captures her speculations on potential functionalities:

FIELDNOTE: Workshop 2: Capturing Drape

> "I can see how this could be used if I was working between the physical and the virtual, but I don't think I would use it if I was just producing for the physical." Alexa muses. "Because when you work on the stand and you often hold something in a certain way." Helen* nods and agrees. "It would be perfect if touch would then be recorded in a programme like Clo3D to see [it visualised], and you could take a quick screenshot of your garment before letting the fabric go on the stand, without having to pin it or to just be more intuitive about it. Maybe if you hold something for longer and look at it for longer it takes a screenshot and keeps it for you. Because you often go

> past the point of the ideal garment you want when you drape, and you kind of end up thinking, what did I do? And have to re-create it. Also, what would come with that tool is you wouldn't have to bring it back from 3D to 2D, which is what usually happens when you have to trace a pattern. And that is laborious and also often loses something in the process."

Helen* also considered the role of digital touch sensors in understanding how designers and makers might use novel garment prototyping tools that engage 'he designer's body in radically new ways.

6.4.4 Crude Tools and Unrealised Promise

The final sociotechnical imaginary relates to 'designers' perception of a socio-technical gap (Rode, 2011) between what current technologies can accomplish and their hopes and expectations for garment design technologies. This is informed by the stark contrast between slick (digital) interfaces and well-developed functionalities in consumer technologies, compared to the still emergent nature of digital tools for garment design. Considering touch, the particular lack of sensitivity in prototypical digital touch tools was perceived as a major barrier to their utility and adoption.

Other than Kat, all the designers who worked in more traditional ways were somewhat enthusiastic about digital technologies and processes but felt that they weren't currently well enough developed to be reliable or replace their current ways of working. Kat is often vocal about her dislike of digital technology, particularly because in her personal imaginary, it removes tangible and felt experiences. During one of our discussions, she recounts an example of a friend on her course who used Clo3D to develop a design but was really unhappy with how it looked when it was actually made. Whether from experience, or reputation, the perception of digital technologies for garment design as limited and not offering a comparable experience to physical design was commonplace.

VIGNETTE: Carla – Visualising physically and digitally

Do you think you would ever trust a digital process, fitting things to a digital body, an avatar?" I ask Carla. She looks thoughtful. "I think it's really cool. I would love a virtual fitting room where you could try on pre-existing clothes, but if I was going to have something custom made, I would still want to have the fittings because you know I like to touch things. It's the same way that we can't figure out how to make a robotic stitcher. There's all these constant adjustments that we make throughout the process, so I guess that's why I don't feel that confident in it because it just is a totally different process." "So, it's those small adjustments on the fly are the things that wouldn't be there for you?" I ask. "Yeah. Also, testing buttons is something I would do on the toile. I would just pin them on. Yeah, that's something for sure I would have difficulty doing in a digital space, I think. Because of the shine of the button." Carla raises her hands, palms flat, one slightly offset behind the other, moving both back and forward, "and the way that the different textures interplay. I'm sure that as digital rendering becomes better, it'll be able to capture a lot more of that stuff." "So, you wouldn't trust a rendering at the moment?" I ask. "Yeah, I think so. And also, when I'm working with clients, it's much easier to show them a physical thing of a button. I think that as a designer, you have enough imagination that you can kind of make the leap from a design to a thing. And I find clients can't."

Despite her scepticism of design software and 3D rendering, Carla has experimented with wearable technology in the past, aiming to foster a sense of human connection through clothing and give garments greater value through awareness of their history and associated memories. I ask Carla whether incorporating the electronics changed the way that she designed the garment in her previous project. "I think I didn't develop the actual design that far if I'm completely honest. It was just a vehicle for the tech. Because it was a garment to be worn under other garments, it didn't really matter what it looked like. I would definitely make it differently if it was for a costume or if I was having anyone else wear it even. Just where I put the wires and things like that. But having to add the tech and the battery pack and figuring out ways to protect the connections without making it too bulky. It would be interesting the next phase of that."

In referring to 'small adjustments on the fly,' Carla echoes comments by Marie (see 7.2.1 for full discussion) on working with the Clo3D interface, in which she describes missing the 'small touches' of sketching or making minute fabric adjustments.

The idea that a garment may become a 'vehicle for the tech' likely derives from the epistemic separation of garment design and the design of technology hardware identified in Chapter 5. Highlighting the fear that garment design may become subservient to or neglected in favour of wearable tech functions. The use of 3D design tools was likely not seen as epistemically separate as the software was subservient to creating a garment (be it digital or physical), reflecting the traditional role of tools and technologies in garment design development. However, as the following chapters will show, although tools may be seen as subservient, they are also (sometimes contradictorily) viewed as agentive and capable of influencing the design of a garment.

The comparison of results from Workshops 1 and 2 indicates the significance of allowing research participants to develop their own technology prototypes when the technology being explored is at an early stage of development. The limited nature of the fabric sensor probe prototype in Workshop 2 appeared to mildly impede participants from speculating on further developments of digital touch, grounding them in the context of location and pressure sensing with visual feedback. This was despite an introductory presentation on different digital touch technologies. Participants attempted to understand the 'probe's limitations and place it in a contemporary garment design studio context rather than extrapolating from it to envisage future technologies. A particular issue was the relative lack of sensitivity of the probes. Despite being able to register a 1028-degree range of pressure, this was not deemed nuanced enough by participants, as reflected by the comments in the vignette below, in which the discussion echoes the significance of 'small touches' discussed in 7.2.1.

"What's interesting is that maybe you need to see a little bit more sensitivity in the whole thing [touch sensor] because actually, the way that you handle the fabric is really quite light. You know, when you're pinning something, you're barely touching it. So, looking here," Helen* points to the screen, "I can't see what I'm doing. It's not telling me enough." Noxi** replies "I'm trying to figure out how I need to touch it to trigger it at the moment." Helen* agrees. "I think I would spend quite some time trying to figure out just how this [touch mapping] works. It's like if you're given a piece of fabric, and you just find out what the best way of working with it is. And that's just an added layer." "I think looking at the screen takes away from your touch experience in a way." Alexa proposes. "I would probably have more of an idea of what I want to do with the fabric if there wasn't a real-time visualisation [of my touch]." Noxi** agrees.

Later Noxi** lays the touch sensing fabric on the foot pedal of an industrial sewing machine and tests whether it registers the changes in pressure as they sew? "With an industrial machine, I saw so many people go straight through the fabric because they didn't have the sensitivity to how the machine would react." "I'd never thought about that, but you do use your foot a lot as a second touch!" Replies Alexa.

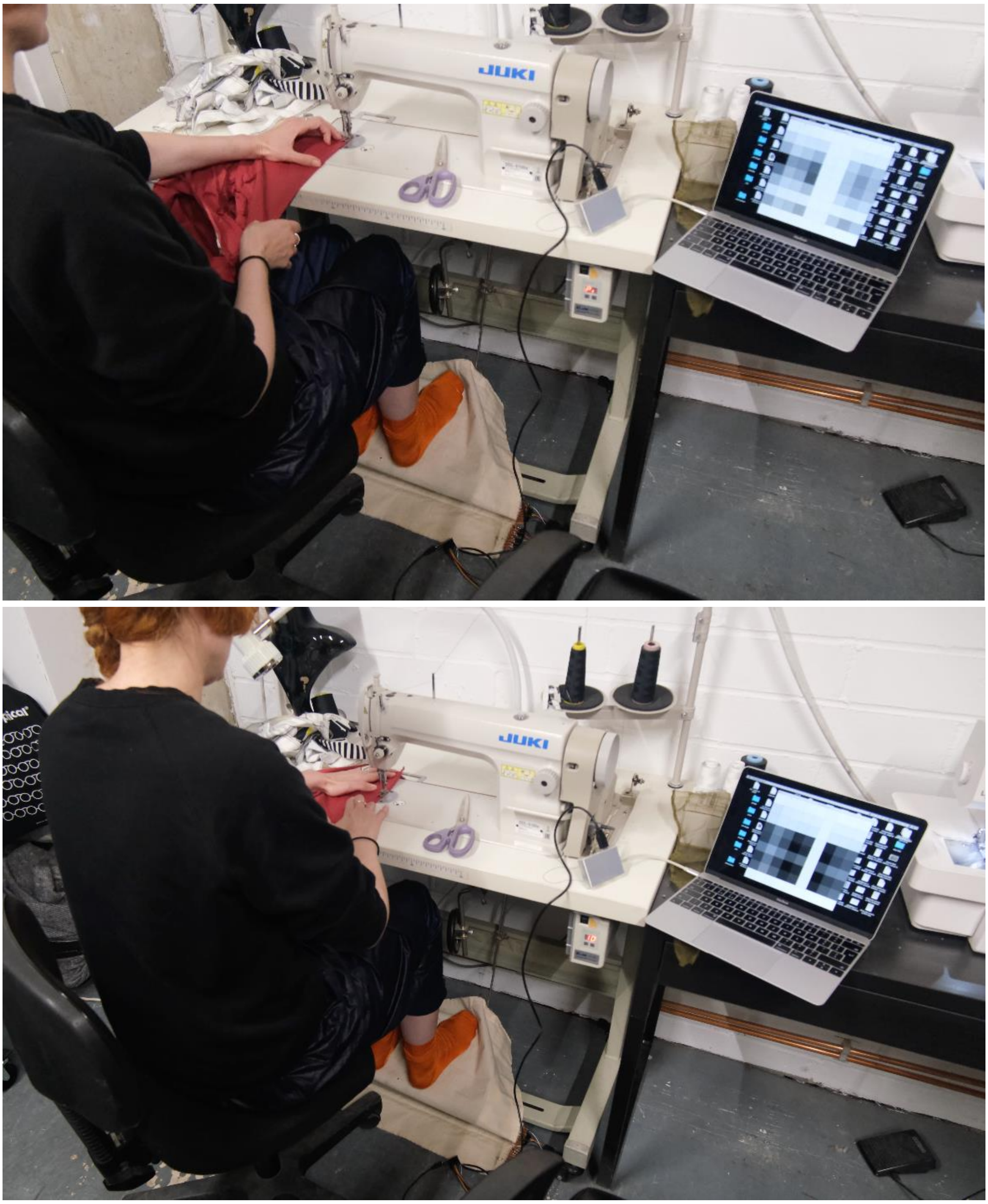

Figure 6.6: Noxi** relating pressure on a sewing machine foot pedal to visualisations of touch

Noxi** takes off their shoes. “I’m just pressing very lightly on the pedal. So, I think I’m not using my whole foot, just the pad.” “You look like you’re actually lifting your toes up to feel that." Helen* comments. "I'm trying to do it just with a flat foot now. Wow, that feels weird! It feels like I've got less control this way. Maybe it's a more relaxed way of sewing? I think I have quite a tense set-up, just naturally, so I can be more responsive." The visualisation has not shown a dramatic difference in pressure up to this point, but when sewing with a flat foot, the change becomes more visible yet still lacks nuance.

In addition to the lack of sensitivity, other criticisms focused on the visualisation remaining in two dimensions when the fabric was manipulated, for example, not folding or creating a 3D form. Yet, this was an advantage for Ella as it helped to relate a flat pattern to a three-dimensional shape. Ella and Alexa proposed drawing a grid on the fabric to make a visual link between it and the visualisation, to the agreement of the other participants.

I also noted that except for Ella, the participants in Workshop 2 were at first reluctant to handle the sensor fabric probes, only lightly touching and rubbing their edges. This concurs with Atkinson *et al.* (2013)'s observation of garment shoppers' behaviour when handling fabrics, in which rubbing the edge of the fabric with the thumb and forefinger was reported as the most common interaction. This may perhaps also be the first form of touch used in Petreca, Baurley and Bianchi-Berthouze's (2015) 'Situate' phase of textile selection before designers move on to more dramatic forms of touch, which include greater use of the textile and their own bodies.

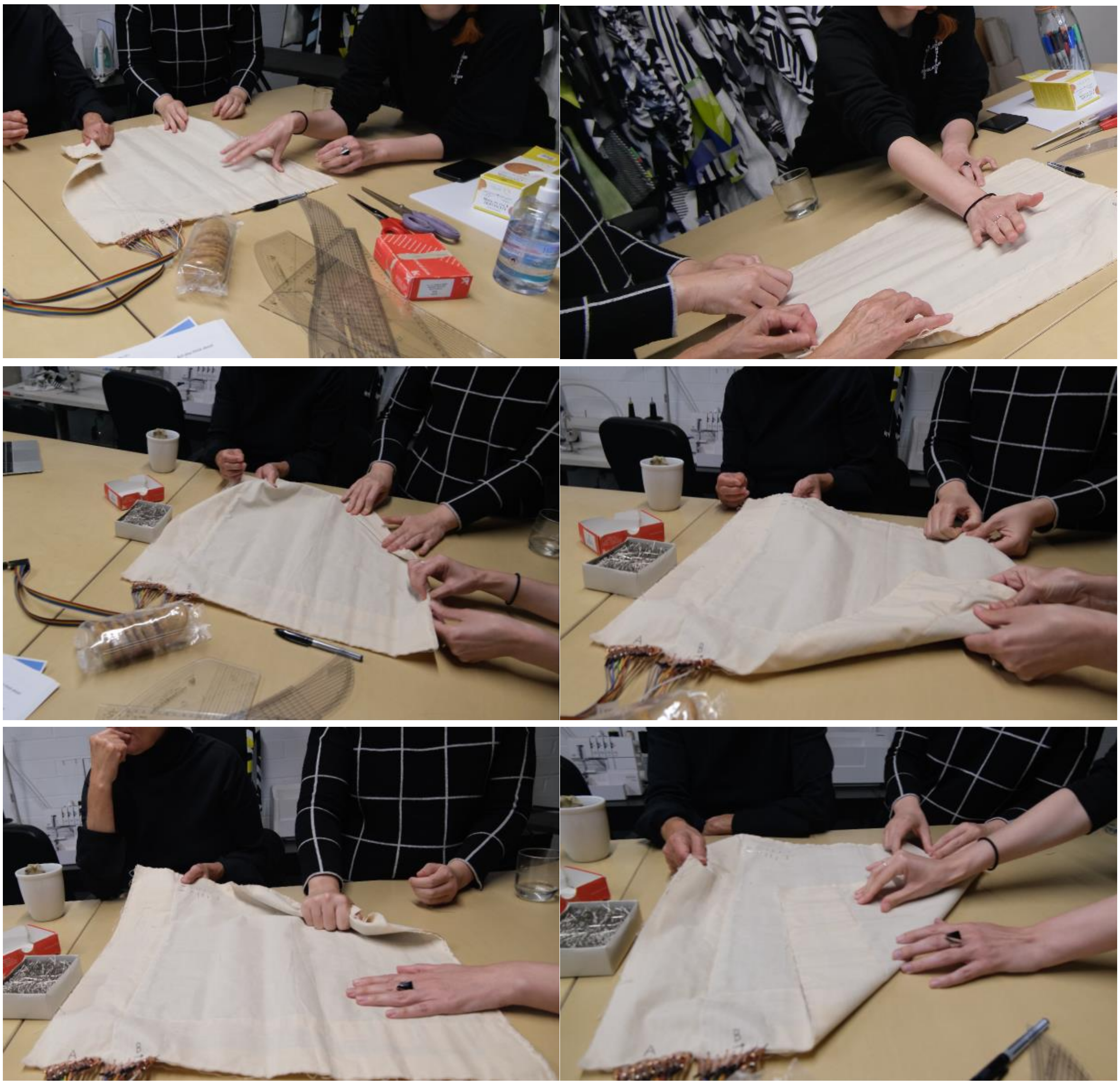

Figure 6.7: Participants' process of familiarisation with a sensor fabric probe. While handling, their attention was mainly focused on the on-screen visualisations and occasionally, their visual examination of the probe

Eventually, the participants began folding and scrunching the fabric, in Helen*'s case pinning it to see if the location of pins could be mapped, then, after some prompting, testing it as a sensor surface on different studio equipment. Ella instantly began to work with the sensor fabric exactly as she did when I observed her developing a pleated chiffon skirt section - folding pleats into it, pinning them in place, locating the pleats on a tailors’ dummy and using basting thread to mark the pleats, finally using a tracing wheel to–mark the basted pleat lines onto pattern paper. At each stage, Ella discussed the differences in materiality between the sensor fabric and chiffon, particularly how they stretched and tensioned.

Figure 6.8: Participants engaged more fully with the sensor fabric probes as they became more confident

The stretch and weight of a fabric were emphasised as material qualities it would be more desirable to measure. Ella considers an understanding of stretch crucial to her practice, as she works primarily with fluid fabrics. In addition, Alexa proposed that stretch and weight were the first qualities she would test in an unfamiliar fabric.

6.5 Conclusion

This chapter discusses the factors that situate and contextualise touch and felt experience during garment prototyping in eras of a designer's life experience or anticipated future - grounding the reporting of particular touch activities in the following chapters. The development of felt histories is linked with greater material engagement in the designers' pasts rather than seniority or level of qualification. For example, Kat recounts her childhood history of making with varied materials, informing her contemporary understanding of how materials can be manipulated. In contrast, Ella bemoans the lack of 'sewing miles', or histories of experimenting with sewing at home, which she sees in contemporary students. Designers developed felt histories both through un-directed material engagement (feeling and handling) and more directed learning in internships, such as the tactile familiarisation process described by Nadine.

Felt histories informed worldbuilding by designers, enabling them to empathically situate and ground designs in the felt experience of both wearing and manipulating materials. The situated and kinetic nature of felt histories is discussed, in relation to Sheets-Johnstone's concept of 'kinetic melodies' in reference to the experience and recall of *felt movements*. This chapter proposes that the association of these felt movements to material outcomes is a key means by which designers develop and recall understandings around physically manipulating and making with materials. This discussion is expanded in the following chapter. The touch practices reported in Chapters 7 and 8 represent a snapshot of the broader touch landscape of garment design development, which felt histories and their associated understandings inform.

This chapter contributes an understanding of garment designers' sociotechnical imaginaries of the role of digital touch technologies in future garment prototyping processes. These sociotechnical imaginaries highlight expectations, hopes, and fears related to prevailing social constructions of technology focused on four central themes. The discourse in Workshops 1 and 2 highlights an association between digital touch technology and *efficiency and value* exemplified by measuring human touch and input as a form of value. But this theme is also represented by Ella's understanding of current digital technologies as tools to streamline processes which are currently labour intensive. On the other hand, the sociotechnical imaginary that digital touch technologies could be used to *supplement or replace* skills is demonstrated by the perception that new job roles would develop to replace roles that could be lost through the digitisation and automation of touch. While in the context of current digital technologies, Marie's use of Clo3D's 'Auto grade' feature demonstrates acceptance of a software feature which attempts to replace a physical pattern drafting process.

The most common sociotechnical imaginary was that of digital touch technologies being applied in the context of learning and understanding. Examples included pressure or tension sensing to indicate the correct technique when crocheting, ideal pressure on a sewing machine foot pedal, or when pressing fabrics. In several instances, the most significant aspects of touch were proposed to be weight and stretch, or tension within a material. Understanding garment fit by wearing a toile or sample garment that visualised pressure on the body was also proposed as a valuable application of pressure sensing, which could be related to the wearer's body through felt empathy. However, participants in Workshop 2 did not believe that digital feedback on touch would be useful for an established designer who had developed felt competencies.

Finally, the perception of current technologies as *crude tools* with *unrealised promise* is demonstrated by participants in Workshop 2's assertion that registering subtle touches (beyond the capability of the touch sensor fabric probes) was critical for digital touch technology. Examples of dissatisfaction with current digital design software are also noted.

Sociotechnical imaginaries indicated by literature highlighting the possible de-skilling effects of digital technology (e.g., Montgomery, Henry and Brotheridge, 2016) were supported by comments from participants engaged in garment design education. Yet positive sociotechnical imaginaries of technology development creating new roles and creative possibilities were proposed by the younger student participants in Workshop 1. However, these contrasted with Kat's technological scepticism, indicating that openness to digital touch technologies was not simply a generational issue. There was also a relatively common perception that current tools were adequate for garment making, though perhaps not the design stage of prototyping. Probably due to the sociotechnical imaginary that existing digital tools were yet to deliver their full promise.

The following two chapters report designers' contemporary touch practices and associated understandings in light of these sociotechnical imaginaries.

CHAPTER 7 – THE LANDSCAPE OF SKILLED TOUCH IN GARMENT PROTOTYPING: MANIPULATING TOOLS AND CONTROLLING MATERIALS

Figure 7.1: Resources in Alexa’s studio

7.1 Introduction

To create an account of contemporary touch practices during garment design development, this chapter describes the types of touch documented during ethnographic observation of six participants prototyping garments as they developed their designs. As this thesis adopts a New Materialist lens, the reporting also focuses on the material, and non-human things present in the designer's emplaced studio environment and which become entangled with the designer during experiential and communicative touch. This data is presented alongside autoethnographic reflections on my use of touch during similar design development activities to those I observe. Ethnographic vignettes and fieldnotes represent significant observations and interactions that informed the analysis.

Despite the individuality of approaches to practice discussed in Chapter 5, there are many touch mediated garment prototyping activities common across participants, though the order in which they appear in the design process and the decision whether to make use of them at all may vary from project to project. These can be considered core touch practices of garment prototyping. Many of the core touch practices may appear unremarkable and unskilled. Even as a relatively experienced garment designer and maker myself, a process of re-conceptualisation was required to foreground the skill inherent in touches I took for granted. Observing practitioners with different levels of experience and different histories of material engagement also aided in developing these understandings.

7.1.1 Chapter Overview

The touches observed across multiple participants are reported in the following sections: 7.2 Pattern Drafting, 7.3 Folding, 7.4 Pinning, and 7.5 Cutting. Primarily these forms of touch relate to designers' bodily interaction with tools and techniques. They are touches to skilfully manipulate tools and materials based on felt understandings, rather than touches to gain material understandings. The more individually specific touches that are exploratory and relate to meaning-making or communication are discussed in the following chapter. This chapter concludes in 7.6 by re-capping the observed touch practices and their significance.

7.2 Pattern Drafting

During the development of a garment design, it is common practice to create a paper pattern from which to cut the pieces of flat fabric, which are then sewn into the three-dimensional garment shape. Increasingly this is being superseded by direct digital creation of garment patterns, but the practice of developing paper patterns is still integral to garment design education. It is also often the only process available to small-scale garment makers due to the cost of investing in digital design and pattern development tools. However, with lower pricing and increased accessibility of some software, this is beginning to change. Historically paper patterns have become a well-understood communication tool for all garment designers and makers educated in the European tradition. Paper and digital patterns can be considered two forms of a communicative mode which is often used to share understandings between geographically separate designers and makers. In fact, the increased distances involved have been a key driver in digitising garment development processes to facilitate remote communication. The use and interpretation of flattened visual geometry in pattern cutting is a crucial garment prototyping skill, reflecting the 'geometrism' - rendering spatial understandings into a visual epistemology (Paterson, 2007) of a process that directly relates to a three-dimensional body. Yet designers' feeling bodies are still present in the process of pattern cutting, as this section will demonstrate.

For the many designers still working with paper patterns, they will be drafted by hand using a fine, or most likely propelling pencil, working with specialist rulers to mark straight grain lines and cardinal lines such as waist, hips, bust, centre front and centre back, or particular curves. These seemingly mundane tools proved to have a surprising influence over this process for the designers I observed. Moreover, drafting a garment pattern often moves beyond a simple act of drawing to encompass kinaesthetic memories of drawing curves, linked to an understanding of how those curved lines will sit on the human body. Sgro (2020) notes:

'The benefits of valuing [garment] patterns as templates or blueprints are that they facilitate acting like templates in the minds of those who use them – this understanding becomes embodied.' (P236)

While Sgro (2018 & 2020) develops her argument by stating that repetition of actions in her practice limited creativity by making certain practices tacit and habitual, I argue that tacit and specifically felt understandings should be separated from habits and can, in fact, scaffold the development of a garment design through prototyping processes. This observation is validated and further explored in the vignette below and the following discussion.

VIGNETTE: Pattern Drafting, Tools and Carla's Sense Memory

Carla looks quizzical and picks up a large, curved ruler called a Styling Design Ruler. "Is this not used here?" She asks. I have to think for a moment, as the specific shape of the Styling Design Ruler is not familiar. Though there are many similar tools, none are quite the same. I describe some of the similar equivalents I have used in the past: Patternmasters and Shoben Curves (see Figure 7.2 below for comparison), which are proposed to be essential tools by Lo (2021). "It would be interesting to see if patterns change depending on the rulers or if this is closer to American patterns," Carla replies. "Because this is exactly an armscye to me" [armscye refers to the armhole on the body of a garment and can also imply the particular curvature of its shaping], she holds up the Styling Design Ruler and gestures towards the bulbous head, "I know how it feels to draft it, like a muscle memory, and when I'm using other rulers, I'm like 'That's not what it's supposed to look like' Carla gestures emphatically towards me with the Styling Design Ruler "because armscye is…" she folds over an edge of the calico she is drafting her pattern on and begins to draw on the reverse. She marks a curve using the round section of the ruler, then quickly pivots it and continues the curve. Next, she adds a horizontal line at the pivot point, indicating the underarm side seam, and a line at right angles to the top of one curve, indicating the shoulder seam. "There we go."

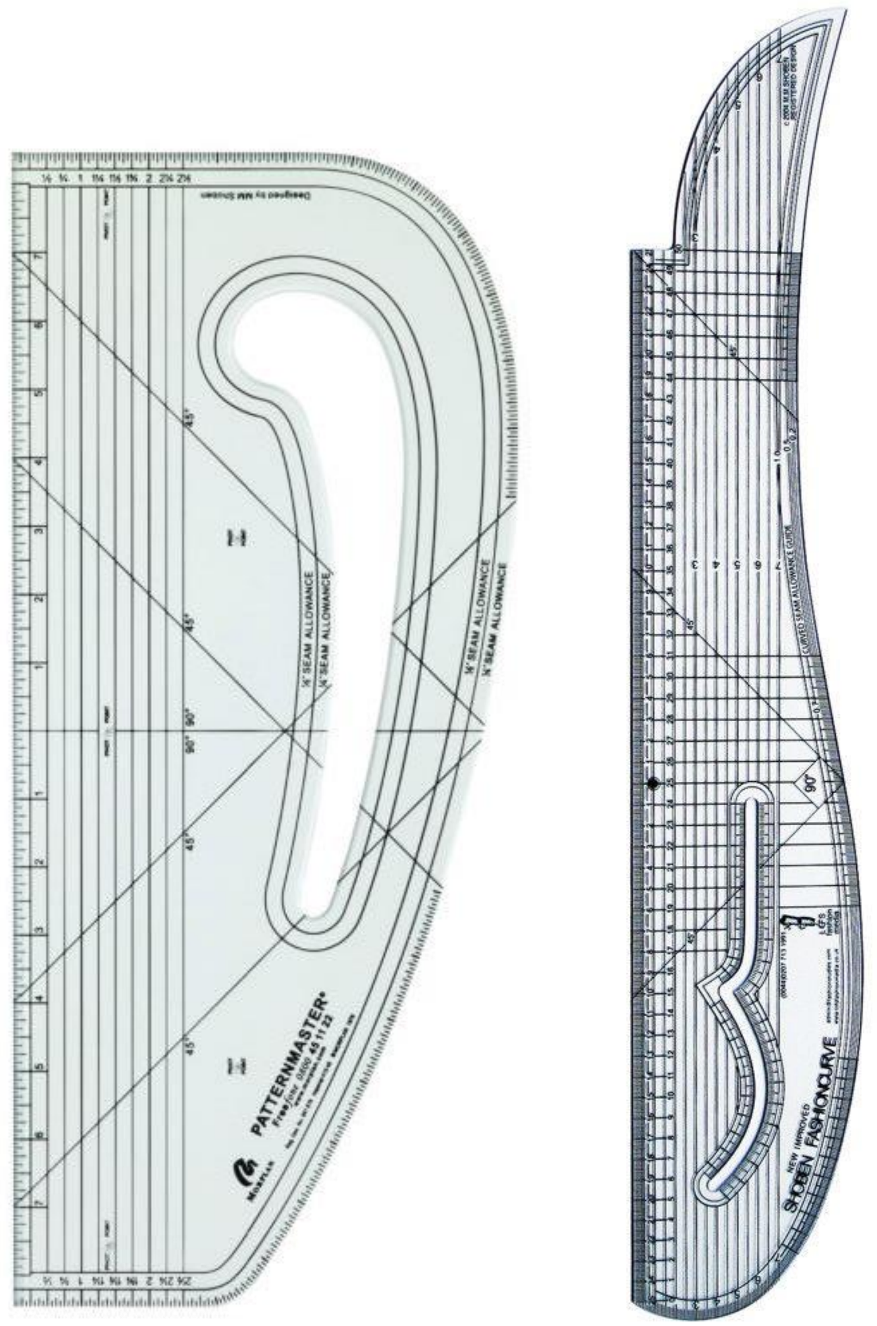

Figure 7.2: A Patternmaster and Shoben Fashioncurve

“And then a deeper armscye is here… if it needs to be more flexible.” Carla flips and pivots the Styling Design Ruler, drawing another armhole curve using a different section of the ruler. This is wider than the first and cuts further into the bodice pattern. I am interested that she links shapes and muscle memory with allowance for body movement. She connects a familiar feeling when drafting with the sensation of restriction or movement in a garment, sensations she has both felt herself and that have been recounted by clients and performers in fittings. “It’s funny how you learn your tools.” She moves the ruler up to a blank section of the calico. “Or like, that’s the hip curve here.” She quickly marks off a shallower curve using another section of the ruler. “That’s a lady's hip curve.” She pivots the ruler. “That’s a man.” She laughs. Her speed and precision at marking these particular curves surprise me.

Later, when Carla checks the neckline on the blouse, I ask, “So is a neckline another shape that you instinctively know how to draft?” She replies, “Necklines are harder than armscyes, but yeah, I think that is another curve that’s pretty familiar. But I’m not as confident in necklines. On the ruler, it’s sort of… here”, she indicates a space on the ruler between her finger and thumb. Picking up the ruler, she slides her thumb and forefinger back and forth across this section “Yeah, and that varies, depending on the size of the neck.”

Figure 7.3: Carla indicates the section of the Pattern Design Ruler which corresponds to a neckline

Figure 7.4: Carla drafting an armhole (armscye) and hip curves using the Styling Design Ruler

After a pause, I ask Carla about drawing and drafting patterns digitally, particularly whether she thought some familiarity with shapes and muscle memory would translate to a digital process? “I think it would be a different process because you’re not doing the physical thing. Even just using the hands differently, like clicking on the mouse, is not the same as, kind of, sketching, or moving.” Carla animatedly re-enacts the use of a mouse and a pencil, then twists her body from side to side. “So, I think it would feel different. And I wonder what it’ll be like the first time I do a design on a computer and then cut it? If it translates the way that I think it will?" She pauses dramatically. "I wonder about armscyes!" Carla laughs. "Because I'm so used to doing it physically, I wonder how long it would take me to learn?"

In the context of this chapter, the above vignette demonstrates the influence of commonly used non-human things on shaping, then inscribing in the body the shared disciplinary touch practices common among garment designers. The use of discipline-specific tools may account for the similarities of these touch practices among the designers. As such, it is reasonable to speculate that they are developed through both sensory engagements with tools and initial direction from other practitioners.

It is helpful to consider the muscle memory and familiar movements recounted in the vignette in relation to the work of Maxine Sheets-Johnstone (2003), exploring movement and memory. In Carla's case, the Pattern Design Ruler first scaffolds the drawing of curves, making the movement an invariant feature of the kinetic melody of armhole drafting as it plays out on different substrates (fabric or paper) or for different bodies. To the point where the scaffold (the ruler) is unnecessary to replay the memorised kinaesthetic experience. Kinetic Melodies repeated with the 'tactile-kinaesthetic body' can be considered to be similar to the *'recurrent patterns of sensorimotor experiences that enable the [garment] prototype to materialize'* identified by (Kristensen and Ræbild, 2016: P4). Yet Kristensen and Ræbild do not elaborate on the sensory aspect of the sensorimotor experiences they describe. Sheets-Johnstone argues that the terms motor and sensorimotor seek to separate movement and experience rather than focus on kinaesthetic experience and memory, which are holistically tied to movement (2003, PP76-79). This appears to be the case in Kristensen and Ræbild's study, in which motor activities are simply considered sensory as they focus on a moving, experiencing human subject. In this sense, they take an approach to their study, which diminishes the active role of non-human tools and materials.

7.2.1 Digital Pattern Drafting

As pattern drafting is one of the core activities of garment prototyping, relying on kinetic melodies developed through familiarisation with spatial and kinetic felt experience shaped by drawing with particular tools, how might this translate into a digital process? Do the commonly occurring touches translate into a digital context, or are they frustrated by the modal affordances of a different communicative mode or agencies enacted in entanglement with different materials? Marie muses on the scale and relationship to the body when drafting in Clo3D in the following vignette. Though the outcome is the same (to draft a pattern), the touch that produces it is no longer scaffolded by a comparable tool.

VIGNETTE: Small Touches, Kinaesthesia and Digital Interfaces

We have been discussing Marie's habit of working digitally but printing out her work and adding it to sketchbooks or moving from digital to physical pattern drafting. She tells me, “Making it physical makes it more clear. I suppose it’s easier to put together a process if you can see it.” “So, do you think that translates into your pattern cutting?” I ask, pointing to her paper pattern pieces laid out before us. “Yeah, maybe; I think you're right. Because on the computer, you just have the mouse”, Marie gestures the use of a mouse, “whereas here you have the pen, and you can immediately fold.” Marie gestures back and forth from her own body to the pattern pieces, clearly thinking of a relationship to her own body, then demonstrates by folding over the edge of a pattern piece. “Whereas digitally, you just do that kind of thing.” She makes the mouse gesture again, moving her hand side to side on one plane.

“As I'm trained this way [working with physical paper patterns], it helps me, but since I believe in Clo, if I get the right understanding of it, the right skill set, I believe it will work. When I get frustrated in Clo, I work in the physical, maybe because that’s where I still have the most knowledge and rely more on it?”

I ask Marie if she has drafted enough patterns to know how certain shapes like armholes should feel to draw (as Carla did). Marie responds that she definitely thinks it is partly to do with feeling, but she doesn’t have enough experience to just use muscle memory. “I can see when I’m doing it, there’s definitely some feeling, yes, but it’s mainly visual. But when I’m drawing some small things, it’s more about feeling. Small touches.” Marie makes small sketching motions, drawing out a curve. “What do you mean by small touches? Like smoothing lines or changing shapes?” I ask. “Exactly!” Marie’s eyes light up with inspiration, and she becomes animated, tapping the pattern pieces on the table. “Maybe it’s because I see these as one-to-one scale, whereas on the computer, I’m always zooming in and out?” It would be great if you could have a big screen so you could actually get it one-to-one scale immediately. That would be super nice, and maybe with those [tablet] pens? I think combining those would be great! Then you can zoom in and get the pattern piece you want and adapt it with a pen?” Marie again draws in the air in front of her. She taps to select and zooms by expanding her fingers, borrowing established touchscreen interface cues.

Interestingly McCullough notes that computer graphic artists use ‘*quick, small and repetitive*’ motions (1996: P19) while creating digital images, yet I argue these are likely to involve less nuance than a process of sketching to generate form. Instead referring to clicking and small mouse movements during which McCullough observes the focus of the eye is no longer on the action of the hand, but its on-screen representation. Tablet and touchscreen interfaces potentially re-connect vision and movement. Implying that while 'small touches’ may be more felt than visual, they are still visuotactile, with vision confirming felt experience (Paterson, 2007).

Similarly to Marie’s comments, Alexa noted the possibility of VR as a means to interact with 3D design software at a human scale, also providing visual and kinaesthetic feedback.:

> “Having just played about with creating an avatar in Blender, I’m really starting to realise just how useful it would be to go into VR and adjust some things. I guess it’s meeting it one-to-one. It’s meeting it in the right size. In a similar impression.”

Though McCullough (1996: P25) suggested motion capture and large screen sizes to support the felt experience of a craft when it is digitised, this has yet to become commonplace, despite significant technology development. Currently, there are limited or no familiar movements in digital pattern drafting to trigger a kinetic melody. Spatial kinetic sequences from a designer’s felt history cannot play out as kinetic melodies at the small scale of the computer screen. As such, the introduction of digital tools is changing the shared touch practices of garment designers and does not fully support existing felt competencies. It becomes necessary to learn the kinetic melodies of drafting with a different kind of tool, which introduces the difficulty of relating scale to the human body. However, the above vignette demonstrates the ubiquity of a felt sense for drawn shapes shared by garment designers, even if it is necessary for designers with less pattern drafting experience to see as well as feel.

7.3 Folding

A thread that ran through the data was a desire to sculpt and create three-dimensional forms. Folding can be considered one example of such a process commonly observed across the designers, providing another means of familiarisation with kinetic melodies through actions that bring forth form, often mimicking or prototyping a material forming process. In this sense, it could be seen to support

Swindells and Almond’s (2016) argument that mimicry and empathy with materials are essential to garment designers’ sculptural competencies.

7.3.1 Paper Folding

As the paper for pattern drafting is a commonplace medium in a fashion studio, paper folding was often used to roughly simulate potential three-dimensional forms and volumes which could be created by manipulating fabrics. The folding of paper represents a means to visualise a form without cutting it from a more expensive or precious material, even calico. A form of corner-cutting, or ‘doing it wrong’. Yet it also requires associated material understandings developed through engagement with the final garment's planned material(s) so that a designer can anticipate how its behaviour may differ from that of folded paper. Sgro refers to a process of 2D paper collaging to explore ‘planar surfaces’ as means to develop ‘spatial creativity’ in a visual design and notes that the embodied process of handling 2D shapes contributed to the process (Sgro, 2018: P133). However, she did not fold or drape the paper. It was not moved or manipulated in any way which would relate to a three-dimensional spatial kinaesthetic understanding. Later Sgro reports using a paper model to prototype a stiff, geometric form which she anticipated being supported by a frame, making use of the stiffness of the paper rather than extrapolating how the same form would behave in fabric (P163 & P194-195).

I also observed designers approaching the difference in materiality between paper and fabric in two ways: attempting to replicate desired qualities of paper in another material (similarly to Sgro) and attempting to understand how a material would behave based on a folded paper prototype. Importantly the process of folding was not only a means to visually assess the resulting three-dimensional shapes but also a way to kinaesthetically engage with the manipulation of the material, gaining understanding through the body of how a shape is formed and literally ‘paper prototyping’ the forming process involved in producing the garment. The development of kinaesthetic familiarity allows a designer to develop a kinetic memory of the way the desired material form is brought forth by the feeling body. This could be considered the mechanism by which designers develop spatial understandings as proposed by Sgro’s (2018) ‘spatial creativity. Although Sgro separates spatial and material creativity, I argue they are linked in the comparison of designers’ felt histories to unfolding kinetic melodies. The following vignette exemplifies the common process of associating felt qualities and structural forms achievable in one material with another, particularly by testing how they can be folded or formed.

VIGNETTE – Folding paper ballgowns with Alexa

> Alexa experiments with folded paper to create dramatic and angular shapes on the tailor’s dummy. She shows me the prototype she has been working on. “I’m making out of paper because I want to be super quick. My idea is that the garments could stand up by themselves in the exhibition. They could become sculptures that the dancers could just put on.” “So, will you be creating a lot of structure?” I ask. “Bine [a member of Alexa’s collective] keeps playing around with thermoplastic, and it’s fantastic.” Alexa hands me a piece of unformed thermoplastic. I note that it doesn't feel how I

expected it to. It has a weave, giving it a texture like a textile. "It's great because it's quite a textiley thing, and it sets really hard." She squeezes this to test its solidity and flexibility, looking thoughtful, and then hands it to me. "If you layer it, it gets even harder, and you can cover it with fabric. So, I'm not quite sure. I decided to think about structure later and do some designing on the stand [tailor’s dummy].”

Alexa flexes and loops a strip of thermoplastic, comparing it to the paper loops of her initial prototype, contemplating how to get the stiffness of the paper into a fabric garment? She observes the loop created when she holds the two ends of the strip flat side by side and feels the thermoplastic's tension. "Would you test something with paper, even if you were planning to make it in a much softer fabric?" I ask. "I was thinking about it because I kind of want to make it out of organza, and organza is quite stiff." Alexa rubs her thumb and forefingers together. "But obviously, it wouldn’t fold like paper." She indicates her prototype. "But I was thinking if I needed to get these volumes, working with paper is just fine, and then I have to probably put some structures in the garment." Alexa steps back to assess the prototype visually and moves the dummy again. "But I normally don't do this with paper."

After some more experimentation, Alexa muses “Am I just oversimplifying it because I’m making it out of paper?” She stares again at the ‘naked’ tailor’s dummy for a long time while thinking. This is a repeated focus for her thought process. The concern of simplification relates to the understanding that fabrics are generally more unstable than paper and behave in nuanced ways which can be harnessed in a design. Working with these nuances is often considered a core garment making competence.

Figure 7.5: Alexa folds a paper prototype

Figure 7.6: Alexa drapes folded paper on a tailor’s dummy

In the above vignette, Alexa considers the properties of each material, which she draws on from her felt history of engagement with them. With an understanding of the materials, she can anticipate whether they are capable of supporting the forms she is creating and translate them between a variety of materials. She links the kinetic melodies she enacts with historical understandings of the outcomes of similar melodies previously enacted with different materials.

Nadine shares the approach of using paper folding as a shortcut, compared to a fabric prototyping process which would involve sewing to create three-dimensional shapes. She feels that the speed at which she can create three-dimensional forms through folding makes her more productive and able to visualise designs more quickly, often leading to unintended outcomes that she finds inspiring. Ella also uses paper folding to test shapes she is creating, but for her, it represents a way to refine a garment pattern rather than simply generate a volume quickly. As one of the designers with the longest history of material engagement, Ella was able to successfully relate the behaviours of a folded paper prototype to the fluid and unpredictable silk chiffon she planned to use for her final garment.

Kat had the most experimental approach to working with paper. During one of our conversations, she recounts an experiment draping on herself with paper. She moved and let the paper tear and split where her moving body put it under tension. "Where it tore, that's where I'd put a vent." Kat found the effects of tension and the edges of the paper standing away from the body interesting, inspiring her to explore using wire in the hems of a garment to fix them in place. In this example, the paper both served to prototype the behaviour of more flexible fabric and to inspire a search for ways to create the stiffness observed in the paper.

7.3.2 Fabric Folding

While the designers used paper folding to simulate three-dimensional volumes, fabric folding was often used to simulate edges for waistlines and seam lines when draping on a tailor's dummy or adapting a toile. In this case, the manipulation of the fabric adds additional understanding to the indication of style lines and edge locations with pins, helping the designer understand the stability and bulk of the folded edge. This helps to choose finishing techniques and assess whether a finished edge will appear 'clean' or ripple and distort?

7.3.3 Digital Folding

So how does digitally manipulating a material compare to folding and sculpting processes that link kinaesthetic experience to resulting material outcomes? Especially as there will be no kinetic melody to memorise in relation to the behaviour of a material and no surface characteristics to add or correlate to a designer's felt history. While movements translated through a mouse, or similar interface device are central to McCullough's understanding of digital tools as providing familiar symbols of an abstracted process, which can be selected and activated through movements of the hand, this is not always the case. Functions which can be specified numerically lose the element of kinetic activation and control. These are often combined with mouse or trackpad movements, but to master this kind of digital interface requires more than the traditional manual control of the maker.

Figure 7.7: Left – Marie’s final physical jacket and Right – Clo3D render of the jacket and accompanying trousers (images courtesy of the designer)

Working with digital pattern development presented challenges in relation to folding and material behaviours. When discussing her prototyping process in Clo3D with Marie, she often mentioned not wanting to develop pockets or collars digitally. Folding was problematic because to fold a digital fabric, she had to specify the angle of the fold or move it with a mouse or trackpad. This process was unintuitive as it assigns a numerical value or unfamiliar gesture to the manipulation of material. This distancing from real-world behaviour was amplified by the fact that folded fabric could be rotated to poke through itself. For example, a lapel, rather than being folded back to sit on the body of a jacket, could fold back so far it appears to puncture the jacket. Marie also encountered this problem with pocket flaps. Prototyping them in 3D was unrealistic and time-consuming, lacking familiar kinetic melodies or the limitations of enacting them in a real-world context: McCullough's productive limitations of a medium. In this case, the digital freedom to do more than a material would allow makes the digital experience of fabric as a medium unhelpful.

7.4 Pinning

Pins are one of the most common tools designers manipulate during garment prototyping. In my observations and discussions, a point of contention was the correct way to pin fabrics. Although the physical action of pinning was similar across all participants, another core shared practice in the designer's touch landscapes, the influence of a pin on the material it fixes and the felt sensation of manipulating the pin are fundamental to how they are used.

> "You can always tell if you give someone who has never made clothing a piece of fabric and a pin! You just look and kind of marvel at what they are doing. It's like *what?*" Alexa makes a perplexed face and tilts her head to one side, peering at the imagined pin in confusion.

A common bodily habit of designers working with pins was to hold them between their lips, highlighting the role of the entire body in informing designers' common felt experiences. Though the felt sensation does not inform the design process, it is an integral part of the sensory and emplaced experience of every single one of the designers I observed. All of them managed the pins they were using in this way, and it is a habit I know well from my practice. Yet try as I might to recall how I developed the habit, I can't.

VIGNETTE: The third hand

> Carla has to remove the pins from her mouth to talk to me, moving them to the front shoulder of her jumper for safekeeping. Out of the way, yet easy to reach across her body with her dominant hand.
>
> I ask Carla whether she picked up the habit of keeping pins in her mouth from anyone, or if she does it because it is ergonomic or makes life easier? Having personally been always taught not to, yet having done it for as long as I can remember and having observed almost every garment designer and maker I know doing it, I am intrigued to know her answer! She smiles. "It's the third hand. You need three hands sometimes, and sometimes I…." Carla mimes bringing a pin to her lips in the right corner of her mouth. "I think it's just a third hand sorting things out!"

The need for a third hand and not being able to hold, manipulate and secure as many things at once as one needs to was familiar for many of the designers. This is also an interesting analogy given the sensitivity of both hands and lips, implying the desire for high sensory fidelity in an entanglement of body and tool. The idea of keeping pins to hand and the sensory feedback from the lips related to my own felt experience when draping fabric and keeping spare pins between my lips.

AUTOETHNOGRAPHIC FIELDNOTE: Holding pins between the lips

> Becoming aware of pins between my lips is a very strange experience. They are surprisingly close to body temperature, smooth and easy to forget, but for the small points of pressure they exert on my closed lips as they rest there lightly. I notice I always insert them with the point facing outwards (perhaps in self-preservation), so I feel the head of each pin as it drags over my lips when I pull it out. Though I can’t feel the individual pins when I have several in my mouth, I can feel the reduction in sensation on my lips as I use each one. This sensation tells me when it is time to reach for more.
>
> There is something strangely comforting about having them on my person. I know intellectually that my hands would be just as busy fetching pins from their box on the table as they would be retrieving them from my mouth, but the box feels too distant. Like I would have to let go of the toile for too long, and perhaps it will fall out of place?

Many of the other designers also stored pins on the chest of their clothing in combination with keeping them in their mouths for convenience and access (See 7.4.4, VIGNETTE: Kat - Circulating concepts of over-working materials). The limitation of working materials with two hands is discussed by McCullough as a major advantage of digital craft, in that digital tools can be combined, locked into relation with one another and manipulated in ways which would be impossible using the physical body. In a digital interface such as Clo3D, a pin tool becomes symbolic of its function to join points of fabric to one another. Designers can place pins in digital fabric, but no longer experience the kinetic melodies of their use. Arguably this frees designers to consider other things, but it will alter their felt experience.

7.4.1 Pinning Seams

Pins are most often used to join materials together along intended seam lines in toiles and draping or hold garment pieces in place for sewing. Yet the choice of how to pin for these purposes is a source of debate, implying that while manipulating pins is a shared felt experience, personal preference, educational and professional histories create individual nuance. A discussion with Carla exemplifies this as she prepares her pattern pieces to be sewn.

VIGNETTE: The various ‘correct’ ways to pin

I ask Carla about how she is currently pinning her fabric – with the pins pointing along the intended stitch lines rather than at right angles to them. “It has been the source of so many discussions!” Carla laughs. When she pins through the fabric, she uses her forefingers on her left hand to secure the fabric, palm flat to the pattern table, while her right thumb and forefinger push the pin through. “So, every [costume work]shop likes you to pin differently, whether it’s across or it’s along.” Carla gestures with her palm vertical, parallel to her body, moving outwards, then at right angles to her body to represent pins along a seam. She then crosses her forefingers. "Or how at the corners if it needs to make a T, or if it needs to do all these different things? So, I don't have a specific rule. I do what works when. Like this, since I'm transferring patterns, transferring lines from one side to the other, it's along the line. But it depends on the fabric. If I'm trying to keep multiple layers together, sometimes I will go across. I generally don't like to run that way because it can create bubbles… Yeah. A lot of debate!"

Carla's reference to 'creating bubbles' relates to the possible distortion of the material when it is laid on the cutting table, or pinned, meaning that when cutting several ply of sheet material, one or more may be stretched or distorted, altering the outline and dimensions of the cut pattern piece. When pinning and cutting, this is frowned upon, as slight distortions in measurements, when added up across an entire garment, have the potential to alter the fit. Distortions in the direction of the grain in a material can affect its drape, stretch and physical behaviour due to the differences in material behaviour when cut on the bias or straight grain. This relates to Carla's use of 'Finger Walking', described further in the following vignette. This is a more obviously skilled touch behaviour which she employs to ensure a lack of 'bubbles' and that the material grain is not distorted when laying the material to be cut.

Figure 7.8: Carla pins along the seam lines she has marked on her toile and through indicative marks so that she can transfer them from one half of the toile to the other

VIGNETTE: Finger Walking

On several occasions, I observe Carla walking her fingertips across a fabric as she lays it and adjusts it. Eventually, I ask: “Is there a particular reason when you’re laying the fabric out that you use your fingernails to push it into shape?” I ask. She stops to think and then begins to re-enact the gesture, talking through it as she does. “It’s err to move the grain of the fabric. So, it makes it move in waves, I guess. I’m holding this end so it doesn’t move.” Carla firmly plants her thumbs on the table. “And then it’s like….” She opens her fingers forward while her thumb holds the fabric in place. I copy her gesture, first on the pattern table, then on a scrap of fabric. I notice the feeling of the fabric weave on my fingernails first, the texture and tiny ridges against the hard surface of my nails. I can imagine that on a fabric woven from thicker yarns, this could give me a strong impression of the direction of the grain. The fabric rises in a soft ridge in front of my fingertips. Carla’s ‘waves’. The fabric behind my fingertips now appears to lie flatter despite already seeming flat before. “I guess it depends on the fabric,” Carla tells me. “This is so stiff it doesn’t really matter. But yeah, you sort of stretch it [with your fingernails] in that direction.” “That’s really interesting. One of the other designers I’m working with, who works a lot with chiffon, she very gently pats it to align the grain.” I comment. Carla grins knowingly. “Chiffon patting, for sure! Yeah, you sort of go like this.” Carla delicately pats the calico laid in front of her with alternating hands, walking them slowly forwards in small increments.

The reference to ‘chiffon patting’ relates to a technique I observed Ella using to remove bubbles and distortions in chiffon and fine fabrics, gently patting a fabric with a single forefinger or her fingertips.

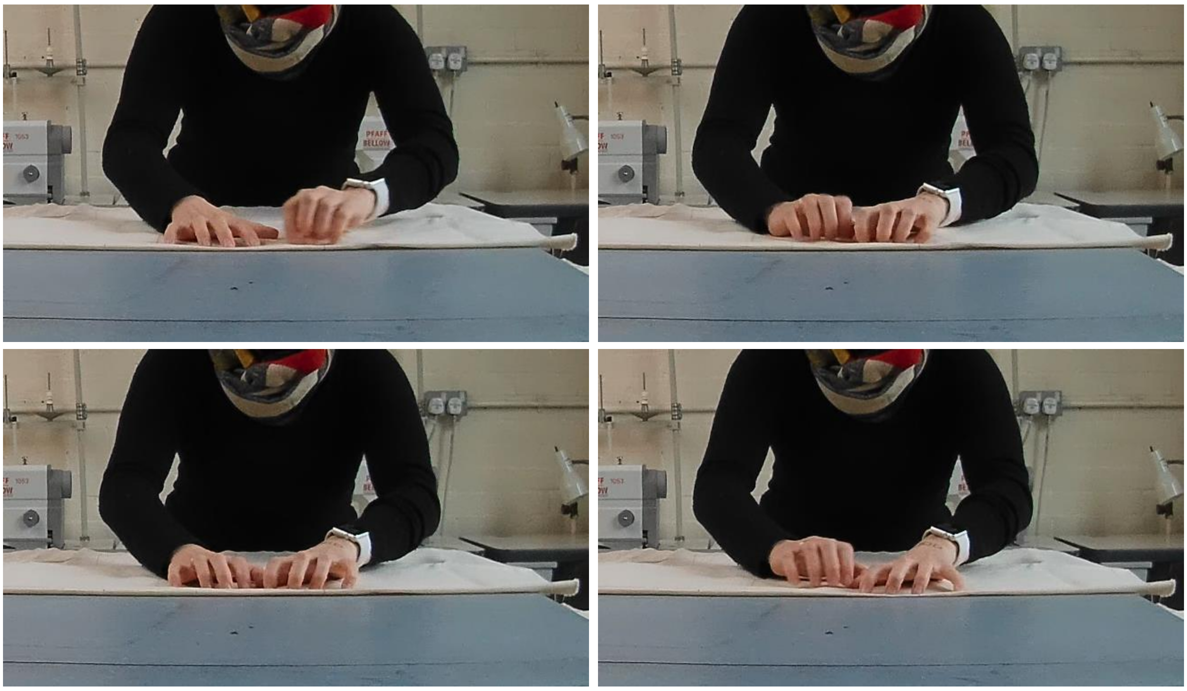

Figure 7.9: Carla demonstrates ‘finger walking’ to align the fabric grain

Laying fabric to be cut involves managing and working with material properties to avoid distortion, ensuring that the fabric is laid naturally without any air pockets, unexpected creases, folds, or distortions caused by gravity, or the designer pulling more strongly on a certain part of the fabric. Knowing to reduce these distortions' impact requires understanding of the issues they may cause, which is gained through previous garment prototyping experience; again, demonstrating the role of a felt history of making. I primarily observed these sensitivities to potential impacts the use of touch may have on material behaviours in participants with a longer history of material engagement, reinforcing the importance of felt histories on designers’ contemporary touch behaviour.

7.4.2 Pinning to Mark

Another use of pins is to mark proposed placements of seams, darts, hems, or details such as fastenings, pockets or embellishments, as well as marking where a fabric might intersect with cardinal points on a body or tailor's dummy. This often relates to the zoning of the body in garment making and related disciplines, as observed by Jewitt, Price and Xambo Sedo (2017).

When using tailor's dummies, it is possible to locate these dividing lines and cardinal points through touch, feeling for the subtle ridge which indicates a seam or taped line such as the waist on the tailor's dummy. This can act as a guide. For instance, when draping a pair of trousers I observe Kat feeling for the crotch seam on a tailor's dummy, pushing the loose fabric she is draping onto the form and marking the seam line with pins. In this way, she defined the placement of the crotch seam as she draped.

Ella went further and used pins to mark points of tension (which she considered one of the most significant feelings for her design process) in her draping and toiles.

FIELDNOTE – Ella marks points of tension

> Ella smooths her hand over the upper waist section of the skirt she is draping. "So here, there's actually quite a lot of tension there. Because it's on the bias, you can make it quite tight." She pulls it more tightly towards the joining point, and the flounce falls over the right leg. She pinches together the fabric, her nails creating a fold line against

the tailor's dummy. "So, I could probably take a couple of centimetres out of that. Maybe even three centimetres? I'll just pin that so I can remember that tension." She pins the joining fabric together tightly against the dummy, and then steps back to look at the effect she has created.

7.4.3 Pinning Fabric Ply

Materials are often pinned onto or adjacent to a surface. Be it a tailor's dummy, a cutting table, or the body of a live model. For this reason, it is important for designers to feel and ensure they do not capture anything unintended with the pin. It is also often necessary to discern how many layers (or ply) of the material they are pinning through. For example, to ensure they catch several layers in a seam and do not leave them loose.

In the case of catching different ply of fabric and avoiding pinning into a substrate, the pin becomes entangled with the body, similarly to the classic discussion of tool usage by Merleau-Ponty (2002). The pin also becomes a transducer after Ingold (2013), a means by which the liveliness and arguably the agencies emergent in the encounter between the designer, the material, the substrate and the environment come into negotiation, perceived through the pin. While Merleau-Ponty (2002) discusses bodily *extension* focussing on 'le corps propre' (one's own body) when ontologically balancing the human and non-human in an *entanglement* with tools and materials, the distinction between human and non-human is troubled, as explored in the autoethnographic fieldnote below.

AUTOETHNOGRAPHIC FIELDNOTE: The Sensation of Feeling Through Tools

I am trying to pin a pattern piece through four layers of fabric. A pair of sleeves cut on the fold as they are symmetrical, plus the accompanying paper pattern.

I am reliant on the sensation received through the pin to do this successfully. I sense the tip of the pin, which I can feel almost as if it were the sharp tip of a finger. Is the pin a part of my body? I can feel distinctly where it ends and where it begins as it rests against my fingertips, but the pin is certainly integrated with my body as part of my sensorium. I feel with it as part of me, while simultaneously feeling it against my skin, separate from me. At once, I feel myself feeling it and feel the sensations I perceive through it. This moves beyond Merleau-Ponty’s (2002) duality of feeling (touching and being touched). The perspective multiplies, adding a third dimension, the feeling I perceive in and through the pin. My body boundary is no longer fixed.

When I first push the pin into the layers of material, I hear a popping sound as the tip punctures the paper feel and the give of the pin as it slides through, followed by some resistance from the fabric. I know that I have reached the final, outer layer of the fabric when I feel the strongest resistance and have to push slightly harder, while the fabric feels like it’s stretching and distorting at the pin tip. The final give and release of tension tell me I have pinned through all the layers of material. The pin again slides more freely.

When I turn the pin to pierce back through the materials, I feel its angle from the pressure on the pin/my fingertip – I can’t really separate the two, the pin and I seem merged – satisfied I have it at the desired angle from the first puncture hole, I push back through. Again, I feel resistance, almost in reverse, until the tip of the pin emerges.

I’m sure I was never taught to feel for these things; they are experiential understandings gained through my felt history of repeated action and feeling. Feeling what went wrong. Feeling the difference when trying to pin fabrics. I can also vividly remember the sensation of feeling *through* the pin to catch an errant layer of fabric, trying to perceive the difference in tension which would mean I had finally caught it - occasionally feeling the skittering sensation of it dropping from the pin tip. A very subtle acquisition and the release of resistance.

As I cut out the sleeves, I realise that the sensory engagement of using scissors to cut multiple ply of fabric is similar. When I cut, I feel through the scissors. I feel the pressure of the scissors against my hand, yet this is not quite the same as the sensation I receive. That I feel in addition to the pressure of contact with the scissors. The pressure tells me of resistance. Of the success of the cut and how many layers I have cut through. The second sensation is located in my hand and in the blades of the scissors. I feel with the blades. Feeling the fabric around them, the resistance and pressure, perhaps vibration in them as I cut. My focus on the fabric's resistance during this encounter supports Hickey-Moody and Page’s (2016) proposition that the resistance of matter in entanglement with the body is pedagogic.

The duality of feeling as bodily bound and located in tools and materials entangled with the body, both accessible through shifts in attentional focus, extends Sheets-Johnstone's construction of kinetic melodies as both automatic and available for attention at will. In the case of touch and tools, designers can shift between a focus on subtly different kinetic melodies, which differently bound the body, troubling the notion of the ontologically separate and complete human.

7.4.4 'Over-pinning' and Material Behaviour

> "I try to pin minimally, especially if it's a nice fabric. I don't want to over-pin it and overwork it. That's what I'm always conscious of. Not stifling the fabric." Kat makes a bouncing and grasping gesture with her upturned hand.

The concept of over-pinning was mentioned repeatedly by Kat as she discussed working with materials and understanding what they 'want to do'. Through this ethnography, I understood over-pinning as fixing material in place so that it distorted or was manipulated and held counter to the natural effects of gravity and the body.

This was one of the few named concepts concerning common touch behaviours which I observed being circulated in a teaching environment. For some time, I thought that it was an idea Kat had developed through her sensitivity to materials until I attended one of her fitting and critique sessions with her tutors.

VIGNETTE: Kat - Circulating concepts of over-working materials

> Kat is testing a toile on her fit model. The top is draped and currently unresolved, so Kat enters the room with pins between her lips. She awkwardly answers the tutors' questions through the side of her mouth as she uses the pins, one by one, to secure the draped fabric around the model's body. It is a sheer, gauzy black mesh. The model is obviously uncomfortable at wearing so little, a feeling compounded by the restrictive garment: a wrap with no sleeves that constrains the movement of her right arm, pulling it tight to her body, fastening at her waist on her left side and leaving her left arm and shoulder exposed, free to move. One of her tutors comments, "So annoying! Sleeve but no sleeve."
>
> Her tutors begin to discuss the draped top and trousers being fitted. They mention the need for "a little bit of control with a light touch" and "not over-working, or over pinning" the materials Kat is sourcing. They feel this is in line with the spontaneity of her focus on found materials and materials fixed in motion. In her responses, Kat mirrors their phrasing and mentions a desire for honesty and authenticity to her materials.

In the above fieldnote Kat's concepts of honesty and authenticity when working and finishing materials reflect her sense of their inherent liveliness and agency. Over-pinning is seen to stifle their agency and work against, rather than corresponding (Ingold, 2013) with their liveliness. This awareness extends to pinning materials in a way that does not stifle their behaviours, as witnessed in many of the designers' practices. Ella was careful to pin pleats along their folds. When draping a pair of fluid trousers, Kat pinned them vertically to the tailor's dummy to allow the fabric to hang naturally and not counteract the effects of gravity. See figures 7.11 and 7.12. In each case, a felt understanding of the materials informed the use of pins, enabling the designers to understand when the material was or might be distorting.

Figure 7.10: Kat's final draped top, trapping the arm, and low-waisted trousers - as shown being draped on the tailor's dummy in Figure 7.12 (images courtesy of the designer)

Figure 7.11: Ella pins the pleats she is draping horizontally along the fold of the pleat to minimise the influence on the fabric behaviour. In this case, she pins the fabric to the tailor’s dummy to locate it on the body rather than to another ply of fabric

Figure 7.12: Top – Kat pins the fabric of her trouser toile vertically to the dummy so that it will drop naturally under gravity rather than be artificially held in place. She uses this tactic to avoid ‘over-pinning’ and ‘stifling the material’. Bottom – Kat uses horizontal pins to mark her proposed waistline

Unlike the designers with more fashion-oriented backgrounds, Carla uses safety pins rather than flat pins when fitting garments. I observed Carla fitting her blouse on herself at several stages of her design process. Often Carla would tell me that getting a garment on a real living body as soon as possible was a priority. Having worked in this way as a costume designer, she has become sensitised to the experience of the wearer's body while fitting and relates to this (Osmond, 2021), as well as the feeling of her own body inhabiting a toile as it is fitted. In this way, she draws on her felt history, as noted in Chapter 6. This collapses Osmond's notion of an embodied conversation into one designer's perceiving and responding body. In one of our conversations, Carla notes that "performers get freaked out by pins". Also, linking back to the discussion of strategies for the mobility of fashion studio resources in Chapter 5.2.2. Carla tells me, "I often have to fit away from the studio, so I need to shove a toile in a bag and have the pins still stay in place until I get it back!"

By focussing on various uses of pins that employ similar kinetic melodies in their manipulation yet create diverse felt responses and lead to a multitude of understandings, this section begins to highlight the contextual specificity of even familiar and shared touch behaviours. Thereby arguing for the role of emplaced context and the presence and intra-action of other non-humans in meaning-making through feeling. This section also reveals how the use of non-human tools common to the garment prototyping process can trouble the ontological distinction between human and tool, bounded body and perceived sensorium. In the following section, this focus is extended to similar felt experiences with other tools.

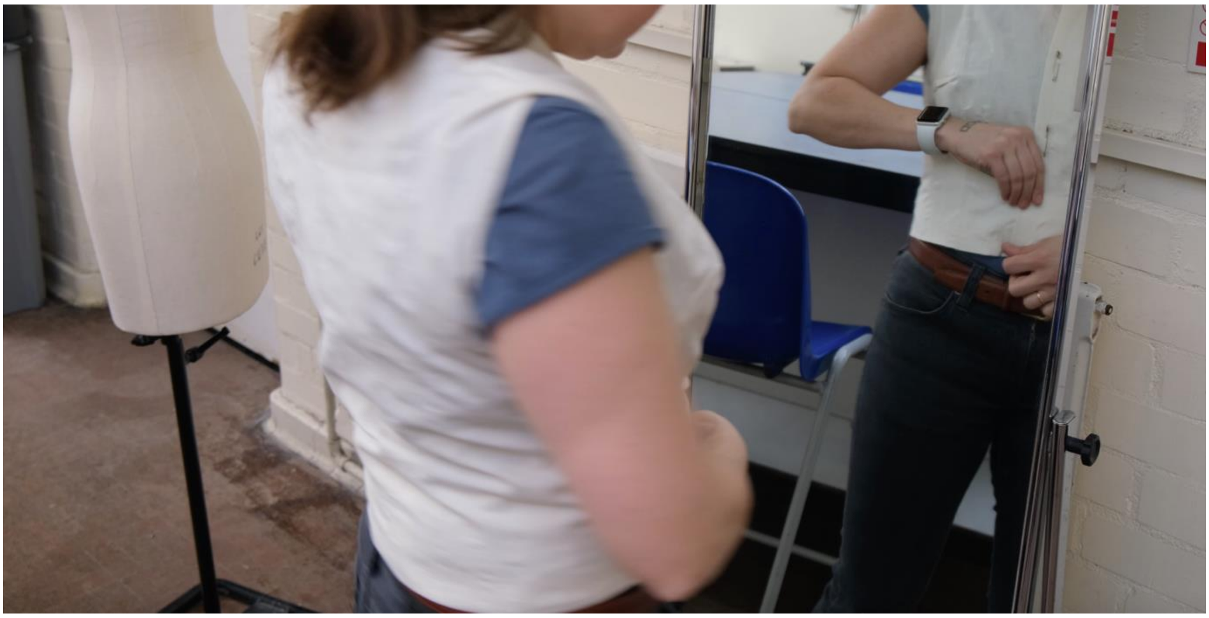

Figure 7.13: Carla fits an iteration of her blouse on her own body using safety pins

7.5 Cutting

The theme of avoiding ‘stifling’ or distorting a lively material even extended to the designers' techniques for manipulating tools and materials when cutting. While the use of scissors or rotary cutting blades may not appear skilled, they are vital tools in garment prototyping, and as such, the felt experience of their use is a core, shared aspect of the touch landscape. Scissors are also often employed in particular ways that aim to negate a material's distortion. Reflecting on my garment design and making education, I vividly remember the rule of “no air cutting!” which was instilled in me during my bachelor’s studies - referring to never cutting out fabric unless it was laid flat on a table. At the time, I had little idea why this was significant but came to realise that this was due to the possibility for even a well-pinned fabric to distort when subject to gravity and shear forces. This issue is exemplified by the techniques and touches Ella developed to cut chiffon, a notoriously unstable and easily distorted fabric.

VIGNETTE – Ella's tactics for cutting chiffon

Ella begins to pin the chiffon to the pattern piece beneath it, holding the chiffon very lightly in place with her forefingers, careful only to catch the pattern and not a further layer of paper below. After adding each pin, she pats the chiffon. She only pins through the edge of the pattern piece, where she has added the seam allowance, as adding it retrospectively with chalk would move or distort the fabric. She begins to cut the chiffon with a very large, heavy pair of scissors (or tailor's shears). After an initial cut, Ella lightly holds the excess side of the fabric (which is not pinned to the pattern piece), keeping it in place and stabilising it. When cutting curves or awkward angles, she sometimes lifts a section of the cut pattern piece to give her better access with the oversized scissors, ensuring the fabric is not distorted by pulling the scissors through it. Ella and I had previously discussed a technique that Nadine and I were both taught for controlling fluid fabrics, involving careful alignment to the selvedge and sandwiching between stabilising sheets of pattern paper. Ella responded that "Life's too short!". As she cuts, she now tells me, "So when I do chiffon, this is how I normally do it. The chiffon will sit on the pattern when you're careful enough about it. When you try to cut and move the fabric with the scissors, then that's when the fabric moves a lot." I move around to get a better view of what Ella is doing. "I think I can see better from this angle. So, you're not moving the chiffon at all, if possible, you're just moving the scissors around." I comment. "Yup", Ella confirms.

A final technique for avoiding distortion when cutting fabrics is to avoid pinning a pattern to the fabric, instead of tracing the outline of the pattern piece with the tailor's chalk. This was Kat's choice for cutting out fabrics. It gives designers freedom to alter the seam allowance in accordance with seaming techniques and their fabric choice. However, it also requires careful handling of the chalk in response to felt sensations.

AUTOETHNOGRAPHIC FIELDNOTE: Allowing for the drag of chalk on fabrics

> The chalk feels smooth and powdery in my hand, its rounded triangular shape satisfyingly ergonomic and sitting comfortably between my fingers and thumb. The edges are sharpened with a scalpel. The finer the edge, the stronger and more precise the mark. On most fabrics, the chalk glides almost unnoticed. Sometimes you need to exert more pressure to leave a mark. At this point, I begin to feel the fabric stretching, gathering and resisting, particularly as I am chalking on the bias or in the direction of stretch. In this case, navigating the fabric behaviour and ensuring it doesn't distort requires a lighter touch or chalk in short marks (like Marie's small touches) a few centimetres apart, like a dashed line. I observed Kat doing this several times.
>
> The feeling is the fabric clinging to and stifling the movement of the chalk, resisting and creating tension which I feel in my hand. A feeling of stretch and resistance, almost like the resistance of a fingertip dragged across the fabric, yet it is the chalk

edge I am feeling with. Oddly the sensation seems to be located in my upper fingers and palm of my hand, rather than an act of physics on the chalk itself.

Figure 7.14: Kat Chalks the outline of her pattern piece onto a wool fabric before cutting

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7.6 Conclusion

This chapter has presented an in-depth discussion of the core shared touch practices employed by the designers I ethnographically observed while manipulating tools and controlling materials. These touch practices have previously received little academic attention, and their documentation is a major contribution of this thesis.

The role of felt experience in the everyday activities of pattern drafting, folding, pinning and cutting is discussed, particularly with reference to movement and feeling during material forming processes. For example, Alexa's enactment of three-dimensional material forming movements when folding paper, the felt experience of which was associated with expected behaviours of other materials when formed in the same way. The acquisition of these touch practices is linked to felt histories in the form of kinaesthetic memory of prototyping actions previously performed or registered through mimicking the movements of peers. In addition, the significance of material engagement, internships and shared verbal concepts in developing touch practices is noted.

These understandings and socio-material entanglements related to felt experience have been grounded in Sheets-Johnstone's concept of kinetic melodies. This is demonstrated in Carla's 'sense memory' of the feeling of drafting armholes in garment patterns, structured by the use of a particular tool. This chapter also notes that kinetic melodies memorised through traditional, physical garment making experiences cannot be instantiated in the same way using digital tools due to the spatial and kinetic constraints of current computer interfaces. This is evidenced by Marie's reflection on her ideal 3D design interface, including a pen or stylus and being at a one-to-one scale with the human body.

The fact that touch practices with tools and materials seek to avoid material distortion through skilled feeling and manipulation is discussed in relation to designer's acknowledgement of material liveliness. The unfixed and mutable boundaries of the feeling body are highlighted through autoethnographic observation on the nature of sensing *through* and *in* tools when engaging in the core touch practices observed - for example, experiencing sensation *in* scissors and pins when cutting and securing fabric. In acknowledging that parts of the felt experience of garment design development are only accessible through tools entangled with the body and that feeling is perceived *in* diffuse parts of this entanglement which may not be in direct contact with the body, the ontological centrality of a human designer/maker is challenged. This may be why I encountered so many anecdotes of ‘what non-humans want to do’ or the anthropomorphisation of machines (Calderin, 2011) and tools during garment design development. Their liveliness is readily acknowledged.

However, these core touches do not demonstrate how a sensory understanding of material is gained or how designers learn to feel for material properties. Instances of communicating and sharing touch practices which specifically relate to gaining felt understanding are reported in the following chapter.

CHAPTER 8 – THE LANDSCAPE OF SKILLED TOUCH IN GARMENT PROTOTYPING: SHARING AND COMMUNICATING TOUCH PRACTICES

Figure 8.1: Marie’s paper pattern pieces and digital print of a virtual garment

8.1 Introduction

This chapter continues the reporting of the skilled touches in garment design development documented through the ethnographic observation of six designers as they prototyped garments. While the core touch practices reported in Chapter 7 relate to the use of tools and the manipulation of materials to avoid material distortion, the touches discussed in this chapter relate to understanding materials through their relationship to the body and processes of moving, manipulating and feeling them in order to understand their properties. Crucially, many of the touches reported in this chapter are demonstrative and *communicative* of how to touch. The chapter notes the significant material and non-human resources for experiential and communicative touch, which are utilised by the designer or available in their studio environment.

The touch practices discussed in this chapter are equal parts familiar and novel to me as an experienced designer. Due to their novelty, they are easier to identify, yet their roles in meaning-making processes are equally difficult to pinpoint through discussion alone. In many cases, their significance becomes clear only through sensory ethnography activities of 'feeling with' and personal re-enactment. Ethnographic vignettes and fieldnotes illustrate key observations central to the analysis.

Among the participating designers, it was a common assertion that the ways they learned to handle tools and materials (discussed in the previous chapter) were developed through repeated personal experience rather than specific direction. However, I did observe instances of touch practices being shared in explicit ways.

The over-pinning of fabrics was previously discussed as a verbally communicated understanding around touch and tool use. However, the majority of communication and sharing I observed concerning touch practices took place through multimodal aggregates. These generally comprised handling demonstrations, gesture and posture demonstrations, eye contact and verbal direction, which rarely mentioned sensation. All of these involved a form of ‘co-feeling’, demonstrating the validity of ethnographic attention informed by both sensory ethnography and multimodal ethnography.

The touch practices in this chapter do not currently have any direct digital equivalents, as I witnessed no sharing of how to touch a digital garment or adapt touch practices to particular technologies. The majority of this learning took place through online tutorials. It was generally autodidactic, though Marie recounted to me a Clo3D workshop she attended, which focused primarily on visual design rather than garment forms. In this chapter, her experiments with physics applied to 3D garments are discussed as the closest parallel to the activities of learning how to weigh or animate fabrics.

8.1.1 Chapter Overview

This chapter begins with an analysis of an encounter during which a designer is instructed on how to weigh fabrics by a more experienced garment maker (8.2), demonstrating the significance of non-linguistic cues and language unrelated to touch in structuring the learning and transmission of designers' touch practices. In 8.3, a further learning encounter is reported during which a designer demonstrated how to activate a fabric using the hands *and body*, creating movement through which to feel the more complex properties and physics of the fabric. In 8.3.1, this is related to the animation of digital fabrics with properties of gravity and physics which are impossible in the physical world, affording experimentation and new creative possibilities. Section 8.4 discusses the mutable nature of the qualities of perceived sensations and aesthetic preferences for them, demonstrating that communicating about aesthetics and mimicking the touch practices of others can alter perceived sensation. Thus, the perceived sensation can be considered to be socio-materially constructed. To conclude, in 8.5, the key arguments of the chapter are summarised.

8.2 Learning how to Weigh Fabrics

This section recounts an example I observed of demonstrating how to feel for a particular material quality, which took place between Alexa and her collaborator Mabel. This was significant as it was one of the few instances when a designer communicated about touch and felt experience to another party rather than me (the researcher). Mabel is a very experienced pattern cutter and maker who has produced one-off showpieces and bespoke garments for some of London's most well-known luxury brands. Her relationship with Alexa is closer to that of a master artisan to a novice. They frequently prototype together, as took place in the instance described below. In this way, through her many collaborations, Alexa continues to learn skills, tricks of the trade, and ways of seeing and feeling throughout her professional career. In doing so, apprenticing in a wider range of practices beyond just garment making, including AR, VR, motion capture, performance and digital design. In an era with little access to apprenticeships, Alexa creates them for herself through collaboration.

The vignette below demonstrates communication around touch between two third parties, rather than the designer and I. It is presented as a form of script to highlight the multimodal nature of Mabel's demonstration of how to judge fabric weights.

VIGNETTE: Alexa's Tactile Apprenticeship

> Today Alexa is working with her collaborator Mabel, and I visit them both in Mabel's studio, another busy and materially rich space. Alexa is excited to show me the printed fabric samples she recently received in the post. These are small swatches digitally printed with a colourful interpretation of dazzle print which I have previously seen on one of her toiles. The white unprinted borders contain reference barcodes, calibration marks and colour matching settings from the printer.
>
> The fabrics vary in translucency and weight from light chiffon and organza to heavier canvases. Alexa now takes them out and experiments with layering them or combining them with other fabrics. After laying each swatch over the half-scale toile she and Mabel have made, Alexa narrows her fabric choices to two options for the base layer fabric. One a lightweight cotton poplin and the other a heavier linen.

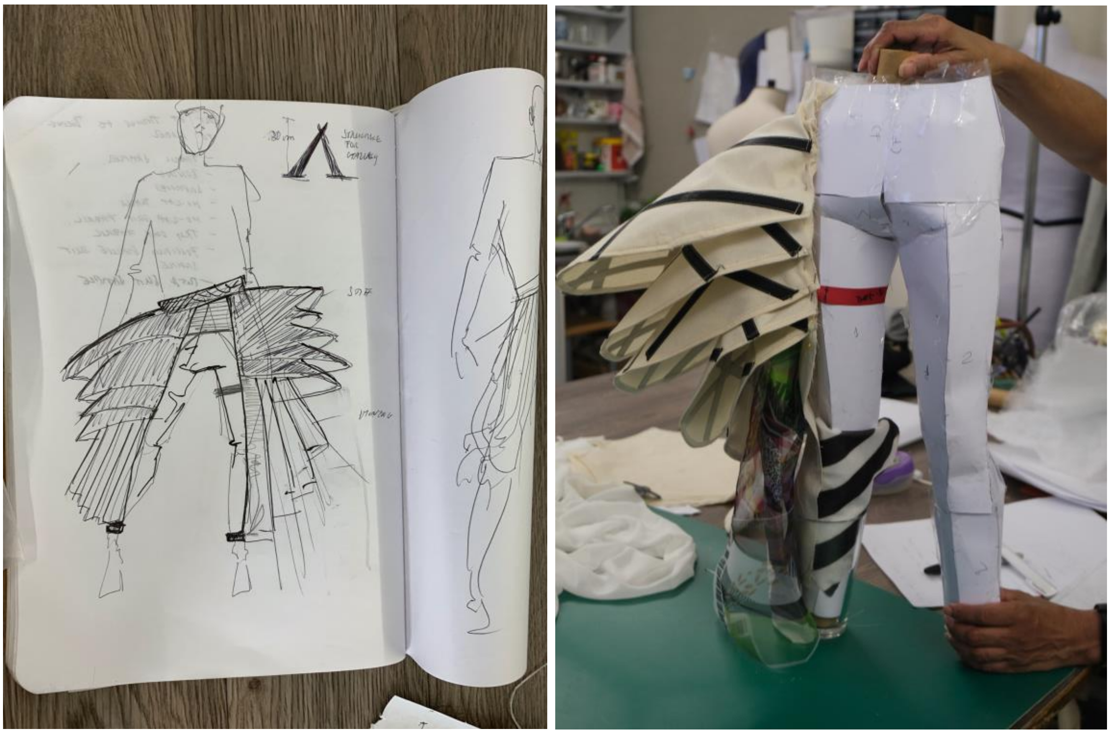


Figure 8.2: Alexa’s design sketch and the half-scale toile produced with Mabel

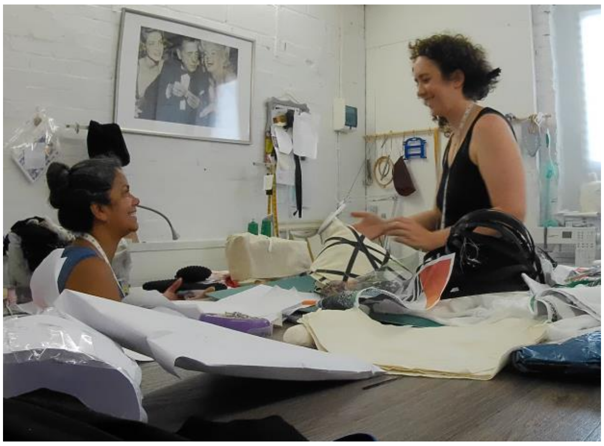
Figure 8.3: Alexa’s fabric swatches and Alexa testing fabric swatches on the hip panels of the half-scale toile

"I'm just worried that it gets too heavy." Alexa comments, hanging the small swatch of each fabric from her thumb and forefingers. She lightly bounces both hands. "Maybe it wouldn't make much difference? What do you think?" She hands the swatches to Mabel.

- Mabel takes one swatch in each hand.
- Rather than holding them between thumb and forefinger, she grasps the swatches in the middle and allows the upper fabric to fold over her extended forefingers.

- She folds the swatches again, creating squares of four layers of folded fabric. Next, she places these on her fingertips and cupped palms.
- Mabel looks thoughtful, not making eye contact, as Alexa watches.
- Mabel lightly raises and lowers her hands, not dramatically bouncing the fabric but allowing the weight to re-settle.

- “Yes.” She says and smiles, making eye contact with Alexa.

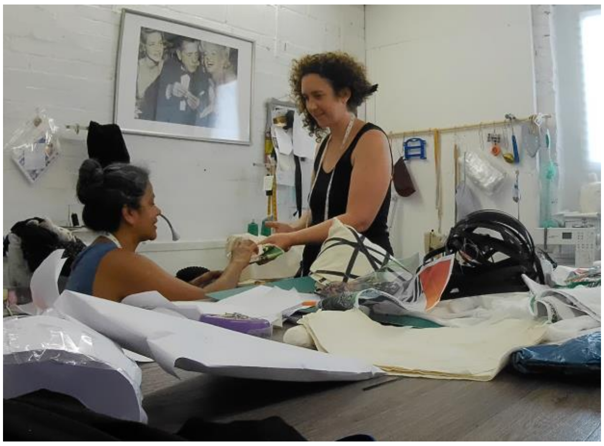


- Alexa visibly relaxes and smiles back, now watching Mabel’s actions more closely.
- “If you do this, you can feel the weight.” Mabel bounces her hands more dramatically, indicating her gesture.
- Alexa reaches for the swatches, but Mabel draws them closer to her body. Still smiling, she makes eye contact with Alexa once again.

- “If you hold it….” Mabel transfers the swatch from her right hand to her left. Then with her now empty right hand, she indicates her cupped palm.

- “Hold it like this.” Mabel rubs her thumb and forefingers of her cupped hand together. “Because this is more sensitive. Yeah?”

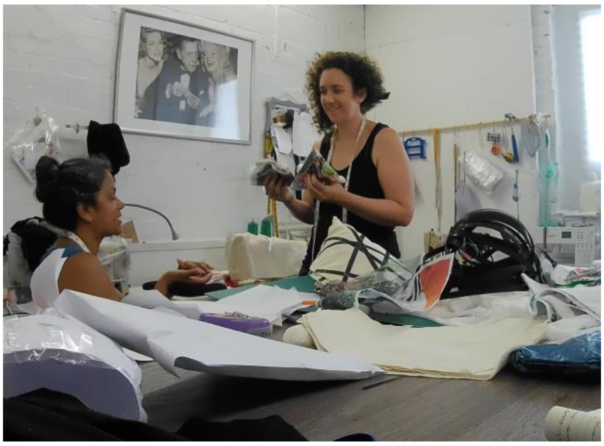
- Mabel re-folds the fabrics and places each one in turn into Alexa’s cupped hands.



- Alexa takes the swatches, looking unsure, but intrigued. She begins to bounce each hand as it receives the swatch.

- "The problem is if you hang it, you just don't feel it", Mabel tells Alexa.
- Maintaining eye contact, Mabel once again holds both palms in the cupped gesture bouncing her hands up and down in time with Alexa.

- Alexa smiles, and her posture becomes more open as she moves. "Ah." She exclaims.
- Mabel touches the fingertips of her left hand to her right.



- Mabel rotates her hands so her palms face downwards, rubbing the thumbs and forefingers of both hands together more dramatically.

- “Because that’s the sensitive part of the fingers, the fingertips!” she tells Alexa.
- Mabel turns her hands back to their cupped position.
- “Yes?” she asks Alexa.
- Mabel sits back and grins, hugging her upper body and rubbing her shoulders.
- “Hmm.” Alexa acknowledges. Having bounced the swatches in her cupped palms throughout this exchange, Alexa finally puts them down. “I just wonder, do you think it would affect how the hip panels stand?”

Having been instructed in a new technique, her attention shifts immediately from the weighing activity to the impact of the fabric weights on her design. Little acknowledgement is given to her new understanding of the swatch weights; it is simply applied. I suggest that the seeming lack of significance this encounter was afforded, and its casual nature, may relate to designers' claims that they were never taught how to feel.

Later I test this approach to weighing fabrics myself. I try it with my palm up, as Mabel suggested to Alexa, but with a larger piece of fabric. This creates more tension over the fingertips, the point most affected by gravity, and therefore brings the full weight of the fabric to bear on the sensitive fingertips. I turn my hand over, allowing the fabric to fall over the back of my hand. Though I have less sense of tension and drag from the fabric, I feel that it is behaving in a more naturalistic way, giving me a sense of how it will fall.

The multimodal aggregates used in this communicative encounter demonstrate that the sharing and learning of touch practices rely on various cues such as eye contact, positive affirmation through smiling and facial expression, which would not be possible outside an interpersonal encounter with a skilled garment designer or maker. Thereby reinforcing the perceived importance of an 'education of attention' (Grasseni, 2004; Ingold, 2013; Gowlland, 2015) and apprenticeship style relationships in garment design education. Though the designers I observed believed that they were not taught how to touch materials or feel for certain qualities, it is possible that the informality of moments of learning, such as the one described in the vignette above, makes them less memorable as educational encounters. The status of the person from whom designers are learning may also influence the perception of whether a touch skill was ever taught. Rarely will tutors on garment design courses share hands-on, technical advice. This kind of information is more commonly passed from university or studio technical staff (such as Mabel) to learners. Given the verbal directions used in the communicative encounter, the sharing of touch practices also appears not to be linked to metaphors for the description of sensation, as highlighted by Petreca, Baurley and Bianchi-Berthouze (2015) and Ræbild (2015)

While the un-directed touch practices described in the previous chapter are used to discern Haug's (2019) 'material produced' knowledge, the directed development of a touch practice detailed in the above vignette can be considered to generate a form of 'interpreter produced' material knowledge as the touch practice revealing the particular material properties is directed by a skilled maker (Haug, 2019: P413-414). This concurs with McCullough's assertion that '*Craft learning is a form of imitative social learning. Movements are physical skills taught directly, whether by demonstration or coaching'* (1996:P223). Yet this exposes a gap in McCullough's arguments as he makes no mention of how digital craft learning might similarly take place. Both in McCullough's discussion and in the research data presented in this thesis, physical touch skills are demonstrated and shared, yet digital skills are developed autodidactically through experimentation (discussed later in this chapter). The understandings developed through touch can be considered to focus on 'know-how' and 'know-why'. How to handle tools and materials for a specific purpose and why a tool or material may behave as it does. Thereby, in McCullough's hylomorphic reading, gaining understanding the potential of a medium and the means to manipulate it. As Haug proposes, these can then be triangulated with other forms of materials knowledge, such as the supplier information on Alexa's printed fabric swatches (know-what), to inform decision making.

However, the question of when a touch practice becomes incorporated into a designer's repertoire of self-initiated actions may problematise Haug's categorisations. When does an understanding derived from a particular touch practice become material produced rather than interpreter produced? The speed of acquisition of a touch practice may again influence the perception of whether it is 'taught'. If, as shown in the above vignette, it only takes a single demonstration to understand how to feel for a material property, developing a kinetic melody as suggested by Sheets-Johnstone (2003), then the perception of a learning process taking place will be diminished. The metaphor of kinetic melodies is also relevant as it proposes that in each 'replaying' of the melody, it is adapted to the context in which it is enacted - thus, leading to the perception that the melody of the touch practice is self-taught. This process is further outlined in the framework of designers' felt enskillment proposed in Chapter 9 (see 9.2).

8.3 Learning how to Assess Fabric Physics

In addition to learning how to discern individual qualities of a material, such as weight, the more complex behaviours of a material in relation to the body, movement and physics were frequently cited as crucial for designers to understand. In an encounter with Ella, she demonstrated how to touch fabrics, activating them with her moving body and directing my attention to the felt response. Again, this was a process of demonstration and direction rather than a verbal discussion of sensation. Ella associated the response felt in the fabric with adaptations to a garment pattern. In this way, understandings relating to the fit and behaviour of a garment, which can be adjusted through the garment pattern, are linked to the felt behaviour of fabric in motion.

VIGNETTE: Ella's Ideal Crepe

Ella takes a wine-red fabric and drapes it over her hand and forearm. "So, this is a silk interlock. I have used this a lot, but unfortunately, I struggle to get this weight again." She takes the fabric from her arm and holds it between the thumb and forefinger of both hands, allowing it to hang in a loose curve. She bounces it slightly. "When I put it on a stand or make it into a dress, it's got a good swing on it." She moves each hand back and forth, shearing the fabric. "I know how much movement I'll get from the fabric from the weight. And I can feel that, as opposed to just seeing it. So, you handle it, and the fabric is there [on your palm], and you can feel how much it's going to move." She bounces it from her upturned palm, then moves her hand back and forth to swing the draped fabric. "When you're dancing, for example, with this piece…." Ella takes the fabric and holds it at her hip, allowing it to fall down her leg. She begins to sway her hip. "I know that the way it's gonna move, the weight is what will make it move." She puts her hand under the fabric, between it and her leg. "So, I have to understand how much weight here", she flicks her hand outwards again, roughly at hip height, "will give it enough movement at the bottom, and that I don't do visually. That I do by feel."

Ella takes another length of fabric and drapes it over her hand. “So, this is a polyester satin crepe. It weighs more, but the way it behaves in relation to the amount you have to do to get it to move, it’s much less responsive”. She flicks it up and down, then takes another fabric offcut. “Whereas the silk satin crepe, if I want to make it move, I can just do this.” Ella drapes it over her hand and shakes her hand from side to side, causing the fabric to ripple and sway. “And it’s really elegant, and it’ll float!” She turns her hand over to cup the fabric in her palm. “This is actually a good weight. Sometimes these come up too light. I really like the heavyweight ones, but you can’t always get the colours in those. It’s the heavyweight satin crepes; they’re just fabulous! Because they’ll just….” Ella makes a whooshing sound and rapidly pulls one hand downwards, closing her fingers into a point. “And you can judge how much you need to put into a skirt by the weight on the hand or hip! You can! Whenever I get fabrics, the first thing I do is look at them and see how much movement I can get when I put my hand underneath it or when it's draped on my hip. I’ll try and do that with it.” She raises her arm slightly to demonstrate and flicks the fabric forward with her downturned hand as if making a shooing gesture under the fabric. “Just to sort of see what it’s gonna do?” Ella turns her palm up and bounces the fabric again. “And also, you can often feel the weight, so you know how much it’s going to drop. Because if you’re cutting on the bias, the weight will come right down. So, on a lighter weight fabric, the pattern has to be longer and possibly narrower. And on the really heavyweight ones, it needs to be shorter and slightly wider.” She smiles. “Because of the amount of drop you’re going to get. So that’s how I judge a fabric.” As she tells me this, Ella has grasped a different fabric in each hand and scrunched them in her palms.

“Here, you have a go.” Ella hands me her initial ‘ideal’ crepe sample. I first notice it collapsing, its weight hanging from my hand. Similarly to my experience with pins and scissors (described in Chapter 7), the sensation appears to be not only located in my hand but *in the fabric*. I drape the fabric over my forearm and begin tapping my hand beneath it, then sharply raising and lowering my entire forearm to bounce it. I feel the bouncing weight of the fabric pulling at my hand and forearm, and just as Ella said, also at the hem of the fabric and in the tension or release across the material between them. In particular, the tension and ‘kick’ as the fabric rebounds with occasional snapping sounds. I sway the fabric draped over my arm from side to side, feeling the air resistance and drag, both against my forearm and in the fabric’s sail-like tautness. I now understand why stretch and tension are the aspects of fabric feel that Ella considers most important.

This experience can be considered an example of Petreca, Baurley and Bianchi-Berthouze’s (2015) proposed ‘simulate’ phase of textile selection. A designer may simulate a textile’s imagined use to feel its response with either the opposite hand or their passive body as the hand animates it. Yet Ella’s additional use of her active, moving body (her leg, forearm and hip) to both trigger and feel the resultant movement of a fabric provides an example of how the authors’ categorisation might be extended for a holistic, feeling body. While the prior vignette with Alexa and Mabel could be considered to represent a case of Ræbild’s (2015) ‘design by handling’, during which the understanding of weight informs a design decision, in Ella’s case, the inclusion of the full body as a feeling informant to garment development makes the exploration of fabric physics equal parts ‘design by handling’ and ‘design by own body’. In Ræbild’s categorisation of design types, I argue that although feeling is not specifically discussed, the full sensing body is more present than in Petreca, Baurley and Bianchi-Berthouze’s construction of ‘passive bodies’.

The location of sensation outside the traditionally perceived boundaries of the body further troubles the binary distinction of human/non-human, which feeling *through* tools problematised in the previous chapter, yet in this case places additional emphasis on the intra-action of the moving body and materials in movement. Where tools are generally solid and their physics predictable, the sway, recoil, pooling, weight and shear of unstable fabrics, their intra-action with air currents and the body all structure the location of sensation, and thus the perception and understanding of what constitutes the body through movement.

Crucially these entanglements between unpredictable, moving and responsive bodies indicate the emergent nature of perceived agencies. The agency of the fabric is both enacted and understood in its entanglement with the moving body. The complexities of these entanglements and their impact on the perceived sensing body move beyond Ingold’s (2013) tool mediated correspondences, during which animacies of a maker, a tool and a material are argued to entangle. In Ingold’s description, the body boundary is never significantly changed or troubled. Through correspondence, the maker understands, predicts, and works with a material, but this takes place through animate *contact* (encounter) rather than through animate *extension*, or empathically ‘inhabiting’ the material (Swindells and Almond, 2016).

I argue that while designers develop basic felt understandings of fabric physics (derived from their felt histories and contemporary touch experiences), which could be considered the fabric's affordances, these are rarely as nuanced as the true complexity of the fabric's behaviour. The remaining unpredictability enacted in the entanglement of designer and fabric represents emergent agencies which even experienced designers struggle to predict. The relationship between expected behaviours based on felt histories and a material's actual felt behaviour can be considered with reference to Sheets-Johnstone's discussion of the adaptation of kinetic melodies when replayed in continually novel, emplaced and entangled contexts.

The entanglement of the sensorium with the fabric is necessary to gain a fuller felt understanding of the fabric itself in movement, rather than the felt experience of the fabric against the hand or (passive) body as proposed by Petreca, Baurley and Bianchi-Berthouze. Not just predicting its behaviours but becoming entangled with a piece of fabric and feeling *through* it to learn its properties in response to the animacy of another human or thing. In this way, touch *in motion* becomes essential to develop a designer's understanding of a fabric's applied behaviours. This entanglement with an individual's sensorium may be why the designers I observed used directions and encouragement on how to feel, rather than trying to verbally describe an experience which will vary between each individual and each fabric.

While fabrics may be argued to have predictable physical properties, which could be associated with how they feel (both as a static swatch and in motion), the complexity of fully understanding them is demonstrated by the long years of development work in computationally rendering fabric physics. Around thirty years have been required to build on foundational research by Magnenat-Thalmann and colleagues at MIRA Lab in the early 1990s (Volino, Courchesne and Magnenat-Thalmann, 1995; Volino and Magnenat-Thalmann, 2000) and only recently has computer hardware advanced to a level where cloth rendering is possible on non-specialist machines. Even so, fabrics still glitch and break the laws of physics in software such as Clo3D. While similar in some ways to emergent physical behaviours, these glitches can break the illusion of realism and the designers' felt empathy with the virtual garment, as proposed by McCullough. This was a source of frustration for Alexa and Marie when attempting to create a realistic garment, indicating how strongly attuned to fabric physics designers must become, yet it was also a source of inspiration.

8.3.1 Digital Fabric Physics

If feeling through movement and *into* fabric is essential to a designer's understanding of it, how might these understandings be communicated through current digital software? If the movement of and with materials is key to understanding how they might behave when formed, is it still possible to communicate this through digital animation? In Clo3D, the relationship between the moving body and the material (as described in the previous Vignette with Ella) will be purely visual. The means of communicating understandings through movement and kinaesthetic sensation is broken by the scale and the restriction of full-body movement to small standard interface devices (as discussed in 7.2.1). Yet communication of fabric properties in digital software is doubly impeded by unrealistic physics and animation of materials. This prevents designers from associating digital materials with kinetic melodies recalled from their felt histories and therefore perceiving them as realistic fabric surrogates.

VIGNETTE: ‘Touch’ and Movement in Software

> I meet Alexa for a walk in a local park, a chance to catch up and find out how her work is going. The conversation turns to Clo3D. We had both thought that the Covid-19 lockdown and the difficulty in accessing the many and various physical resources used to develop garments was a perfect context to try and learn a digital garment development software. I ask what she thought of it, and her frustration is quickly apparent!
>
> “I just don’t really think it’s very realistic. I don’t quite trust it. Oh god, and the little hand tool!” Alexa exclaims [Clo3D includes a tool represented by a symbolic hand icon, which allows digital fabrics to be pulled from a single point and manipulated]. “Is that what they think touch is? Just pinching fabric from one small point and being able to pull it anywhere, even through the avatar, or ways a fabric just can’t!” It is clear that she finds the interpretation and approach to touch reductive and unhelpful. The breaking and bending of the laws of physics prevent Alexa from considering the Clo3D interpretation of touch as a realistic simulation.

"Also, it really doesn't understand folding! I tried to make a zero-waste pattern for the Tuta suit[7] in Clo, and OK, that wasn't' too bad, but placing it on the avatar was impossible! Because for the Tuta suit, you have to slash the pattern and fold the arms and legs into tubes, but they are still joined to the body. The placement points, the blue dots in Clo [which allow the designer to assign garment patterns to points on the avatar body], are just all in the wrong place. It tries to fold arms and legs the way it expects a regular pattern to work, to make separate tubes and join them. So, everything curls around the blue placement point, but not the way it should. It all goes the wrong way or collides with the avatar."

The criticism of folding can be linked to the understandings that designers gain through enacting and feeling the kinaesthetic experience of movements used to manipulate and form materials (see Chapter 7). The fact that a material manipulation which feels intuitive to Alexa is impossible to enact again breaks down her expectations of physics and movement in a digital space. Perhaps this is why Alexa and Marie both experiment with impossible physics in Clo3D? It is not seen as a realistic simulation, communicative of the physics and associated kinaesthetic experience of real-life garment prototyping. So its other material possibilities are foregrounded for exploration.

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[7] The Tuta suit is a key inspiration for Alexa. Designed in 1919 by the Italian Futurist Thayat (Ernesto Michahelles), it is often discussed as one of the first examples of a jumpsuit and formalised zero waste pattern cutting. The name Tuta is derived from *tutta* in Italian, meaning all in one or a unified thing. Cut from a whole cloth, a single garment, for the whole body and wearable by all people.

For both Marie and Alexa, the ability to work with pattern pieces with different properties from a conventional fabric allowed them to conceive creative possibilities that folding and draping fabric would not (see 7.3). Yet translating these into a physical garment was still problematic and, in some cases, a reason to keep a design purely digital, as evidenced in the vignette below.

VIGNETTE: Marie's Experiments with Gravity

"Have you tried to make a Clo design in a more unstable fabric? It seems like you've worked with stable woven fabrics mostly?" 'Err, no, I haven't. Apart from this one." Marie points to a printout of a 3D render stuck to the window of her studio. It shows the avatar of a girl wearing an elaborate coat and head-dress seemingly made of a fluffy material, which Marie tells me is cut straw. (See Figure 8.4, page 354). "I've definitely no plans to make it!" Marie laughs. "But that one, I was working a lot with the properties. Same with the crown. That also took a while to make! Because when you put on the simulation [in Clo3D], then it reacts as if gravity comes on." Marie makes a gesture implying something falling and draping over her body. "So, I needed to give that one really solid structure" Maire pats her hands together several times. "They don't have "this is going to be metal" [options in Clo3D]. They only have metal buckles. So, then you need to change the existing material properties. It was quite fun! Also, when it comes to the bottom, for example." Marie points to the flared hem of the skirt in her render. "It was first…." Marie moves her arms toward her legs, indicating something is collapsing. "You can play with the pressure." She raises and opens her arms, then

> allows them to collapse several times. "And it becomes, like, inflatable. That change is really fun!" She smiles.

The creative use of impossible or 'paused' fabric physics appeared to be a key motivation for working digitally, either providing inspiration similarly to the folded paper garment experiments described in 7.3.1 or affording whole new creative possibilities not bound by a real-world relationship to material physics.
In this sense, digital design retains an epistemic separation from physical garment prototyping, where understanding and working with material physics and bodily interactions is critical to the success of a garment. Yet prototyping in the digital space still requires an understanding of the physics of materials in movement, acknowledging that the materials will exhibit different behaviours than a designer will associate with felt understandings of their physical counterparts.

This brings into question whether materials in digital design software should be considered digital materials in their own right? This is how designers often seemed to treat them, manipulating, exploring and altering their properties to discover 'materials-produced knowledge' (Haug, 2019) or 'the hand of the digital' (Smitheram, 2016; Joseph *et al.*, 2017) from their animate behaviour. Further questioning whether digital materials should be considered communicative representations of physical materials, as their creators likely intended? Representing the physics of a real-world counterpart which designers could visually associate with their felt histories. In this case, the understandings gained from interacting with them should more properly be categorised as Haug's (2019) 'representation-produced' knowledge.

I argue that as designers such as Marie refer to their playful experiments to understand digital materials' properties and the forms they may take, such experimentation should be considered Haug's material-produced 'know how' and 'know why.' These experiments constitute the productive play McCullough describes as crucial to understanding how tools (Clo3D functions) and mediums (digital materials) might be used. Digital materials (perhaps unintentionally) do more than represent their physical counterparts; they exhibit their own complex, otherwise impossible behaviours and liveliness. For this reason, designers' felt histories and associations are not directly applicable to digital materials, and therefore they must engage in a process of familiarisation with them, learning their potentials through practice.

Similarly to the previously discussed emergent agencies enacted by moving bodies meeting moving materials, it is in their animation that unique behaviours of digital materials can be perceived and communicated - both in response to digital bodies and the designer's input to manipulate the material. The designer must learn new forms of touch between digital materials and avatars and new effects of physics on digital material animacy, but in this case, with no sensory reference. If this is a productive design resource, should digital garment prototyping aim to be more lifelike and remove unrealistic material behaviour? Or attempt to provide sensory references for altered physics? Would designers have a frame of reference for this in their felt histories, or would it produce completely alien felt experiences that are not recognisable or communicative of any current experience?

Figure 8.4: Clo3D render of Marie’s straw crown and coat. An experiment with material properties and rendering, inspired by Guild imagery and ‘waste’ material in MMORPG gaming worlds (image courtesy of the designer)

8.4 Touch to Share Aesthetic Understandings

Touch was not only used to judge and quantify materials. It also had a core role in shaping perceptions of materials. By mimicking a designer's touch, I changed my perception of a fabric to more closely align with theirs, even when my initial response to the fabric was relatively strong and different from that of the designer. This is exemplified in the following vignette, in which Kat while laying a fabric to be cut, discusses her love of the fabric and encourages me to touch it similarly to her.

VIGNETTE: Feeling Quality and Preference with Kat

> Kat picks up her pattern pieces, visually inspecting them before smoothing them onto a dark navy fabric spread across her pattern table. "I love wool! I try and always work with it. When you iron it, the smell that comes off it really reminds me of being a child and wearing dressage jackets." Kat tells me. "My Mum would always source really high-quality wools, and I'd have one tailored for me every season because you grow so much when you're little… So, I'm using this fabric." Kat leans over the table, strokes the flat fabric lightly with her fingertips, and then passes me a sample. I exclaim as the reverse of the fabric is very different - synthetic, crisp and papery feeling as I briefly rub it between my thumb and forefingers. Even the wool side feels unappealing. "It feels a bit like Tyvek[8]," I comment. "They've waterproofed it, but

[9] Tyvek is the brand name of a non-woven textile used in medical garments, PPE, envelopes, packaging and construction. Although it feels very similar to paper (like a hybrid of paper and plastic film), it is a film created from compacted plastic fibres. Similarly to paper, it can be cut without fraying

it's an Italian wool. It's weird, isn't it!" Kat replies, turning a corner of the laid fabric over, gathering, pleating it, then stroking gently with her fingertip again. Next, stroking the back of her fingers over it. "With this, I love the way it's got the nap." Kat slowly strokes the fabric with her palm in a wide arc away from her body. "I think about it going down. You would rub your hand on it and have it going down your leg." Kat strokes down her outer thigh. "It's smooth. It feels really luxurious, doesn't it?" She strokes it again. I am aware that it certainly didn't feel smooth to me. I had perceived it as coarse on the wool side and crisp and plasticky on the waterproof face. Kat flattens the fabric again in broad, light strokes. She continues stroking the wool side, and I copy her gesture, brushing my open palm lightly over the fabric surface. To my surprise, it now feels soft and smooth! "Sometimes you can just feel it. The Italian wools are so nice! I do always stroke it." Kat grins. We continue our discussion, mirroring each other's slow brushing and stroking movements, my perception of the fabric completely changed.

Later I meet Kat while she is working with another unusual material: safety netting left over from the construction works taking place on her university building. Kat has told me about various finishing techniques she has tried with the net, showing me small samples. "So, did you start with sampling then, rather than trying it out as a big piece?" I ask. "No, I put it on as a big piece on myself." Kat makes a shrugging motion around her body. "Just to try and create the shape that I was originally going

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and easily printed on. Tyvek was developed in the late 1950s and early 60s. Prior to increased awareness of plastic pollution, it was considered cheap and disposable.

to make this garment into, but it wants to do something a bit different. It’s still the same feeling when you look at it, but it wants to move in a different way. It’s just quite soft.”

Figure 8.5: Kat and I feel her building netting

Kat gestures a falling motion from her shoulder. “It’s not really got any weight at all. I like that, but I think I’m gonna have to work with it. It’s not going to be the shape that I’ve designed in my drawing or in the collage that I did. And as much as I could probably try and make it, it doesn’t really want to work that way anyway! It’s too bouncy.” Kat makes a throwing gesture with both upturned palms. “The way it bounces back a little bit. It’s kind of springy… when you lay it on the body, it kind of springs. It’s really nice!”

When feeling Kat’s small samples of the netting, it felt like the netting citrus fruits are often packaged in. Smooth, crisp strands, still gritty from the pollution of a busy London street. I get no sense of softness or bounciness until I crush a large piece of the netting in my hand at Kat’s direction, experiencing the soft give of several layers and feeling it very slowly spring back from being crushed. Although it still feels plasticky, I begin to understand Kat’s appreciation of the netting’s properties.

The changes in my tactile perception recounted in the above vignette have several implications. Not only is the sensing body mutable (as discussed in Chapter 7), but the received sensation is also socio-materially constructed through the specific emplaced entanglement between the toucher, the fabric and the surrounding material context (including others who may be directing the touch). Each time the phenomenon of feeling a fabric is enacted, there is potential for this to change. Thus, the received sensation is not a property of the fabric and the toucher alone (as psychophysics studies would argue) but also of socially directed kinetics of motion.

When reflecting on this experience in relation to my own history of learning how to touch materials, I was reminded of working in a fabric shop as a student. In this context, value judgments around a fabric were not only related to fibre content or structure but also to how it was handled and the degree of reverence it received. Gentle, slow and reverential touches have much in common with slow stroking behaviours, which are linked to the pleasant assessment of touch with textiles (Singh *et al.*, 2014). This presents the possibility that the touch itself is creating an impression of pleasantness, which may not be derived from the fabric, but also the kinaesthetic qualities of the touch. This would support the proposition that movement structures experience and perception, in this case demonstrating the link between movement and aesthetic preference.

8.5 Conclusion

This chapter has presented instances of designers sharing and communicating touch practices, both with me as an observer and between one another in the case of Alexa and Mabel. Thereby demonstrating that touch practices are shared among communities of designers through multimodal communication, often involving the guidance of a more experienced designer or maker. This empirically contributes to understandings of the ways touch practices and associated meanings are shared among garment designers. For example, Mabel’s instructing Alexa on how to feel the weight of fabric swatches through gesture, movement, gaze and verbal encouragement. The instances of copying touch practices discussed in this chapter demonstrate that touch practices can be shared through empathy, mimicry, or more directed processes, regardless of the level of a designer's experience. This contradicts Ræbild and Petreca, Bianchi-Berthouze and Baurley's assertions that communication around touch and sensation occurs through metaphor. I have suggested several possibilities for why it is that designers do not always acknowledge such moments of sharing, including the informal, fleeting and readily absorbed nature of the learning experience and the construction of the person passing on the understanding as not a traditional educator.

The chapter has also argued that agencies are emergent in the unpredictable behaviours which occur when bodies in movement and materials in movement encounter one another. In doing so, identifying the critical role of the felt experience of movement, both of the body and materials, in communicating material properties and understanding how a design might be adapted accordingly. This concurs with Ingold's foregrounding of animacy and similar New Materialist readings by authors such as Malafouris, who argue that agency is a non-localised phenomenon enacted in the *coming together* of humans, materials and things. It also goes some way to indicate why many previous studies have focused on gesture rather than sensation.

In comparing the role of understanding fabric physics through touch to the exploration of fabric physics in 3D garment design software, a productive distinction between digital and physical material physics has been identified. Referring to Haug's materials knowledge types, this chapter also argues that designers explore and experiment with the properties of digital materials rather than treating them as representations accurately portraying (communicating) familiar physical counterparts.

Building on the troubling of the bounded body (see Chapter 7), felt experiences recounted in this chapter have again brought the location of sensing and, therefore, the separation of the feeling subject from the felt material into question. This chapter also makes a key contribution by highlighting the mutable, socio-materially constructed nature of perceived sensation. Arguing that sensation can be structured and differently experienced through sharing aesthetic preferences and the movements used to infer them. This is demonstrated by the instances of Kat sharing her felt value judgements of a fabric and practices of touching it, which then altered my felt perception of the material when I adopted them

The empirical data reported in Chapters 5 to 8 are discussed in the following two chapters. First, focusing on designers' process of developing felt understandings and competencies (Chapter 9), leading to the creation of a theoretical Framework of Garment Designers' Felt Enskillment. Second, using three different agential cuts, which differently structure the agency of the designer during the prototyping of a garment (Chapter 10). Each of these agential cuts is related to a possible approach to digitising designers' touch practices, offering alternatives to more faithfully reflect the sometimes-contradictory nature of designers' perceptions of non-human agency.

CHAPTER 9 – DISCUSSION: THE FELT ENSKILLMENT FRAMEWORK

9.1 Introduction

The four preceding empirical chapters have detailed the emplaced and socio-material nature of touch during garment prototyping, along with the individuality of designers' touch practices (Chapter 5); developed the concept of felt histories, alternate presents and futures as means by which designers situate their felt experiences and project them into current designs, or speculative futures (Chapter 6); proposed that skilled touch practices during garment prototyping involve managing material distortion by feeling *into* and *through* tools (Chapter 7); and demonstrated that the *movement* of things, materials and the feeling body is crucial to feeling *into* materials, communicating, and further, that through mimicking touch movements, sensory perceptions can be shared and re-shaped (Chapter 8).

Building on the ethnographic data, this chapter proposes a Framework of Garment Designers' Felt Enskillment (9.2), detailing the acquisition and circulation of their touch practices. It situates the framework in the empirical data (9.3) and concludes by outlining its key arguments and contributions (9.4).

9.2 A Framework of Garment Designers' Felt Enskillment

Based on the thesis' findings concerning the development and sharing of touch practices, I propose a framework of felt enskillment in garment designers. This framework offers an initial attempt to map designers' development of touch practices to a theoretical model, accounting for the complexity of their sometimes contradictory understandings of the processes of developing them. The framework draws together significant theories adopted by this thesis and accounts for the shift between boundaried and entangled understandings of touch and felt experience in the empirical data. This framework contributes an emergent mapping and is intended to be adopted and refined by future researchers, supporting them in exploring this space.

The framework consists of a cycle of touch practice instruction, adoption, adaptation and sharing. This is formed of three nodes. Each node highlights a particular, consecutive moment of analytical significance in designers developing touch practices: ‘How to Touch’, during which touch practices are shared with designers by another designer or maker; ‘Response/Feel’, during which a designer explores the response to their touch and feels into it, thereby moving from a socially directed felt experience, to a personally experienced pedagogy of matter; ‘New Touch Practices’ are then formed as the designer instantiates and contextually adapts the kinetic melody of the touch practice while attending to the changing response/feel in multiple situated contexts; finally the new touch practice is shared with other garment designers, completing the cycle.

Between each node, the roles played by kinetic melodies in the evolving touch practices are highlighted. This draws analytical attention to the central role of kinaesthetic experience in shaping developing touch practices and skilled sensitivities to feeling. First by inscribing an initial kinetic melody in the body after a designer is shown how to touch, next by instantiating and adapting (if only slightly) a kinetic melody to the current emplaced context in relation to the response/feel it triggers, and finally affirming the kinetic melodies of new touch practices through demonstration to other designers.

Emphasising their epistemological significance to understandings derived from touch practices, designers' felt histories are placed at the core of the cycle. The relationship of felt histories to the transition between each node of the cycle is also highlighted, indicating the link between currently experienced kinaesthetic sensation and the development of felt histories, productive resistance to them, or sharing the felt history of adapted touch practices.

The framework is also split vertically. On the right-hand side are aspects of the cycle during which designers attend to micro gestures and associated feelings, for example, when initially re-creating the kinetic melodies of a shared touch practice and attuning to the response it triggers. On the left-hand side of the cycle are aspects that incorporate micro gestures and feelings into larger macro gestures and sensations, such as instantiating kinetic melodies in new contexts and building micro gestures into larger actions of material manipulation and formation. These larger actions are more commonly demonstrated during internships and technical instruction by skilled designers and makers, while smaller gestures attending to the nuances of touch are often developed as designers respond to the feeling of the macro gesture. The framework is illustrated below (Figure 9.1).

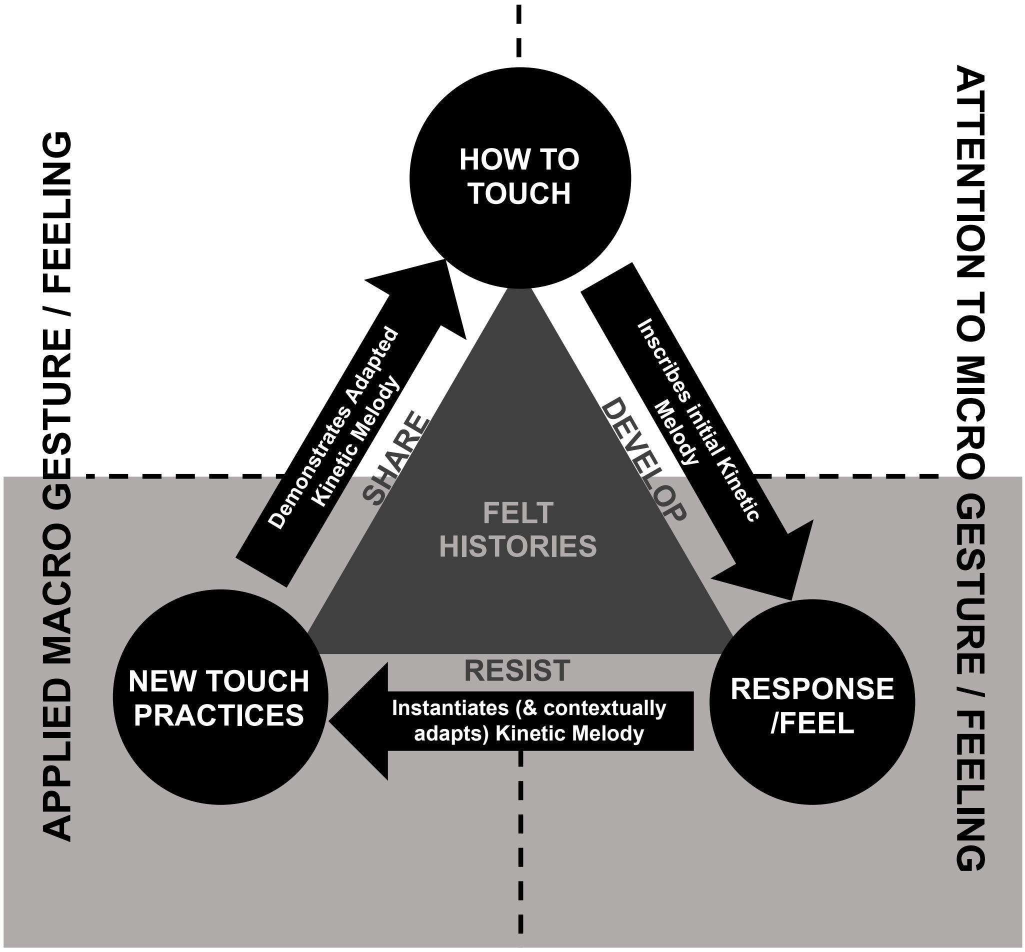

Figure 9.1: Framework of Garment Designers' Felt Enskillment

Along with the cycle of touch practice acquisition and development, the framework horizontally maps designers' contextual understandings of their touch practices during each phase. For example, whether the process is self-directed or socially directed by peers and educators, the duration of the process of touch and enskillment, and understandings of bodily entanglement, or pedagogic value afforded to the touch practice. For this reason, the upper and lower nodes of the cycle are mapped to the differing contextual understandings (represented to the left of the cycle in the shaded lower and white upper sections of the diagram). See Figure 9.2.

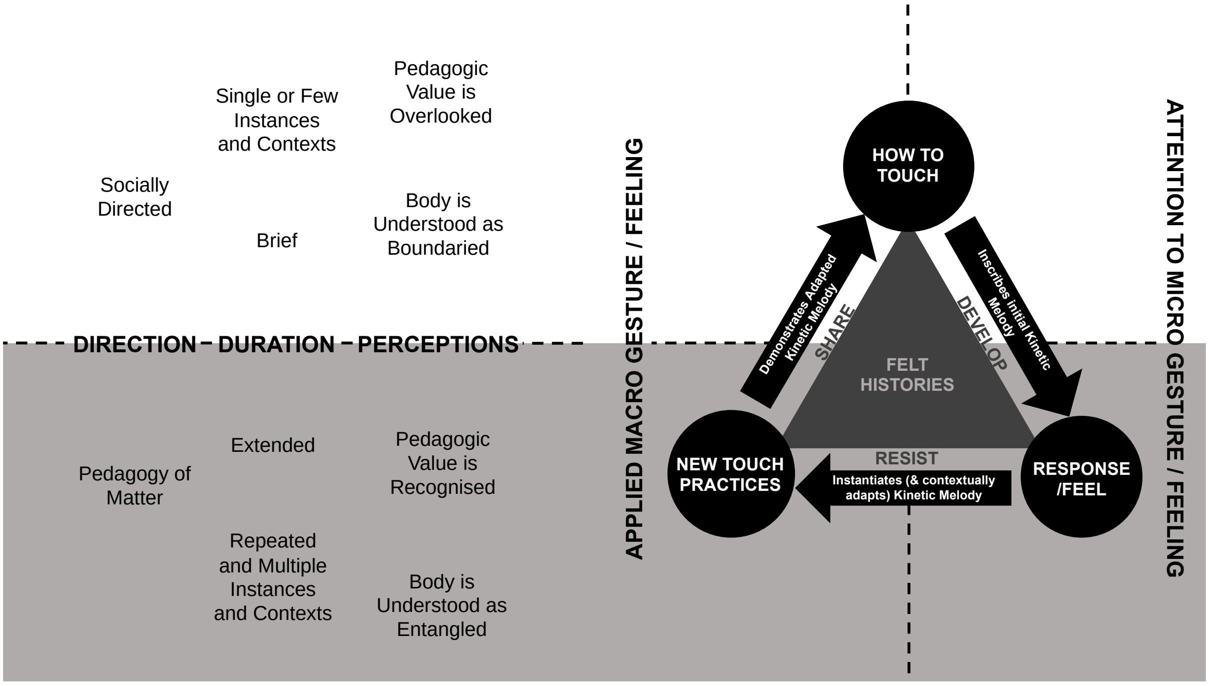

Figure 9.2: Conceptual Understandings of Garment Designers' Felt Enskillment

9.3 Situating the Framework in Empirical Data

The ethnographic data offers up instances of skills sharing through multimodal demonstration and encouragement to perform touch practices, along with the contextual development of touch practices through internship and circulation of specific verbal concepts. In particular, these highlighted the contemporary relevance of an 'education of attention' through peer direction alongside pedagogies of matter. Yet crucially, the data also demonstrates the informal and overlooked nature of such learning encounters, concurring with Page's (2018) assertion that material and embodied learning is often overlooked and accounting for designers' common perception that “no one ever showed me nothing” (Prentice, 2012). While these moments of communication and developing sensitivities and understandings were overlooked, they were possible to understand as communicative, and through analysis to infer the sensitivities being communicated through the encounter. While Ræbild (2015) and Petreca (2016) argue that their participants engaged in tacit processes as they did not discuss them during interviews, the data presented in this thesis indicate that at the time of the encounter, such actions were not overlooked by designers, albeit their acknowledgement was brief. In other words, the understandings gained through such encounters were not tacit. Though they are rarely told of (particularly through language) or acknowledged in the longer term, they are recognisable and articulated. The concept of resistance to conventional processes was also revealed in the data as a means through which designers develop (and readily acknowledge the acquisition of) new touch practices.

As evidenced, for example, by Alexa’s introduction to weighing fabrics (see 8.2), initial moments of socially directed instruction in how to touch and feel are brief and occur singly or infrequently. They are therefore unrecognised as moments of learning and enskillment. Still, they are crucial in inscribing an initial kinetic melody of a touch practice in the learner's body. They also focus on directing designers to attend to nuanced felt experiences, making them easy to overlook due to their subtlety. This process of direction forms the direction to touch in Norris’ (2012) touch-response/feel model. The ethnographic data supports Norris’ proposal that teaching touch-response/feel is achieved through multimodal aggregates rather than verbal direction alone. This does not negate the importance of talk in touch concepts such as ‘over-pinning’, which are also shared in relatively informal, though educational, contexts. In this case (see 7.4.4), only the concept is introduced and linked to other concepts such as ‘light touch’. While this does not immediately inscribe a kinetic melody in the learner’s body, it encourages them to perform actions and movements to discern the concept which has been introduced. In this case, to feel for instances of over-pinning.

Both approaches constitute the ‘How to Touch’ node of the framework. They invite the learner to enact and inscribe an initial kinetic melody with tools and materials in their body. At this point, before enacting the kinetic melody, the body is perceived as conventionally bounded. The learner then triggers and feels into a material response: The framework's ‘Response/Feel’ node. At this point, the process of enskillment becomes a pedagogy of matter (Hickey-Moody and Page, 2016) rather than a socially directed learning process. Initial kinetic melodies can be multiply repeated by the learner in differing contexts. Through this repetition and extended duration, designers come to recognise the process as one of learning and enskillment. As kinetic melodies are contextual and adaptive, changing with each situated enactment, designers perceive that they are not formally taught how to touch but develop felt competencies themselves through autodidactic processes, despite the initial kinetic melody being socially directed. It is also through discovering the response/feel of a tool or material that designers come to feel the entanglement of the sensing body with materials and things, and the conventional understanding of touch at the body boundary dissolves. As designers instantiate, develop, and adapt kinetic melodies as part of larger macro iterations of a design, they become more recognisable in the design process. They may morph and eventually be considered by designers as ‘New Touch Practices’, the third node of the framework. It is through this materially mediated adaptation that designers develop the perception of individual practices and shortcuts (see Chapter 5) that define their practice as innovative or unique. The perception, direction and duration of these touch practices are similar to the Response/Feel node of the framework.

A lifetime of material engagement and being in the world informing felt histories has been identified as crucial alongside more directed learning. Designers who recounted greater material engagement in their personal histories demonstrated more nuanced understandings of touch and the meanings revealed through feeling. Therefore, the framework's core (sitting within and contextualising socially directed and materially mediated understandings) represents designers felt histories. The relation of the core of the framework to the acquisition of felt enskillment (the outer triangle) demonstrates the role of resistance in designers' development of new touch practices. Both from materials which do not form as a designer might anticipate and in resistance to socially directed touch practices. The nature of pedagogies of matter as a form of resistance to conventional structures of power and gatekeeping through learning (Hickey-Moody, 2016b; Hickey-Moody and Page, 2016), or means to rupture them (Page, 2018), is adopted to account for material influence in developing novel practices contra to peer-directed learning. Once alternate or new touch practices have been developed, designers’ materially adapted kinetic melodies can then be demonstrated to new learners, beginning the framework cycle again.

Through demonstration, the designer cements their practices (McCullough, 1996) and more fully understands their uniqueness.

9.4 Conclusion

In this chapter, a framework has been proposed, contributing an initial attempt to map a previously un-theorised aspect of garment designers' creative practice: their development of skilled touch practices and associated nuanced understandings of feeling. It highlights analytically significant moments of garment designers' felt enskillment, mapping the epistemological significance of designers' felt histories to the present experience of kinetic melodies. The framework may have broader implications for research exploring the development of skilled practices or attention to nuances of felt experience in other disciplines that foreground material manipulation or have developed from apprenticeship-based learning models.

The mapping of garment designers' development of touch practices in the proposed framework sets the scene for the following chapter, which discusses the possibilities of digitally supporting them. In Chapter 10, the empirical data is discussed through three agential cuts and alternate readings to explore how touch during garment prototyping might be most effectively digitised.

CHAPTER 10 - DISCUSSION: DIFFRACTIVE ANALYSIS AND DIGITAL TOUCH SUPPORT FOR GARMENT PROTOTYPING

10.1 Introduction

This thesis has explored touch during garment prototyping from a New Materialist informed perspective, attending to both humans, things and the emplaced environment, exploring the potential for agency to be enacted in socio-material entanglements among them. In this chapter, the empirical data is diffractively analysed using three agential cuts (10.2), which enact differing theoretical understandings (in this case, three differing understandings of the agency of the non-human) as they make the phenomena of touch during garment prototyping observable. These 'cuts' are enacted to create diffractive readings of the data that explore and entangle differing interpretations of the observed touch practices and explore new perspectives on supporting them with digital touch technologies. Most technologies are created with particular epistemologies in mind and an understanding of humans as 'users' exerting agency on a digital tool. A reading shared by McCullough's (1996) discussion of digitising craft processes. In light of the possibilities for digitising garment designers' touch practices revealed by the diffractive analysis, shared themes are proposed in an entangled reading. To conclude, the central arguments of this chapter are summarised (10.3).

As the limitations of current digital tools for garment prototyping were a significant theme in participants' sociotechnical imaginaries, it is important to consider how digital touch technologies might be developed. To address the question of how differing agential cuts, representing understandings of agency, might shed light on approaches to the design of digital touch technologies for garment prototyping; along with the key aim to make recommendations for digital touch technology development which might support current touch-based meaning-making and understandings, this chapter now utilises diffractive analysis to explore possible routes to digitise touch during garment prototyping. The three diffracted agential cuts foreground hylomorphism, pedagogies of matter, and transducers and correspondence (for definitions of these concepts see Chapter 3). As hylomorphism is a primarily ideological agential cut, it is discussed in the following sections (10.2.1 and 10.2.2) in relation to the other agential cuts, which directly relate to possible digital tool or interface designs.

10.2 Diffractive Analysis and Digital Touch Support for Garment Prototyping

As diffractive readings foreground differing perspectives and their entanglement, each agential cut is first explored through illustrative examples from the empirical data. These are followed by a discussion of possible alternate readings of the data from the perspective of the other two agential cuts. Finally, an entangled reading is offered in 10.3, proposing how each approach to agency and digital interface design might be accommodated when creating a digital touch tool or interface for garment prototyping.

10.2.1 - Foregrounding Pedagogies of Matter

Handling materials to learn their unique behaviours and qualities was common to Kat’s materials led design processes and Nadine’s process of learning about materials during her internships. Physical handling of the materials was pedagogic. During their processes of feeling and handling materials, Kat and Nadine added and compared them to their felt histories (see Chapter 6). In this way, their familiarisation with materials helped to inspire designs.

This thesis has demonstrated the significance of experienced kinaesthetic sensation and movement (kinetic melodies) in linking a designer's felt history with a current touch experience. This implies that focusing on forms of surface touch, such as vibrotactile feedback, heat and pressure, is too limited to account for garment designers' felt experiences and touch practices. Furthermore, it suggests that the relationship of movement and kinaesthesia to body surface sensation, or cutaneous touch, is also critical. As such, a technology capable of delivering body surface sensations mapped to the designer's movements, and the physics of a (virtual) material in response to those movements offers the possibility to more fully support meaningful felt experiences. This could be achieved through a combination of motion capture (either external to the body using infrared technologies and depth cameras or on-body using accelerometers or EMG sensors) with feedback from haptic gloves and bodysuits. Most contemporary haptic gloves and bodysuits primarily give vibrotactile feedback to replicate surface textures, along with temperature and pressure in more advanced microfluidic systems such as HaptX (HaptX Inc., 2021). Sensations identified as pertinent in this thesis were stretch, tension and weight, which are not currently supported. The sensations of stretch and tension are created in the entanglement between a designer and a material rather than being innate and replicable properties of the material itself. This again points to the need for a more complex mapping between movement and sensation in any digital touch interface for garment prototyping.

Ultraleap technology (Ultraleap Ltd., 2021) combines infrared gesture tracking with mid-air ultrasound haptics. This technology would address the mapping of movement to sensation. However, it currently has several limitations: it can capture nuanced hand gestures, but only if these are not occluded by fabric. Additionally, Ultraleap sensors focus on the hands rather than the whole body as Ultraleap's haptic technology is currently directional, projecting ultrasound waves onto one plane. In contrast, when designers experience the sensations of fabric on their bodies, they do so concurrently on multiple three-dimensional surfaces.

The conceptualisation of digital technologies as tools to support garment prototyping is problematic when considering pedagogies of matter, as it presupposes that a designer is using digital tools to achieve a particular outcome. The types of casual, undirected touch of materials observed in designers' studios (see 5.2.2) and by Ræbild (2015) are not often considered in the design of a digital tool. McCullough highlights that task oriented data structures establish which symbolic representations of craft processes can be manipulated in a particular software. Creating constraints *'like the grain of a material'* (1996: P157). While McCullough argues that constraints are productive it appears that he does not consider constraints preventing casual play to be similarly helpful, as he later argues that play with a craft medium is essential to gain an understanding of its potentials. I argue that understanding the relational agencies of materials and tools enacted through casual, un-directed touch is critical for building felt histories, particularly in educational tools, if students are increasingly coming to higher education garment design courses with less prior experience of materials and making. As such, ‘free play’ with materials should be considered a core function of any digital touch technology for garment prototyping. This proposition is supported by Paterson’s (2007: P139-140) identification of the significance of the playful and performative nature of sculpting virtual clay with a haptic interface.

Solutions such as targeted mid-air haptics and haptic gloves or suits would also be appropriate for designers experimenting with folding and the kinetic melodies of forming materials. Although, when considering the sensation of folding materials, any digitised experience must consider their changing responses to surface touch and movement when materials are experienced in multiple layers. Yet technologies that are responsive to kinetic melodies pre-suppose that a designer has built an adequate felt history of material engagement, manipulation and forming. Technologies such as the Teslasuit (VR Electronics Ltd., 2021) and similar electrical muscle activation devices could be used to instantiate kinetic melodies in designers’ bodies which they could learn to mimic, similarly to the process of alerting learner paper makers to which muscles were activated by a master artisan performing the same task (described by Hiyama *et al.* 2011). However, the electrical stimulation of muscles to enact kinetic melodies contradicts the exploratory nature of learning through pedagogies of matter, as the kinetic melodies would not be self-directed. It is also unknown if kinetic melodies would be perceived differently when self-instantiated or electrically stimulated. An electrically stimulated kinaesthetic experience has no link to the emplaced and material aspects of felt histories, only the spatiotemporal.

Further, pre-supposing that designers are attempting to match the felt experience of digital materials entangled with transducers to physical counterpart experiences negates the possibility of exploring digital fabrics as materials in their own right, as demonstrated in 8.3.1. This potentially limits designers' sense of exploration and the relevance of digital touch tools for creativity. Designers were keen to assert their individuality and creativity through practices and processes they adapted and perceived as unique (see 5.3). This may explain the proposition by Ashdown (2013) and Gully (2009) that garment design students saw little relevance in learning techniques by rote. Enacting a learned process rather than creatively applying understandings gained through felt histories may be of less interest to designers. While interface design studies such as Wibowo *et al.* (2012), Inui (2013) and Dines and Biddulph (2019) created novel touches for designers to learn, once mastered, these would similarly become fixed and fail to support the evolution and adaptation of touches during garment prototyping. Therefore, options for creativity and personalisation are likely to be critical to the adoption of a digital touch tool by garment designers.

10.2.1.i – Alternate Readings: Directed Learning

As this thesis has demonstrated, designers do not acquire felt histories of material manipulation through undirected material handling alone. To support social sharing through an education of attention (Grasseni, 2004; Ingold, 2013; Gowlland, 2015), any form of digital material handling must incorporate a means to compare and communicate touch practices with others. Opportunities for co-located, group material handling could also be included in existing garment design pedagogies.

Whether this truly contradicts pedagogies of matter's focus on 'learning with' is subject to debate. Yet such formalised opportunities are currently overlooked in garment design education, either because they are assumed to be an implicit part of designers' creation of garments and receive little pedagogic focus or because of a perception of design competencies as being increasingly detached from material making. Any digital touch technology supporting collective material handling preferably needs to support either full-body, visual communication or employ a process of training designers to touch similarly to experts, such as the system of muscle activity mapping and vibrotactile prompting proposed by Hiyama *et al.* (2011).

The communicative aspect is easily supported by current video calling technologies' visual and audio capabilities. However, multimodal communication between designers (demonstrated in Chapter 8) requires a different focus from many contemporary visual communication mediums. Speech, gaze, body posture, movements and associated sensation are vital, concurring with Norris' (2012) observations on teaching touch-response/feel and Yang and Lee's (2021) identification of the significance of avatar posture and direction of attention in VR collaborative environments.

Making the whole body visible in a remote communicative encounter requires new approaches to capturing emplaced details while also allowing learners to focus in and look more closely, such as the process of zooming in and out of digital design software. The preference for garments, patterns and avatars at a one-to-one scale with the human body (concurring with McCullough) raises the issue of display size. Current digital display sizes may limit remote communication of kinaesthetic experiences when representing body movement and garments or materials at unfamiliar scales. A further question is whether a screen-based representation of a particular touch practice can communicate it as effectively as the three-dimensional, visual experience of seeing it performed live. It is likely that remote communication of touch practices through avatars in navigable virtual spaces (which could appear at a one-to-one scale using VR or AR technologies) may be preferable to 2D video communication. This finding also concurs with McCullough's proposal that VR and AR technologies have the potential to better match existing human skills in digital spaces and reduce the reliance on visual understandings. VR and AR spaces also have the potential to re-connect vision with action, restoring McCullough's 'hand-eye union'. Yet I argue that this union should be extended to a union of the eye with actions of other hands, tools and materials in social VR or AR spaces. Beyond visual attention to movements facilitating kinaesthetic empathy, Paterson's (2007) proposal that current digital touch technologies create feelings of closeness and serve to collapse the distance between remote users argues favourably for the incorporation of touch feedback between designers (as well as between designers and things), in digital spaces for co-presence.

10.2.1.ii – Alternate Readings: Hylomorphism

Learning from material engagement can be considered an opposing hylonoetic (Malafouris, 2014) viewpoint to hylomorphic understandings of design as enacting a preconceived idea on materials. Yet despite its hylomorphic framing (presuming that designers select materials for pre-conceived designs), Petreca, Baurley & Bianchi-Berthouze's (2015) framework of situating materials, simulating and stimulating design ideas through touch with active hands and passive bodies, can be interpreted as a means by which designers experience pedagogies of matter through touch. However, this reading gives little attention to material liveliness and agency. Alexa and Ella prove that a hylomorphic perspective is significant in relation to pedagogies of matter as they match material expectations to design expectations. In both Ella and Alexa's garment prototyping processes, they worked to develop and perfect mentally held or sketched design ideas in physical materials. Touch was used to form materials to a desired outcome. While both engaged with materials to understand their weight or physics (see Chapter 8), touch was used to understand which materials might support a pre-conceived design idea, similar to the context proposed by Petreca, Baurley & Bianchi-Berthouze. In other words, could materials be formed to Ella and Alexa's desired shapes? During Alexa's experiments with paper (see 7.3.1), the prototyping process developed a design idea for which a similar material or stiffening technique was then sought. In this sense, Ella and Alexa attempted to link a defined design idea with a method of execution, or production, rather than adapting the design based on material properties. Therefore, their design and prototyping processes could be considered to meet Ingold's (2013) definition of hylomorphism.

Despite the difference in perceptions of agency, this framing still requires a digital touch technology to provide a nuanced simulation of the behaviours of materials (even if they are not considered a significant factor in the adaptation of a design) as an understanding of their properties aids designers' *selection* of materials appropriate to a pre-existing idea.

10.2.1.iii – Alternate Readings: Transducers and Correspondence

While the concept of a transducer appears to negate learning through direct material engagement, it is important to consider that matter can still be pedagogic when explored using tools. Matter is still responsive to the movement of, and crucially sensed *through* and *in,* the tool. The critical difference is that for pedagogies of matter to occur through a transducer, they must be undirected in their correspondence with a material. This could be considered a mediated form of Ingold's (2013) 'art of enquiry' or Malafouris' 'creative thinging' (2014, 2020). This again highlights the need for 'free play' in any digital touch technology for garment prototyping but adds a further mediating influence in the entanglement. McCullough discusses digital tools as metaphoric and symbolic ways to translate or amplify the designer's actions in an interface. In this sense all digital tools can be considered to be transducers. If a transducer mediates and translates movements with materials, it may be more important to learn different movements and their consequences in digital spaces and for digital materials through pedagogies of matter, than to faithfully replicate a physical experience.

10.2.2 - Foregrounding Transducers and Correspondence

Common to both Marie and Carla's practices was questioning the influence of tools, be they manual pattern drafting rulers or digital garment prototyping software. As indicated by Carla and Marie's exploration of pattern drafting tools (see 7.2, 7.3 and

8.3.1), a successful understanding of the role of a transducer in relation to the body appears to rely on meeting the tool and material at human scale to allow for comparison of garment pattern pieces to the designer's body. This supports the development of human scale and body-related interfaces, such as the tangible interface using a tailor's dummy proposed by Wibowo *et al.* (2012). Scale is also vital in learned kinetic melodies of physical pattern drafting, during which full-body movement along with smaller micro gestures to understand nuance in 'small touches' inform the kinaesthetic experience. Small touches could be considered necessary adaptations or deviations from the invariant features of an existing kinetic melody, adapting it to a new context based on the difference in felt sensation which correspondence between material, designer and transducer, or indeed the agencies enacted with a transducing tool, bring about.

As with free material manipulation and folding to create three-dimensional forms, this requires a detailed mapping of movement at human scale to correlate to touch feedback, yet it introduces the transducing tool to convey feeling to the designer. Pinning and cutting materials are demonstrated to be particular contexts in which designers experience sensation in and through transducing tools, to understand and mitigate the distortion of a material. This is perhaps one of the most difficult aspects of touch during garment prototyping to digitise, not only due to the calculation of the complex physics of material and tool interaction, but also given that designers experience sensation beyond the conventionally assumed boundaries of the body. This will require foundational research into how sensation is experienced *in* tools and materials in conjunction.

Established haptic interface technologies such as 3D Systems ‘Touch’ device (3D Systems Inc., 2018), a haptic pen, consisting of a stylus mounted on a motorised arm which can resist pressure from the user, can still exhibit unexpected quirks of behaviour and often provide novel touch feedback, rather than accurately representing physical experiences. In this sense unexpected forms of touch are the ‘ghost in the machine’, breaking immersion for McCullough and frustrating Marie and Alexa, but productive for creative designers such as Thiel (2017). The operating principle of the 3D Systems Touch is similar to the creation of sensations of resistance and solidity when encountering ‘solid’ virtual objects with haptic gloves. In the case of haptic gloves, the fingers are restrained from moving into a virtual object by tensioning cables on the back of the digits e.g., the HaptX (HaptX Inc., 2021) 'exotendons', rather than a robotic arm resisting the force applied to it. While these solutions may prevent the equivalent of frequently seen visual glitches in which a 3D viewpoint moves *through* a solid surface (for example folding pockets and collars in Clo3D, see 7.3.3), they create a problematic ontological framing in contrast to the observation that designers become entangled with tools and materials and feel in and through them. The common theme of these technologies is their creation and reinforcement of the boundary of the designers’ body and the tool or material they virtually touch. This form of digital touch exists *around* things. It is neither joining with things nor felt within them. Thus, a pressing question for the design of digital touch to support garment making, is how a sense of sensation occurring externally to the conventionally understood body boundary might be replicated? Indeed, a further question is whether a sense of feeling in and through the tool already occurs in existing haptic tools such as the 3D Systems Touch?

Paterson (2007) argues that the PHANToM haptic pen (a precursor to the 3D Systems Touch) proves the interrelationship of the senses, the haptic feedback *verifies* the visual, resolving the ambiguity of experiencing a 3D visualisation on a 2D screen and providing a sense of presence. Paterson notes that in a trial of the device he experienced not only *'localized kinaesthetic forces by the fingertips alone, but [the experience] engendered a visceral feeling'* (P138) which he attributes to the synthesis of visual and haptic feedback. Whether this visceral feeling refers to kinaesthetic feeling, a sense of feeling into the tool and virtual material, or to the emotive experience of transgressing a virtual body in a medical simulation (the haptic simulation Paterson discusses) is unclear, thereby suggesting an avenue for future research.

Supporting the felt experience of the entanglement of a designer and a material via a mediating tool is likely to necessitate a tangible interface rather than the generic stylus of the 3D Systems Touch. Tangible interfaces suffer from a high degree of specificity as they are often constructed with specific tools or materials related to a particular activity. While it may be possible to research and replicate the perception of sensation in pins, or scissors specifically, creating an interface which can replicate sensation in and through a variety of tools and things will be a complex challenge. Initial research could explore the development of devices like the 3D Systems Touch with multiple tool tips, yet this would only replicate the experience of corresponding with a material through a transducer. It would not support 'direct' handling of digital materials, meaning that the different agential cuts in relation to the experience of touching would call for different technology solutions. Dines and Biddulph (2019) problematise the current variability and location of virtual tooltips in contemporary VR applications, indicating the need for further technology development in VR as well as associated haptic interfaces.

In foregrounding transducers and correspondence, it is inevitable that the digitisation of touch will alter the experience, rather than directly re-creating a physical garment prototyping process. Though McCullough discusses the abstraction of craft processes into symbolic processes and novel movements to apply them, he primarily considers ways to move beyond this level of abstraction, to make digital tools more directly related to their counterpart physical processes. Yet, if agency is non-localised in the entanglement of designers, tools and materials then it will be altered by the addition of digital mediation. It follows that if the role of transducers is to be taken seriously this should be acknowledged and encouraged while attempts at digitising touch with complete accuracy or fidelity should be questioned. Not only for the likelihood of their success, but also their usefulness to designers. This aligns with designers' exploration of digital materials as more than simply representations of physical counterparts.

To extend the possibilities of digital touch, a psychophysics approach to mimicking physical touch with maximum fidelity can be replaced or augmented by touches created through randomisation or machine learning, introducing variation in the predicted sensory feedback. Designers already make use of such glitches for creative purposes (Atkinson, 2017, Thiel, 2017) implying that in other modes such as the visual, a lack of predictability and realism is considered a benefit of engaging with a digital process. Considering digital materials, it is also productive to question whether an unexpected feeling or behaviour can genuinely be considered a glitch, if the material has no physical referent.

This approach to the liveliness of a tool begins to re-position digital technology as creative and inspiring design challenges, rather than an efficient perfector and standardiser of designs (see 6.3.1). In this way technology could move from enacting Pye's (1995) 'workmanship of certainty' to supporting digital materiality (Smitheram, 2016) and a workmanship of *digital* risk (McCullough, 1996) in which a designer can demonstrate skill and authorship by engaging with and mastering the liveliness of a digital touch interface. This addresses the comments of participants in Workshop 2 that digital touch technologies would be of little relevance to skilled designers who had already developed felt histories and sensory competencies necessary for garment prototyping. By providing an uncertain and lively tool (or representation of the entanglement of tool, material and designer), the designer is newly and constantly engaged with negotiating the changing kinetic melodies of digitised touch. Thereby providing a playful context of use for digital touch technologies beyond garment design education. This also concurs with Petreca (2017), Petreca *et al.* (2019) and Schoemann and Nitsche's (2017) arguments for the need to introduce playful interactions in creative tangible interfaces, rather than strictly replicating an existing experience.

10.2.2.i – Alternate Readings: Hylomorphism

Building on the hylomorphic reading suggested in the previous section, designers could be seen as merely feeling for expected kinetic melodies of tools entangled with materials. In this sense designers are attempting to correlate the feeling of tools acting on materials to previous experiences in their felt histories, matching felt experiences rather than negotiating emerging agencies of a tool, or interface. For digital touch feedback to be beneficial to the designer in this interpretation the interface must have no influence and accurately replicate the feeling of the entanglement between body, tool and material. To what degree it will be possible to truly limit or minimise the influence of a haptic interface is currently unclear, as such technologies are still emergent, unstable and inherently somewhat intrusive.

10.2.2.ii – Alternate Readings: Pedagogies of Matter

It could be argued that the material experience of the use of a tool is pedagogic, for example Carla's account of sewing on an industrial machine for the first time (noted in 6.1). Therefore, learning to manipulate tools and in turn materials through their entanglement with tools, could be considered mediated pedagogies of matter. Yet tools are often proposed to have more defined ways of working with them than unformed materials, suggesting that a mix of directed learning and peer advice with pedagogies of matter informs touch practices. In this sense an element of hylomorphism enters this reading as designers will be instructed in how to operate a tool to achieve an aim. Yet as the examples of Marie and Carla contemplating the influence of their tools show, designers in postgraduate education appear to move beyond these instructions of tool use, to explore their transducing roles.

However, classic garment design tools section and zone the body, for example in the use of disembodied torsos in tailor's dummies, and these have translated into digital spaces and tools to create familiar mediums and contexts (McCullough, 1996), as noted by Jewitt, Price and Xambo Sedo (2017). Examples include the specificity of pattern drafting rulers to the shapes of armholes and hip curves, and the disembodied grasping hand tool in Clo3D observed by Alexa (see 8.3.1). If digital touch tools are to support existing garment prototyping practices, then it can be argued that they should support such body zoning. Particularly as the specificity of tasks which tools address may help designers to understand their usage and benefits, through a pedagogy of matter, developing kinetic melodies via experimentation with the tool.

Contra to the role of transducers in entangling the body and animacy of the designer with materials and the transducer itself (Ingold, 2013: PP102-103), existing tools and interfaces serve to separate not only the designer from tools and materials, but also separate and divide the body they design for. While Clo3D presents full-body avatars, rather than disembodied tailor's dummies, the grasping hand tool represents the designer's touch, thereby limiting designers' manipulation of digital materials to the hand forming them on a passive avatar body, similarly to the construction of touch in Petreca, Baurley and Bianchi-Berthouze's materials experience framework for textile selection. In this case the manipulation of the medium (digital fabric) and the symbolic tool representing the process, fail to align with expectations derived from the counterpart physical process of draping.

Jewitt *et al.* (2021) argue that the presence of disembodied hands in VR environments (also observed by Yang and Lee, 2021) prevented users from feeling that their whole body and sensorium were immersed in the experience, leading to perceptions of either not truly touching, or of functional digital touch which lacked nuance. This suggests the need for representation of, and sensory feedback to the whole body, rather than depicting disembodied hands or transducers in a digital interface. Jewitt *et al.* (2021) further note that breaking touch expectations based on felt histories disrupts the users' sense of experiencing touch. This occurs in Clo3D, as the avatar body cannot be touched, while a fabric upon it can be manipulated in ways which stretch (sometimes literally) or contradict real-world material properties.

10.3 Entangled Reading

I now offer an entangled reading of the previously discussed agential cuts, focussing on their shared themes. Beyond the question of whether the digitisation of an experience should itself enact liveliness or agency, or whether it should maintain the maximum fidelity to the original experience, there are many commonalities between the readings which the three agential cuts enact. In entangling the discussions of each agential cut and bringing forth their central features the following recommendations for the design of a digital touch tool or interface can be made.

This thesis highlights the significance of the visibility of the designer's body and the representation of designs at the scale of the human body so that material forming and manipulation can be related to unrestricted, full-body movement. This helps maintain a sense of physical presence and supports designers' established kinetic melodies of material formation and finishing, developed through felt histories. In a digital environment which supports co-presence, it also supports the observation and formal or informal adoption of touch practices. This is crucial to support the initial social direction of 'how to touch' in the Framework of Garment Designers' Felt Enskillment. 'Small touches' are identified as highly significant and so high-resolution capture of fine movements is desirable. Surface touch feedback should be provided to the full body and mapped to body movements taking into account the above considerations.

This thesis recommends including freedom of play and experimentation in digital touch interfaces rather than creating task-directed digital touch tools. This supports designers to develop felt histories which have been proposed to be impoverished due to a comparative lack of material engagement and experimentation through making in childhood and contemporary daily life. To allow designers to develop kinetic melodies based on particular entanglements of movements, materials and tools, it is recommended that a digital touch interface enable users to feel the experience of entangling a variety of combinations for reference: perhaps selectable from a palette of transducer/material/movement, much like RGB codes in a colour palette, and allowing users to save custom combinations.

Both the aspect of co-presence during material handling and the opportunity to explore combinations of materials, tools and movements can be delivered in non-digital pedagogy design, through the allocation of dedicated curriculum time for collective ‘free play’ with materials and varied tools. Consideration should be given to the construction of an informal environment if the perception of learning as autodidactic (when in fact it may be quite the opposite) is important to designer’s enskillment (see Chapter 9). This argues that a form of studio construct will remain significant for garment design pedagogy. As previously discussed, the separation of design ‘studios’ and digital ‘labs’ creates a problematic divide which reinforces the epistemic separation between learning digital prototyping and garment prototyping skills. For this reason, this thesis recommends first and foremost that any digital touch technology be located within the designers’ studio space, rather than siloed and considered specialist equipment.

To address conflicting desires for material agency in a design process, the felt experience should offer options for customisation, for example, using a sliding scale of animacy and influence ranging from major sensory ‘glitches’, to accurate replication of physical feeling. Each aspect of the felt experience: the movement, material, tool and digital touch interface itself should be independently customisable. In this way, a digital touch experience could offer continuous novelty and challenge to designers, potentially providing inspiration in much the same way as the juxtaposition of physical materials during undirected handling in the studio (see 5.2.2). This would give designers a way to work with personal ideologies, or skill levels in relation to materials and felt histories. Should a designer who expressed a desire to explore and work with the liveliness, or agency of materials and tools, wish to harness this in their design development they would have the option to do so.

Designers would also have the option to tailor an individually subjective experience to their particular sensitivities and perceptions in relation to touch. However, this raises the question of how a scale of agency and animacy might be measured or meaningfully represented to a designer?

10.4 Conclusion

This chapter has discussed the empirical data through three agential cuts and alternate readings, exploring how to digitise the observed touch practices. These agential cuts included foregrounding ‘pedagogies of matter’, in which the crucial role of sensory feedback to the whole body in motion, while directly and freely exploring materials is highlighted. Technologies suggested to support this are motion capture, body-mounted accelerometers or EMG sensors. The critical role of capturing and responding to nuanced micro gestures (‘small touches’) is also highlighted. The mapping of captured movements to surface touch using haptic gloves and suits, or possibly an evolved version of Ultraleap technology (Ultraleap Ltd., 2021) is proposed.

A further agential cut foregrounding transducers and correspondence identifies the scale of a digital touch interface in relation to the body as critical. Highlighting issues of digitising mediated touch experienced through tools, particularly identifying the lack of research into how designers experience entanglement of the feeling body *into* and *through* transducing tools. Tangible interface design creating touch feedback through particular tools or things is problematised when attempting to support designers feeling in and through many varied items such as scissors, pins and sewing machines. The argument for creating lively digital touch tools (whose own influence in the processes they replicate) is proposed and extended to include the creation of digital materials whose felt qualities may be unmoored from the physical world. This thesis suggests this may be an incentive to engage designers with digital touch interfaces for creative inspiration.

The exploration of approaches to digitising garment designers’ touch practices has problematised current digital (touch) technologies as fragmenting the body and locating touch *around* bodies, tools and things, at boundaries which the technologies enact or reinforce. Thereby failing to support designers’ touch perception in and through tools and materials.

Through the entanglement of the readings, central features of a digital touch technology or interface for garment design have been identified. These include focussing on mapping and relaying sensation to the full-scale body in motion; allowing social sharing of handling and material forming activities; providing an exploratory, rather than task-focused space for un-directed touch; and allowing designers to experience the feeling of different materials, tools and movements in entanglement. All to enable them to inscribe these kinetic melodies in their felt histories. In addition, to balance different readings of material agency this thesis recommends that any digital touch technology allows personalisation in relation to the degree of liveliness which the technology itself, or virtual tools and materials may exert.

The pedagogic significance of free play with materials in a social context, experience of different combinations of tools, materials and movements, and drawing learners' attention to their full body are discussed as opportunity spaces for digital and in-situ physical learning.

In the following chapter the thesis concludes, briefly recapping how it has addressed the research questions and aims, discussing the significance, implications and contributions of the research, then proposing limitations of the thesis and opportunities for future research.

CHAPTER 11 – CONCLUSIONS AND FUTURE WORK

11.1 Empirical Findings of the Thesis

In this chapter I draw out the more generalisable themes and insights realised through the research (11.1). I then turn to the matter of the broader contribution (11.2), significance and implications (11.3) of the research I have undertaken and presented in this thesis. Finally, I address potential limitations of the research (11.4) and opportunities for future studies (11.5). I close by situating this thesis as a timely study of touch practices in a state of accelerated change due to the Covid-19 pandemic (11.6)

11.1.1 Garment Designers' Touch Practices and Their Associated Meanings and Understandings

This thesis has demonstrated that touch, matter and meaning are fundamentally entangled in the emplaced process of garment prototyping, and that seemingly un-remarkable touch practices make use of skilled understandings of sensory feedback from the body and materials in movement. This has indicated the critical role of kinaesthesia in designers' felt experience. These aspects of feeling are often overlooked in the design of digital touch interfaces, which at the time of writing generally focus on delivering sensation to the surface of the body in localised areas, or provide touch feedback in a limited area which restricts users' freedom of movement. This limits digital touch from supporting felt histories of kinetic melodies (Sheets-Johnstone, 2003) developed through material engagement throughout designers' lives. The thesis has noted that such histories cannot be developed through formal education alone. Yet alongside un-directed material engagement this thesis has demonstrated that designers do acquire touch practices through observation and re-enactment in a process of ‘education of attention’ (Grasseni, 2004; Ingold, 2013; Gowlland, 2015). However, the informal, non-linguistic nature of such encounters mean that designers often overlook them as forms of learning and enskillment. This process is detailed in the Framework of Garment Designers’ Felt Enskillment proposed by this thesis (see Chapter 9). This implies that the process of learning to touch digitally (and perhaps differently) may be equally overlooked if it is not foregrounded as a vital part of our evolution with technologies.

Within the documented touch practices, moments of the designers’ felt experience entangling into and through tools and materials were observed, troubling the understanding of the designer as both a bounded and solely agentive entity. Further, this thesis has demonstrated that perceived felt sensation is socio-materially mutable, influenced by empathy with, and mimicry of, the touch practices and aesthetic perceptions of other designers. This argues for an extended view of touch and felt experience, which moves beyond biology and psychophysics to represent a more fluid experience.

11.1.2 Speculations on Digital Touch Technologies for Garment Prototyping

The thesis has successfully engaged designers in prototyping their own digital touch tools, as well as exposing designers to ready-made digital touch prototypes. In all cases the discussions around the digital touch technologies reflected prevailing social and discipline specific attitudes toward technology (e.g., increased efficiency, industrial monitoring, skills loss and replacement of human labour), demonstrating that their imaginaries were sociotechnical (Jasanoff and Kim, 2015). However, the broader consideration of touch and associated sensing technologies afforded by engaging participants with the design and prototyping of digital touch tools highlights the critical role of the entanglement between the designer and the material when eliciting speculations on digital touch technologies. Thus, demonstrating that imaginaries of digital touch technology are not only sociotechnical, but also *socio-material.*

Speculations on the application of digital touch technologies included their use as tools for education and feedback on garment making techniques. The value of digital touch feedback to skilled practitioners was questioned, indicating a perception that digital touch tools were not necessary or helpful once felt histories had been acquired, or applicable to design rather than execution of a prototype garment. Additionally, the possibility for digital touch tools to shortcut the durational nature of skills acquisition was questioned.

11.1.3 Using Agential Cuts to Explore Touch Digitisation

An entangled reading across three agential cuts has enabled this thesis to reveal a large number of recommendations for digital touch technologies which transcend onto-epistemological considerations. These include the importance of representing and directing touch feedback to the full body, rather than disembodied tools and hands, along with the representation of bodies, tools and designs at human scale to facilitate natural movements, similar to, or developed through physical practice. The sensing of body movements must be high resolution to capture and represent the nuance of ‘small touches’ and unrestricted, to allow designers a full range of motion. Any digital touch feedback is recommended to be directed to the entire body surface, while also relayed through tangible interface tools.

An entangled reading also highlights the importance of emplaced, social sharing (both formal and informal, or subconsciously through observation of the full body), experimentation and play in a digital touch interface. While a specific task-oriented tool may support understandings developed through physical practice, it will not facilitate the development of felt histories and associated kinetic melodies, which are derived from casual touch and experiments in feeling the juxtaposition of materials, tools and movements. This finding supports McCullough’s (1996) identification of play as a significant means to understand materials, tools and structures within a design space.

Through highlighting the differences that make a difference (Barad, 2007) in the concerns represented by each agential cut, the analysis has proposed a digital touch interface allowing designers to control the degree to which a virtual material, tool, or indeed the interface itself exerts liveliness in the experienced sensation. Thereby allowing one digital touch interface design to suit multiple needs, rather than necessitating a variety of technological solutions. This can make it adaptable to more faithfully replicate individually subjective sensory experiences, rather than an assumed norm of touch, or conversely to create new material experiences. In this way touch feedback can become unmoored from merely replicating a non-digital experience. The thesis further argues that this offers designers opportunities for creative inspiration and adds relevance to digital touch interfaces for garment prototyping beyond education and learning.

Considering current digital touch technologies highlights their construction of touch and felt experience as taking place at boundaries of the body and things. A problematic position in relation to the observation of designers' sense of feeling being entangled into and through non-human things. This suggests an important consideration in future touch technology design, arguing that existing digital touch technologies fail to account for a critical aspect of felt experience.

11.2 Academic Contributions to Knowledge

Through the reported ethnographic encounters this thesis contributes empirical data on the little studied role of touch and felt experience in the garment prototyping process, along with associated meaning-making, during a period of rapid digital transition. The Framework of Garment Designers' Felt Enskillment proposed by this thesis (see 9.2) contributes a model through which designers' development of touch practices can be understood, in relation to both perceptions of never having been taught to touch and the development of individual practices as part of designers' identity formation. The framework also refutes the construction of designers' touch practices as tacit, noting that the communicative encounters which disseminate them are quickly integrated and overlooked.

This thesis extends current literature in the field by providing in-depth data to challenge largely theoretical and abstract discussions of the impact of digital technologies, and narratives of diminished touch, on designers' practices. I have shown that although working with digital technologies reduced the time designers dedicated to hands-on felt experience with materials, this was still accompanied by physical making using touch practices common to designers working in traditional ways. Histories of material engagement were identified as more significant to the development of skilled touch practices than educational seniority, while spatially and epistemically separating digital prototyping from studio practice (when it was not accomplished through a visual digital design technology) was proposed as a potential reason that digital technologies detracted from material engagement.

This thesis develops existing categorisations of textile selection activities (e.g., Petreca, Baurley and Bianchi-Berthouze, 2015), by arguing against the concept of hands as animating touch and bodies passively receiving it. I demonstrate that designers both animated materials and felt their touch with their full bodies. Further this thesis supports Ræbild's (2015) argument for the significance of casual touch with materials and things during garment design development. I identify instances of designers manipulating resources found in the studio which were not project specific, to advance a design concept. The thesis also develops Ræbild's studies, providing greater depth of description of felt sensation, to accompany Ræbild's focus on gesture and action.

This thesis argues for the previously unexplored, central role of feeling in worldbuilding processes such as those identified by Nicewonger, when designs are conceived and situated in alternate presents. During these processes designers draw on their felt histories to empathise with the sensory character of an imagined design.

The thesis theoretically contributes to understandings of touch during design and making by discussing the entanglement of the sensorium into tools and materials, troubling the concept of the boundaried human body and senses, as well as questioning the distinction between humans, materials and things. In this way the thesis contributes a novel New-Materialist reading of garment prototyping activities. This is absent in current literature, which uses posthuman theory to focus on artefact analysis of finished garments (Smelik, 2018, 2020), or more philosophical discussions of entanglement between garment and maker as a justification of personal practice (Y. Lee, 2016; Sampson, 2018b), rather than exploring the role of entanglement as a critical aspect of the garment prototyping process.

The thesis contributes to understandings of touch as a multi-faceted experience in which the felt experience of movement is crucial, along with sensations of touching materials and things. This thesis situates designers' felt kinaesthetic experience in Sheets-Johnstone's discussion of 'kinetic melodies'. An adaptable response to repeated experiences of movement and associated feeling. The development of kinetic melodies is central to the proposed Framework of Garment Designers' Felt Enskillment (see 9.2).

This thesis makes three significant methodological contributions:

First, the thesis proposes a diffractive, rather than tradition and discipline bounded attention to ethnographic fieldwork, which better lends itself to inductive development of theory and understanding in relation to often contradictory ethnographic experiences. Diffraction works with the 'mess' (Law, 2004) of ethnographic data, allowing it to speak without forcibly fitting to disciplinary expectations. In the case of this study the diffractive attention read multimodal approaches to ethnography through sensory ethnography practice and through autoethnographic data. I argue these three forms of attention to a site and culture can more fully account for touch and felt experience than any one approach in isolation. In this respect diffractive ethnographic attention using these three disciplinary lenses offers a method which is transferrable across disciplines, from sensory studies, to dance, to material culture, to HCI. More broadly diffractive ethnographic attention can be applied to other contexts than touch, by adding, removing and changing the approaches to ethnography which are diffracted.

Second, the thesis contributes to the methodological development of materially informed research studies. The use of sensor fabric probes as a means to visualise designers' touch and bring their engagement with non-human things into focus, is novel in an ethnographic, situated context rather than lab-based studies. This contextual use of smart materials to highlight how we touch everyday things has numerous potential applications in studying the entanglement between humans and the material world we inhabit - transposing actions and behaviours which may be overlooked into a different communicative mode which reveals them. Thereby prompting discussion around the mapping and digitisation of touch, which could be seen as changing the capacity of participants to act in relation to a form of technology which is emergent, unfixed, little understood and rarely brought into their everyday context.

This leads on to the third and final methodological contribution of the thesis in facilitating designers to engage with and create digital touch technology prototypes. This in-depth engagement with technology prototypes supports designers to understand their potential and speculate on future roles such technologies might play in their everyday, situated practices. In doing so, uncovering sociotechnical imaginaries which will likely inform technology development. As such the creation and use of technological probes in situated contexts has great potential when studying a wide variety of emerging technologies and their real-world usage.

11.3 Significance and Implications of the Thesis

Little academic attention has been given to the role of touch in garment design development, with comparable studies focussing on the general role of the body (Ræbild, 2015) and touch during the limited activity of textile selection, removed from an emplaced context (Atkinson *et al.*, 2013; Petreca *et al.*, 2013, 2016; Petreca, Baurley and Bianchi-Berthouze, 2015). This thesis speaks to that gap in the research literature. It is significant in exploring touch in the situated context of designers' prototyping processes in their studio environments, building on ethnographic studies of garment design which lack a sensory focus (e.g., Moon, 2009, 2011; Nicewonger, 2011; Lisewski, 2018). It is also notable in adopting a New Materialist perspective on touch during garment prototyping, in that it moves the field beyond a phenomenologically informed perspective which prioritises the centrality of the human designer. In particular this thesis contributes to and advances arguments for the entanglement of the social and material in the acquisition of touch practices, and the structuring of felt sensation itself during a garment prototyping process. This perspective is significant in rejecting hylomorphic narratives of design, i.e., imposing a mentally held design concept on material perceived as inert and lacking agency, thereby excluding the continuing influence of the non-human on the evolution of a design.

This thesis has addressed Ræbild's (2015: P31) twin criticisms of prior studies as focussing entirely on student designers and therefore failing to account for the role of the designer's body (and touch) in non-educational settings, or attempting to interpret finished work rather than witnessing and documenting the role of the feeling body in garment prototyping processes as they unfold. This thesis has instead explored touch practices and feeling *as designers prototype* in a multi-sited design across educational levels and independent practice. In doing so, the thesis is significant to garment design educators in providing nuanced examples of how touch practices are acquired and demonstrating that designers often continue to acquire new touch practices throughout their careers. Additionally, this thesis demonstrates that the development of touch practices is not only informed by specialist education and as such may be noteworthy for educational policy makers.

This thesis has demonstrated that the development of sensory competences and felt histories is not simply informed by educational level, but instead predicated on designers' general histories of material engagement and specific un-structured moments of learning. This presents a challenge for creative education as it implies that materials exploration should be incorporated into curricula from a much younger age, and that creative subjects in higher education should specifically include dedicated time for material experimentation. This pedagogic issue is compounded by the current education strategies of the UK Government, which diminish arts education in schools in favour of a STEM focused curriculum. As such, the findings of this thesis have implications for educational policy making from early years education onwards.

The pedagogic implications of this work (including the significance of free play with materials and tools, and the continued relevance of an 'education of attention' through observation of others' touch practices) highlight potential physical activities which might achieve this goal while digital touch technology matures.

Specific benefits of this research to HEIs providing garment design courses include the thesis' contribution in understanding the significance of studios as an environment in which designers structure and locate resources for felt experience. Indicating that studio space is still a key concern in evolving garment prototyping practices. Further, the thesis' demonstration that learning still occurs through an education of attention argues the need for peer-group environments and co-location with more experienced designers and makers to facilitate subconscious and overlooked learning.

For individual garment designers (both students and established practitioners) this thesis offers insights into their own touch practices and the processes informing them, which have considerable potential to contribute to their ongoing development. Pedagogic recommendations which can be implemented in physical learning as well as future touch interfaces, can be adopted by designers as part of their current engagements with tools and materials. Thereby prompting creative exploration which may newly foreground felt experiences and contribute to their discussion through practice and in design literature.

The thesis is both timely and significant in the recommendations it makes for the digitisation of designers' touch practices. While technologies to deliver the recommended experiences remain in their infancy, the recommendations set out above and throughout this thesis to inform digital touch research and development, offer up useful insights and considerations to engineers and interaction designers. Particularly in relation to felt experience mapped to the full, moving body and not just the hands, as well as the proposition that digital touch feedback offer new digital sensations and materials in their own right, beyond the attempt re-create physical experience (the primary concern of much contemporary digital touch research).

The thesis' recommendations on the process of creating more 'tactile' experiences are of use to digital designers and students on new specialist digital fashion courses (see 11.6) who are exploring ways to create a felt, bodily experience of an intangible garment. For example, by creating interactions at the full scale of the body and showing the designer, or wearer's body in virtual spaces, rather than disembodied grasping hands.

Finally, the data on skilled touch practices presented in this thesis has the potential to benefit future researchers. It provides a comprehensive, comparative snapshot of contemporary touch practices which may be valuable for future studies as technologies advance and are increasingly integrated into garment prototyping. Researchers in diverse fields such as the anthropology of design, crafts and making, creative subjects' pedagogy, interaction design, haptic and touch technology engineering, or sensory studies will be able to make use of the data in discussions and exploration of haptics and the sensory.

11.4 Potential Limitations of the Thesis

Though limitations were balanced with potential methodological benefits in the study design, three aspects of the thesis may introduce potential limitations: the nature of DIY fabric touch sensors and their presentation as technology prototypes, the lack of participating designers working in larger-scale businesses and the relatively recent introduction of digital technology to the garment prototyping process. Each is discussed further below.

While allowing me to create prototype technologies in a form familiar to garment designers, working with fabric-based touch sensors presented several possible limitations. DIY approaches to the creation of touch sensing fabrics (such as those using Arduino, as opposed to industrial textile electronics) are limited in sensor fidelity and generally rely on analogue electronic signals which are prone to fluctuation and variance. This impacted the ability of the touch sensing fabric probes used in the thesis to account for subtle nuances of touch. Designers may have had different responses to engagement with touch technology prototypes and speculated on differing applications of the technology had its fidelity met their expectations.

Additionally, while the mapping of pressure and location by the sensor fabric probes was perceived as limited, failing to include aspects such as tension and stretch, it also formed the core function of many of the designers' speculations on digital touch technology applications. This demonstrates that when introducing relatively novel technologies as a prompt for speculation, participants will be heavily influenced by the functionality of the prototype.

In Workshop 1, the use of user-centred methods to develop participants own digital touch technologies provided greater scope for imagining 'blue sky' technology applications yet to come. This distinction is potentially significant when choosing methods for HCI studies, depending on whether the aim is to explore applications of a specific technology, or broadly understand how technologies might address a particular field.

In exploring the trajectory from undergraduate garment design student to educator/practitioner in terms of touch practices, the thesis did not engage with designers working in larger industrial contexts. It is possible that designers in small to medium size businesses which retain some in-house prototyping may differently construct the studio as a resource and consider a prototype for mass production differently to a prototype for one-off or limited production. However, the informal and overlooked development of touch practices is likely to occur through similar processes to those reported in this thesis, regardless of the professional context.

Finally, the relatively recent introduction of digital technologies to garment prototyping means that contemporary designers will have received some training in traditional, physical garment prototyping processes. For this reason the impact of digital technologies may be impossible to fully discern yet, despite contemporary claims of lessening material competencies (Ræbild, 2015; Almond, 2016; and Montgomery, Henry and Brotheridge, 2016). However, this thesis has indicated that a lack of familiarisation with materials is a wider issue than simply the content of garment design education, as physical making and material experimentation become rarer in people’s everyday lives more generally.

11.5 Future Research

This thesis points to three areas of research required to inform the digital support of garment designers’ current touch practices: investigating the extension of the sensorium through haptic technologies; exploring the modulation of felt experience derived from digital touch technologies, when directed to touch in particular ways by other social actors; and the development of Thing Ethnography methods to explore touch.

To develop digital touch technologies which support the perception of feeling in and through tools or materials, it is vital to understand whether the perception of sensation beyond the body occurs in specific materials and things. Particularly whether designers experience an entanglement of their sensorium with current haptic tools such as haptic pens?

It is currently unknown whether perceived sensation and felt experience received from a digital touch technology would be modulated when a designer is directed how to touch (either the technology itself, or how to touch virtual things and materials through it) by peers.

Finally, though this thesis has utilised touch sensing fabrics as probes to prompt discussion, the touch data captured by the probes was not analysed. In relation to the methodology of the thesis, future research could explore the correlation of quantitative touch data to ethnographic data in a process more closely aligned to Thing Ethnography (Giaccardi, Cila, *et al.*, 2016; Giaccardi, Speed, Caldwell, *et al.*, 2016; Chang *et al.*, 2017). Perhaps also taking the approach of embodying or personifying a fashion thing when analysing the data (Chang *et al.*, 2017).

Any future study taking a thing ethnography approach should consider how touch data might be meaningfully presented so that it could be usefully interpreted by the researcher(s). In Thing Ethnography studies to date, data has been primarily visual and related to location. By contrast, touch sensors output numerical data. While this can be mapped visually, the visualisations used in this thesis were not perceived to be useful by the participating designers. Whether their perception would change if they were presented with higher resolution visualisations in three dimensions is another question for future studies.

In future studies using touch sensing fabrics, the ability to sense stretch, tension, and weight has been identified as significant, as these are critical aspects of touch for designers. Future studies could explore how to meaningfully present such data, alongside visualisations of touch location and pressure - investigating whether visualisations are meaningful for designers and how to present these multiple simultaneous aspects of touch to researchers so that they can be productively analysed. Indeed, given the complex, emplaced and kinetic nature of touch and felt sensation discussed in this thesis, is it productive to continue separating aspects of feeling into different modes or channels of feedback to designers?

11.6 Digital Touch and 'The New Normal'

As the Covid-19 pandemic progressed, digital technologies increasingly informed the practices of the designers in this study. I also observed that their practices began (newly) to overlap. While my ethnographic observation primarily focused on designers working in a more traditional, or digital way, for most the two approaches became increasingly interchangeable. A process accelerated by the pandemic. For these designers, the digital has firmly established itself in their sociotechnical imaginary of what constitutes a garment design development practice, if perhaps not yet fully entered the resources of the studio. It has achieved this without displacing the traditional skills and approaches I observed the designers using prior to the Covid-19 pandemic. It should be noted however that the designers are primarily adding to their existing repertoire of physical and material skills. That this change was visible even in the few years the research for this thesis covers, highlights the rapid transition garment design is undergoing.

In an educational context it is likely that garment design pedagogy may always prioritise some link to physical prototyping, as it will always retain a relation to physical products. People will continue to need clothes. However, garment design education may fragment to cater for specialised career paths. Indications of this outcome can already be seen in the rapid rise in popularity of digital garments, promoted by companies such as Dress X (DressX, 2021) and the Fabricant (The Fabricant, 2021) along with the launch of specialist digital fashion masters degrees at University for the Creative Arts and Leeds Art University in Autumn 2021. If this is a likely future for garment design education, it may be possible in future to observe greater differences in processes and skillsets among designers of digital and physical garments.

It is to this accelerated moment of transition; of learning how to create and wear digital garments (including those unmoored from physical constraints); of learning to map a physical experience of feeling a material, or trying on a garment, into digital space for physically distant shopping; even of creating physical immersion and emplacement remotely, that this thesis speaks. It provides a snapshot of physical practices in garment prototyping which may change far more rapidly thanks to Covid-19 and makes a first step in recommending how they might be digitised as part of 'the new normal'.

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APPENDIX 1: LITERATURE SEARCH CRITERIA AND PROCESS

The focus of this thesis is garment design development through prototyping, with a particular emphasis on touch as the felt and kinaesthetic experience of the body of the designer entangled with non-human things. This has a number of overlaps with other areas such as studies of material culture, the felt experience of wearing garments, creative process and craft practices. In this section, I outline why these were excluded from the remit of the literature review.

The review does not include literature on visual design development processes for garments e.g., Lee and Danko, (2017), or creative process studies e.g., Black, Freeman and Stumpo, (2015); J. S. Lee, (2016) which do not discuss prototyping. Indeed, authors such as Osmond (2021) and Ræbild (2015) observe the marginal, or absent nature of the body in research on creative and design processes. Concurring with this observation, the body (and particularly feeling) are generally absent from design process and creative process texts cited by authors such as Ræbild whose works feature in in this literature review. In addition the cited texts often focus on a standard ‘problem definition’ based model of design process. The idea of finding a model process applicable to all the designers who participated in this thesis quickly proved unrealistic and artificially structuring of the highly diverse practices I observed in the field. Moreover, the term creativity is broad and ill-defined. Finally, as Malafouris (2014) notes, understandings of creativity often deny material engagement and agencies enacted through it in creative processes, instead supporting hylomorphic (Ingold, 2013) understandings of design and making. For these reasons, literature on creative process was excluded from the search unless specifically addressing touch and garment prototyping.

Within material culture studies there is an adjacent body of literature detailing the felt experience of wearing garments (Miller, 2010, Robinson, 2018, 2019) and the influence this has on the formation of identity (e.g., Entwistle, 2000; Chong Kwan, 2016), sustainable use behaviour and relationships with garments (Stanes and Gibson, 2017; Durrani, 2019; Stanes, 2019). However, this literature does not explore the initial design and prototyping of garments and as such is beyond the scope of this thesis.

A significant adjacent body of literature also explores thinking in and through craft-making processes (e.g., Pye, 1995; Adamson, 2007; Sennett, 2009; Marchand, 2008, 2010b, 2010a, 2012, 2016). However, none of this literature explores *garment* making and primarily focuses on making processes which use the hands. It also prominently focuses on making with raw, rather than processed materials. For example, pottery throwing with clay, and textile making from raw fibres, as opposed to garment making from an industrially manufactured textile. Where digital technology *is* discussed it too is related to processes of hand making (e.g., Nimkulrat, 2019), representing a leap from the handmade to the digitally mediated, without an intervening stage of mechanisation such as that represented by the sewing machine. Though both authors fall into this category, the work of Tim Ingold and Lambros Malafouris is notable in taking a New Materialist inflected stance on craft making processes and as such is reviewed and discussed in Chapter 3.

Nimkulrat demonstrates a further issue with this body of literature by referencing canonical craft theorists Flusser, (2014) and Streeck (2009)'s focus on gesture, *not* sensation. Rather, sensation is implied through gesture and what is felt *for* is either not discussed, or is related to a sense of rightness or philosophical meaning (Flusser, 2014). It is also assumed that intellectual rationalisation and knowing are linked to bodily doing (as in embodied cognition), yet the exact nature of this relationship is rarely expanded upon. For these reasons, the body of literature on craft 'knowledge' and touch is not reviewed in greater depth.

The review also excluded literature on 'Somatic Practices' and 'Somaesthetic Design', an emerging area in HCI. Derived from dance and costume research (Dean, 2011) such studies can be considered autoethnographic in that they contain first-person accounts of otherwise inaccessible bodily (somatic) experience, particularly those relating to movement and sensation (Wilde, Schiphorst and Klooster, 2011; Höök *et al.*, 2016; Núñez-Pacheco and Loke, 2017; Loke and Schiphorst, 2018; Núñez-Pacheco, 2018). Many of these studies use sensitising activities to help the researchers become more attuned to their somatic experience, including body scanning and Feldenkrais exercises (Höök *et al.*, 2016). Further methods include the creation of estrangement or destabilising established practices of movement and bodily experience. The creation of estrangement is discussed by Wilde, Vallgårda and Tomico (2017) as performing established tasks in new ways, using on-body props, or interacting with a material in an unexpected context, similar to Petreca, Baurley and Bianchi-Berthouze's, (2015) 'Stimulate' phase of material experience.

As Wilde, Schiphorst and Klooster argue, *'These activities promote 'non-verbal, or "extra-discursive" reflection that in turn informs our designs'* (Wilde, Schiphorst and Klooster, 2011: P22).

While these activities may facilitate attunement with felt experience, their use in an ethnographic context is potentially disruptive to the everyday practices this thesis seeks to explore. The primary focus of these studies is on attending to the body through movement and sensation, rather than exploring the movements and sensations inherent in prototyping worn items using a traditional process. While Tomico and Wilde, (2016b) propose a shift from Human-Computer Interaction (HCI) to Human-Garment Interaction (HGI) they do so in the context of interactive garments. As such this thesis may be useful in informing somaesthetic interaction design, providing an account of the roles of sensation and movement in traditional garment design processes. Despite these links, the somaesthetic studies do not shed light on the role of touch in traditional garment design development.

To facilitate the literature search, matrices of key search terms and more commonly used synonyms were created. See Table A1.1.

Table A1.1: Preliminary literature search terms

	(Pedagogy OR Teaching OR Learning OR Education OR Instruction OR Training OR Apprentice*)	AND	(Touch OR Tactile OR Feel OR Embodied OR Sens* OR Hand OR Tacit)
"Fashion Design"			
"Garment Design"			
Cloth*			
Sew*			
Drap*			
Moulage			
Tailor*			
Dressmaking			
Couture			
"Costume Design"			
"Fashion Making"			
"Garment Making"			
"Costume Making"			

The following resources were searched:

Databases Reviewed: ACM Digital Library; Art & Architecture Source; Art Full Text; BASE - Bielefeld Academic Search Engine; Bloomsbury Cultural History; Bloomsbury Fashion Central; British Education Index; Design & Applied Arts Index (DAAI); Education Abstracts; ERIC (Education Resource Information Centre); EThOS -

e-theses online services; Google Scholar; JSTOR; ProQuest Central; SCOPUS; Sociological Abstracts; SSRN (Social Science Research Network); Web of Science; Wiley Online.

Trade Publications Reviewed: Business of Fashion; Drapers Record; Vogue Archive; WGSN Reports; WWD (Women's Wear Daily)

Library Searches: The British Library; Royal College of Art; University of the Arts London (including London College of Fashion); University College London (including The Institute of Education)

Results were filtered to exclude texts relating to fashion business and entrepreneurship, or design for context-specific performance garments, e.g., protective, medical and smart garments or sportswear, which related to their scientific development or functional requirements. The term 'haptic', though providing numerous hits, was excluded as it returned too much literature focused on technology development. Two further exclusions were added to narrow the usage of the term 'feel' as it primarily returned literature discussing emotions and opinions, rather than sensations. Therefore, the phrases "feel about" and "feel that" were excluded to narrow the search.

APPENDIX 2: EXAMPLE THEMATIC ANALYSIS TABLE

Table A2.1 Thematic analysis sheet for an ethnographic encounter with Ella

		TOPIC:	TOUCH LANDSCAPE
			INSTANCES
			Description
THEMES			
Body as Reference via... (to body, across bodies, what is a body?)	Felt Sensation (tactile properties and touch)		C0023.mp4 - Ella begins sketching another design for her client on a scrap of pattern paper. Her drawing looks like a classic stylised
	Body Movements and Articulation (Kinaesthesia - Limbs/Joints/Connections)		don't get it." She comments. It is only a partial body. Ella draws an asymmetric dress with only one shoulder and sleeve. "Originally she Ella elaborates. "Because you have to change the way you hold somebody whilst you're dancing. If it's consistent, if you're dancing wi would sit. "It literally just finishes here. It's different. The back, where you hold the back is different because you've got skin and quite oft depending one which side of the dress you hold?" I ask "Yeah, exactly." - "So what I might do is…" Ella draws a collar and second slee ON THE BODY - Empathy for the Felt experience of the Wearer
	Bodily Traces Role of the human?		
	Locating on the Body??		C0025.mp4 "So I did some experiments. This was the first one and you can see how labour intensive it was, and I thought this just isn't g basting thread used to mark the rows of gathering. TRANSDUCTION "So is this all to mark the distance between gathers?" I ask Ella. "Y of shirring." Ella uses the edge of her hand to indicate a level on the neck of the dummy. - Next she shows me three different iterations o WEIGHT - In relation to the iron on diamanté. "What I'm going to have to do next is iron this onto that." Ella taps a velvet she intends to emb open it up here and button it." Ella uses her index finger to draw a short line down the inside of her wrist, then strokes her wrist with her As we talk Ella draws out possible arrangements for large rhinestones and smaller, glue on diamanté strips. She fetches some sample rotates it and moves it to a different position. Rotating it again and again each time she moves it further around her wrist. - Decision Maki over the dummy in various places. Her fingertips lightly comb through the gathers in the chiffon. She pulls the armholes and certain sec she prefers the armhole which she finished with a binding ribbon as it lays flatter to the body of the dummy. Though she acknowledges comments "I'll probably shirr it all the way down. I'll lay the skirt over the shirring." Ella fetches her recently pinned skirt toile with the hip drawing a line upward along the pleating from the left to right hip of the dummy. "To be honest the shirring probably means I can just sew skirt, then holds her hand over the shirring at the front waist. "I'll probably have to make this smaller after the fitting as my client's smaller seventy centimetres maybe? Whereas this is seventy five." She says, reading off the measurement of the tailor's dummy's waist. "She' don't have to worry about the top [because of the shirring] that's good!" While we speak Ella has traced a line down the centre back of th back seam." Ella traces down the centre back again "put the slit in at the back", she points to the hem then back to the waist, "just have a will go there." She indicates a line down the shoulder of the dummy, around four centimetres further in than the armhole of the dress. "It w extra strap that goes up here." She draws a line up from the underarm, to a point roughly a quarter of the way around the back neck, fini
Body Zoning and Segmenting			
Non-Human Agency in...	Tools (Focusing Media?) Role of the human?		
	Environment/Emplacement		
	Materials (Focusing Media?)		during a fitting. She shows me photographs on her phone as we chat. Her client liked a grey, printed chiffon which Ella had in her collec then a black, which she things emphasises the print more. As the fabric would be a double layer Ella was concerned that it may not beh elements of the design using two layers. Both the final fabrics she intends to use. MATERIAL AGENCY/CREATIVE REFERENCES "Here you tell if the fabric is strong enough?" I ask Ella. "I was pinning it across the back and again it's the tension! So I think that's going to nee small offcut of the black chiffon and gesticulates with it for emphasis. "So I'll do a layer of the black and a layer of the print and I'll pleat the originally I cut the neck shirring, the bodice, the waist shirring and the skirt all in one and that didn't sit well. It didn't sit where I wanted it to sewing a seam with shirring elastic to gather the chiffon. This is the join between the blouse section and the gathered waist. She is using Once again, after securing the elastic at the start of the seam, she does not pin, or fix the seam, simply feeds it through the machine. "It's "So the elastic is under tension? But the fabric itself…?" I clarify. "Yeah and the fabric I just manipulate. It's just lying there. The biggest pro see there it's under full tension." Ella moves her hands away from the machine, to show me how the chiffon has gathered where it is em let it lie, align it, lay it so that it's flat, pull the elastic and just let the… Also to a greater or lesser degree, give them a bit of flex in the pattern. I' I won't know until I put it on my client, to see whether it's the right length? Or whether there's too much fullness? This fabric is closer to the it's too tough on my eyes. I never use black! There's only one client I make black dresses for." - Performance / Material Properties / Tac next to her scissors, phone and pattern weights. She examines the elasticated seam she has just sewn. "I put the elastic on the top inte and bottom of the elasticated neck of the toile, the top is indeed neater, seeming more regular and the fabric more level, despite the gathe pleating radiates. "Probably what I'll end up doing is working it out on the flat, pleating it and then putting it on the stand. And I'll probably en up and down in front of her body. "Because the two chiffons will work differently. Although this, it's not too dissimilar." Ella turns away from edge of the black chiffon toile. "It's just doing that. Making sure you can put the two together and that you catch them." Ella layers the two throughout our conversation becomes tangled in between the layers of chiffon, causing Ella to let go of the fold and extract it. She places hands, commenting on its quality and speculating that it probably came from Italy. She picks up an edge of the black chiffon toile and lay challenge would be, OK, do I topstitch it in here?" Ella uses her little fingernail to indicate the folded edge she has just created, then turns amount? Going back to the tension thing, will the tension be the same?" SKILLED TOUCH "So do you ever hang the fabrics, in case the agrees. MATERIAL AGENCY Performance / Material Properties / Decision Making / Enjoying Touch? - C0035.mp4 - Ella has unwrappe pleats, re-pinning them so that the pins face towards the folded bias edge which constitutes the waist of the skirt, then smoothing the edg thinking OK, lets just pleat, flat, and then I'll put it back on the stand and then I'll see whether or not it's right. Also, now I've got the straighter see whether or not my assumption is correct?" TRANSDUCTION - Gentle smoothing, tapping, re-pinning repeatedly - Performance / M lines start to curve, so at this point I've got to rationalise it a bit and just see whether or not I can get the paper to fold?" TRANSDUCTION -
	Creative References (Focusing Media?)		
	Other		
Skilled Touches... (Skilled Mediations?)	Demonstrating and Adopting		
	Petreca's Hand Types (these lack context, are they skilled mediations in the same way? Maybe they are too artificial as categories?)	Active Hand	
		Active Tool Hand	
		Passive Body	
		Situate	
		Simulate	
		Stimulate	
	Tool Usage Role of the human?		C0027.mp4 - Ella is adding a lightweight binding to the armhole of the blouse section of her toile. She is using a special foot to feed the ta both hands to feed the binding and control the chiffon, without a hand behind the machine needle to further stabilise the fabric. It is clearly is adjust the needle really really minusculely. Which is useful." Ella begins to sew again, slowly, having obviously returned the needle t shouldn't, but still… I lost it for about two centimetres, but it's fine, it's only for a toile. Most of it's there." Ella picks up and turns over the edge not sewn. - Performance / Material Proprties of tools - C0028.mp4 - Ella pulls the lower three of her machine and swipes the upper threa same direction, so that all the threads trail to the right of the machine foot. She only places one pin in the side seam of the toile, at the begi the seam loosely through the machine with her fingertips. COMPARE TO NADINE & CARLA? - Checking & Assuring????- C0032.mp4 - while she feeds shirring elastic with her right thumb and forefinger "So you're trying to smooth out the section you've already gathered? her right hand. "A bit of feel here." She stretches and relaxes the already sewn waist seam with her left hand to demonstrate. "And a bit o screenshots - Checking / Assuring - C0036.mp4 - ALSO SKILLED TOUCH WITHOUT TOOLS - To find the grain of the chiffon, Ella take thumbnails of both hands to separate individual threads and pinching one she pulls on it to draw it out. She flattens the fabric with her op basting thread. TRANSDUCTION - Next she bastes two rows of stitching at right angles to the pleats, indicating the start and finish of the the skirt section to indicate the waistline. Here and along the grain line she does not leave long loops of thread to cut through, as these r and forefinger and pushes it through the fabric, while holding it in place with the thumb and forefinger of the opposite hand. Sometimes sh Ella pulls a length of thick, bright pink basting thread the width of her arm span - MOVEMENT? She sews along both the folded edge of th particular way to hand sew for basting. Checking & Assuring? - C0041.mp4 - Smoothing and patting her basted toile to flatten it on the pa the bottom of a sheet of pattern paper already marked with another draft. She is using a tracing wheel to punch through the fabric, rolling with her forefinger, it's handle nestled in her palm. There is a lull in our conversation and the studio is largely quiet - is Ella focusing on to uses a large set square to draw dashed lines over the holes punched in the pattern paper by the tracing wheel. Checking & Assuring
	Other		C0029.mp4 - Ella unpicks the side seam using an unpicker. She re-sews it and hangs the blouse section from her forearm, threading h Assuring? - C0037.mp4 - Having basted the key reference points to mark them on the skirt section of the toile, Ella re-drapes it on the ta between her forefingers and pulls it across. Finally with both sides of the pleated section in place and correctly tensioned across the b she removes it and re-drapes it around the dummy. "So I did that too low, it needs to be higher." She tries several placements, pulling the LOCATING ON THE BODY - MATERIAL AGENCY - She pins the edge of the fold to create a crisper edge and holds this in place again." around and pulls the fabric down over the bottom of the dummy until it is taut. She then returns to the pleats again, unpins and re-pins the runs her fingertips inside the waistline. "This goes back to this tension thing here. So you can feel that tension on that line and you know THE BODY & MATERIAL AGENCY - Performance / Material Properties / Checking & Assuring / Decision Making - C0040.mp4 - NB. Doe very gently pulls the pleats open, using her fingertips inside the pleat, nails at the inner edge of the fold, she holds the pleat below in plac of scissors, yet still connected by basting threads, Ella takes her tailor's shears and cuts the threads. This leaves a short thread hangi MA is whether this level of detail is possible [in 3D CAD]?" SPECULATION - TECH POSSIBILITY - Once the chiffon is largely flattened Ella do it tomorrow I'll forget." She lifts the sheet of fabric and drapes it onto a sheet of patten paper. TRANSDUCTION - MATERIAL AGENCY -
Tactile World Building			
Tactile Metaphors			
Touch and Emotion/Affect			
Touch Description (is this doubling up on felt sensation?)			
Visuotactile Judgements			
Material Crossings			
Physical/Digital Crossings (note, this is transduction, but is it different? Are Ingold style transducers present?) Marie & Alexa cross, Nadine separates Role of the human?			
Touch Trajectories FIND INSTANCES TO REPRESENT (into future?) Monitoring/surveillance, Tech Applications			

	Modes Used and Communicative Things Present (e.g. toile, speech, drawing, gesture)	Transduction Through Touch checking & assuring? Y/N ?	Hylomorphism Y/N ?
wanted that I think, but her husband said no, because he doesn't like dancing with those dresses." At my slightly horrified expression h somebody and they're wearing, for example a strapless dress." Ella indicates the line across her chest at which a strapless dress on those are corseted. Whereas with this you've got to change the way you hold somebody all the time." "So is it different traction, or grip ve. She continues to muse on the design as she draws, indicating a hemline with a strong back and forth pencil line. ALSO LOCATING	Pattern paper, drawing, pencil, speech, facial expression, gesture, indication on body		Y?
gonna be sustainable!" Ella shows me the neck of a toile on her tailor's dummy. It is made of black chiffon and the neck is furry with white 'eah! And it was just like actually, really? And it took ages to do it! So I've changed where I wanted it to sit and I've just done a straight band f the neckline technique, locating each on the dummy. - Decision Making / Checking & Assuring - FIELDNOTES ON DIAMANTE AND bellish. "It won't let me have any stretch though. Once this goes on it stops any stretch. So I'm going to have to, on the wrist, I'm gonna entire hand. Creative Inspiration / Decision Making - C0026.mp4 - We are discussing where she can place diamanté trim on the design. rhinestones and begins to physically arrange them on the table. Next she holds up her left forearm and places one on her skin, then ng - C0033.mp4 - Ella tries the blouse and waist section of the dress on the tailor's dummy. She pins it closed at the waist and smooths it tions of the waist shirring away from the dummy, re-placing them. Pinching and smoothing. CHECKING ASSURING - Ella comments that that it may still sit differently on her client. Stroking downwards over the rows of shirring she has already sewn at the waist Ella pleats fixed in their intended positions and drapes it over the blouse section, securing it in place. "I lined up the pleats." She comments, the skirt section onto the bodice. I won't be worrying about whether or not it will fit her." Ella smooths her hand over the upper edge of the than this." Ella goes to fetch a tape measure from her pattern table. "Although she's not that small on the waist. She's probably about s probably about seventy one, seventy two. I'll make this as it is and then I'll fit it to her on Monday. But if I just have to do the skirt then I e skirt section with her fingertip. I ask if she is planning to add a zip or a seam there? "Yeah I think so, especially because I'll do a centre a little zip down here. And then all she has to do is open up here" she points to the back of the collar "and just step into it. And the leotard vill be a halter neck." She draws two diagonal lines down the chest of the dummy from the sides of the neck. "And then we'll have an ishing by pointing to both the origin and terminus points of the strap. Checking & Assuring / Decision Making	Tailor's dummy, chiffon toiles / samples, speech, gesture, indication on tailor's dummy, indication on body, rhinestones, velvet fabric sample, tape measure	C0025 - Y, C0026 - Y	Y?
tion of fabrics. As this is fairly transparent Ella has experimented with plain coloured chiffons to layer it over. First a complementary grey, ave in the same way as her toiles and so she shows me photos of her experiments with quickly draping the pleated and gathered I was also seeing if I thought the fabric was going to be strong enough to do the skirt detail that we thought about last week." "So how do d to be mounted." She points to the photo of the draped grey chiffon. "That needs to probably be on the black chiffon." She picks up a m together. Which..." Ella groans. Moving on to another photo of a design iteration she tells me about changes to the pattern. "So sit." - ALSO CREATIVE REFERENCES - Performance / Material Properties / Creative Inspiration / Decision Making - C0030.mp4 - Ella is g a zig zag stitch to secure the elastic in place, feeding it through a gap between the prongs of the machine foot and stitching over it. quite a wide zig zag, but of course because it's chiffon it disappears." Ella laughs. "And I literally pull the shirring elastic as far as I can." oblem I might have with this is I might have to do it in sections as I won't be able to manipulate it where I want the shirring to go. But you can erging behind the machine needle. "When I started I was putting everything under tension. I would pull the fabric too much. So now I just ve added a bit of length. Every time I add the length it always keeps on disappearing, so I have to keep on putting it in again. To be honest actual fabric. I would use the polyester, but it's too stiff. It's not soft enough." ALSO SKILLED TOUCH INFORMING CHOICE "I hate black, tle Apprenticeship Enskillment - C0031.mp4 - Ella has laid her toile on the pattern table after joining the waist section. It sits in a bundle restingly. I don't know why I put it in the top, other than it just lays a little bit flatter." She proceeds to show me the difference between the top ring. - Decision Making - C0034.mp4 - "I need to work out how to secure this lot." Ella points to the central focus from which her skirt d up doing it in the two layers at the same time. So that we get the two layers of chiffon together." Ella moves her closed fists alternately her tailor's dummy to the table behind her, picking up the fabric she intends to use for the outer layer of the final garment, then finding an fabrics and manipulates them to create a pleated edge with both fabrics folded into it. The tape measure she has held in her hand it around her neck. Ella unfolds the grey spotted chiffon which will become the outer layer of the dress and tensions it between her ers it behind the grey once again. Using her thumb and forefingers she manipulates it into another double layered pleat. "So the he fold to hang downwards. She strokes down the folded section several times with her opposite hand. "And will it give the same y stretch on the bias?" I ask. "No. Usually I design them so..." Ella shrugs and pulls a face. "So it doesn't matter?" I prompt, and Ella d the draped skirt section she has been pleating and laid the entire length of fabric on the pattern table. She carefully manipulates the e into a straight line. She comments "Oh right, OK, so this is doing this." MATERIAL AGENCY "So now I'm getting to a point where I'm grain going down here." Ella indicates a line at an angle to the pleating with the edge of her hand. "I'll tack the straighter grain so I can aterial Properties / Checking & Assuring - C0041.mp4 - She comments "Quiet often, when you pleat on the cross [bias] all your pleat - MATERIAL PROPERTIES - To help her visualise the pleats she shades half of the upper pleat and draws arrows on it to indicate the	Speech, photographs (on phone), gesture, gaze, chiffon sample, sewing machine, shirring elastic, toiles, pins, basting thread, hand sewing needle, tailors' shears, small scissors, paper pattern, paper scissors	0035 - Y, C0041 -	Y but also responding to material
pe into the machine and fold it correctly, slightly stretching the binding by pulling it against the machine feed. This means that she is using notas exactas Ella would like. She swears. "It's run off!" Ella adjusts a setting on her sewing machine. "What I can do with this machine o the right position. TOOL AGENCY / MATERIAL AGENCY "So while it's still in the fabric you can move it?" I clarify. "Yeah, I probably s she has already sewn, examining the stitching. When she finishes, she shows me the final effect and the point where the binding is d away from the needle and foot as she places the toile under the foot to be sewn. She pulls the loose threads of the toile away in the nning of the line to be sewn. Once the stitching has secured the beginning of the seam, she removes the pin and guides the remainder of - Sewing the next row of shirring elastic at the waist, Ella is sewing in parallel with the waist seam, but using her left forefinger to pull it flat, ?" I ask. "Just a little bit. Just to make sure it's sewing in the right place. It's a combination of feel here." Ella pulls on the shirring elastic with f visual on the left. Stretch on the right, visual and touch on the left." SKILLED TOUCH WITH MATERIAL & MACHINE - Good for s her tailor's shears and cuts into the selvedge at a 90 degree angle. She rubs her thumb over the cut in the fabric, then uses the posite hand as it gathers along the pulled thread. The mark left by the pulled thread indicates a line which Ella now stitches along with section which is secured by pins and thus the section where the pleats are closed. Finally she bastes along the folded bias edge of ows of stitching do not indicate meeting points between layers, but lines on a single layer of fabric. She holds the needle between thumb e pulls the chiffon along the thread to keep the fabric loose, rather than stretched and distorted. - Checking & Assuring? - C0039.mp4 - e pleat and the line at which it meets the base fabric, leaving loose loops of bright pink thread. Skilled technique - is this tool usage? It is a ttern table, Ella carefully ensures the fabric is laying flat. She begins to trace the pattern from her opened and flattened, basted toile on to it along the lines she has basted and also puncture the pattern paper, to copy the marks from fabric to paper. She presses down on it uch or needing to concentrate? She certainly seems focussed. TRACING WHEEL - TRANSDUCTION After lifting away the toile, Ella	Binding tape, chiffon toile, sewing machine, specialist sewing machine foot, speech, gesture, gaze, pins, basting thread, hand sewing needle, tailors' shears, small scissors, pattern paper, tracing wheel	C0036 - Y, C0039 - Y, C0041 - Y	Y
her arm through both the armholes. She allows the blouse section to hang, bouncing it lightly. BOUNCING AGAIN - Checking & ilor's dummy. She holds one side of the pleated section against the dummy with the back of her forefingers, while she grips the other ody, Ella holds the meeting point of the pleats in place with one hand and steps back to assess the skirt. Rather than pinning it in place, m together at the converging point of the pleats. She folds the fabric backwards along the line she basted to indicate the straight grain. I need to match those pleats up." She indicates a line across the seam where the pleats meet with her fingertip. She turns the dummy m once more. She smooths her hand down the edge she has folded along the straight grain, which is hanging down the right thigh, then it's going to be OK." Tension = CHECKING ASSURING - Pulling, pinching smoothing = CHECKING ASSURING - ALSO LOCATING ON s this count as tool usage? - Ella is undoing the pleats which she has tacked through with basting thread to mark their placement. She e and ensures that the bright pink basting threads are not pulled out of the fabric. Once the pleats are wide enough apart to insert a pair ng from both sides of the pleated fabric, indicating where it was stitched together. SKILLED TOUCHES "What I'm really interested with my tells me "Unfortunately because I've got so many layers things have come out. I might need to do it [trace the pattern] today, because if I Performance/Material Properties of Tech - understanding how to. handle material? / Checking & Assuring / Speed?	Unpicker, sewing machine, chiffon toile, gesture, speech, indicating on tailor's dummy, pins, basting thread, hand sewing needle, tailors' shears, pattern paper	Y	Y but also responding to material

APPENDIX 3: SENSOR FABRIC PROBE DEVELOPMENT

The touch sensing fabric probes used in this thesis are based on iterations of a tutorial created by Hannah Perner-Wilson and Mika Satomi for the well-known e-textiles resource Kobakant.at (Perner-Wilson and Satomi, 2021b, 2021a). These tutorials detail the development of a location and pressure-sensing matrix in soft materials. Both location and pressure (along with heat) were deemed significant to their practice by participants in Workshop 1. This was later supplemented by the identification of the significance of stretch, tension and weight during Workshop 2 when the touch sensor fabric probes were used with participants. The Arduino code which reads the input from the conductive fabric matrix and the Processing code which visualises it as a greyscale matrix required some adaptation from publicly available code related to the Kobakant tutorial (Perner-Wilson and Satomi, 2021a). This was accomplished in collaboration with researcher and creative coder Maria Dada. The development process is detailed below.

The location and pressure-sensing matrix is constructed from three fabric layers, the outer layers including horizontal and vertical traces of conductive material or thread, with an inner layer of non-woven piezoresistive material, which varies in electrical conductivity when pressure is applied to it (see Figures A3.1 to A3.6). When the electrical current flowing between a particular row and column increases this can be used to determine the location of the touch. The amount of pressure can also be calculated based on the amount of current. Via the sensor fabric probes, this is visualised in a greyscale grid, similar to a chessboard, in which squares darken from white to black as pressure increases (See Figure A3.1).

‘Velostat’ material was used for the piezoresistive layer as it is inexpensive, lightweight and available as a sheet material. The conductive traces were created from sticky-back nylon fabric tape, as this proved to have less influence on the deformation of the outer fabric layers than stitching rows of conductive thread, which created fold lines in the fabric. During construction, it was observed that it was important to leave the Velostat layer floating, as sewing through it to fix it altered its electrical properties.

To ensure that the sensor fabric probes were not visually or texturally distracting, the outer fabric layers were created from medium weight, unbleached cotton calico. A cheap, generic fashion workroom material that is generally proposed as the default material to toile a garment.

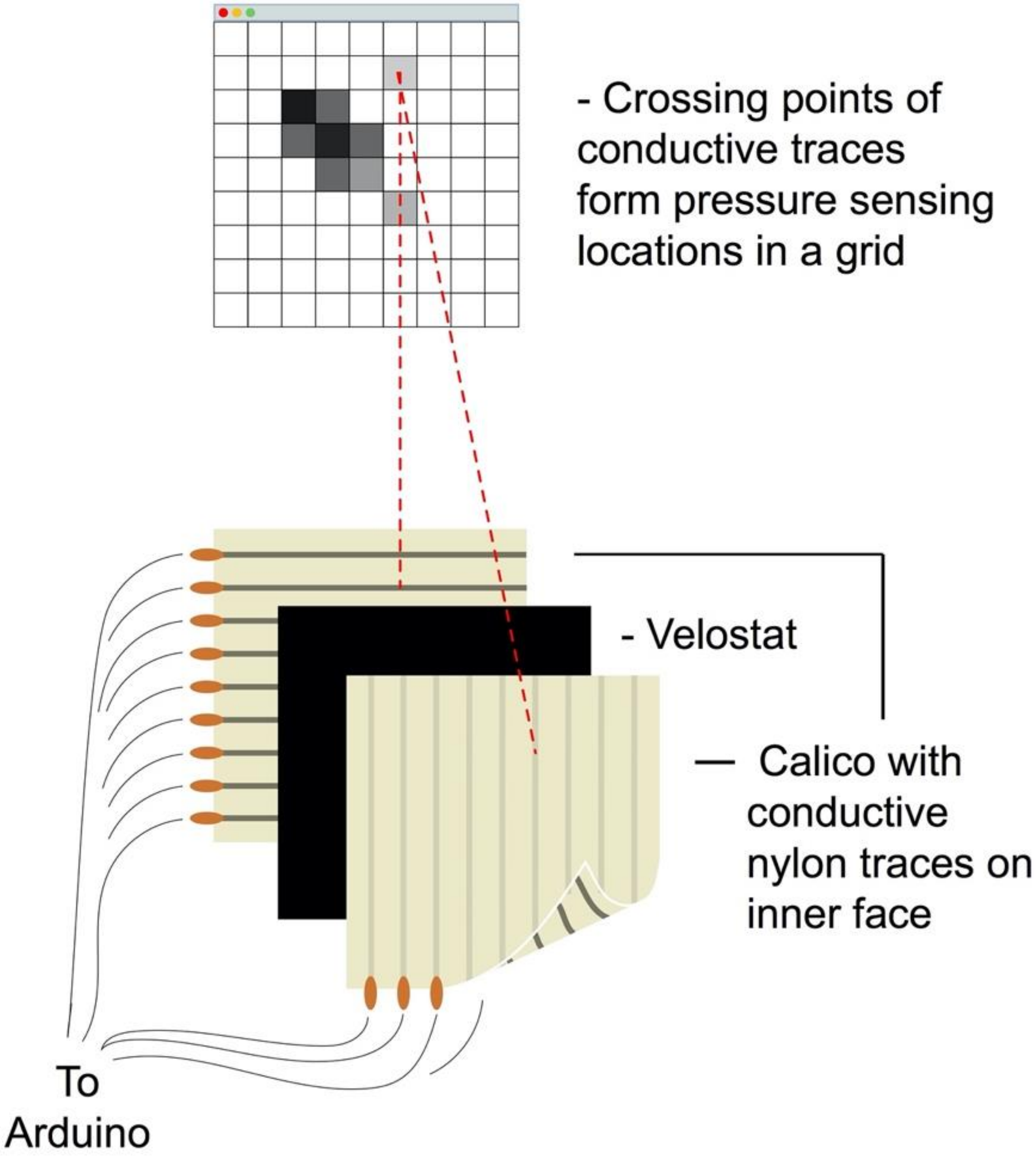

Figure A3.1: Sensor Fabric Probe diagram, showing visualisation of location and pressure

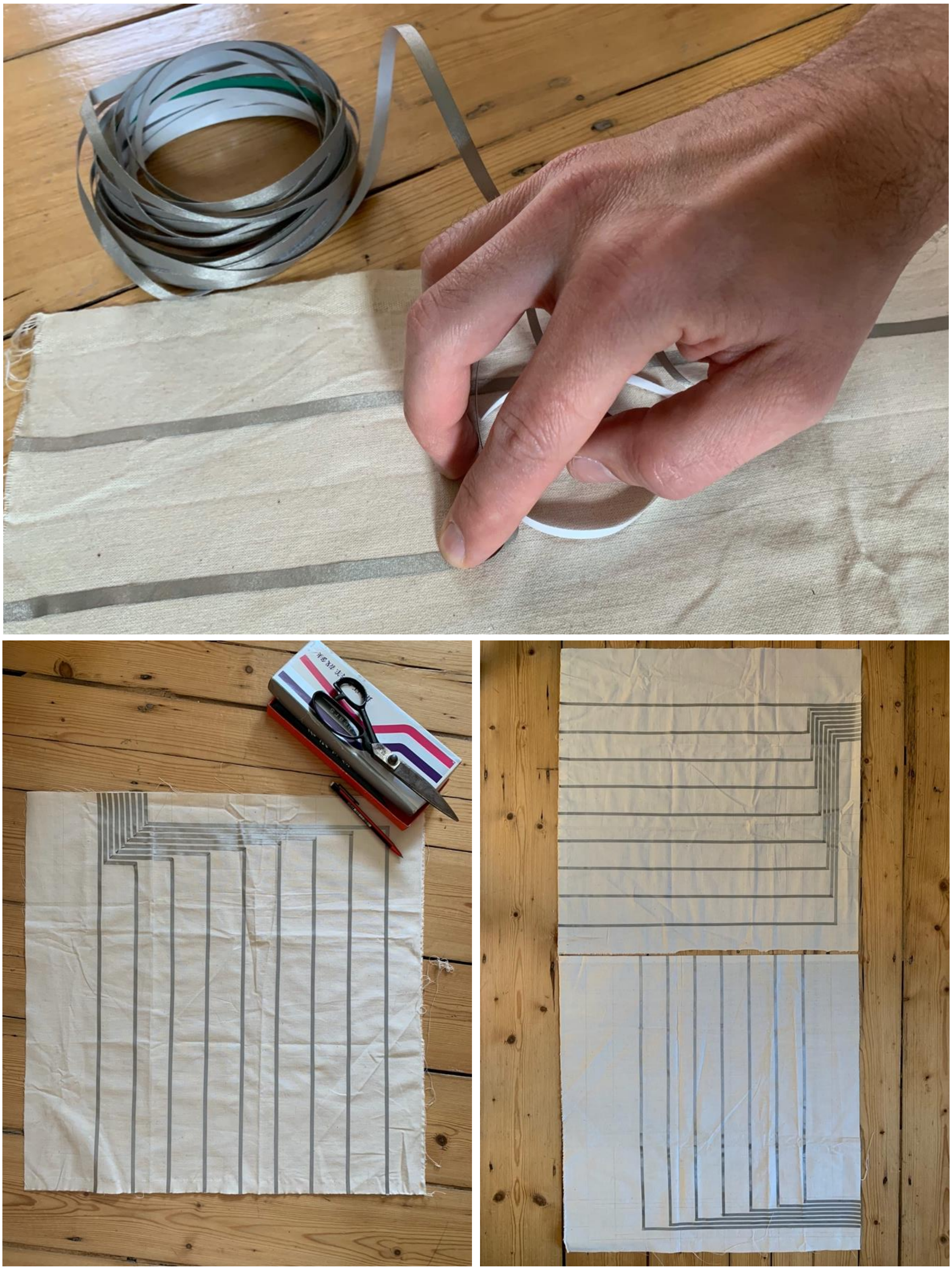

Figure A3.2: Forming a grid of conductive fabric traces using conductive nylon tape

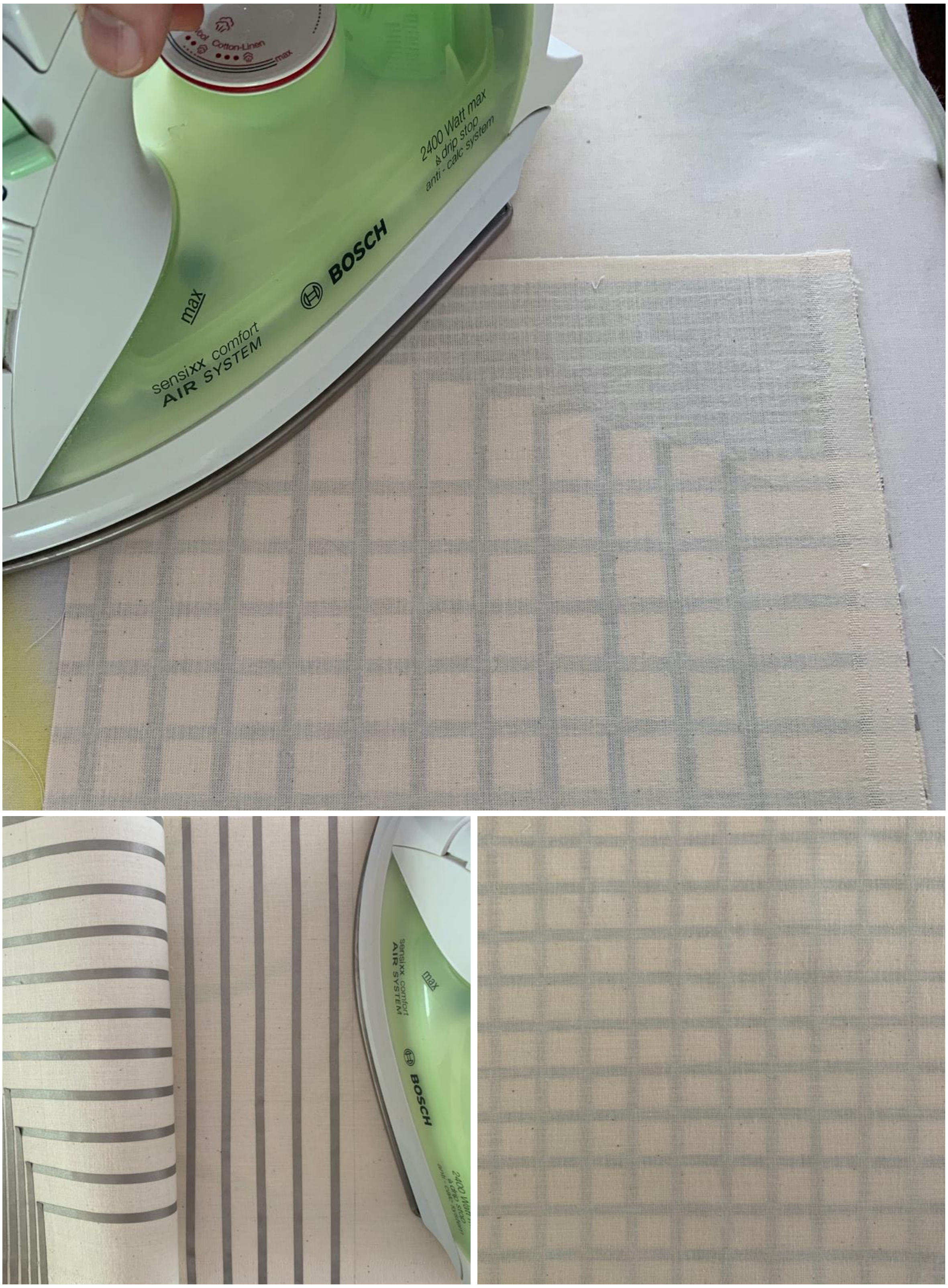

Figure A3.3: Pressing a completed fabric sensor grid to fix conductive nylon tape

The maximum number of analogue inputs on an Arduino microcontroller available at the time of writing was 11 meaning that the maximum ‘resolution’ of a touch sensing matrix was an 11 by 11 grid. Initially, as large pieces of fabric which could be manipulated at scale by participants were desirable, the first prototype was developed as a 90cm square grid of 9 x 9 traces. This meant that each visualised square represented an area of 10 x 10 cm and as such was not perceived as accurate enough to give meaningful feedback. A second iteration with a 45cm square grid of 9 x 9 traces was better received by test participants, despite the squares still representing an area of 5 x 5 cm (as shown in Figure A3.2). Even smaller, higher resolution probes were also constructed (as shown in Figures A3.3 to A3.6), but while they provided the highest resolution for small movements and localised touch, they could not map manipulation of fabrics at the scale of the human body.

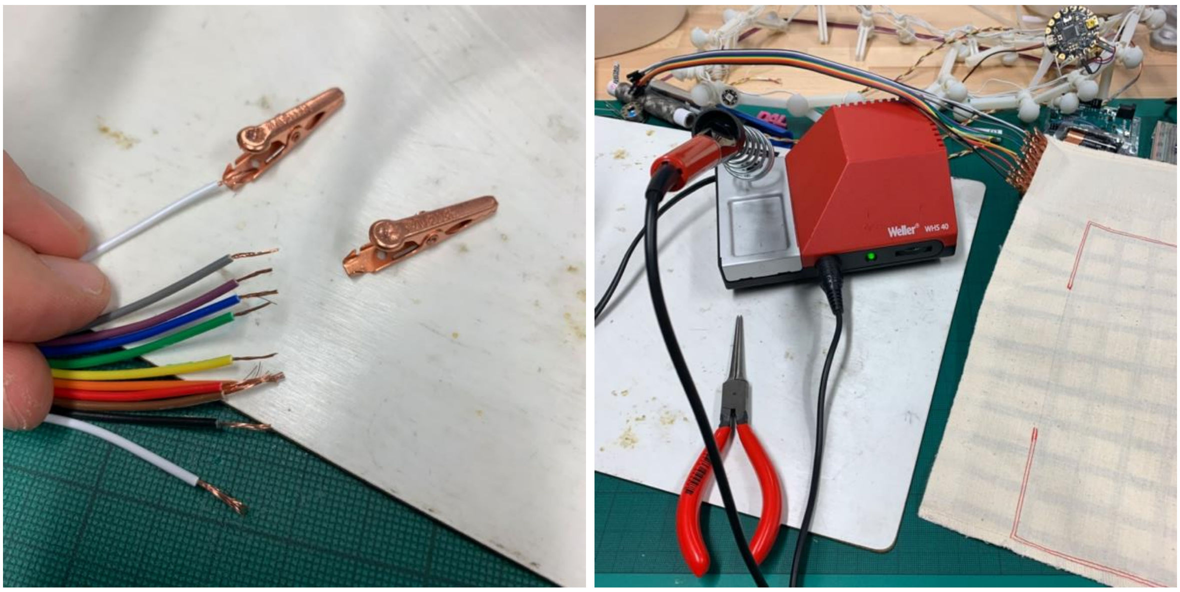

Figure A3.4: Soldering conductive crocodile clips to connecting cables

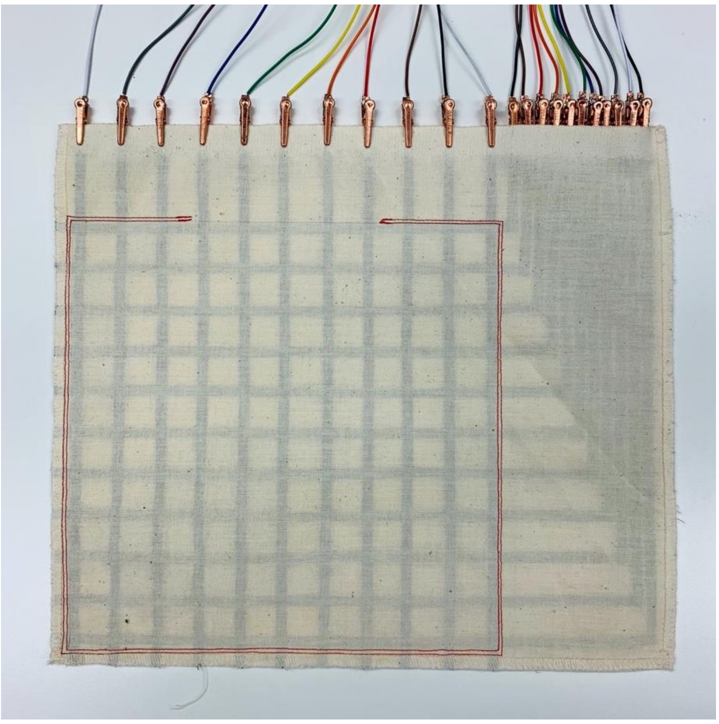

Figure A3.5: Finished sensor grid before insertion of Velostat piezoresistive material, showing connections to the Arduino microprocessor. Red stitching indicated the touch sensing area and held the Velostat in place

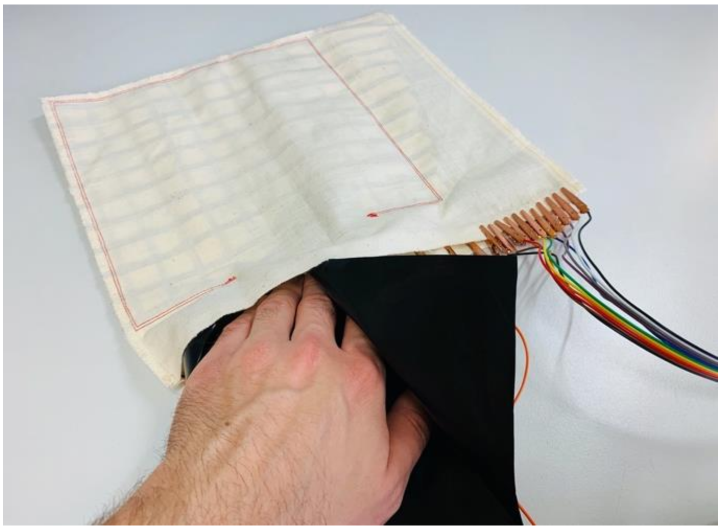

Figure A3.6: Inserting Velostat piezoresistive material into the ‘pocket’ of the sensor fabric probe