Weavesound: interactive woven textiles that emit the sounds of being touched

V J HAIRE

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Victoria Jane Haire

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Abstract

This research employs a practice-based approach to examining the multi-sensory relationship between textiles and the body. Eczema, the highly sensitive skin condition, is used as a conceptual prism to scrutinise this relationship. Its rough three-dimensional surface is the basis for a range of electronic woven textiles that have been made into garments. The textiles are constructed from materials also used in the treatment of eczema, although the fabrics are not intended to be therapeutic. When the textiles are touched, their amplified sounds of being touched in real time is emitted through speakers. The sounds evidence the materiality of cloth and refer to the materiality of the body, whilst also highlighting the sounds of textiles themselves. The project also highlights the importance of touch in relation to textiles and the embodied nature of clothing.

The research contests the historical western hierarchy of the senses, in which sight is privileged above all others, and challenges the dominance of sight in the appreciation of artworks. It is informed by recent developments in neuroscience, experimental psychology and sensory anthropology, as well as the sensory and material turns in the arts and humanities. The approach to the research has been cross-disciplinary and straddles craft, textile technology, electronics and computing, sound recording, and medical science. The enquiry has employed a process-led methodology of learning through making, combining traditional hand craft skills with digital technology.

The research uncovered findings in three areas. The first concerns the delicate reciprocal relationship between textiles and eczematous skin, the second concerns the sounds of textiles being touched, and the third concerns public engagement with eczema research. These areas are generally investigated through scientific outputs, but in this research they are scrutinised through an interactive artistic output that reveals the multi-sensory experience of wearing textiles and the materiality of the body and cloth.

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Glossary of terms

Terms in the thesis marked with a * indicate to the reader to refer to the glossary of terms for further information.

Acousmatic sound : Sound whereby one hears a sound without seeing its origin. The term acousmatic was devised by *musique concrète* composer, Pierre Schaeffer, and the writer Jérôme Peignot, in order to define how one should listen to *musique concrete*, Schaeffer stating that this type of listening allowed for the focus of attention to be on hearing alone.

Art textiles: Art textiles are located in a contested space straddling fine art and craft. Textiles have traditionally been placed low down in the hierarchy of mediums within Western art due to their being associated with women and the domestic sphere. However, due to its pervasive use in everyday life and culture, cloth can be used as a medium to interrogate different aspects of human experience, such as gender, identity and politics.

Atopic : Atopy has a genetic cause and is often associated with allergies, eczema and asthma.

Bias-cut : Fabric that is cut diagonally (at 45 degrees) across the warp and weft threads. This method of cutting produces a more flexible fabric than that cut parallel to the warp and weft threads.

Capacitance : A system that can store an electric charge.

CAT scan : A computed axial tomography scan uses x-rays and computers to give Doctors detailed internal images of the body.

Condenser microphone : Condenser microphones pick up vibrations in the air.

Contact microphone : Contact microphones pick up audio vibrations through contact with solid objects.

Conductive : Having the property of carrying energy.

Count : The number of threads in the warp or weft of a fabric.
Deformation (of fabric) : This refers to the malleability of the fabric.

Dobby : A loom mechanism that enables the weaving of geometric patterns. The loom is usually programmed by computer software.

Early Modern Italy : The period extending from the early fifteenth century through the seventeenth century.

Electrolytes : These are substances that when dissolved in water create a conductive solution. In the human body these include: bicarbonate, calcium, chloride, magnesium, phosphate, potassium and sodium.

End : An individual warp thread

Epcm : Ends (warp threads) per centimetre

Epi : Ends (warp threads) per inch.

Extra-weft : A secondary weft yarn that creates a pattern in a woven textile.

Fabric handle : This refers to how a fabric feels when handled, such as crispness, softness, sponginess and stiffness.

Faced : Backed by another fabric to create stability.

Feedback (acoustic) : A type of loop that occurs between an audio-input (such as microphone or musical instrument) and an audio-output (such as a loudspeaker), and tends to create unwanted screeching sounds.

Figured silk : A patterned woven silk fabric.

Filament silk : A continuous very smooth thread which originates from a silkworm cocoon.

Frou-frou : a rustling sound, often of silk fabric

Generative system : A system with set parameters that generates autonomous patterns.

Graphic score : A visual representation of sound.

Ground weft: The primary weft yarn in a woven textile, when extra (secondary) wefts are employed.

Haptic : pertaining to the sense of touch.

Hertz : Hertz (Hz) is the measurement used for the rate of vibration (frequency), 1 Hz being a rate of 1 vibration per second.

Histology : The study of cells by microscope.

Hylomorphic : when a fixed idea of form is imposed on a material.

IFFTI : International Foundation of Fashion Technology Institutes

Insulated : Isolated from an electic current. An insulator does not conduct electricity.

Jacquard : A method of weaving figured patterns on a loom invented by Joseph Marie Jacquard (1752-1834) between 1801 and 1810. The original jacquard loom mechanism was controlled by a punched card system that selected which threads were lifted in order to create the pattern. Nowadays the loom mechanism is controlled by digital weave files designed on computer software.

Lamella : A thin layer or membrane

Maker movement : The Maker movement encourages the use of artisan skills to create innovative products and has an inclusive DIY ethos. Traditional skills are often employed in combination with technology.

Making the warp : involves winding a continuous thread around a warping mill or frame a given number of times, depending on the width of the warp, the fineness of the yarn, and the structures to be employed. The warp threads then have to be pulled through the loom heddles (similar to the eye of a needle) in the correct order. Denting involves pulling the warp threads through a comb-like apparatus that ensures the warp threads are distributed evenly across a given measurement. The threads are tied on to the loom, ensuring that tension is completely even across the warp. Weaving can commence once the loom has been programmed with required designs.

Melton : A thick wool coating fabric, traditionally used in the red jackets worn for fox hunting (it originated in Melton Mowbray, renowned for its fox hunts, hence the name of the fabric).

MRI scan : Magnetic resonance imaging uses radio waves and strong magnetic fields to give detailed internal images of the body.

Open source code : code that is free to use and modify.

Oxidise : Metals oxidise when they react with an atmospheric non-metal, the latter usually includes oxygen. This causes the metal to discolour; in the case of silver, it turns it grey or black.

Passementerie : Decorative braids, tassels and fringing, used for furnishings or military uniforms.

PETA : People for the Ethical Treatment of Animals

Pick : An individual weft thread

Pilling : Fabric pilling is when small bobbles of yarn appear on the surface of a fabric. This is caused by a combination of abrasion and the properties of the yarn used.

Pitch : The pitch of a sound indicates how low or high it is.

Plain weave : the simplest weave structure, where every other warp thread is lifted in alternating odd and even rows, creating a criss-cross pattern.

Ppcm : Picks (weft threads) per centimetre

Ppi : Picks (weft threads) per inch.

Process-led : the development of a series of ideas, each step informing the next.

Programmatic music : A genre of music that evokes the environment.

Radio frequency shielding : Protection against electromagnetic frequencies and used to prevent signal interference. One example of usage is in the creation of wallets for car fobs that protect against car theft.

Rapier : The mechanism on a loom where a weft carrier (rapier) shoots through the warp from each side of the loom, meeting in the middle and transferring the weft thread to the other rapier, which carries it across the rest of the warp.

Resistance: electrical resistance refers to how much an object resists the flow of an electric current. This is measured in ohms (Ω).

Satin : a fabric where most of the warp threads are on the surface of the fabric, creating a lustrous effect.

Shear (of fabric) : How much a fabric can be stretched in various directions.

Short circuit : A fault in an electrical circuit where two or more conductive areas touch, thus interrupting the circuit and making it fail.

Scroop : The onomatopoeic word 'scroop' describes the sound of friction between silk fibres and originated in the late eighteenth century. Manufacturers of synthetic fibres have attempted to imitate silk's scroop sound.

Shotgun microphone : A highly directional microphone.

Silk noil : This is a yarn made from the short fibres of the silkworm cocoon. It is lumpy and uneven in texture.

Sound art : The academic Alan Licht has two definitions of sound art: 1. ' An installed sound environment that is defined by the physical and/or acoustic space it occupies rather than time and can be exhibited as a visual artwork would be.' 2. 'A visual artwork that also has a sound producing function, such as sound sculpture.' (Licht, 2019:6)

Spectrogram : This is a visual representation of sonic frequency across a period of time.

Spitalfields silks : Jacquard woven silks, mostly created by French Huguenots (Protestant refugees) in the Spitalfields area of London in the eighteenth century.

Stave lines : In Western musical notation five parallel horizontal lines known as staves are employed as the framework for the inscription of sound. Notes are drawn onto the stave lines or in the spaces in between them and they each represent different pitches of sound.

Subtle : The word subtle originates from the Latin *subtexilis*, which literally translates as under-woven.

Taffeta : A crisp, stiff fabric, traditionally made from silk.

Teensy : The Teensy development board is a small microcontroller system that can be programmed with Arduino software.

Twill : A fabric with a diagonal weave construction.

Warp : The threads that run the length of a loom

Weft : The threads that are woven through the warp, across the width of the loom

White noise : This is sound that has all frequencies at even strength throughout the audible frequency range (20 to 20,000 Hertz).

Windshield : A fluffy cover for a microphone that gives audio protection from the sounds of moving air and improves general sound quality.

Z-twist crepe : Z-twist crepe yarns are spun in an anti-clockwise direction and have a high degree of twist. Once woven and washed the fabric shrinks in certain areas, the degree of which depending on what structures are used.

1 Introduction

1.1 The aim and focus of the study

The aim of this research concerns the development of woven textiles that function as haptic* electronic interfaces for controlling the output of the amplified sounds of these fabrics being touched. The study interrogates this tactile interaction through focusing on the rough and varied surface of eczematous skin, which is used as a conceptual probe to interrogate the very sensitive relationship between textiles and skin. Although much of the enquiry is devoted to practical concerns surrounding the development of the electronic textile interface, it is approached as an artistic investigation, located in art textiles*, which addresses the far broader topic of the human experience of wearing textiles (art textiles are a field of practice which utilises cloth as an artistic medium). The interactive nature of the textiles and their references to the multi-sensory materiality of the body have opened up discourses surrounding the holistic body and the reciprocal experience of being in the world. Eczema has acted as a prism that reveals these symbiotic connections through its sensitivity to environmental factors. The textiles are intended to engage audiences in the public domain to draw attention to these issues, and open up conversations about eczema and the sensory perception of textiles.

In order to situate the artistic research in its contextual field, a broad range of topics are explored, and are applied through the lens of textiles. It has been particularly important to investigate how philosophical attitudes towards the perception of the senses have changed since the classical period, as this research contests these narratives. Similarly, discourses concerning the hierarchy of the senses in art history are examined and contested. This research challenges the privileging of sight in sensory philosophy and in the appreciation of artworks and argues that non-hierarchical multi-sensory experience can reveal new encounters with our environment, particularly in our relationship to cloth and clothing. This research also straddles art and anthropology in its approach, as it examines through an artistic output how culture shapes our sensory perception. Cultural outputs,

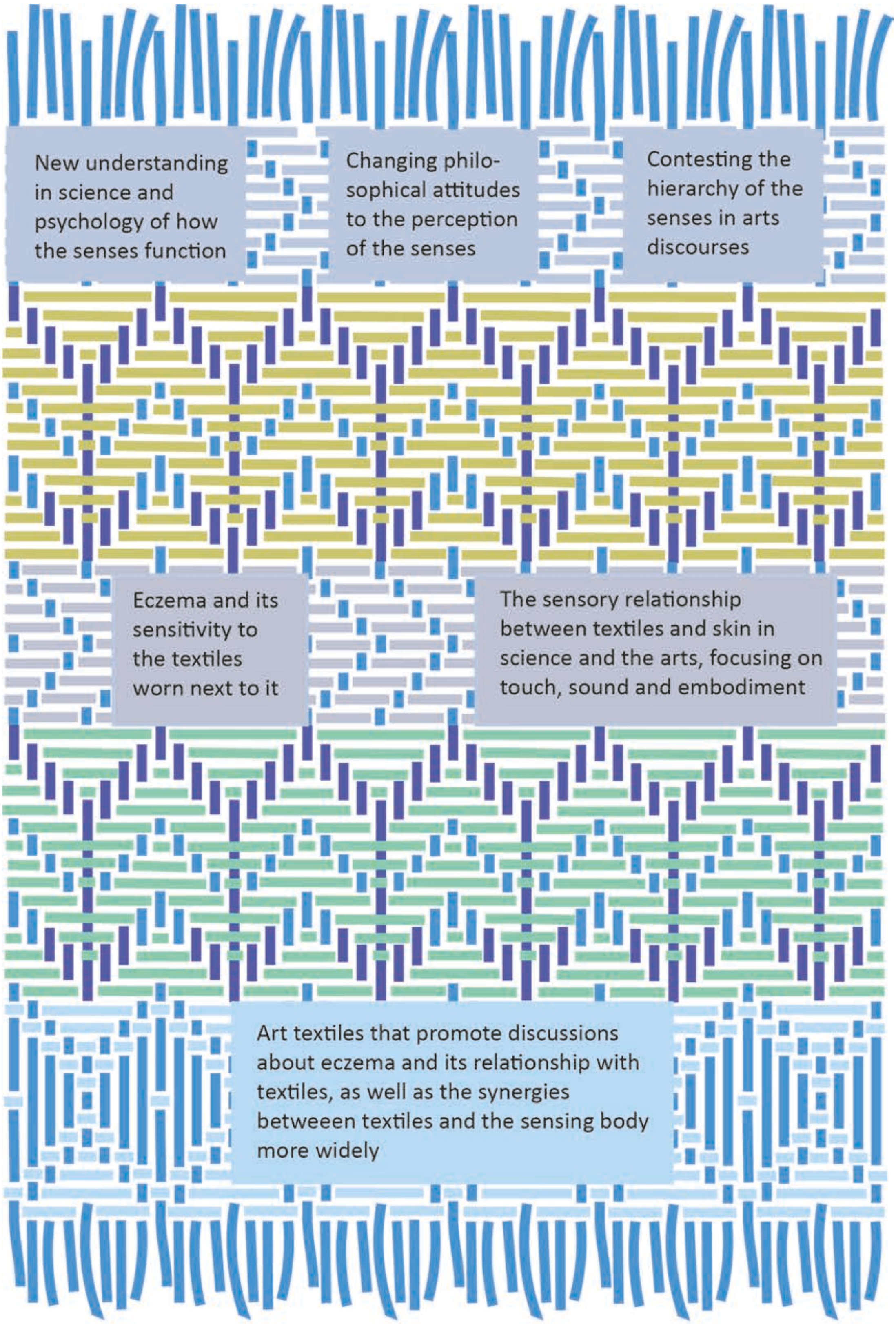

Fig. 1 The interrelated themes

such as literature and cinema, are referenced in order to explore how the relationship between the body, skin and textile have been perceived in creative arenas other than fine art. In addition, scientific studies have informed the research as they offer objective evidence-based approaches to sensory perception and the experience of wearing textiles, in particular the examination of the tactile and sonic perception of fabrics in the domain of textile science. Dermatological research, particularly regarding eczema, has been very influential in the development and contextualisation of the textile designs. Recent research in experimental psychology has also influenced this research as it has shown that the senses do not operate in isolation but operate as a holistic interactive system.

There are six main strands to the artistic research which interrelate and come together through the means of woven textiles. The first is the investigation of the medical aspects of eczema and its 3D surfaces and patterns. This informed the second strand, the design of the woven textiles. Photographs of eczema have been translated and developed into woven textiles whose 3D surfaces emulate the nature of the skin condition. The textiles have been woven from silk and silver yarns; these materials are also used in the treatment of eczema, although the textiles are not intended to be therapeutic. The design of the textiles is informed by the third strand, the development of the electronics, the silver yarn having a dual purpose as it is highly conductive* and forms part of the electronic interface. The fourth strand, the development of the sound recordings of the textiles being touched, has also informed the design of the textiles, as the tactile surface of the textiles affects the sonic output. All these elements have been brought together in the fifth strand: interactive garments that have been made from the conductive textiles that are intended to be worn on the body and exhibited as part of a public engagement programme. These have been connected to the electronic micro-controllers and loudspeakers. When the textiles are touched, this action triggers the pre-recorded sounds of the varying surface features being touched. The sound evidences the materiality of the cloth, and the cloth surface refers to the materiality of the body. The touch-sensitive sonic garments emphasise the multi-sensory embodied nature of wearing clothing, and the synergies between textiles and skin. The contextual studies mentioned in the previous paragraph are the sixth strand, which informs the other five.

1.2 The structure of the thesis

The structure of the thesis is loosely modelled on a poem by Jean-François Chabrun (1920-97), *Quatre Tapisseries pour la Châtelaine de Vergi* (Chabrun, 1947:55-56) (pp.144), which was later set to music by Witold Lutoslawski (1913-94) and named *Paroles Tissée* (Lutoslawski, 1965), in which the singer and instrumentalists are equal participants. Words and phrases are repeated in slightly different forms through the four stanzas of the poem, to create a verbal tapestry. The four chapters that form the body of the thesis (chapters four to seven) weave together the practice research with many-stranded contextual threads. Each chapter addresses different aspects of the sensory perception of textiles whilst also detailing the development of the interrelated aspects of the artistic research mentioned above.

The fourth chapter investigates the complex symbiotic sensory relationship between textiles and skin, and focuses on eczema as the source of the textile designs. It describes the nature and structure of the skin and its sensory capacities as well as analysing the similarities between the skin and the textiles that are worn next to it. It explicates the nature of eczema and its treatment, as well as its sensitivity to clothing and describes how photographs of eczema were collected and developed using Photoshop software. The chapter also addresses eczema as a skin pattern as well as a 3D surface, and analyses the synergies between animal camouflage patterns and patterns created from eczematous skin.

The fifth chapter describes the significance of touch in relation to wearing and making textiles, as well as discussing the development of the woven textile designs and the interactive electronics. A range of approaches to touch in different spheres of knowledge has influenced the research. The lowly status of touch in philosophy and art history has been addressed, as well as a revision in thinking regarding touch due to recent developments in neurobiology and psychology. It explains the importance of the materiality of cloth to this research, and how touching textiles enhances our perception of them. The process-led* development of the woven textiles is described, including how the utilisation of a combination of hand craft and computer skills has affected this development. The chapter closes with an account of the development of the electronics and analyses the difficulties faced in creating electronic textiles.

Chapter six situates this research partly in the field of sound art*, but also refers to other contexts, such as textile science and acoustics. It describes historical attitudes towards hearing and listening to natural and man-made sounds, in the latter case relating to both music and background noise. It explains how sound art developed via all these domains, how it was augmented by advances in audio-technology and why this research is partially located in this field. The chapter then addresses why audio-tactile interactions are important to this research, describes the development of the sound recordings, and discusses the perception of the sounds of textiles being touched.

The seventh chapter draws together the senses to focus on the embodied multi-sensory nature of wearing clothing. It addresses the historic disavowal of the body and contests this narrative through its approach to the multi-sensory body's somatic experience of cloth and clothing. The chapter describes the design development of the garments, including their integration with electronic components, and explains how interactive garments can extend our senses and enhance embodied experience. In order to demonstrate how the garments might be worn and 'performed', some graphic scores* have been created. These indicate, through imagery, how the fabrics might be touched in order to create a variety of sonic responses. The chapter concludes with reactions to the interactive garments when worn by an eczema sufferer, and how the garments could engage wider audiences through artistic presentation in understanding the nature of eczema and its sensory relationship with textiles.

The methodology for the artistic research has involved a cross-disciplinary, process-led approach to making the various elements involved in the development of the interactive garments. As stated previously, there are six aspects to the artistic research: the development of images based on photographs of eczema, woven textile design, sound recording, electronics and computer programming, garment design and construction, all supported by contextual studies. These elements were developed simultaneously in an iterative process, with each element mutually informing the others. A combination of artistic and scientific methods was involved in the design development of the garments, using a mixed methods approach of qualitative and quantitative analysis. The method of 'learning through making' has been employed throughout, by reflecting on the results of what has been made and then making adjustments to create improvements (Gray and Malins, 1993).

1.3 Motivations

The project emanated from a distillation of experiences within my artistic practice and personal life. Whilst studying silk weaving in the 1980's in England and India, I gained knowledge and expertise in the structure and design of figured* silks. This knowledge has been utilised and developed in the project. In the 1990's I worked with weavers in India for development aid charities, and this involvement aroused an interest in anthropology, particularly in relation to textiles and human experience. It has informed discourses relating to sensory anthropology in the project. Also during this period, through reading books on anthropology and ecology, I developed an interest in systems , both in the sciences and arts. I began to make work which linked different art forms, these man-made systems being used as a metaphor for those formed by nature. The project has also emanated from my personal experience of eczema, and an understanding of the effects that this skin condition can have on our relationship with the textiles that are worn next to eczema.

1.4 Contexts

All the above influences have been woven together in this project. Art, craft, and sound are linked in the interactive garments woven from silk and silver. The visual, tactile and audible aspects of the garments also refer to the body's sensory system and its perception of clothing, eczematous skin being the prism though which this is perceived. These interests and experiences have been developed and expanded by situating them in broader contexts, in particular, shifts in thinking regarding the senses and materiality. The sensory anthropologist David Howes (Howes, 2005) believes that the dominance of structuralism and linguistics throughout much of the late 20th century, (whereby human thought and action are analysed as structured by language) is being replaced by the dominance of sensory experience. He asserts that Western culture has separated the senses, both in science and aesthetics. Howes also believes that we are encountering a 'dermalogical turn' (Howes, 2018:225) where the skin, as 'object and means of perception' (Howes, 2018:225) is increasing in importance in the field of body studies, and a material turn where the agency of matter has gained prominence.

Western attitudes towards the senses originated in the classical world (Jütte, 2005: 33). There was a sharp division between the mind and the body's senses as the former was believed to be epistemologically and metaphysically superior. The senses were perceived to be related to animal instincts, and humans were superior to the rest of the animal kingdom because of our ability to reason. A hierarchy of the senses was also developed, the most influential being proposed by Aristotle (Synnott, 1993:132). Sight was accorded primacy as it was equated with the mind and reason, followed by hearing and smell. These senses were associated with the human whereas taste and touch, at the bottom of the hierarchy, were associated with the animal.

The hierarchical thinking that laid the foundations for Western thought promoted the ideal that the human was the subject and the centre of the world, and the environment was passive and to be acted upon (Bolt, 2013:2). This anthropocentric narrative has been challenged by recent developments in a diverse range of fields. Discoveries in science have de-centred the human as subject, and philosophical, social and political theories have questioned the privileging of the human over the non-human, and challenged the impact that this narrative has had on ecology, politics and ethics (Bolt, 2013:3). It has led to a new narrative, known as new materialism, whose discourses focus on the agency of matter, where material is not passive and simply to be utilised as raw material by humans. Matter can include the human body and other living organisms as well as natural and man-made environments. It can also include abstract concepts such as imagination and thoughts, whilst although not actually material in themselves, may affect the production of matter.

Coterminously, there has been a re-appraisal of the senses in a number of fields. Cross-cultural studies in anthropology have played a prominent role in this re-evaluation by concluding that the Western hierarchy of sensory perception has led to a disregard of the corporeal and its senses and their relationship to the environment (Howes, 2006). It has also been informed by scientific research. The past ten years has seen a rapid development in neuroscience research regarding the functioning of our senses, largely due to new technology such as MRI* and CAT* scanning. This research has indicated the plasticity of the brain and the collaborative nature of the senses. Research in experimental psychology into cross-modal perception has reinforced the findings in neuroscience, showing that the senses do not operate in isolation and modulate each other (Gallace and Spence, 2014).

The hierarchy of the senses has profoundly affected the types of artwork produced in Western culture. The dominance of sight has elevated the status of visual art, whereas touch, at the bottom of the hierarchy has been disallowed in the appreciation of an artwork. The philosopher Immanuel Kant's (1724-1804) promotion of disembodied vision was entrenched in the modernist period by the art critic Clement Greenberg, whose formalist approach to art regulated and bureaucratised the senses, and promoted a policy of 'eyesight alone' in art appreciation (Jones, 2005). This research was motivated in part by a desire to counteract the historical dominance of sight and the neglect of the other senses, particularly in relation to artworks, in order to create a more participative and less hierarchical approach to their perception. It adopts Howes's approach, to focus attention on the integration of the senses, interrogating the multi-sensory experience of the body wearing textiles. New materialist discourses concerning the materiality of the body and cloth have also informed the research. Specifically, scientific and anthropological research into the multimodal and multi-sensory serves as a framework for this project which converges movement, touch and sound. The above contexts to the artistic research will be expanded further in the literature review and the chapters of the thesis.

The Literature Review will also situate this research within other artistic outputs that have addressed the multisensory experience of textiles. These include twentieth century artists such as Filippo Marinetti (1876-1944) and Hélio Oiticica (1937-1980), who unusually for their time tried to counteract the dominance of vision in art appreciation. The former created tactile boards from a range of materials including fabrics, the latter created performative garments that were designed to be participative and enhance multi-sensory perception. More recently, partly due to the renewed interest in materiality, the artists Felicity Ford and Berit Greinke have created sound works that emanated from sonic interactions with textiles. These outputs also relate to the development of sound art, whereby all sound is considered to be of artistic value, rather than solely music. In addition, the work of artists (Zane Berzina, Myrto Karanika, Berit Greinke and Cathy Treadaway) who use textiles as an interface that require tactile and/or sonic interaction will be discussed, as well as the work of jacquard* weavers Ismini Samanidou, Philippa Brock and Reiko Sudo. How these outputs relate to my research, and why my research expands beyond them to find its own niche will be discussed.

In addition, in the Literature Review a rationale is presented for the audience for the research being based in dermatology public engagement. Several university and hospital dermatology departments have sought to engage with eczema sufferers through public engagement events where artistic presentation can offer opportunities to raise awareness, and offer insight through these creative renditions. These presentations have included mixed media artworks (Lifespace, 2017b; ASCUS, 2017) or theatre productions (Fusco, 2018). My research goes beyond these methods and seeks to engage with eczema sufferers, but through an artistic presentation of interactive textiles that examines eczema and its sensory relationship with cloth.

1.5 The contribution to knowledge

The garments create new participative encounters with textiles, through focusing on multi-sensory interactions that highlight the materiality of the body and cloth through sound. Whilst there have been artistic outputs that engage with the materiality of the skin (Berzina, 2004), (Shepherd and Donger, 2010), and others which create textiles that emit sounds (Greinke and Altavilla, 2012), (Greinke, 2012), (Treadaway and Kenning, 2015), none have used sound to evidence the tactile surfaces of skin and cloth. This research contributes new perspectives on the multi-sensory relationship between skin and the textiles that are worn next to it. By positioning eczema as a conceptual prism for examining this relationship, the symbiotic connections between these two membranes are highlighted. The sounds of the eczema-based textiles being touched indicate how damaged and sensitive eczematous skin can be, and how important it is that clothing does not aggravate this condition. Most research on the multi-sensory perception of textiles, particularly regarding touch and sound, is located in the fields of psychology and textile science. This project draws from research in these areas but moves the perception of these interactions into artistic contexts, specifically through textiles and its haptic and sonic capacities. The research contributes to new knowledge in the area of dermatology public engagement. The interactive textiles based on the surface of eczema offer new perspectives on the sensory relationship between textiles and eczematous skin, and draw attention to the importance of the materiality of cloth for eczema sufferers.

2 Methodology

2.1 An overview of the methodology

This research has taken a cross-disciplinary, process-led approach to the development of electronic textile (e-textile) haptic interfaces. There were six main areas of investigation: image development, woven textile design, sound recording, electronics and computer programming, and garment design, supported by contextual studies. The areas were mutually constructed, each one informing the other. The objectives of the research were:

1. To develop woven electronic textiles (e-textiles) that emit sound when touched by a human hand.
2. To investigate the patterns and textures of eczema so that they could inform the aesthetic dynamics of the woven designs.
3. To test conductive yarns and weave structures for their suitability for the creation of woven e-textiles with 3D surfaces.
4. To ascertain how textiles with 3D surfaces can become capacitive sensing interfaces.
5. To research the utilisation of microphones in the recording of low volume sounds.
6. To investigate how capacitive sensors can trigger the amplified sounds of the textiles.
7. To design and make interactive garments from the e-textiles.
8. To contextualise the practice-based research within the wider field, and elucidate the audience for the project through artistic presentation, in order to support and communicate a conceptual framework for the research.

The development of the interactive textiles as an artistic investigation utilised a combination of scientific and design-based methodologies, and mixed methods (which integrate quantitative and qualitative analyses in order to understand data more fully) were employed in the development of the research. Fig. 2 illustrates the cross-disciplinary nature of the enquiry, indicating how different strands of the research were woven together.

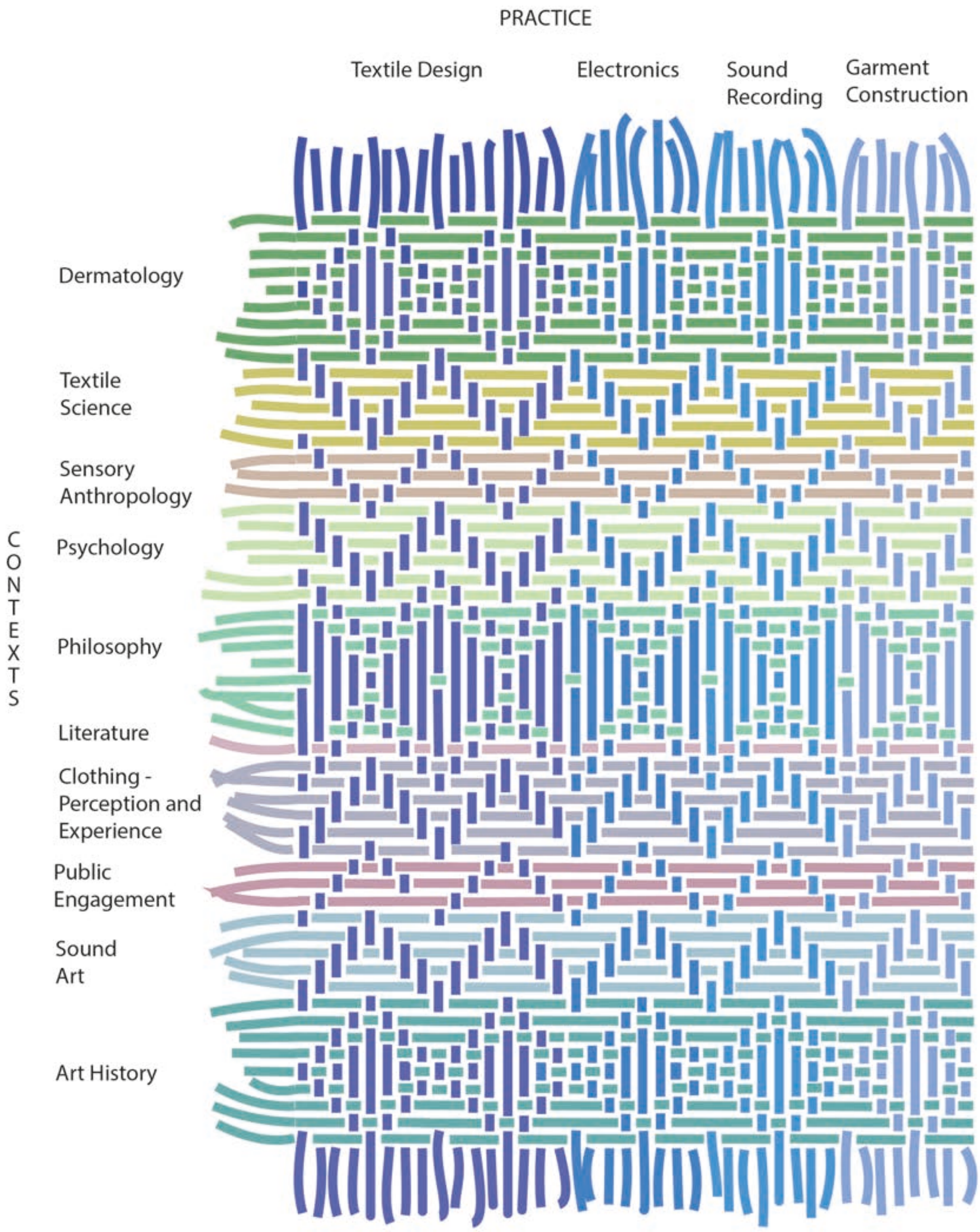

Fig. 2 The fields of enquiry

I conducted the research as a 'participant/observer' (Malins and Gray, 1995 :8) and reflective practitioner, where the designer has a 'reflective conversation' (Schön, 2016:103) with her materials using the method of learning through making. This reflexive improvisational approach involved action and reaction to develop the research, whereby one iteration of an item was created, followed by reflections on that iteration. The design was adjusted according to the outcome of the reflections.

Established design procedures have been utilised that involve:

a. Collecting data
b. Selecting the most appropriate data for development
c. Analysing and synthesising data
d. Testing for performance
e. Gaining human responses to the designs
f. Altering the designs with regard to their function and manufacture.
   (Gray and Malins, 1993:8)

These procedures partly incorporated scientific methodologies in order to test certain aspects of the research, such as the development of the electronics and the conductive fabrics, where quantitative methods of analysis were required. A mixed methods approach facilitated the blending of technical and artistic approaches to the research that are necessary for the development of the cross-disciplinary study.

2.2 Specific methods

This section addresses how responding to materials informs the making process. The anthropologist Tim Ingold writes that to make a craft object 'it is a question not of imposing preconceived forms on inert matter but of intervening in the fields of force and currents of material wherein forms are generated' (Ingold, 2010:92). The methodology of learning through making employs this concept of learning from how materials interact and working with them rather than against them. This approach has been used in the development of the woven interactive textiles because I have discovered from much past experience, that responding to the

interactions of materials in an iterative and improvised process generally produces the most creative results. If a pre-conceived idea is made, using what Ingold refers to as the hylomorphic* model (Ingold, 2010:92), it does not take into account the 'vitality of materials' (Ingold, 2010:94), and remains static and constricted.
The diagram below is intended to demonstrate this iterative process and how each element of the design process mutually informs the others. The elements are mutually constructed in order to ascertain how they respond to each other. This is not necessarily a linear process; some components regenerate and recycle other stages.

Tacit knowledge – instinctive knowledge gained through the practitioner's repeated engagement with materials that cannot necessarily be articulated - has also been employed in the development of the research. I have had many years' experience of creating woven structures with different types of thread but have not previously tried to create 3D effects. However, tacit knowledge has informed my understanding of how materials and structures might react to one another and I used this knowledge as a research tool in the development of the interactive fabrics and garments. Intuition as well as learned knowledge have contributed to the progression of the research. This is demonstrated in Chapter 4 regarding the development of the woven textiles with 3D surfaces.

<u>2.3 Image development</u>

The starting point for the artistic research has been the collection of photographs of eczema, either by taking photographs of my own eczema or obtaining them from other sources. This is because I needed good quality close-up images of different types eczema in order to help understand the visual and haptic properties of the skin condition, and to provide source material for the woven textile designs. The sources have included anonymised photographs obtained from the dermatologists with whom I have been corresponding, and scientific photograph libraries that contain anonymised photographs of eczema. Many photographs were examined and those with the most potential for development, in terms of the three-dimensional surface features of the eczema, were selected.

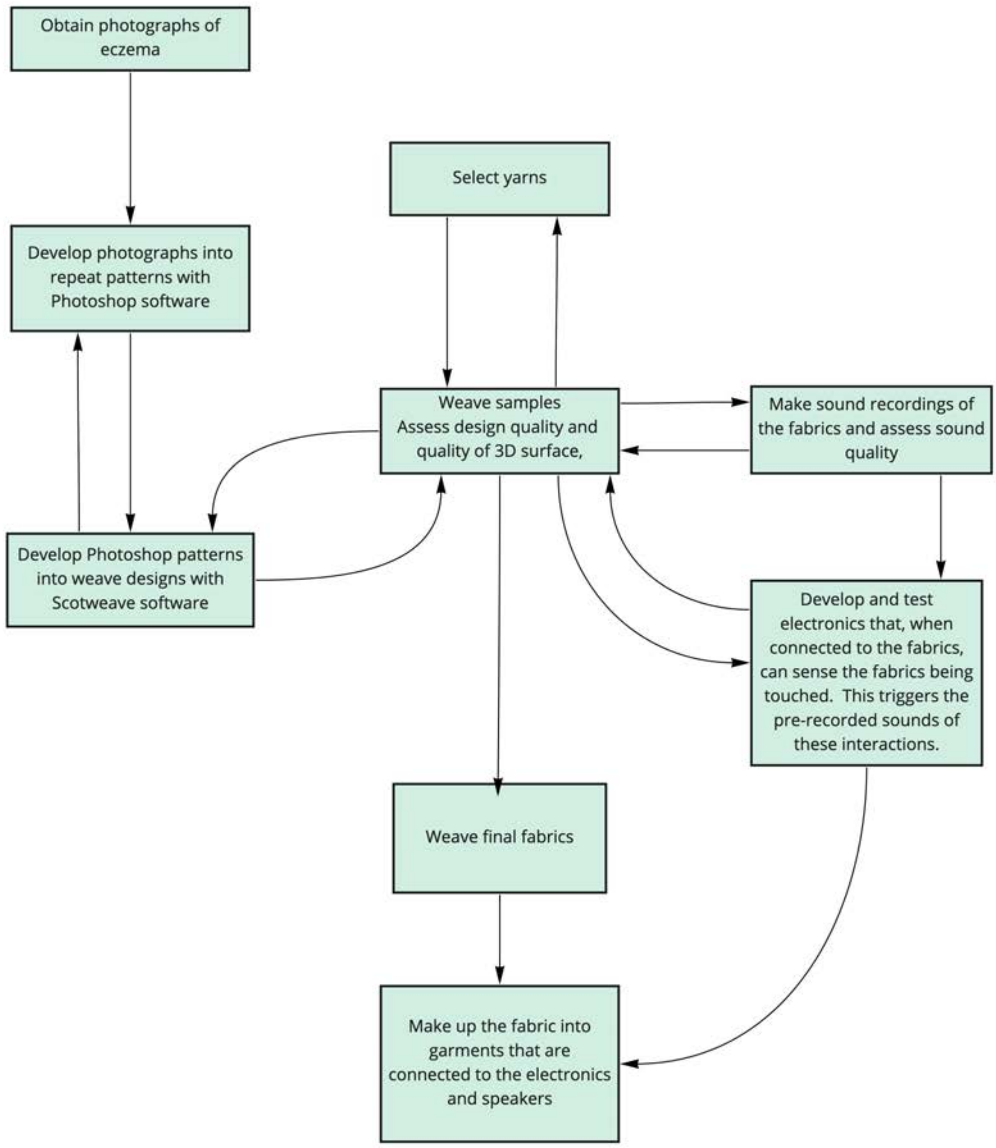

Fig. 3 The design process

An initial investigation into the fabrication of 3D models of the eczema took place by applying acrylic moulding paste to thick card. This was abandoned as the medium did not accurately reflect the nature of eczema, but alternative three-dimensional modelling techniques could be taken forward to further develop the rendition of images in future research. The progress of the study has indicated that an earlier interpretation of a 3D model of eczema into a 3D fabric would have benefited the progression of the textile designs, in terms of the visualisation of how a 3D fabric could be developed.

2.4 Woven textile design

The Scotweave software needed to design the woven textiles requires a Photoshop image as the basis for the designs which requires extensive work with 2D computer images. Scotweave requires this approach since each colour in a photoshop image file represents a weave structure in the Scotweave software. As each photograph of eczema contained about 250 colours, these needed to be drastically reduced, as 250 weave structures was not practical or desirable in terms of aesthetic outcomes. The eczema photos imported into Photoshop were initially edited so that the number of colours were reduced to about 12, in order to reduce the weave structures in the design. This first phase still produced fabrics with too many weave structures and consequently an overly busy design with minimal surface features. The design underwent a further reduction of colours to no more than six. This produced designs that were quite simple and bold with few weave structures, which facilitated the development of the 3D surfaces.

The silver yarns selected to weave the fabrics were initially chosen for their conductive properties, and latterly for how suitable they were for the two different jacquard looms that were being used in the research. These were the hand jacquard loom at MMU* and the power jacquard loom at R.A.Smart in Bollington, Cheshire. Two types of silk yarn were needed, one for the warp* and one for the weft*. The former was quite easy to choose. The jacquard loom at MMU works best with particular thread counts* and so yarns around this count were ordered from two companies and tested on the loom. The power jacquard looms at

R.A.Smart have silk warps of a particular thread count already wound onto them so it was necessary to work with this thread only. The fineness of the thread on these looms has benefited this study, as it enabled more detailed figuring* than on a hand loom, as well as creating fabrics with a higher lustre and sophistication than those that were hand-woven. Choosing the silk weft threads was much more complicated. As stated previously, visualising the 3D fabric surfaces has certain speculative challenges in terms of representing the image. Initially I tried weaving the designs with a standard spun silk but this produced very two-dimensional fabrics (see objective 3 which seeks to develop the weave designs). Shrinking silk yarns were then employed in the weft so that areas of the fabric would shrink, resulting in a more three-dimensional surface. This proved to be the case. However, after much sampling it became apparent that the most three-dimensionality occurred when certain weave structures were used in combination with the shrinking threads (see p. 81).

2.5 Electronics

At the same time as the weave samples were being developed, two separate but related activities were investigated. The first was the development of the electronics. Each weave sample was tested for conductivity. If it was not sufficiently conductive, amendments were made to the design, or it was abandoned completely. The samples were also connected to the touch-activated electronic components that had been developed to test their functionality using and modifying open source coding*. This method was effective for developing the touch sensors but open source coding was not available for the connection of audio-producing components to the touch sensors, programming all the components so that the touch sensors triggered pre-recorded amplified sounds. This shifted this aspect of the investigation into a collaborative phase and to use expertise in interactive electronics, to realise circuitry into the textile fabric.

2.6 Sound recordings

The second and related activity was the development of the sound recordings. These were initially created as test samples by recording the sounds of fingers being drawn across the weave samples with a hand-held Roland Edirol R-09 microphone, in order to ascertain the quality of the sounds produced and verify the quality of representation of the surfaces of the fabrics. The recordings contained too much background noise, but gave some indication of the sounds of the textiles being touched, and allowed for the most successful weave samples (in terms of sound quality) to be selected for further development and for the cycle of making and testing to begin again.

The second round of testing was conducted with two microphones, each of which picks up different types of sound. The first was a home-made contact* microphone, and the second a DPA 4060 Lavalier condenser* microphone. The same sound capture method was used for consistency, the recordings being of the sounds of dragging fingers across the fabrics. These recordings were of higher quality than the first ones created, and gave a better indication of the quality of the sounds produced by touching the woven textiles.

The third round of testing came after the final fabrics had been woven, when the sounds of these fabrics being touched were recorded in a recording studio. There were three types of sound recorded for each fabric: 1) Fingers being dragged across the fabric; 2) Fingers being dragged down the fabric; 3) Fingers moving all over the surface of the fabric. The microphones used were a DPA 4060 Lavalier condenser microphone with windshield*, and a Sennheiser 8060 mini-shotgun* microphone. The sound files were then assessed for their quality and edited to reduce the length of the recordings (the original recordings were of repeatedly touching the fabrics and only one iteration of touching was required). After further selection, the relevant sound files were copied onto SD cards for insertion into the audio-components.

2.7 Garment design and construction

Once all the above components of the research had been completed, the garments were designed and constructed. Patterns were developed based on simple historic garments that utilised loom width fabrics, partly because of the simplicity of construction and also because very little fabric would be wasted. The latter is important because the fabric was very expensive to produce due to the types of yarn employed. One garment was made from the two fabrics woven on the ivory warp at R.A.Smart, and the second was made from the two fabrics woven on the black warp at R.A.Smart. The garments were constructed using a combination of machine and hand techniques. It was imperative that the two fabrics in each garment were completely separate from each other, otherwise the electronic circuits would not function as intended and the fabrics would not emit the correct sounds when touched. A strip of braid backed by a wider piece of fabric was inserted in all seams, in between the two conductive fabrics in order to ensure that the conductive fabrics were kept separate. In the process of construction, a strip of conductive tape was attached to the back of each conductive fabric that was intended to be touched, to which the touch sensors could be attached when needed.

2.8 An analysis of the methods

In order to assess each iteration of the textile designs, data tables were developed which methodically documented the development of each design (pp. 159-180). These include a photograph of the woven textile, the yarns employed in the textile and their settings, the weave structures used, how three-dimensional the textile surface was, the resistance* of the fabric, how conductive it was, and the quality of the sound recording of the fabric. References to associated files have also been included. Some of the above data required quantitative analysis (e.g. how conductive the fabric was), but the majority involved qualitative analysis of visual, tactile and sonic aesthetics. The fabrics which were assessed to be the most successful using the above criteria were chosen for further development and some were woven in quantity, either by hand or on a power loom.

The development of the electronics and the construction and programming of the sensors and micro-controllers were documented separately (pp. 185-197). These include images and details of the components for the trials, the connections used in the circuit, the code used to programme the components, and any comments regarding the results of the test. Quantitative methods were used to evaluate the data, based on whether the circuit functioned as intended.

Mixed methods were employed to conduct and evaluate a survey of students' responses to the sounds of the woven textiles being touched. The survey was conducted at Manchester School of Art, the participants being students of woven textile design. The students were questioned about their responses to the recorded sounds of the fabrics being touched whilst touching the fabrics at the same time. They stated their preferences for each fabric sound presented, in terms of how well the sounds represented the feel of the fabrics. The survey can be found in the appendix (p.203-204). In addition, an interview was conducted with a member of staff from the Manchester Fashion Institute, Kelly Joseph, who has suffered from eczema throughout her life. The intention had been to hold the interview in person at the Institute, with Joseph interacting with the garments, but due to the Covid-19 pandemic the semi-structured interview was conducted via video conferencing software, and was recorded via the software. She was shown the fabrics and the relevant sounds for each fabric were played. She was questioned regarding her reactions to the eczema-based fabrics, relating to whether she thought the fabrics successfully relayed her experience of eczema and whether the sounds of the fabrics being touched enhanced her experience of them. The interview can be found in the appendix (p. 222).

2.9 The presentation of the work

The interactive garments were presented in a number of photographs and a short video in my digital portfolio. The garments were worn by models who were photographed, both separately and together, and were instructed to demonstrate how the garments would be interacted with, both for the photographs and the video. They wore close-fitting undergarments that co-ordinated with the garments, underneath the garments. The undergarments had long arms, long sleeves and high necklines, to form an insulating layer between the conductive body and the conductive cloth, so that the sensors in the garments did not receive conflicting signals. By placing the garments on the body and recording this interaction, the circularity of the research is realised and animated. The garments act as a site for the reception and transmission of sensory information.

The purpose of the photographs and video is to demonstrate the results of my research, and to enact an artistic presentation that realises the original aim of the research. This was to create woven textiles that function as haptic electronic interfaces which emit the sounds of the fabrics themselves being touched in real time, for the purposes of engaging with audiences in the public domain to open up discussions about the relationship between textiles and eczema. The models interacted with the garments by drawing their hands across the different fabrics in the same manner as when the sounds were recorded, so that their actions correlated with the sounds that were emitted, e.g. a hand was drawn across a particular fabric which activated the pre-recorded sound of a hand being drawn across that fabric. These sounds evidence the materiality of the fabrics at the same time as referring to the materiality of the eczema on which they are based.

3 Literature Review

3.1 Introduction

The following review situates this research within a number of intersecting fields. This interdisciplinary practice-based study is primarily located in textiles as an artistic production including its haptic and tacit knowledges (more specifically weave), the sonic spheres of field recording and sound art, and it connects with sensory discourse. It investigates technologies which probe the link between the sonic and haptic capacities of textiles and is further informed through the sensitivity and character of eczematous skin. The synergies and connections between these disciplines will contribute to the development of electronic textiles as a haptic interface in artistic practice. In addition, this thesis will review thematic areas of artistic practice that are most relevant to this study in the context of the haptic, sonic and somatic experience of textiles, as well as reviewing public engagement programmes that have raised awareness of eczema. The literature review begins by expanding on contexts to the research outlined in the Introduction regarding the philosophical hierarchy of the senses and its impact on the appreciation of artworks.

3.2 Sensory hierarchies

In Aristotle's ranking of the senses, sight, hearing and smell were considered to be superior to taste and touch as they were perceived to be closer to human intellect (Synnott, 1993:132). Plato accorded primacy to sight as he perceived it to be the basis of philosophy and 'the sense that leads to God and Truth' (Plato cited in Synnott, 1993:131). Equating mind and soul with sight has continued for many centuries. Thomas Aquinas (c.1225-74) theologically sanctioned the dominance of sight: ''the highest and perfect felicity of intellectual nature consists in the *vision* of God' (Aquinas cited in Synnott, 1993:137). The early Christian ascetics perceived the body to be a source of shame and guilt (Negrin, 2013:142) as it was believed to lead to temptation and damnation. They encouraged the debasement and denial of the senses through fasting, scourging and mortification of the flesh (Synnott, 1993:138). This dualism, the separation of mind and body, sight and the lower senses, was further entrenched by Descartes (1596-1650) (Synnott, 1993:139) Descartes' dualism became one of the foundations of the Enlightenment (Synnott, 1993 :139).

In the aesthetic hierarchy of the senses, only sight and hearing were considered to be 'vehicles of beauty' (L. Marks, 2008:239). Smell, taste and touch were largely disregarded in the appreciation of an artwork. Aquinas stated: 'Those senses are most concerned with beauty which are most concerned in apprehension, namely the sight and hearing, which ministers to reason. For we speak of beautiful sights and sounds but do not give the name of beauty to the objects of other senses,' (Aquinas cited in Kambaskovic and Wolfe, 2014:113) Immanuel Kant's (1724-1804) views on aesthetics have been highly influential, advocating the privileging of sight and hearing in Western art practices. He encouraged the detached visual or aural contemplation of the 'five arts' (music, painting, sculpture, poetry and architecture), but touch, smell and taste were excluded on the grounds that they were too base to be meaningful (Howes, 2006:168).

Hegel (1770-1831) deemed that 'Smell, taste and touch have to do with matter as such and its immediately sensuous qualities …. For this reason these senses cannot have to do with artistic objects, which are meant to maintain themselves in their real independence and allow of no *purely* sensuous relationship. What is agreeable for these senses is not the beauty of art' (L. Marks, 2008:240). This separation of the senses in the appreciation of an artwork is the antithesis of the thinking behind this research. It has been a multi-sensory investigation, both in terms of its creation and in its intended appreciation. The hand and eye judge the surface of the fabrics at the same as hearing the sounds produced from the tactile interaction. It is tactility that creates the sound, not vision.

3.3 Contesting sensory hierarchies

Since Kant, there have been a number of attempts by artists to counter this division of the 'higher' and 'lower' senses, most notably by Marinetti (1909-1944) and the

Futurists. Marinetti claimed 'The distinction between the five senses is arbitrary. Today one can uncover and catalogue many other senses'(Marinetti, 1924a). In 1921, Marinetti published a Manifesto of Tactilism – whereby there were six categories of tactile surface. He created collages from these groups, creating 'tactile boards' or 'hand journeys' (Classen, 1998). The categories are as follows:

'First scale, flat, with four categories of different touches – First category: certain, abstract, cold touch. Sandpaper. Emery Paper.
Second category: colourless, persuasive, reasoning touch. Smooth silk, Shot silk.
Third category: exciting, lukewarm, nostalgic. Velvet. Wool from the Pyrenees. Plain wool. Silk-wool crepe.
Fourth category: almost irritating, warm, wilful. Grainy silk, Plaited silk. Spongy material.
Second scale of values – Fifth category: soft, warm, human. Chamois leather. Skin of horse or dog. Human hair and skin. Marabou.
Sixth category: warm, sensual, witty, affectionate. This category has two branches: Rough iron. Light brush bristles. Sponge. Wire bristles. Animal or peach down. Bird down.'
(Marinetti, 1924b)

It is noticeable that three of the six categories include textiles, particularly silk. Another category consists of different types of skin and hair. Textiles are used in this research study as the tactile surface, but they are specifically created in pliable silk and silver textiles to investigate its tactile properties that are based on eczematous skin. However, unlike Marinetti's textiles, these textiles are not fixed to a board but are worn next to the body, thus increasing the contact between skin and texture. The sounds emanating from touching the textures evidences their surface, thus combining touch and sound and the 'higher and 'lower' senses as unified, co-existent and indeed operate as 'one' sense. Six different textures of fabric have been created for the purposes of this study which relate to Marinetti's original definition – smooth, scratchy, two bumpy and two ridged, each surface emitting a slightly different sound when touched. Whereas Marinetti exposed the character of the tactile surface, and indeed the surface to be touched as a responsive site, this study develops new textile surfaces linked to the intimate relationship with the body, and which forge the close connection through this character of textile with sound.

At the beginning of the twentieth century, textiles emerged to a limited extent as an artistic medium (as can be seen in the work of Marinetti) rather than as the material upon which paint was applied. This tendency gathered pace in the 1960's as a result of developments in interdisciplinary approach and the redefinition of art forms, feminism and post-structuralist discourses (Constantine and Reuter, 1997:32-35, 38), (Nixon, 2007:228-233). There was a rejection of the ideas of critics such as Clement Greenberg, who had developed an elitist notion of the linear progression of avant-garde abstraction. He believed that art should be medium-specific, autonomous, and that the aesthetic experience of an artwork should be intensified through the privileging of the visual and the rejection of materiality. Counter to this ideology, artists during this period such as Robert Rauschenberg, Eva Hesse and Claes Oldenburg were drawn to using textiles partly because of their disruptive aesthetic possibilities, their materiality, and their reference to the utilitarian (Constantine and Reuter, 1997 pp. 32-35, 65).

Textiles have a universal language due to their ubiquity in everyday life, and consequently they have accessible communicative powers and semiotic potential. Therefore, as an art form, textiles have great capacity to express ideas about the human condition. In this research the medium of textiles is employed to probe the multi-sensory relationship between textiles and the human body. The research contests boundaries not only in sensory hierarchies in the perception of fine art, it also contests traditional mediums and formats accepted within fine art. Although garments have sometimes been exhibited in fine art sculpture contexts such as the work of Yinka Shonibare (Shonibare), very few works have offered the opportunity to wear garments on the body.

One example is the textile works of the Brazilian artist, Hélio Oiticica (created during the 1960's and 70's) which have been a particular influence on this project because of his focus on fabrics as multi-sensory experience. Oiticica combined western ideas on aesthetics and the privileging of sight with indigenous Brazilian culture, which is centred on multi-sensory bodily experience. Colour was of primary importance in Oiticica's practice and his work developed from brightly coloured paintings into spatial form, which he called 'habitable paintings'. This move into the third dimension developed further into body-centred performance works called 'parangolés' (sensory capes), created between 1964 and 1979. These were tents, flags and banners made from a variety of materials, such as jute, plastic bags, striped, printed and painted fabrics, stitched together and sometimes stencilled with text. Through this wearable art Oiticica 'merged the tactility, movement and lush sensuality of materials into the whole chromatic experience' (Ramírez et al., 2007). Crucial to the development of the parangolés was Oiticica's involvement with the samba school in the favela of Mangueira. 'It was during his initiation to samba that the artist went from the visual experience in all its purity to an experience that was tactile, kinetic, based on the sensual fruition of materials, where the whole body, which in the previous phase was centered on the distant aristocracy of the visual, became the total source of sensoriality' (Osthoff, 1997). The parangolés did not function unless they were embodied and performed, Oiticica referring to the wearers of these works as a 'participador' (participator) (Dezeuze and Anna, 2004). Like Oiticica, the garments that have been created in this research are designed to be worn on the body, animated by body movement, in a multi-sensory experience of the materiality of cloth. However, I am not inviting the audience to participate in wearing the garments for conservation reasons. The performative nature of the garments will be intimated in a video displayed when the garments are exhibited, in conjuction with the other audio and graphic material.

3.4 The Sound of cloth

Textiles as an art form has recently received a renewed critical engagement with material practices. This is partly due to a re-engagement with materials, as the result of discourses surrounding new materialism, and as an antidote to the loss of tactility in digital culture. However, art textiles as a material site have not been investigated in any depth in regard to their sonic potential. This project aims to draw attention to the overlooked sounds of the everyday, the domestic foreground noise, and to present the work within the context of artistic practice. The proximity of textiles to the body, means they are constantly being rubbed and touched unconsciously and we rarely notice the sounds that this interaction produces. From the late medieval to the Edwardian period, large quantities of fabric were often used in the creation of wealthy women's dress; the skirts, bustles and trains would have rustled conspicuously as the wearer moved. The quantity and type of fabric was generally designed to evidence the wearer's wealth and social status and the sound of the dress would announce the arrival of the wearer in a room (Lebing, 2013). During the Belle Époque period, the sound of *frou-frou** petticoats next to satin corsets and pantaloons lent an erotic charge (Entwistle, 2015) (Lebing, 2013). In the 1920's flappers wore noisy dresses for a different reason: the beaded garments 'were designed to flap and slap against the dancer's knees as she did the Charleston' (Lebing, 2013) thus enhancing the percussive elements in the jazz music. The performative nature of this clothing, and its links with music and sound are relevant to this research, in that the tactile contact between garment and body emits the sound of the interaction.

Today most women wear quieter, close fitting garments where comfort and ease of movement are the primary concerns when choosing clothing. Close fitting clothes also serve to emphasise the body shape of the wearer. This research re-establishes the connections between textiles and the sounds that they emit, that moves beyond the tactile to the broader multi-sensory experience of dress. The woven textiles produced in this study have been designed specifically to emit a variety of sounds, in relation to contact and movement with the body. The sounds of the garments are not intended to evidence the wealth of the wearer, but to facilitate the internalisation of the haptic experience by emphasising the collaborative nature of touch and hearing, and evidence the materiality of cloth.

'Without a body, dress lacks fullness and movement: it is incomplete' (Entwistle, 2015). The body activates and animates our clothing and experiences the sight, sound, smell and touch of the textiles from which they are made. Our experience of dress is that of embodied multi-sensory materiality, and the garments that have been made address this essential relationship between the body and clothing. Viktor and Rolf also referred to this connection in their Autumn/Winter 2000 collection. They staged a catwalk shrouded in fog from which garments covered in brass bells appeared, so that they were heard before they were seen. This approach towards the sound of clothing is reminiscent of the importance of the sounds of dress in previous centuries mentioned above. 'The runway show proposed the notion that sound (over vision) is more in line with fashion as a three-dimensional embodied experience. Each garment took on the spectacle of the show, reaffirming the sensory experience of dress; the 'outfit' is only complete on the body and in motion' (Echeverri, 2013).

In a similar vein, SHOWstudio (SHOWstudio, 2006) recorded the sound of the fashion collections of several designers in a hemi-anechoic chamber*. The garments of 11 designers, including Christian Dior, Hermes, Giles Deacon and Alexander McQueen, were recorded. A model animated the garments through movement, crushing and rustling the silk taffeta Dior dress. McQueen's dress was made from silk tulle and covered with metallic embroidery; the model rubbed the sleeve of the dress against the body of it, triggering the jangling sounds of the metal beads abrading each other. All the while the model's breathe could be heard as she moved, highlighting the embodied nature of the garments. Other sounds recorded include feathers, velvet, zips and metal chains. The aim of the project was to approach the perception of fashion collections from a sonic perspective rather than the usual visual interpretation, whereas this research is concerned more broadly with the multi-sensory perception of clothing.

Due in part to the material turn in contemporary art and craft, there has been a small but growing interest in the sound of the materiality of textiles. The sound of the textiles being interacted with gives agency to cloth, and highlights its textures and surfaces. The growth of sound art has also played a part in this development. This has its origins in the early part of the 20th century, particularly with the Fluxus and Futurist movements (Kelly, 2011). John Cage encouraged all sound to be considered music and that sound should be listened to for its own sake (Kelly, 2011). ‘Wherever we are, what we hear is mostly noise. When we ignore it, it disturbs us. When we listen to it, we find it fascinating. The sound of a truck at fifty miles per hour. Static between the stations. Rain. We want to capture and control these sounds, to use them not as sound effects but as musical instruments’(Cage, 1968). This research is informed by this attitude to environmental sound, not so much as in using it to create compositions, but in order to draw attention to the overlooked sounds of the everyday. It is also informed by field recording, which evolved from its roots in wildlife recording and ethnographic research and involves listening intently to the physical world (Lane and Carlyle, 2013) .

Also utilising field recording techniques, the sound artist Felicity Ford makes sound recordings that explore the social, historic and geographic aspects of textiles. These provide a useful indicator for textiles as a medium for sound production, and the soundscapes of the production of textiles provide a commentary on the details of their material character as they are processed. The material substance of textiles is captured in minute detail through recordings with contact microphones. Ford created sound recordings that explored the textiles utilised in Richard Tuttle’s Tate Modern turbine hall commission *I don’t know. The weave of textile language* (Ford, 2015). These included recordings of silk and viscose fibres being spun on a spindle and the sound of viscose yarn being chemically created. Her field recordings have demonstrated the variety of sounds that can be produced from the making of textiles, and most importantly, the overlooked nature of the sometimes very quiet sounds of textile production.

Using a different approach to recording the sounds of fabrics that is not related to field recording, Berit Greinke’s research explored the sounds that textiles can produce when touched via interactive e-textile interfaces. Like myself, her research investigated the sound of fabric itself being touched. The *Twiddletone* project (Greinke, 2012) involved a collaboration with the sound artist Alessandro Altavilla to investigate how fabrics are handled, by electronically enhancing ready-woven fabrics so that sounds are produced when they are touched. Through this research they identified four different types of fabric handle* – stroking, scrunching, sensor-focused and integrative. The aim was also to explore textiles as a sound interface.

Since this initial research they developed performance pieces that use embroidered e-textiles as a haptic interface for delicately controlling sound and creating sonic compositions. *An Arbitrary System for Tuning Fabrics* was presented at an exhibition at the Marrakech Biennale – *On Geometry and* Speculation (Khalidi, 2012) in 2012. The links between textile pattern and sound sampling were explored, the intention being to advance the quality of music produced from e-textile interfaces, and to create engaging live performances. During a conference in London that I attended (Greinke, 2014), Greinke suggested that the audience at the Biennale were more interested in the sounds of fabric being touched than the compositions that she and Altavilla devised from the interactions. This observation confirmed my belief that there was an opportunity to exploit in this area. Although Greinke and Altavilla's collaboration began with the sounds of fabric being touched, they developed these into a sound art composition. This research's approach to this area is more specifically related to field recording.

3.5 Textiles as interface

Textiles as a wearable membrane operate as a 'second skin' (a term conversant with textiles and its relationship to the body) in the form of clothing made from textiles. These textiles can perform a number of practical functions, such as thermo-regulation, protection from rain, wind and snow, protection from hazardous substances, as well as having medical applications. The garments that have been created in this research reference textiles as a second skin and sensory interface, and the skin surface as the basis for textile designs. The fabric designs are based on photographs of eczema and are intended to imitate the rough surface of eczematous skin. They also refer to the treatment of eczema with medical textiles made from silk or silver with anti-microbial properties that protect the skin from bacteria. The textiles are not intended to be a treatment for eczema but refer to the potential for smart fabrics to be second skins in medical applications (see 4.5 for applications related to the treatment of eczema).

Zane Berzina's doctoral research also addresses textiles as second skin (Berzina, 2004), although she does not employ sound or interactivity in her fabrics as this research does. She views the body as an extended network and the skin as the outermost interface of the body, skin as the fabric of the body - our protector and largest organ, and the point of contact with the world and tactile experience. This research has been influenced by her experiments with different materials and processes to imitate skin and skin-like surfaces, and her examinations of various skin conditions and body decoration. These include spots, hair, warts, eczema, tattoos, branding, and surgery. Her innovative use of materials suggests different approaches to designing textiles that replicate skin surfaces. Her use of bio-medical research and its methodologies to inform artistic practice, such as examining skin under a microscope has informed this research, as bio-medical photographs were used as the basis for the weaves. The use of silver ink on some of her textiles, referencing silver's use in medical textiles has parallels with this research's investigations into silver as an anti-microbial agent. However, she does not use silver as a conductive pathway for electronics as this project does.

Electronic textiles can be programmed to be interactive and are a suitable technology for touch responsive interfaces that emit sound. This interactivity can be used in textile sound art projects, such as this research or Greinke's, or for more practical research with medical applications. At the *Sonic Pattern and the Textility of Code* conference (Greinke, 2014), Greinke elucidated how difficult it was to activate sound from embroidered e-textiles and that textiles with larger conductive areas for sound production would be preferable. From examining her delicate embroideries, it could be deduced that there might be issues concerning the transmission of data from the embroidery to the sound software, as the surface to be interacted with was small and fragmented. This led to the development in this research of woven structures with most of the conductive thread on the surface of the fabric to increase contact with the fingers. It has also been ensured that connections between the fabric and micro-controller are strong and well insulated*.

Also working with haptic interfaces that emit sound, Myrto Karanika created a large embroidered rug that makes sounds when touched, whereby kinetic pressure is translated into an acoustic signal. The embroidery on the rug is brightly coloured and very tactile, so people are drawn to investigate it further by walking or kneeling on it and touching it. ‘As the rug is being walked on, touched, stroked and pressed, the sound software encodes these gestures on different spatial and temporal scales, continuously generating sonic output that ranges from short, staccato bursts to expansive, harmonic sound fields in relation to people’s interaction.’ (Karanika, 2014) Karanika has created an immersive multi-sensory experience and is interested in examining how people respond to the visual – haptic – sonic – kinaesthetic experience of the rug. Her project offers a different insight into multi-sensory perception than that traditionally proposed by scientific research. Karanika’s research and this study are the only investigations in this review that have been specifically influenced by research into cross-modal perception. Motivated by Interest in the therapeutic applications of tactile/sonic interfaces, Cathy Treadaway’s research includes design for dementia. As part of her research, she and her collaborators have been working with e-textiles to enhance the sensory perception of garments and blankets to be used by people with advanced dementia (Treadaway and Kenning, 2015). Her team produced several sensory aprons that were personalised for specific people to reflect their interests and preferences. Some of the aprons contain interactive textile elements which play sounds or vibrate when touched (LAUGH improves wellbeing, happiness and quality of life of people living with advanced dementia, 2018). Treadaway has used highly tactile textiles to encourage interaction and give pleasure to the participants. The sounds emanating from the interfaces were not of the textiles themselves but brought back sonic memories related to the items that were touched, e.g. football chants related to the team that the dementia sufferer supported coming from a soft football sewn to one of the sensory aprons. Her research indicates that haptic/sonic/somatic e-textile interactions can be of medical benefit. Both

Treadaway's and my research utilise interactive textiles in an arts and health environment but for different purposes.

During the present research into e-textile haptic/sonic interfaces, very few woven e-textiles were discovered and none that have 3D surfaces. This is likely to be because of the simpler and quicker facility of sewing an electronic circuit. However, weaving with conductive thread can create larger areas of conductivity than e-textiles that are sewn, and the connections are more secure. The jacquard loom has been chosen to weave the e-textile fabrics as this technology allows for the interpretation of figurative images in woven form, and also facilitates the design of textiles with large areas of silver thread on the surface that are beneficial for the conductivity of the cloth. The silver and shrinking yarns that have been used can be woven in different areas of the cloth to create the undulating surface needed to produce variations in sound when touched.

Weaving textiles allows for the development of integrated structures, in contrast to those which are decorated with surface patterns such as print and embroidery. The interconnected nature of the threads facilitates experimentation with combinations of yarns and structures, and the jacquard loom enhances this further through its image making possibilities. Ismini Samanidou has been at the forefront of innovation in pictorial jacquard weaving since leaving the RCA in 2003. She interprets the surface qualities identified in her preliminary photographs and drawings and translates them into cloth, experimenting with different structures to achieve this. One of her projects involved working with the sound-artist Scanner (Robin Rimbaud) in their WeaveWaves project in 2013 (CraftsCouncil, 2013). For the first piece, Scanner and Ismini recorded the sounds of their own breath and then visualised this with Spectrogram software and iZotype Insight software. The data was then translated for loom software and woven on a digital jacquard loom. For the second piece software was used to map the loudest areas of sound in both London and Manchester. The interpretations of the city were woven and the sounds recorded in the locations mapped were also audible. In this project the sound was played whilst looking at the weaving, but there was no physical connection between them. Had the textiles been interactive, the links between textile and sound would have created a more symbiotic experience. My jacquard-woven textiles connect the audible with the haptic in an interactive multi-sensory experience, in contrast to Samanidou and Scanner's more disjointed approach to linking weaving and sound.

Very innovative jacquard fabrics (although not interactive) have been produced by Reiko Sudo and Philippa Brock. Sudo has designed many fabrics with textured and 3D surfaces for Nuno Corporation (Hemmings, 2006), whereas Brock has specialised in 3D structures. The latter are woven on a jacquard loom with two beams, allowing for 2 warps to interact with each other. Brock's innovative use of structure allowed her to create fabrics that appear multi-layered. She has also used this technique with smart yarns that are not electronic but have phosphorescent and fluorescent qualities in different lights (Brock, 2012). Sudo has specialised in working with industrial yarns in fabrics inspired by traditional Japanese aesthetics. I would like to have been able to create 3D weave structures but unfortunately have been unable to access a jacquard loom with 2 beams. I have also been very restricted in the yarns that I can use, due to my decision to work with only silk and silver because of their connections with medical textiles. This has restricted my ability to create innovative structures.

It is intended that this research should be disseminated through artistic presentation, particularly relating to eczema sufferers, but it could also be used to raise awareness of eczema more widely. Several British universities and hospitals have organised public engagement events that have publicised their research into eczema and its treatment partly through artistic outputs.

Professor Sara Brown at the University of Dundee worked with ASCUS Art and Science (who organise cross-disciplinary art and science projects) and Eczema Outreach Support (a patient support group), to develop public engagements projects. These communicated information about eczema using art-science collaborations. The artist Beverley Hood worked as artist-in-residence in the Brown

Lab, which investigates eczema genetics, to create digital artworks that highlight the research undertaken in the Lab (ASCUS, 2017). An exhibition, 'Beyond Skin' (Lifespace, 2017b) which toured Scotland, was also organised and included the work of four artists (Gordon Douglas, Trevor Gordon, Beverley Hood and Josie Vallely) alongside objects from the University of Dundee's collections . This displayed interactive and reflective artworks that revealed the challenges of living with eczema and the nature of the research at the Brown Lab. In addition, family art workshops were conducted so that young eczema sufferers could express, through visual art, their feelings about living with eczema in collaboration with their family members. The workshops also offered opportunities for a two-way dialogue between patients and their carers, and researchers. It enabled the latter to explain the research they are conducting, and the former to offer their perspectives on it. Only one exhibit utilised textiles as an art medium. 'Dream Den' (by Josie Vallely) (Lifespace, 2017a) was a small tent with soft play interior for children. The tent was made from textiles decorated with hand painted images by children who suffer from eczema. Other exhibits involved ceramics, photography, drawing and video.

Manchester University also organised creative workshops (CMFT, 2018) with local artists to help sufferers of certain skin conditions learn new creative methods of expressing ideas with paint and paper about their ailment. The London School of Hygiene and Tropical Medicine took a different approach and organised creative writing workshops (LSHTM, 2019) for adult eczema sufferers and their families to write stories about their perceptions of the condition. These stories became the basis for a play by Maria Fusco, *ECZEMA!* (Fusco, 2018), commissioned by the National Theatre Wales (NTW, 2018), and also performed there and which was also performed at South London Gallery (SLG, 2019). This was intended to raise awareness of eczema in the general public. Another approach was developed by the University of Bristol (Gilbertson et al., 2021). They delivered two events that sought to disseminate information and advice to diverse communities in Bristol, which partly included the involvement of artists to break down barriers to participation. Craft activities were offered to children, during which time they discussed what weather and materials affected their eczema. The event also gave families the opportunity to gain more information about the treatment of eczema. My project offers a different methodology for opening up discussions about eczema and engaging with eczema research. The interactive textiles exhibited based on the surface of eczema, and made from materials involved in the treatment of eczema, would be an ideal starting point for dialogues about the skin condition and its interactions with the textiles worn next to it. It is also anticipated that art workshops making textiles based on the skin could be conducted, that are related to an exhibiton of my research (see Future Directions p. 32).

3.6 Summary

Approaches towards the multi-sensory from anthropology and science provide a contextual framework for the research. The project references precedents of multi-sensory art in art history through the work of Marinetti and Oiticica, and also refers to the focus on materiality in the art textiles movement of the 1960's. The aim has been to create sculptural artworks that have the sensuous materiality of works by Oiticica or Hesse but using electronic digital technology to evidence this materiality through sound. Historical and current approaches towards the sounds of the tactile embodiment of cloth and the subsequent movement of garments in relation to the body have also been referenced. Sound art and field recording practices have influenced the research further through an interest in the sounds of domestic everyday life. Practices concerned with the use of textiles as a sonic/haptic interface have been examined, as have practices that exploit the three-dimensional haptic potential of jacquard woven textiles. Finally, the contexts to the potential audiences for the research have been outlined.

4 Sensible Skins

4.1 Introduction

This chapter draws together factual, experiential, impressionistic and metaphorical approaches to textiles and skin. The writing will weave together the biological and psychological aspects of skins with textile science and artistic investigations, to present the case for a re-examination of the relationship between skin and second skin. Research into the relationship between skin and textiles has generally been restricted to textile science and dermatology. This research will reference these areas in order to examine the importance of the scientific connections between skin and textiles to this investigation, but expand beyond these fields in order to study the parallels between textiles and skin from other perspectives, such as research in philosophy and anthropology of the senses, literature, and material culture.

The chapter describes the structure and function of the skin, particularly its sensory faculties, and explain why this knowledge is important to the research. It addresses the similarities between textiles and skin, the symbiotic relationship that textiles have with the body as a second skin, and the double-sided nature of embodied clothing. It describes the nature of eczematous skin, which informs the context of this study, its medical treatment, and how this information has informed the research (see objective 2, p.11). This chapter then goes on to describe the development of the Photoshop designs that are the basis for the woven textiles, developed from photographs of eczema, that render the skin surface into textile form, and which re-enforce this symbiotic relationship of skin and textile. The use of textile patterns developed from animal skin patterns is explored and the absence of textile designs based on human skin is commented on. In animals, skin patterns are used for the purpose of camouflage, which is investigated here. This research has created camouflage clothing for the human body using its own skin as the basis for a patterned covering, and explores notions of permeability between the two membranes.

4.2 Sensory skin

The skin protects our internal organs, is our primary interface with the world and our largest sensory organ. Tactile experience shapes our knowledge and understanding: 'The world imparts its forms, volumes, textures, shapes, masses and temperatures to us through its endless layers of skin' (Le Breton and Ruschiensky, 2017:95). We cover this sensitive membrane with textiles for protection against inclement climates and other hazardous situations. Textiles are also membranes and interact with both the skin and the surrounding environment. Their surface invites touch, and when embedded with electronic sensors, they can sense touch. This chapter explores the synergies between these two pliable coverings and the nature of their similarities. This will be referred to, particularly in the relationship between eczema and textiles. The textile writer, Jessica Hemmings, interestingly notes there are 'alarming' (Hemmings, 2003) similarities between textiles and skin, suggesting their correspondences as flexible coverings of the body. This research adopts this idea by representing the skin as textile and aims to highlight the materiality of both coverings. The textiles created in this project are informed by the nature of skin, its multi- sensory 3D surface and the patterns created from this three-dimensionality. Textiles not only have the potential to be sensory skins (when embedded with electronic sensors) but also to emulate the skin's patterns through their pliability.

The skin as a metaphor has often been interpreted as container, envelope, or boundary. However, its visual liminality can be deceptive, as from a scientific perspective it is a multi-functional, multi-sensory membrane. It is selectively permeable (Jablonski, 2006), regulating the ingress and egress of fluids, and informs the rest of the body about the world around it through a variety of sensors. 'The skin is the meeting, not just of the senses, but of world and body' (Connor, 2004). The vital importance of the skin is demonstrated by the fact that if we lose more than one seventh of it, we will die (Anzieu, 1990:64). The skin is our site of exchange between internal and external environments and offers protection from mechanical, thermal, chemical and microbial threats. The largest organ in our body, it weighs on average 5kg, and is approximately $2m^2$ in area (Jablonski, 2006). The skin secretes perspiration and triggers piloerection (goose bumps) to maintain and regulate temperature. It also plays a part in the digestive, circulatory, respiratory, and reproductive systems (Anzieu, 2016:16).

Sometimes referred to as our 'brain on the outside' (Tobin, 2006), or 'external nervous system' (Montagu, 1986), because in the embryo, the skin is physically connected to the brain through the ectoderm. Touch is the first sense to develop in the womb when the embryo is approximately three centimetres long (Paus et al., 2006) (Benthien, 2002). 'Even before they are born, the young of the human species are introduced by cutaneous sensations into a rich and highly complex universe, which remains diffuse but awakens the perception-consciousness system' (Anzieu, 2016:14). According to the psychoanalyst Didier Anzieu, not only is the skin the body's sensory interface but also a projection of the psyche. When an infant is born, it explores the world through its body, particularly through its skin. In order to move forward from the shared cutaneous relationship with its mother, it has to develop a 'Skin-ego', acquiring a physical and mental skin of its own. This ego is developed not only from experience of tactile sensations, but from experience gained from other sensory organs too, so that all the senses form the skin of the psyche. 'The skin can in one sense be regarded as the ground or synopsis of all the senses, since all the organs of sense are localised convolutions of it' (Serres, 2017:3). This study explores the comprehensive, enveloping nature of skin, which folds in and out of the body's orifices, including the other sensory organs - the ears, eyes, nose and mouth, the skin thus connecting the sensory system.

4.3 Sensation

There are many different types of sensation in the skin, such as pain, itch, pressure, temperature, and movement. Additionally, tactile sensations can include texture, roughness, stickiness, and spatial density – microgeometric aspects, and macrogeometric aspects including shape, size and structure of objects. Tactile sensations such as wetness, tickle and tingling are considered to be sensory blends, as they result from the activation of multiple receptor systems (Spence and Gallace, 2014). This research will highlight the importance of tactile sensation in relation to textiles, our primary encounter between skin and man-made materials. The textiles created in this project are intended to be examined closely through the tactile sensors in our skin – their textures, roughness and smoothness, micro and macrogeometric aspects.

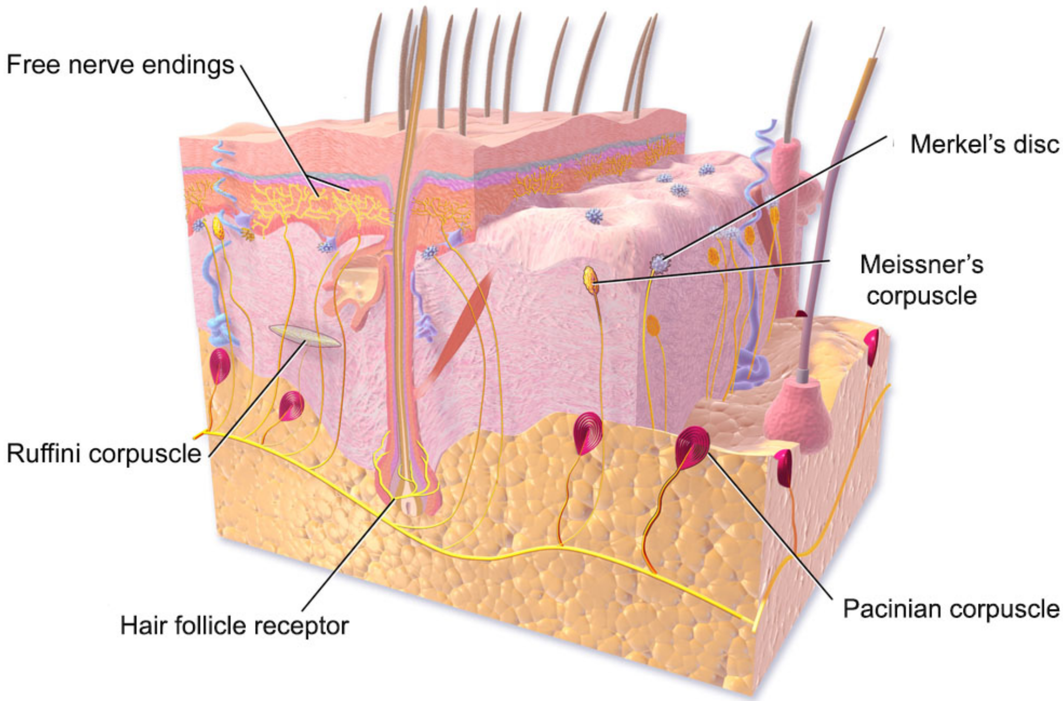

Fig. 4 Tactile receptors in the skin

Courtesy: Medical Gallery of Blausen Medical 2014

There are six primary tactile sensors in the skin. Pacinian corpuscles are activated by high frequency vibrations of 200-300hz, and Ruffini's end organs by deformation of the skin, where the sensation is deep in the skin. Merkel's discs are activated by sustained touch and pressure. Free nerve endings respond to tissue damage, contact and temperature change, and the hair follicle receptors respond to the stroking of the skin through changes in the position of hairs. Meissner's corpuscle detects changes in texture. It is situated in the body's extremities, particularly the fingertips. Fingertips and lips are able to detect very weak stimuli and are the most sensitive areas of the skin. The sensitivity of a region is dictated by the number of receptors in that area. The fingertips and tongue have one hundred receptors per square cm, whereas the back of the hand has only ten (Spence and Gallace, 2014).

4.4 Skin and second skin

This section examines perceptions of the similarities and synergies between skin and second skin. In Michel Serres's philosophical treatise on sensory perception, *The Five Senses*, he employs the *Lady and the Unicorn* tapestries as a metaphor for the mixing of the senses, and textiles as a metaphor for skin. There are six tapestries in the series, all but the last referring to a different sense. The sixth is said to represent the mixing of the senses. Serres perceives the woven fabric to be a skin which unites touch, hearing, taste, smell and sight. The nerve endings of this skin that inform the senses, are the subtle* (under-woven) threads that weave the sensory system together.

'This is the secret of the unicorn: the secret of the five or six subtle senses. The skin hangs from the wall as if it were a flayed man: turn over the remains, you will touch the nerve threads and knots, a whole uprooted hanging jungle, like the inside wiring of an automaton. The five or six senses are entwined and attached, above and below the fabric that they form by weaving or splicing, plaits, balls, joints, planes, loops and bindings, slip or fixed knots. The skin comprehends, explicates, exhibits, implicates the senses, island by islands, on its background. They inhabit the tapestry, enter the weaving, form the canvas as much as they are formed by it. The senses haunt the skin, pass beneath it and are visible on its surface, the flowers, animals and branches of its tattooing, eyes that stud the peacocks tail; they cross the epidermis and penetrate its most subtle secrets' (Serres, 2017) . Like the skin, woven textiles are an integrated structure whose over and under-woven threads create a connected whole.

Fig. 5 The sixth of the *Lady and the Unicorn* tapestries

Wool and silk c. 1500

Collection: Musée de Moyen Âge, Paris

There are parallels between Serres's interpretation of these tapestries and the textiles in this project, the latter weaving together the senses of touch, sight and hearing through electronic interactivity. The textiles in this project are similarly a skin, the undulations of the fabric caused by the subtle under-weaving of shrinking thread mimicking the character of eczema. The conductive thread can be compared to the 'inside wiring'. These furrowed, wrinkled, bumpy, conductive surfaces invite touch. Meissner's corpuscles in the fingertips detect the changes in the texture of the fabrics. At the same time, the ears pick up the vibrations that emanate from this mutual exchange. Sight observes the interaction, following the fingers movement across the fabrics, suggesting that they investigate other textures. The encounter with the textiles results in a multi-sensory experience. Serres is illustrating the ancient, symbiotic relationship between skin and textiles. Textiles have been utilised for millennia as second skins to protect us from inclement weather and toxic substances, or for reasons of modesty, immodesty or adornment (Horn and Gurel, 1981). Textiles and skin have sometimes been referred to as if they were interchangeable, the skin being a ‘cutaneous garment’ (Serres, 2017), ‘corporeal dress’ (Benthien, 2002:viii) or a ‘prodigious fabric’ (Montagu, 1986:6). Textiles can be equated to skin; both are protective, soft, flexible, tactile, porous or non-porous, wrinkled or smooth. The sarongs of the Indonesian Manggarai have been likened to a ‘super-skin’ as they ‘accentuate some of the ordinary aspects of skin’ (Allerton, 2007). They are ‘lived garments’ (Allerton, 2007), wrapped around the body, worn from birth to death and even after death as a shroud. As well as protecting the wearer, they absorb both bodily excretions and the liquids and substances with which they come into contact in everyday life. The skin and textiles are both double-sided. The former has an inside and outside, as tactility has the distinctiveness of being both active and passive (Anzieu, 1990:63). Textiles on one side have an intimate proximity to the body and skin, and on the other face the outside world; they are touched on both sides. There is a mutual exchange between textiles and skin; they are both touching and touched. The skin senses the textile, and now, with the advent of clothing embedded with electronic sensors, the textile can sense the skin. In this project, the textiles sense the touch of the fingers, and at the same time the fingers sense the varying surface of the textile.

There is much discourse concerning embodied textiles (Entwistle, 2015) (Cavallaro and Warwick, 1998) (Wilson et al., 2001) which relates to the importance of the somatic experience of cloth. The human body is a clothed body, and as such experiences textiles as an all-encompassing sensory interaction between two membranes. Catherine Harper writes of her response to the textiles of Reiko Sudo as being sensuously somatic ‘….. my body literally speaks to this affective fabric. This is a different kind of desire for tactility to that of the hand (with its direct connection to the head). Rather the organ that is my skin (with its direct haptic connection to the heart) responds across its area to the fabric plane ….nerves, pores, papillae reach out to Reiko Sudo's fabrics for contact, all over contact…' (Harper, 2005). The visual and visceral similarities between these flexible membranes are explored in a poem by Théophile Gautier *To a Pink Dress*. The pink fabric is compared to the skin that it covers, not just in colour but in its luminous, soft, sensuous materiality.

'Silvery electricity glides
From skin into the silky mesh,
And light, in pink reflections, slides
From the material to the flesh.

How did this strange dress come to you?
Where do your flesh and dress begin,
A living weave the light shines through,
So its clear pink becomes your skin?' (Gautier and Dutton)

The interchangeable relationship between textiles and skin, where skin is used as a metaphor for textile and vice versa in literary culture, exemplify the synergy between these membranes. Clothing has been referred to as a 'quasiphysiological system, an extension of the body which interacts with the body' (Fourt and Hollies, 2002), whereby body and cloth interrelate in a reciprocal process. Not only can garments protect the wearer but they can also have an adverse effect on the body. The skin is very sensitive to the textiles that are worn next to it due to their close proximity. Clothing is not a passive skin covering – it interacts with and changes the skin's heat regulating functions and affects the movement of the body.

It is difficult to quantify textile comfort according to textile science researchers (Hosseini Ravandi and Valizadeh, 2011:61), as this depends on the psychological and physiological perception of the garment wearer at any given time. However, the level of friction between textile and skin is often a source of discomfort: 'If friction is high, or if the external surface contacted is too stiff, then the skin may rub, subsequently causing severe pain with the possibility of an open sore developing' (Slater, 1991). The thermo-physiological inadequacies of clothing can also cause discomfort. If a fabric has poor moisture absorbance, such as polyester or acrylic (Hosseini Ravandi and Valizadeh, 2011:63), perspiration clings to the skin and the thermal equilibrium of the body is disrupted. Wool has excellent thermal properties but is often perceived as being prickly, although fine wool is less irritating than thicker wool (Hosseini Ravandi and Valizadeh, 2011:66). The structure of a fabric also affects comfort perception, woven fabrics generally having smoother surfaces than knitted ones (Hosseini Ravandi and Valizadeh, 2011:75).

The poet André Gide was very sensitive to the clothes that he wore and wrote in detail about his experiences of uncomfortable or irritating clothing. He was particularly critical of the starched shirts that he was forced to wear as a child: 'Imagine the unhappy child who, unknown to all the world, winter and summer, at school or at play, wears hidden under his jacket a sort of white breastplate ending in an iron collar; for (no extra charge, no doubt) the laundress would also starch the neck-band to which the collar was fastened. If – as was the case nine times out of ten – the collar did not fit exactly, it formed excruciating creases, and if you happened to sweat, the shirt-front was quite unbearable' (Segal, 2009b). As an adult he became particularly obsessive about the garments worn closest to the skin - his underwear, becoming notorious amongst his social circle: 'Every one of his friends has some vest or underpants story to tell about him.' (Segal, 2009a:99). During a trip to the cinema, one friend warned that he would walk out when Gide whispered that he was too hot and needed urgently to remove the second pair of pants he was wearing (Segal, 2009b:88).

The comfort of underwear was reportedly of great importance to astronauts in the 1960's and 70's. They had to make certain that all underwear was completely smooth and un-wrinkled before putting on their space suits, otherwise they would have to endure unscratchable itches and unbearable discomfort for the whole space flight (Connor, 2004:235). The very close proximity of textiles with skin can cause comfort or discomfort, depending on the condition of the skin and the nature of the fabric. The sensitivity of the skin towards fabrics is particularly important to this project as the textile designs are based on the skin disease eczema, which is very prone to aggravation by environmental factors, including the fabrics worn next to it. The textile designs are not only based on eczematous skin's patterns and surfaces, and also explore the complex intimate, profound, symbiotic relationship between textiles and sensory skin.

4.5 Eczematous skin

Dermatologists understand that, for sufferers of certain skin diseases or burn victims, the sensation of fabric next to the skin is crucial. If the skin is damaged in any way it is likely to be more sensitive than usual because its protective function has been disrupted. This is certainly true of eczema sufferers, whose inflamed broken skin can be severely aggravated by textiles that have a rough or prickly surface, cause overheating or are unable to absorb moisture. This research has been partly motivated by the researcher's own experience of eczema, and in particular the relationship of eczema to the textiles worn next to it. A severe infection followed the wearing of tight clothing over eczema, that caused the skin to overheat and allowed the bacteria on the skin to grow faster than usual. The small patch of eczema developed into disseminated secondary eczema (DermnetNZ), where the disease covered the whole body.

In the UK, one in five children and one in twelve adults has eczema. There are a number of different types of this skin condition, the most common one being atopic* eczema. The textiles created in this project are informed by the nature of this form of the disease, which is characterised by inflamed, wrinkled, bumpy and flaking skin. Healthy skin provides a protective barrier from infection or irritation. There is an outer layer, a middle layer which is fairly elastic and a fatty layer underneath that. Each of these layers is made up of skin cells, fats and water that in combination protect and maintain the skin's health. The water in the skin cells forms a protective barrier from irritation or infection, the fats and oils act like a seal

to help retain the water as well as preventing bacteria and other harmful substances from entering our bodies.
Sufferers of atopic eczema tend to produce insufficient fats and oils to retain the water in their skin cells. Consequently, the protective barrier is reduced allowing irritants or bacteria to enter. Substances such as soap or detergent will remove oil from healthy skin but in people prone to eczema, these irritants will break down the skin very quickly, leading to inflammation. The breakdown in skin barrier can also lead to allergens and bacteria penetrating it, whereas the fats, oils and anti-microbial peptides present in healthy skin fight off bacteria. Emollients are used to try to retain skin moisture. Eczema can be extremely itchy due to inflammation and breakdown in barrier function. Most sufferers find it difficult to resist the urge to scratch their skin which worsens the condition.

Atopic eczema sufferers are particularly prone to infections from staphylococcus aureus bacteria. This is partly due to cracks in dry skin, scratching and general loss of barrier function, but also they seem to have a reduced ability to counter this common bacteria. There is a reduction in anti-microbial peptides. Infections cause the eczema to worsen and the usual treatments, such as emollients and topical steroids, become less effective.

Eczema can be very painful when touched due to the broken and inflamed nature of the skin. For eczema sufferers, the choice of textiles worn next to the skin is vitally important as many can aggravate the condition. They should be non-irritating - not scratchy or rough and must not cause over-heating. Consequently wool or synthetic fabrics are unsuitable; cotton and silk are most commonly used. Cotton is a plant fibre, cotton yarn being spun from millions of short stubby fibres that can absorb up to 10% of its own weight in moisture. However, cotton does not have temperature-regulating properties and when sweat cools down, the skin temperature lowers and this triggers an increase in body temperature. Also when the fibres absorb moisture they contract and twist, causing irritation to sensitised eczematous skin.

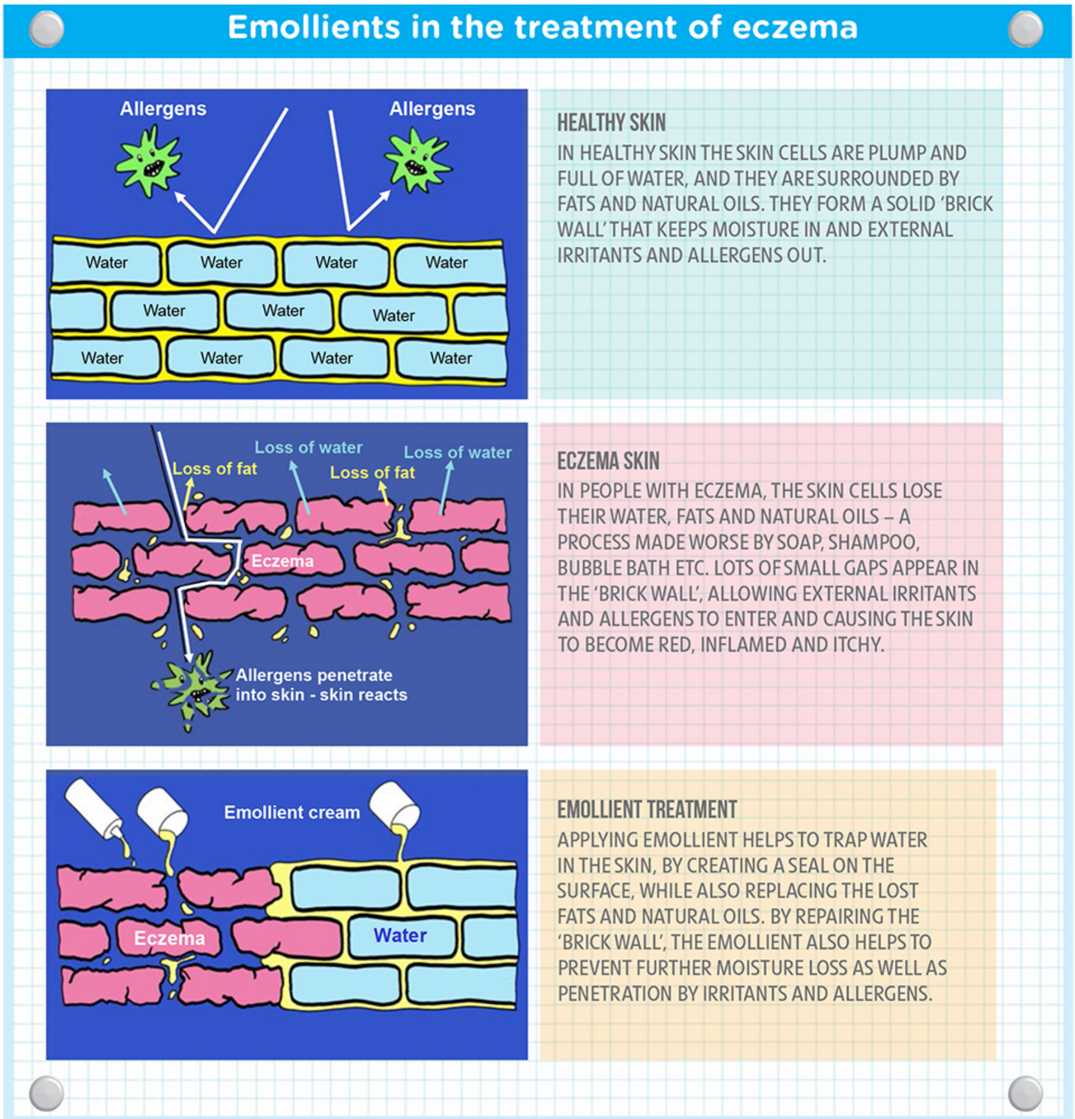

Fig. 6 Emollients in the treatment of eczema
Courtesy: National Eczema Society

Silk is an animal fibre made from silkworm cocoons, a protein resembling human hair both in its chemical and physical structure. It also has thermo-regulating properties, absorbs more moisture than cotton and is composed of long smooth fibres, making it more suitable for clothing for eczema sufferers. However, the silkworm cocoon is 'glued' together by a substance called sericin and this can be an irritant, so has to be removed when silk is used for medical reasons. Silk thread is used in surgical procedures as well as being knitted into under-clothing for eczema sufferers. Silk yarn has been used in this research in reference to its suitability in the treatment of eczema.

This project was informed by research carried out by Professor Kim Thomas, of Nottingham University's Centre for Evidence Based Dermatology. She has recently conducted the first large independent clinical trial into the efficacy of anti-microbial silk clothing in the treatment of moderate to severe childhood eczema (K. Thomas, 2014). The clothing tested was manufactured by Dermasilk® and Dreamskin® as they are the primary suppliers of this product. Dermasilk garments (Dermasilk, 2014) are knitted from medical grade silk that has been treated with an anti-microbial (AEM 5772/5), which has been permanently bonded to the fabric and consequently cannot leach onto the skin or into the environment. This anti-microbial physically kills bacteria (rather than poisons it). It punctures and electrocutes bacteria and fungi, causing them instant death. It attracts the negatively charged microorganisms thanks to its positive charge, which destroys the bacteria's cell membrane. Dreamskin® garments (Dreamskin, 2012) are made from knitted silk, each strand of silk being coated with polymer molecules via nano-sphere dispersion. The lamella* structure of the polymers imitates the human epidermis as it is both hydrophobic and hydrophilic, thus helping the skin with moisture retention and protection against irritants. It is also coated with a zinc-based anti-microbial. However, the randomised, controlled, observer blind trial concluded that there was beneficial impact on the children's eczema by the specialist clothing, but insufficient improvement to justify the extra expense compared to the conventional treatment of emollients and topical steroids (K. S. Thomas, et al., 2017).
Another type of anti-microbial textile, Padycare ®, is used in the treatment of eczema and is made from micromesh polyamide (80%), and lycra woven with silver filaments (20%). Despite being made primarily from polymer-based fibres, the textiles do not absorb humidity and allow the skin to breathe. The textiles are made into bandages and under-garments. The silver in the textiles is bacteriostatic and helps prevent the development of staphylococcus aureus.

Silver has been used as a biocidal since antiquity, the ancient Phoenicians using silver jugs to make water potable. It is a broad-spectrum antibiotic not associated with drug resistance and is also thermo-regulating. Silver-coated materials are frequently used in surgery (external fixation) and urology (catheters) and for treating burn wounds (Silver, 2014). It is not fully understood how silver prevents the growth of bacteria. Research undertaken to date suggests that when treated with ionised silver, bacterial cell membranes become more permeable, which compromises the cell's metabolism. This leads to the overproduction of oxygen compounds, which is toxic to the cells. Silver also prevents bacterial replication as it attaches itself to the DNA and RNA of the cells (Lansdown 2002; Castellano et al., 2007) (Abbasi and Morsali, 2011). Silk and silver yarns have been used in this project in reference to their beneficial impact in the treatment of eczema. However, it should be emphasised that the fabrics created from these yarns are not intended to be utilised as medical textiles. Moreover, due to the textiles uneven and sometimes rough surface, they would be highly unsuitable for eczema sufferers, who need as smooth a textile surface as possible next to their skin. The textiles created in this research *refer* to the treatment of eczema and are not intended to be therapeutic

Professor Christopher Griffiths (Foundation Professor of Dermatology at University of Manchester and Consultant Dermatologist at Salford Royal Hospital) has also assisted this research by providing anonymised photographs of eczematous skin. One of these photographs has been used in the development of the final fabric designs (Fig. 7).

Fig. 7 Eczema image 1
Courtesy: University of Manchester

It has been difficult to obtain high resolution, close-up photographs of eczematous skin, even from the dermatology departments of universities. Images taken of the skin condition tend to be either standard photographs or histology* slides. The DermnetNZ website (DermnetNZ) has been a particularly useful resource for this research, but their photographs have also not been suitable for the project due to the low resolution of the images. One photograph used in the development of the final textile designs was purchased from the Science Photo Library (library, 2017) (see fig. 8).

Fig. 8 Eczema image 2
Courtesy: Science Photo Library

The majority of photographs (pp.151-153) are of the researcher's own eczema, as it has been possible to choose the content and detail required for the development of the textile designs. Many photographs were taken (see appendix pp. 151-153 for an edited number), but the images shown in figs. 7 & 8 were selected as having the most potential in terms of design development. All images were chosen because of their differing surfaces and the obvious contrasts between light and shade. When interpreting images as jacquard weave files in Scotweave software (used with the jacquard loom at MMU), each colour is interpreted as a different structure. In each of these images of eczema there are at least two hundred and fifty colours, far too many to be practical in a woven textile. Therefore the number of colours had to be drastically reduced, and the images were abstracted as much as possible in Photoshop, usually down to four to eight colours (see section 4.7 for further details).

Eczema is a condition that tends to repel touch by non-sufferers. Anzieu refers to eczematous skin's 'painful lacerations, rough feel, humiliating appearance' (Anzieu, 2016:116). Physical defects can induce abjection through a fear of contagion (Kristeva and Ddc, 1982:71). Disease is somehow considered shameful and induces fear and disgust. There is a rejection of materiality of the body and a repression of the senses. Ignorance about eczema fuels concerns about infectivity; it is also possible that non-sufferers are concerned about the sensitivity of eczematous skin and therefore do not wish to cause discomfort to the sufferer. The textiles created in this project are based on an unattractive skin disease, yet they are intended to attract touch rather than repel it. Participants are invited to explore through their own skin, the textiles that are based on the eczematous skin of others. In this case, there is no fear of contagion or discomfort to the sufferer, allowing a tactile investigation of textile masquerading as skin. 'It is worth remembering that the aesthetic contemplation only happens because we are safe' (Lousa, 2017). Art has the capacity to transform the abject into something acceptable – the unpleasant is sanitised. Damien Hirst suggests, when referring to his diamond encrusted skull *For The Love of God*….. 'You don't like it, so you disguise it or you decorate it to make it look like something bearable – to such an extent that it becomes something else' (Damien Hirst cited in Lousa, 2017). The textiles that have been made in this research have translated the repellent rough surface of eczema into very tactile luxurious textiles made from silk and silver.

These luxury yarns, used throughout history in a variety of geographic regions to denote the wealth of the wearer, are also used in medical textiles, including in the treatment of eczema. The textiles refer to their historic precedents woven from silk and precious metals (such as Spitalfields silks*, Benaras brocades, Ottoman and Venetian silks) yet also to more contemporary medical uses of these yarns. Silk is not just beautiful but highly useful in terms of its smoothness and chemical similarity to human hair, thus making it suitable for surgery and other medical applications. Silver is an expensive decorative metal yet has many other qualities which render it useful in a number of industries, including electronics and medicine (Silver Institute, 2018).

The physically unattractive nature of eczema has been exploited in this project to create innovative approaches to designs based on human skin patterns. Eczema disrupts the regular repeating pattern of the skin's cellular structure due to breakdown in the barrier function. There are remnants of this regular pattern around the edges of the patches of eczema in the images above. The eczema is an eruption that breaks out of the pattern, in some cases forming new more three-dimensional repetitions. It is these eruptions that have been investigated in the development of the textile designs.

4.6 Skin patterns

'*Our cutaneous garment bears and exhibits our memories, not those of the species, as is the case for tigers and jaguars, but those of the individual, each one with his mask, or exteriorised memory. We cover ourselves with capes or coats from modesty or shame about revealing our past and our passivity, and in order to hide our historiated skin, a private, chaotic message, an unspeakable language, too disordered to be understood and which we replace by the conventional all exchangeable impression of clothes and by the simplified order of cosmetics. We never live naked, in the final analysis, nor ever really clothed, never veiled or unveiled, just like the world. The law always appears at the same time as an ornamental veil. Just as phenomena do. Veils on veils, or one cast off skin on another, impressed varieties.*' Michel Serres

Human skin is autobiographical. It carries the traces and memories of our lives; wrinkles, laughter lines, frown lines, scars, moles, freckles, blotches, birthmarks, and skin diseases, our 'elastic identity card' (Serres, 2017:25). A life spent working outdoors inscribes the skin more deeply than one spent out of the sunlight. The patterns on our fingertips are unique to each of us, even for identical twins (Paus et al., 2006). In foetal development, the epidermis is stratified and most of the lines evident on the surface of the skin are established. However, it is currently unknown what mechanisms activate the size and shape of tissues (Polakowska et al., 1994). The skin markings on different areas of the body are similar, but they remain specific to each person. The lines generally flow in the direction of elasticity, and in combination with the pores, form the topography of the skin. The lines become further engraved with age and the damaging effects of the sun. There are conspicuous topographic differences between different areas of human skin, for example, the palm of the hand and the back of the hand, far more so than any other mammal. The distinctive lines found on the palm of the hand and soles of the feet are known as dermatoglyphics and are unique identifiers for each individual.

Skin patterns are created by interactions between cells, patterning in biological forms (including skin) evolving from growth and developing over a period of time (Thompson, 1961). Mathematical rules often underpin this growth and involve the break-up of symmetry, homogeneity or randomness (Ball, 2012). This is demonstrated in Alan Turing's revolutionary theory of morphogenesis (1952), which applied mathematical principles to biological systems. Through the use of equations he theorised how patterns develop from a fertilised egg that has a uniform outer membrane. Two chemicals (morphogens) spread out over the skin, one changing the skin pigment and the other trying to inhibit it, this interaction creating stripes. If two sets of interactions occur, one crossing the other, spots are created (Turing, 1952). In addition to skin patterns, this mechanism is believed to account for the patterns on feathers and the formation of hair follicles (Widelitz et al., 2006). Patterns are specific to each species so the combination of genetic and epigenetic factors produce individual designs on each skin (Widelitz et al., 2006). Human skin patterns have been exploited in the design of the textiles in this research.

Cellular automata models may also explain pattern distribution on skin. In a group of discreet cells (not necessarily biological cells), each cell can be in only one of two states. Across a period of time steps, each cell will alter its state according to the state of its neighbouring cells (Widelitz et al., 2006). This process was discovered by mathematician John von Neumann in 1948, the most common example of it being Conway's Game of Life (Wikipedia). Research has shown that the south-western European lizard gradually gains its intricate adult scale colour and pattern initially through morphogenesis, but then develops via a cellular automaton system

(UNIGE, 2017). The juvenile brown colour of the scales develops into green and black, but individual scales flip from green to black and black to green throughout the life of the lizard, thus continuously changing the pattern. Kippenberger at al. have shown that the development of human skin lesions can be modelled through cellular automata, thus presenting opportunities for targeted prevention treatments (Kippenberger et al., 2013).

Dermatology and dermatopathology rely on pattern recognition in the diagnosis of skin diseases. ‘Dermatological diseases are highly patterned because the molecular make-up of skin is also highly patterned: pattern reflects function, function reflects morphology, morphology reflects molecular structure and disease reflects molecular perturbation’ (Paus et al., 2006). The patterns and marks on our skin are rarely thought of in the same context as the larger scale patterns on the skin of other species such as tigers and jaguars, which are often used as the basis for textile designs. Healthy human skin is highly patterned and mostly homogenous in colour but the patterns are primarily microscopic in scale compared to the patterns found on furred animals such as those in the cat family. The designs created in this project have converted the microscopic to the macroscopic, enlarging human skin patterns to the scale of those found on the fur of domestic cats or leopards.

4.6.1 Wearing Skins

It has been suggested that the reason that humans have persisted in wearing animal skins since the advent of woven textiles, is because they have ‘skin envy’ (Paus et al., 2006), as our skin does not exhibit striking colours or patterns. However, the motivations are more complex than this. It is unknown exactly when humans began wearing animal skin clothing, but it is suggested to have been up to 500,000 years ago. The academic Elaine Igoe states: ‘As is understood, textiles and cloth were often historically created to mimic natural surfaces such as hair, fur and skin, not only for their function but for their sensorial qualities’ (Igoe, 2018). Animal fur or skin has continued to be worn alongside textiles by all strata of society. However, in fourteenth century Britain, Edward III brought in sumptuary laws that regulated what could be worn or eaten by peasants, merchants or nobility

(Emberley, 1998). These laws persisted until the seventeenth century, and encoded fur as a 'visual representation of social difference'(Emberley, 1998:11), the type of fur worn by a person denoting their social class.

Leopold von Sacher-Masoch's book 'Venus in Furs', fostered the idea of fur and leather clothing as sexual fetish. For Masoch, fur symbolised sexual power. The psychoanalyst Krafft-Ebing argued that 'certain materials, such as fur, velvet, and silks, take on the character of the fetish because of the tactile sensations associated with them; the fetishist displays a hypersensitivity to physiological stimulation' (Krafft-Ebing cited in Emberley, 1998:76). According to Freud, fur and velvet are a 'fixation at the sight of pubic hair (Freud cited in Emberley, 1998:76). Animal skins and fur in particular, therefore, became associated with wealth, status and sex. In western contexts, fur had both libidinal and economic power in its symbolic and material characteristics (Emberley, 1998:4).

Highly patterned furred skins, such as leopard skin, are symbols of masculine power and virility in Africa and are worn by the Zulu aristocracy. However, big cat skins or textiles based on these have become a fashion staple in women's wardrobes particularly in the last one hundred years. In part due to the women's suffrage and women's liberation movements, women were equated to cats – the dangerous female. These ideas were founded on ancient idols in Egyptian art, in particular the 'cat-woman' goddess, Bastet. Mary Jo Deegan refers to a 'psychic felinism', where women are regarded as stealthy, catty, or a sex-kitten. The latter concept developed further, from the 1940's pinups onwards, but became prominent in the 1960's and 1970's when the feminist movements came to the fore (Bolton et al., 2004:117). Big cats are the signifiers of a predator, a confident, sexually liberated woman. Dolce and Gabbana stated 'Without animal prints there could be no divas, or even divinities' (Bolton et al., 2004:120). The interest in feline patterns set a precedent for prints based on a broader range of animal skins, such as snakeskin (Bolton et al., 2004:117). Rudi Gernreich (1922-1985) explored the concept of second skins in his innovative fashion designs. In addition to adhesive 'tattoos' that resembled animal markings, in the 1960's he became renowned for his head-to-toe animal print garments that had a graphic ‘pop-arty camouflage’ sensibility (Bolton et al., 2004:137). The ensembles created a ‘’total look’ concept, designed by coordinating each animal pattern to emphasize the sense of a complete second-skin transformation, with animal skin patterns covering the human skin (Bolton et al., 2004:137).

The changing attitudes in society towards humanity’s relationship with animals is reflected by the use of animal skins in fashion. The animal rights movement has campaigned against wearing animal fur since the 1970’s (Emberley, 1998:23). Campaigners from PETA* used the slogan ‘Wear Your Own Skin’ in topless demonstrations outside London Fashion Week in 2018, in a protest against the use of fur in fashion. Textiles based on animal skin patterns have been in fashion for much of the last century; this research proposes the wearing of our own skin and that human skin patterns could also be the basis for textile designs. Human skin patterns are subtle and although their micro-scale does not have the graphic power of leopard or tiger skin, when greatly enlarged and with the homogeneity reduced they have the potential to be equally striking. The textile patterns created in this research evoke animal skin patterns but are based on damaged human skin.

4.7 Camouflage

Some of the designs produced in this research are reminiscent of camouflage, both animal camouflage (a primary skin pattern) and the designs created by humans for military disguise (a ‘second skin’ pattern). Many different types of animal have skins, feathers, or scales that camouflage them in their natural environment and protect them from predators. Sir Edward Poulton pioneered the investigation into the pattern and colour of animals’ skin that acted as a disguise, subterfuge, or concealment in their natural environment in his ‘Colours of Animals’ (1890). In some cases the animal blends into the environment; e.g. a stick insect can be mistaken for a twig in the daytime when motionless, coming out to feed at night. With discontinuous variation, the body changes according to its setting e.g. a crab spider changes colour according to the flower head it is on, then ambushes prey that also lands there.

However, the basis for most twentieth and twenty-first century camouflage emanated from Abbott Thayer, who investigated the concept of disruptive colouration in his wildlife paintings. Disruptive colouration is 'the employment of strong arbitrary patterns of colour that tend to conceal the wearer by destroying his apparent continuity of surface' (Behrens, 2009:127). Animals with highly patterned skins that would seem counterproductive in terms of camouflage, are in fact blending into their environment through a type of optical illusion. The zoologist Hugh Cott elucidates further: 'Provided an animal is seen against a broken background, it is probably true to say any pattern of darker or lighter colours or tones will tend to hinder recognition by destroying to a greater or less degree its apparent form …..but in order to achieve effective results the colours, tonal contrasts and pattern employed must conform to definite optical principles …..In the first place the effect of a disruptive pattern is greatly strengthened when some of its components closely match the background, while others differ strongly from it . Under these conditions, by the contrast of some tones and blending of others, certain portions of the object fade out completely while other stand out emphatically' (Newark, 2007). This results in the body of the animal appearing to disintegrate and the viewer sees discontinuous planes of colour.

Eczema, like camouflage, is disruptive. The epidermis of healthy skin has a regular almost geometric pattern that is fairly homogenous in its colouring. Eczema disrupts this pattern because it is caused by the breakdown of epidermal barrier function. It physically and visually disrupts the normal surface of the skin (see eczema image 1 [p.51] in particular). Healthy skin has a pattern, but it is only after it has been disrupted by the forces of eczema that the patterns (once enlarged) resemble camouflage. However, the design of most camouflage textiles are based on the surrounding landscape of the wearer, whereas the textiles in this project, like animals in the wild, are derived from the skin itself. This research has discovered that abstracting the initial images into a few colours has not only created similarities with graphic animal skins patterns, but also, through the use of a combination of structures and yarns, has enabled the development of a more three-dimensional surface than had previously been achieved (see figures 9-12).

The limited colour palette of black, grey, ivory and silver was dictated by the yarns that were available (see Chapter 5, p. 87). As will be discussed in more detail in Chapter 5, it should be noted that the three-dimensionality caused by the shrinking of the weft yarn, has optically added more colours and surfaces, thus greatly diminishing the graphic nature of the original design. However, the linings of the garments are made with a silk weft that does not shrink, so the designs retain their graphic sensibility. Most importantly, the three-dimensionality has also created the pronounced tactile surfaces that are essential to this project, as they create greater variations in sound than a smoother surface.

This research has shown that the skin is profoundly affected by its interactions with its second skin, clothing, and that the two coverings have many similarities. The sensors located in the skin respond to the effects of clothing and inform us whether what we are wearing is appropriate for our needs. This is particularly true of eczema sufferers whose skin has heightened sensitivities. The composition of the textiles is especially important to them, regarding both yarn type and the structure and materiality of the cloth. Eczema's disruptive effects on both the patterning of the skin and its sensitivity to the fabrics worn next to it have been examined and have been exploited as the basis for the textile designs created in this research. The designs have transformed an unattractive skin disease into second skin luxury textiles that highlight the symbiotic relationship between textiles and skin.

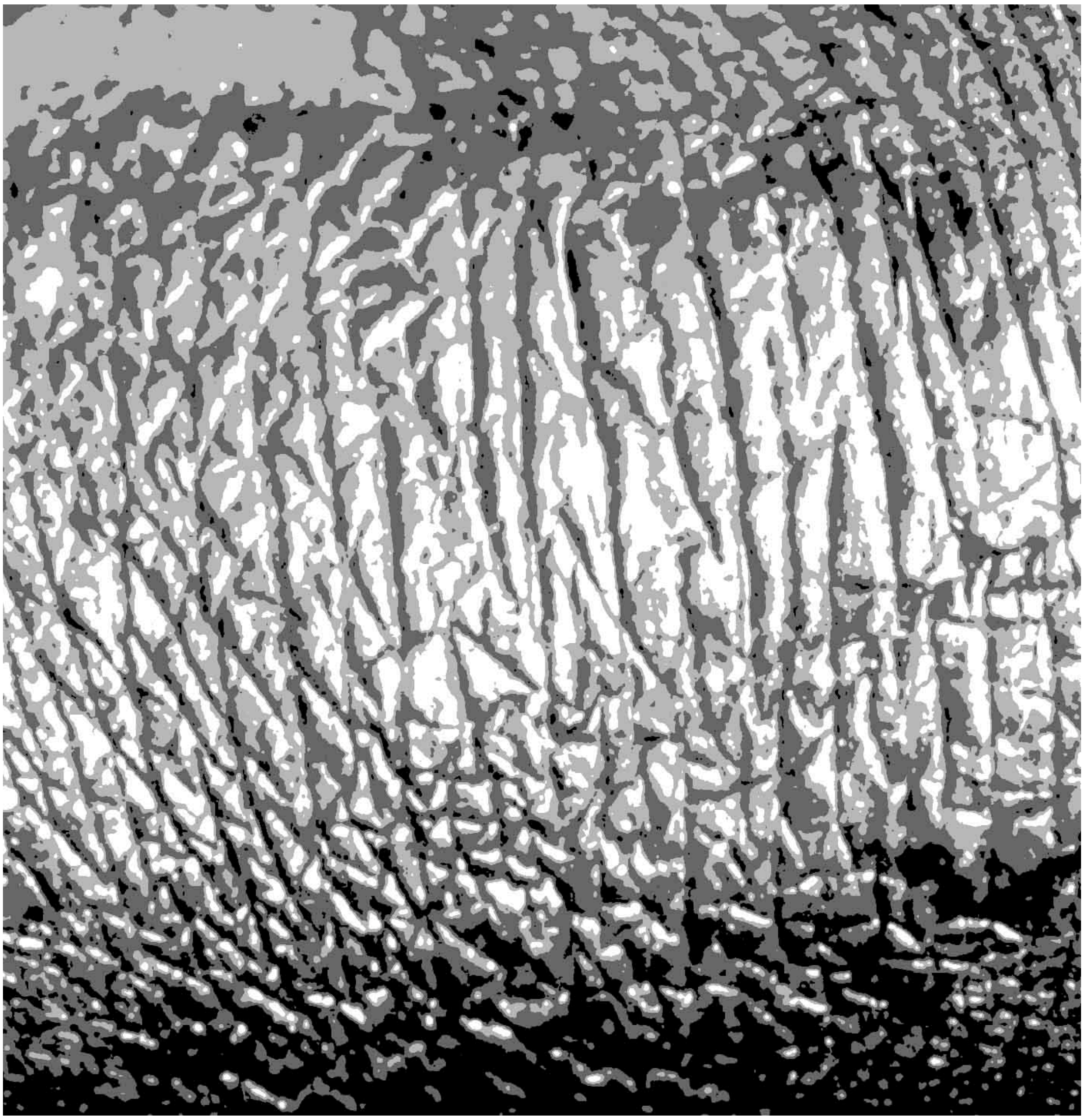

Fig. 9 Initial cropping, black and white conversion, and colour reduction of eczema image 1.

Fig. 10 Final block (a) based on eczema image 1, ‘blackblock’.
The palest grey areas denote where the silver will be.

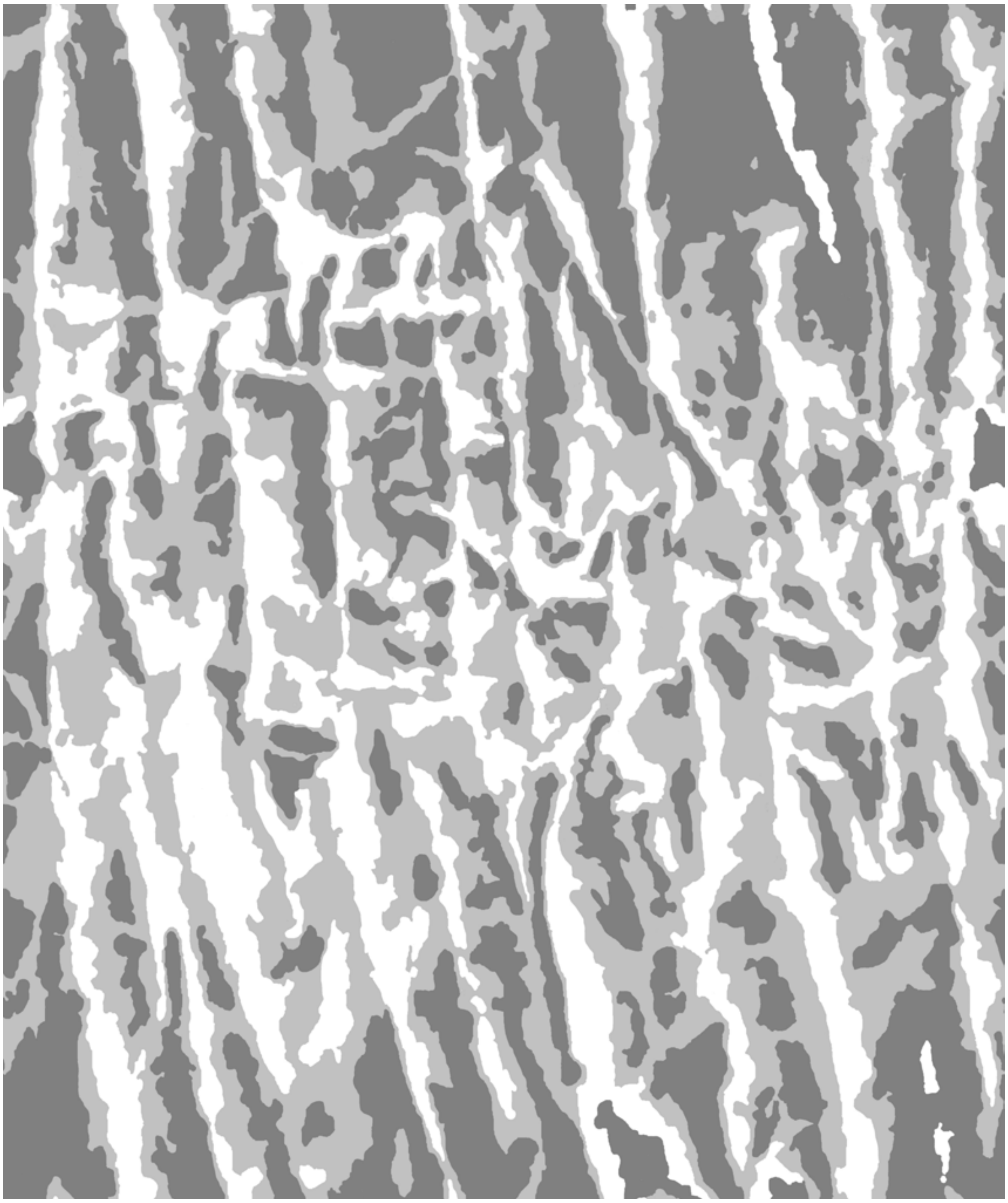

Fig. 11 Final block (b) based on eczema image 1, 'ivoryblock'.
In this case, the darkest grey areas denote where the silver will be.

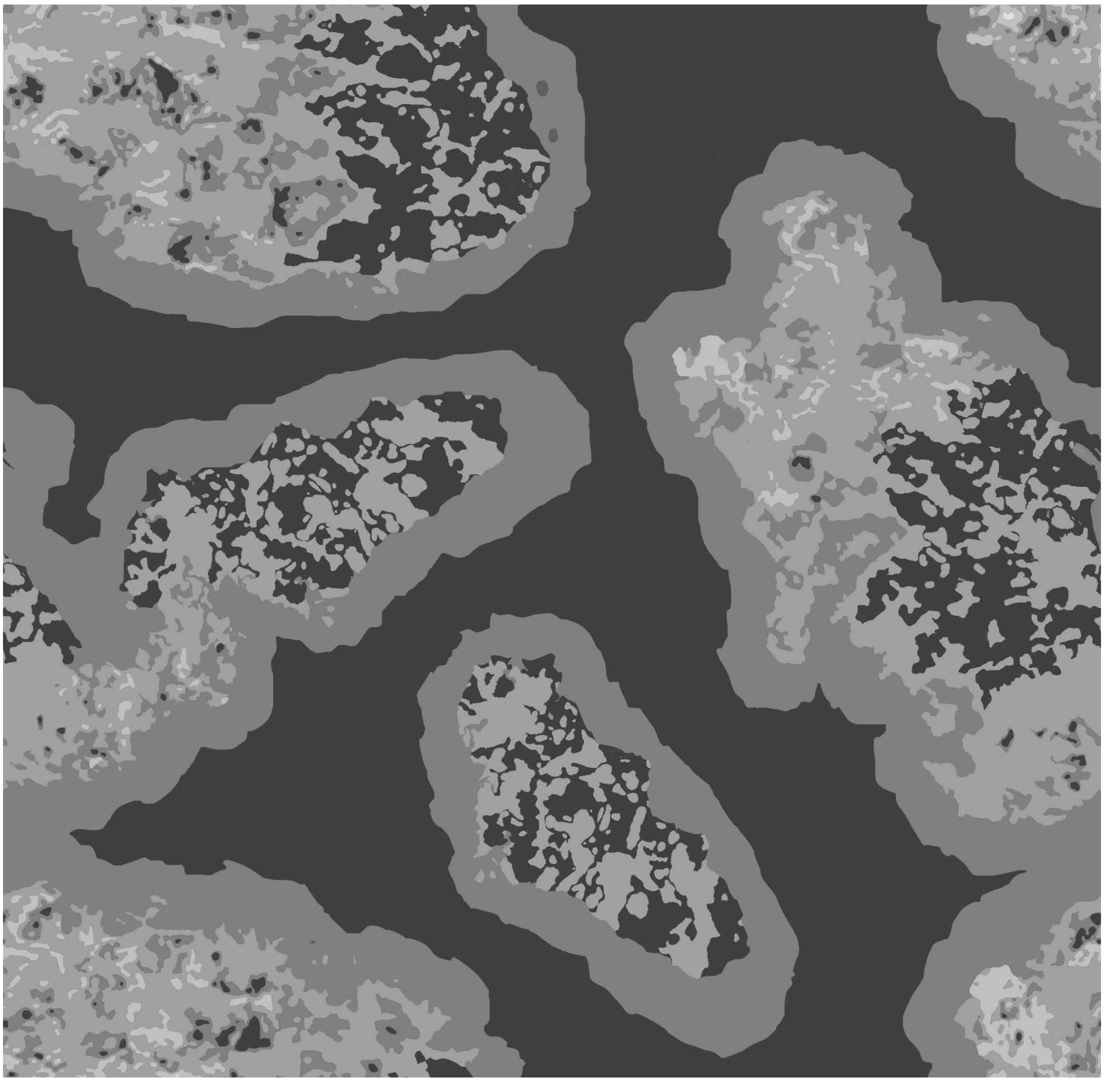

Fig. 12   Final block based on eczema image 2, ‘eczemaspl2c’.
The second palest grey area denotes where the silver will be.

5 Touching Textiles

'….we live in a society of the image, a markedly visual culture, in which, while there may be many representations of touch, there is often nothing actually there to feel'
Constance Classen

5.1 Introduction

This chapter elucidates the importance of touch to this project and how the research has been influenced by different approaches to touch in diverse spheres. The historic lack of importance given to the sense of touch in art history, and its recent re-evaluation due to advances in scientific knowledge will be addressed. It also challenges the neglect of touch in the appreciation of artworks. The significance to this project of the materiality of cloth and its textures and structures will be examined and how touching fabrics augments our perception of them. It will articulate the value of both tacit knowledge in making practices and process-led learning through tactile making, and how combining hand craft and computer skills has affected the development of the woven textiles. Finally, the challenges of developing touch-sensitive woven electronic fabrics will be addressed. Touch, in this research, is perceived as felt from within and without, the skin and textiles receiving and transmitting information.

5.2 The neglect of touch

Touch has generally been placed at the bottom of the aesthetic hierarchy of the senses, and this lowly status has led to the tactile appreciation of art being discouraged. The sculptor Rosalyn Driscoll notes: 'Touching of any sort is taboo for most artworks in most museums' (Driscoll, 2011:107). Attempts were made in Early Modern Italy* to promote the tactility of sculpture, with sculptors such as Giambologna (1529-1608) creating small bronze statuettes designed to be held and examined by collectors. These were intended to convey the tactile qualities of his larger sculptures which were often out of physical reach (Johnson, 2011:65). There was a long-standing practice of touching religious statues for devotional reasons and so the manual engagement with sculpture was not uncommon during this period (Johnson, 2011:66). The hand of the sculptor and his tactile engagement with materials was also believed to be important (Johnson, 2011:67-68). However, also during this period there were also many critics of the practice of touching artworks, the artist and art historian Giorgio Vasari (1511-1574) asserting that knowledge and judgements about art in particular were best obtained through vision rather than touch: 'it is necessary to have the compasses in the eyes and not the hand, because the hand works and the eye judges' ' (Vasari cited in Johnson, 2011:62).

The modernist art critic Clement Greenberg's promotion of disembodied vision entrenched the neglect of touch in the 20th century, stating ''most definitely, the need to have the picture occupy so much of one's visual field [is] that it loses its character as a discrete tactile object and thereby becomes that much more purely a picture, a strictly visual entity' (Greenberg cited in Jones, 2005:422). He also believed that sculpture should only be examined by the eyes (Getsy, 2008:108). The British art historian, Herbert Read (1893-1968), in a long running spat with Greenberg, tried to make a case for the tactility of sculpture, stating that 'Sculpture is an art of *palpation* – an art that gives satisfaction in the touching and handling of objects…….It is only as our hands move over an object and trace lines of direction that we get any physical sensation of the difference between a sphere and a square; touch is essential to the perception of subtler contrasts of shape and texture' (Getsy, 2008:111). However, it is still rarely permissible to touch artworks in galleries or museums, partly for reasons of conservation, preciousness and value.

Read particularly promoted the sculpture of Henry Moore (1898-1986). The only work of sculpture that I have touched is a piece by Moore, in the Yorkshire Sculpture Park – 'Reclining Figure: Arch Leg'. It felt permissible to do this as it is displayed outdoors, outside the conventions of the gallery. The bronze shapes were mostly smooth, warm where the sun had shone on them and cool in the shadows. The bulk of the sculpture could be appreciated by the eye, but the weightiness and solidity of the solid bronze cast could only be appreciated by touch. This multi-sensory appreciation of the sculpture enhanced and added agency to the work, and I felt a sense of loss in not being able to examine artworks elsewhere in this manner. This is indicative of touching textile sculptures, and this research attempts to redress the loss of touch in examining artworks by actively promoting this engagement.

One is expected to perceive 'the tactile within the visible' (Paterson, 2007:83) when experiencing artworks. Haptic visuality, whereby 'the eyes themselves function like organs of touch' (L. U. Marks and Polan, 1999:162) assumes the eye can stand in for the fingers, by imagining what the object might feel like through summoning memories of encounters with similar surfaces. This research argues that eyesight's tactile associations are not a substitute for the skin to object contact enjoyed by our senses of touch. Eyesight may be able to distinguish whether an item is rough or smooth but cannot tell if it is cold or warm. Sight '*is a grasping of essences'* (Kambaskovic and Wolfe, 2014); it leaves a superficial impression on our sense perception.

The humanist Benedetto Varchi (1502-1565) sums up: Vision 'is not the most reliable sense, indeed it often deceives ……[while] the most reliable sense is touch …..[W]hen we see something and we are doubtful about it, …..we use touch to verify it' (Johnson, 2011:70). This research aims to challenge the dominance of the visual by demonstrating that tactile apprehension can greatly enhance our appreciation of an artwork. It argues for the importance of physically touching an artwork in order to further understand it, and in particular for the importance of experiencing touch in combination with other senses. The multi-sensory appreciation of art augments not only our perception of a particular artwork, but of reality itself. Drawing attention to several senses at the same time gives us a more rounded, complete experience than the distant, remote encounter of using sight alone.

5.3 The re-evaluation of touch

Not only has touch been neglected in the fields of philosophy and art history, its importance has also been overlooked by most researchers in the domain of perception research (Gallace and Spence, 2014:340). This is possibly due to the fact that touch imparts less information to the brain than vision or audition (Gallace et al., 2012). In a table created from the data from three research projects, psychologists Alberto Gallace and Charles Spence have analysed information processing by different senses, which suggests 'the bandwidth of touch is lower than that of other senses' (Gallace and Spence, 2014:14). However, they argue that the results of this research are contentious as they do not take into account other factors. For example, the emotional and hedonic aspects of touch can outweigh other limitations (Ho and Spence, 2013). It is also important to note that our sense of touch is actually the complex product of the 'synergetic activity of multiple distinct neural systems' (Gallace and Spence, 2014:19) (see 4.3 for further details). In addition, recent research has shown that there are crossmodal correspondences between tactile and other stimuli, so that 'what we see, hear, and smell can all change what we feel through the skin' (Spence, 2011:85).

Depending on the object/surface being examined, one sense tends to dominate the others. For example, when the structural properties of an object are examined, vision tends to dominate over touch (Rock and Victor, 1964). However, in Charles Spence's research into roughness perception of the surface of pilled fabric samples, touch alone was more accurate than vision alone in assessment of the fabrics (Spence, 2011:89) . In addition, touch dominated vision when assessing the comparative roughness of samples (Spence, 2011:89). Auditory cues can also have a profound influence on tactile perception, as Jousmäki and Hari's 'parchment skin illusion' exemplifies (Jousmäki and Hari, 1998). The research showed that people's perception of the feel of the skin on the palms of their hands was greatly affected by the sounds that they heard whilst doing this. Research such as this has influenced my project greatly, highlighting the fact that our experience of objects and surfaces is far more multi-faceted than we realise. One aim of this project is to draw attention to the multisensory dynamics of touch, interacting with the garments suggesting that hearing the sounds of fabrics being touched can enhance our experience of them.

Despite the fact that artists, designers and craftspeople have employed the sense of touch for the creation and perception of their work, very little scientific research has been conducted to investigate this topic. This is particularly true in relationship to the more hedonic aspects of tactile perception. There is a lack of shared language to describe tactile sensation in relation to aesthetic perception. Insufficient research has been conducted into what materials and textures people like and dislike touching (though see section 5.4.1 and Dacremont and Soufflet for examples (Dacremont and Soufflet, 2006).

As has been stated previously(p.36), the sense of touch is the first sense to develop in the womb (Benthien, 2002:7). Factors that might affect our perception of tactile aesthetics may be founded on those early experiences; for example we are more likely to associate sensations that are soft and warm with those that are pleasurable than not. Gallace and Spence (Gallace and Spence, 2014:293) have suggested that these types of pleasurable sensation should be considered to be 'beautiful', in terms of an aesthetics of touch. Certain parts of the brain, such as the orbitofrontal cortex, specifically respond to tactile experiences that are perceived to be pleasant, such as the feel of velvet on the skin (Francis et al., 1999). 'Somehow, from the artist's perspective, touch seems to lead to a closer, more sensuous, and deeper knowledge of reality as compared to the visual modality…. For this very reason, tactile art appears to be more perceptual and emotional than conceptual in nature' (Spence and Gallace, 2014:280-281). As will be discussed later in this chapter, the emotive effects of touching certain textiles, whether positive or negative, can affect greatly the choice of fabrics we wish to wear next to our skin. This factor has influenced the design of the 'eczema' textiles, the rough surface of the fabrics creating interactions around perceptions of tactility and beauty.

The recent research into the multisensory perception of touch has implications for designers. If products are designed with an understanding that other senses can affect tactile perception, this should create a more rounded experience for the user. In addition, an understanding of tactile aesthetics and multisensory perception could be helpful to fashion designers in designing garments that affect the mood of the wearer. It could also influence the design of environments that enhance well-being and design for people with sensory impairments. My textiles are not intended to enhance well-being, but their interactive technical aspects could be utilised in these types of environments.

5.4 The Materiality of Cloth

'Across diverse disciplines, there is a re-engagement with materiality. For many, weary of the demands of the computer screen and the relentless advertising of corporate brands, there is a desire for tactility and sensorial experience, to touch and make material things.' Anne Wilson

As suggested in the quote above, the materiality of things is becoming increasingly important as an antidote to the digital realm where tactile engagement, if available, offers little in the way of texture. The next section examines the significance of the materiality of cloth in the creation and perception of textiles.

5.4.1 Materiality in domestic textiles

One's first instinct, after visually selecting a textile or garment, is to touch it to test its softness, crispness, smoothness, texture or other tactile attributes, because of its proximity to the skin. The materiality of cloth is so fundamental to our lives that it is often overlooked. Many fabrics are specifically designed for their sensorial qualities (as well as other aesthetic attributes), such as the softness of cashmere, the crispness of cotton poplin shirting, or the smoothness of silk satin. However, the mass production of textiles for fast fashion has reduced the variety of textile surfaces readily available for purchase and there is consequently a loss in materiality (Clark, 2012). Fast fashion fabrics are designed to create a particular 'look' and are often flimsy and not intended for long term use. Consequently, there is no incentive to spend time and money on creating fabrics that have quality surface interest. The textiles produced in this project are intended to counteract this trend.

The textile industry has two main systems for measuring fabric texture and handle*, the FAST and KES-F systems. The FAST (Fabric Assurance by Simple Testing) was developed in Australia to test the suitability of wool fabrics being made into garments (Li and Dai, 2006). It measures how well fabrics resist deformation* (Giorgio Minazio, 1995). The KES-F (Kawabata Evaluation System for Fabrics) is more sophisticated than FAST, and objectively tests fabric properties and fabric handle (Li and Dai, 2006). An additional trial for upholstery fabrics is the Martindale test, which measures abrasion resistance (Textor et al., 2019). All these tests are very technical and are performed by machines or computers. This is to give consistent results, but somewhat removes the human end-user's sensory system from the equation. The tactile properties of the fabrics are limited to the mechanical and do not include the affective. This research draws on this knowledge but as part of an artistic project.

Tactile experiences of fabric can relate to cultural and emotional contexts. In research into the responses of American and Chinese design students (Delong et al., 2007), the Chinese students reported strong emotional associations with touching silk fabric, often linked to memories of silk clothing worn by female members of their family. They also much preferred woollen textiles to the American students, the latter finding them rough and scratchy. This could be because wool is considered a luxury item in China but is much cheaper in the USA. This suggests that the perception of value influences the perception of touch, as well as social and cultural factors. However, overall 'there was a universally expressed preference for soft over rough, smooth over coarse and familiar over strange'.

The FAST and KES-F tests do not take into account the designers' tactile perception when creating the textiles (Petreca et al.). There is an imbalance in how the tactile experience of textiles is assessed between different industries. Textile technology offers objective approaches, whereas designers use tacit and implicit knowledge. The textile designer Reiko Sudo describes how she develops her designs: 'The first image that comes to mind is the feel and touch of the material, its texture. Before considering its use, I always begin with how coarse or smooth it feels. I use my fingertips' (Hara, 2004:162). This is also true of my design approach; the potential tactile qualities of the cloth are paramount.

In developing the textiles in this research, the priority has been to focus on the tactile nature of the fabrics as this has influenced and informed other aspects of the project. In general, textiles are designed with a view to feeling comfortable next to the skin. However, the aim in this research is to produce textiles that create friction through their uneven surfaces, as more friction will create louder sounds. The creation of the textiles has necessitated an intuitive understanding of how structure and materials interact. The anthropologist Tim Ingold states: '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' (Ingold, 2013:29). This tacit knowledge, often under-acknowledged, emphasises the importance of touch to this project, not just to the wearer of the garments, but to the maker.

5.4.2 Materiality in art textiles

Art textiles offer a different approach to the materiality of cloth compared to the technical methodology of textile technology. This is a useful reference in positioning my research within an artistic field. Artistic approaches which use textiles seek to evoke sensations and memories associated with the everyday use of fabric or refer to the ciphered associations of cloth (such as feminism, psychoanalysis or the relationship between text and textiles), without being useful.

The emphasis in art textiles is often on cloth and its relationship to the corporeal, due to its capacity to refer to the human condition. The artist and academic Maxine Bristow states: 'In common with other objects of material culture, I would suggest that it is this embodied non-verbal materiality of the medium that makes textile a particularly potent vehicle of cultural and artistic expression. Placed in direct proximity to the body, implicated in practices, rhythms, and routines of our everyday experience, and continuously and invisibly negotiating the relationship between self and other, it provides us with what may be a silent yet undoubtedly powerfully convincing testimony' (Bristow, 2012:49-50). The textiles created in this project, although potentially usable as couture fabrics, are presented as an artistic study, examining their reference to the body, as well as scientific research and philosophy of the senses. The fabrics have an exaggerated surface; they are meant to be touched and have their surfaces investigated. The intention is to create a dialogue between worn textiles and an artistic representation.

5.4.3 Materiality in electronic textiles

As has been stated previously (p.33), most e-textiles are sewn or embroidered on ready- made fabrics; very few have been woven specifically for projects. Most e-textiles have little surface texture, with the exception of those created with the specific aim of enhancing people's sensory experience, particularly in the case of healthcare environments. E-textile products developed for enhancing the lives of those with autism or dementia are of particular interest. One of the intentions (see objective 3, p.11) of the project was to expand the possibilities of woven electronic fabrics by introducing enhanced surface textures that facilitate interactivity. The materiality of the conductive cloth and its textures and structures is fundamentally important to this interactivity as they enable the varied sonic output of the fabric.

5.5 Weaving

The medium of woven textiles has been chosen for this project for two reasons. The first is that woven textiles are an integrated structure. This allows for the development of a variety of surfaces and textures, from the smooth to the three dimensional. This is crucial to creating a fabric which would have sufficient surface variability to emit a range of sounds when touched – an even textured fabric would not do this. The weaver Anni Albers stated that the structure of woven textiles in combination with the yarns chosen can bring about interesting surfaces, and that it essential to have a good knowledge of weave structures in order to create surface effects (Albers, 1974:64-65).

Secondly, weaving with conductive thread enables large areas of fabric to become conductive as the conductive thread is integral to the fabric. It is also much easier to achieve than embroidering conductive yarn onto pre-woven fabric, and creates more reliable electronic circuits. Large conductive areas are necessary for this project because in order to trigger the sound of the textures of the cloth, the hand must stroke across the fabric of the garment. Some of the fabrics produced were hand-woven on a jacquard loom, with threads that could not withstand commercial manufacturing, a very labour-intensive process. Most were woven on a power jacquard loom at R.A.Smart. These fabrics were woven entirely from yarns that can tolerate power loom production and thus can be woven at much greater speed and produced in greater quantities.

5.5.1 Learning about touch through weaving

Weaving is a very technical method of producing a fabric, requiring an almost intuitive knowledge of mathematics and binary coding. It is also necessary that the weaver is very systematic in their approach to making the warp*, threading and denting and then weaving it, otherwise minor mistakes can have major consequences, such as faults running throughout the fabric. Weaving is a generative system*, where elements of the proposed design are pre-planned. The order of the coloured threads in the warp and weft in combination with how the warp is threaded and the weft lifted generates the structure and pattern. Every minor change to the system generates a different structure and pattern. In weaving, rigorous planning is combined with process-led experimentation with structure and materials. The more the design process tends towards process-led experimentation, the more innovative the resulting textile.

The development of the conductive fabrics for this project has relied on a combination of hand craft skills and computer-aided design (CAD). Both of these have their advantages and disadvantages. The former allows for an intuitive tactile exploration of materials and form but can be very slow, whereas the latter greatly reduces the amount of time spent pre-planning weaves but only visualises the end result. There is no ability to touch the design and perceive what it feels like in the hands. Anni Albers comments: ‘Modern industry saves endless labor and drudgery; but, Janus-faced, it also bars us from taking part in the forming of material and leaves idle our sense of touch and with it those formative faculties that are stimulated by it’ (Albers, 1974:62). Sampling was conducted on a dobby* loom and then on a hand jacquard, and also on a power jacquard. Many samples (p.159-180) were woven on the hand jacquard loom to test combinations of yarns and structures, the main aim being to develop a fabric that is highly conductive, has a three-dimensional surface, and resembles eczema.

The parameters of the research have dictated that the textiles have to be made from silk and silver yarn, because they reference the fibres utilised in medical textiles and the treatment of eczema. This has caused both problems and opportunities. One of the problems has been that there is an extremely limited range of highly conductive silver yarns that can be woven on a power loom. Initial trials were conducted on a hand dobby loom to test the conductivity of several silver yarns as weft on a silk warp. The yarns were woven in blocks, using structures where the silver was fully or partially on the surface of the fabric (p. 159). Two yarns were selected, one from Statex and the other from Karl Grimm (p. 181). These yarns were then tested on the power loom at R.A.Smart with simple jacquard designs based on a print of eczematous skin. The Karl Grimm yarn proved to be unsuitable as it would not weave on the power loom, which has a rapier* action, the yarn being too slippery to transfer from one rapier to the other. The Statex yarn proved to be very successful on the loom, and the resultant fabric performed well when tested for conductivity (p. 160).

Trials of the conductivity of the fabrics showed that it would be necessary to have as much silver yarn in the weft as possible, particularly on the surface. It was ascertained that the type of structure most suitable to achieve this was brocade, which has historically been used to weave luxury textiles, often made from silk thread and yarn wrapped in precious metals. It is found in textiles around the world going back several centuries, from Renaissance Italian brocaded velvets to Indian wedding saris and English Spitalfields silks. The textiles produced in this project refer to these historic textiles but bring the use of fabric woven with precious metals into the 21st century by combining them with electronics.

Fig. 13 Section of a silk and gold-plated silver brocade shawl , Varanasi, India (1984)

However, these historic textiles have a relatively flat surface and this research has developed a brocade structure that has a 3D surface. Brocade is woven thus: a background colour is woven (this is known as ground weft*), then subsequent wefts create the pattern of the fabric (these are known as extra-wefts*). Most jacquard brocades have several extra-wefts that create the coloured pattern. It became apparent through the first trials that only one extra-weft should be used (the silver yarn) in order for the fabric to be as conductive as possible (p. 160). Wefts in other yarns/colours would reduce the quantity of silver in the fabric.

The surface of the initial brocades was too flat (pp. 161-168). This was in large part due to the researcher being overly influenced by the Photoshop images that became the artwork for the jacquard designs. The photographs of eczema were edited so that they became 2D images with a very limited range of colours. It then became very difficult to imagine how those flattened images might represent a fabric with a 3D surface. Joseph Lim states 'When the representational means becomes the media in which the design process operates, then the construction/material system is constrained by the representational means' (Lim, 2009:9). It was only by manually experimenting with different ground weft yarns and testing structures in different areas of the design, that it became possible to develop textiles with a more 3D surface.

CAD can save a huge amount of time in the weave design process: jacquard weaving prior to computerisation involved drafting designs on graph paper and then hand-punching cards to be attached to the jacquard mechanism on the loom. This could take several days. Nowadays the same process could take half a day. There are great similarities between weave notation and computer software as they are both binary systems, and in fact the earliest computers were based on the punch card system of the jacquard loom (Essinger, 2004). Most weave software converts photoshop image files into binary coding that instructs the loom to lift certain threads that will create the pattern. However, an emphasis on designing with computers can lead to a lack of engagement with materials and how materials and structure react to one another. Rachel Philpott conducted her doctoral research into 3D textile structures based on origami-type folding techniques. As in this project, she used a combination of hand and CAD techniques. She also found that an over-reliance on CAD was detrimental to the development of her designs. 'My use of the computer software simplified the design process, however, this came at the cost of a full, embodied understanding of the relationship between the two-dimensional representation of the origami pattern and its three-dimensional folded form'(Philpott, 2012). CAD also distances manual touch from the design process. When a 2D image is displayed on a computer screen it is difficult to envisage the tactile nature of the textile design.

Fig. 14 Design 'myeczema'

The silk yarn used for the warp on the hand jacquard was chosen for its suitability for the loom setting and its low pilling* properties. The warp yarns at R.A.Smart were their standard supply of Italian silk filament*. A number of silk weft yarns were trialled on a silk warp; initially plain weft yarns were used (p. 181) but it became apparent that in order to create brocade weaves with a 3D surface, it would be necessary to experiment with shrinking silk yarns in the ground weft in order to allow the silver extra weft areas of the design to become more prominent. Only two shrinking silk yarns have been found, the first a black pure silk z-twist crepe* yarn from Japan, the second an ivory silk and spandex mix from Belgium. It was not possible to weave the Japanese yarn on a power loom. This is because the yarn is hand-twisted on an ancient hacho nenshi silk throwing machine and can only be reeled onto traditional wooden bobbins. The bobbins would not fit onto the cone holders on the power loom, and it was not possible to transfer yarn from the bobbins onto a modern cone as the thread broke under tension. Initially the silk and spandex yarn was rejected, as it is not pure silk and therefore less suitable for eczema sufferers. However, it was decided to use it as the textiles refer to the treatment of eczema and are not intended to be used in the treatment of it, since this research is through an artistic investigation. The silk and spandex yarn also gave by far the best results in terms of achieving a fabric with a 3D surface. Initial trials were not very successful because the choice of structures was not suitable for achieving the required effect. The fabrics had a slightly wrinkled texture (pp. 157-158)

The structures were changed from those that were quite similar to each other in terms of warp and weft ratio, to those that were dissimilar: satin* and sateen* (pp.182-183) structures where the warp or weft floats across eight threads, in combination with structures that only cross one or two threads (such as plain weave* or 2 and 2 twill). This meant that some structures were loose and others were tightly woven. This allowed the shrinking yarn to pull in parts of the design after washing, so the other areas were pushed up. A length was woven of this fabric. However, the overall effect was that of a ribbed fabric (fig. 16), whereas a textile with less evenly distributed areas of protrusion was desired as this would be most similar to the surface of eczema.

Fig. 15 Design 'MMU11silber4' prior to washing

Fig. 16 Design 'MMU11silber4' after washing

Fig. 17 Design ‘MMU1924’ before washing

A breakthrough was made by weaving a narrow area around the shapes to be woven in silver yarn with both wefts together in a closely woven structure. This was facilitated through altering the way that the Scotweave software inserts the weave structures into the designs. The default process of inserting extra-weft weave structures into a design is managed by the software, but this did not allow me to weave both wefts together, as described above. I created compound weaves (pp.182-183) that combined the ground and extra-weft within the same structure, that overrode the software’s default method of creating extra-weft structures. Weaving both wefts together had the effect of compacting the narrow area around the shapes which made the silver area in the middle of it bulge up (figs. 16 and 17). Prior to this, the silver extra weft floated across the entire back of the fabric when not showing on the surface. In these designs, the Statex yarn was replaced by the Karl Grimm yarn as it is thicker and shinier, producing fabrics which were heavier and more varied in surface. A length was woven of this fabric. It became apparent during the weaving process that weaving two wefts together in certain areas caused a build-up of weft, causing problems with the tension of the warp. This was taken into account when designing the subsequent textiles, and the build-up areas were more evenly distributed across the cloth.

Another factor learned from weaving 'MMU11silber4' is that as few weave structures should be used as possible – no more than six, and that the jacquard designs should have larger areas of each structure than previously used. This combination of design elements created the cloth with the most 3D surface so far as this allowed each area to bulge up or down more prominently. It became apparent that simplicity of design and reduction of choice (of yarn and weave structures) produced the most successful designs of fabrics with 3D surfaces.

Fig 18 Design 'MMU1924' after washing

Sampling then took place on the power looms at R.A.Smart. Despite testing yarns and weave structures on the hand jacquard loom, weaving them on the power loom altered the results, due to different warp yarns and different loom settings. In addition, the samples woven on the hand jacquard had mostly employed the Japanese hand-twisted yarn as the ground weft, but this would not work on the power-looms so the silk and spandex yarn was used. The Japanese yarn tended to create a ribbed effect, which was useful in that it resembled the texture of dry skin associated with eczema. However, it did this in areas where it was not necessarily desired. The silk and spandex yarn did not form ribs and also shrank more than the Japanese yarn, (50% and 32%) thus creating a more 3D surface and a more varied surface. There were initial problems with a build-up of weft in the double weft areas, but this was ameliorated by slightly reducing the pick* count. The nature of the looms and the silk warps at R.A.Smart created a much denser fabric than could be hand-woven, so that the fabrics felt similar to taffeta* before they were shrunk. This was an unexpected bonus, as silk taffeta is one of the stiffest and noisiest of fabrics and was historically used to make ball gowns that sonically announced the arrival of the wearer (see p.27).

Five of the final seven designs woven at R.A.Smart were actually based on one photograph of eczema (fig. 7, p.51). This was interpreted for weaving on both the black and ivory warps, but at different scales, the design for the black warp being smaller than that for the ivory. In addition, there were two different versions of the ivory design that arose from moving around the structures into different areas. This exemplifies how experimenting with combinations of yarn and structure can produce varied results from the same source. Two fabrics, one with a black background and the other with ivory, were used for the lining of the garments and were woven without the silver or shrinking yarn in the weft, so they were pure silk.

Fig 19 Design ‘ivoryblockc’ (silver rib) after washing

Fig. 20 Design ‘eczemaspl2c’ (blackblob) before washing

Fig 21 Design ‘eczemaspl2c’ (blackblob) after washing

5.5.2 Weave research conclusions

The problems of finding suitable yarns were partially compensated by the opportunities that have arisen. By restricting the materials available, greater inventiveness has had to come into play. Anni Albers suggested that self-imposed rules often benefit the design process (Albers, 1971:64). As stated previously (p. 82), simplicity and reduced options can often produce the most beneficial results.

The colour palette also had to be restricted. The silk yarn chosen for the warp of the jacquard loom at MMU could have been dyed any colour, but the looms at R.A.Smart have warps solely in ivory and black silk. The structures that were developed required two wefts – one needed to be the conductive silver yarn and the other a shrinking yarn. The only two shrinking silk yarns available come in black or ivory. Hence the final fabrics had to be monochrome and silver. But there are also advantages to this restriction: the lack of colour makes the textures of the fabrics more visible. The Japanese designer, Kenya Hara, is well known for the avoidance of colour in his designs and his interest in tactility. Writing about Hara, trend forecaster Li Edelkoort states 'He is a color escapist because he knows that by avoiding color, tactility can and will speak up' (Hara, 2007:9). If the fabrics had been woven from coloured silks along with silver, the colour would have visually interfered with the surface textures, so that the tactility of the fabric would not stand out.

Although the computer software (Photoshop and Scotweave) saved a great deal of time in planning the weaves, it created a disconnect between the inspiration for the textiles and the medium and materials. In retrospect, it would have been better to make 3D tactile models as the basis for the weaves, rather than flattened images. Using Photoshop as the starting point of the designs was detrimental to their development, as there was too much focus on the 2D. The use of embodied knowledge would have been beneficial, for example handweaving without using any computerisation to gain an understanding of materials and structures before commencing work on CAD. Philpott states 'Making processes that rely entirely on CAD/CAM not only remove opportunities to develop embodied knowledge of the materials of the craft but also reduce practitioners' chances to gain embodied knowledge of aspects of the making process. This can have a negative impact on the development of a comprehensive understanding of methods used' (Philpott, 2012). A hybrid practice using hand and machine skills can produce innovative results, with a focus on an intuitive response to materials rather than over-reliance on planning designs on a computer.

5.6 Touching surfaces

The textiles created in this project have been designed to induce tactile exploration through their variable surfaces. Although the eyes are initially drawn to a surface, only through embodied interaction can we really understand it. The sculptor Rosalyn Driscoll says of tactile art - 'It is intimate, drawing us into relationship with what we are touching. It is active rather than passive, requiring us to reach out and explore. It grounds the experience in perception rather than concept. Aesthetic touch deepens our knowledge of sensuous reality. We recognize an apple by looking at its colors, shape and size; by touching it, we come to know its weight, mass, temperature, texture and ripeness. If we are touching a sculpture, we feel the massing of forms, the texture and temperature of surfaces, the qualities of materials, the nature of spaces.'(Driscoll, 2011). Haptic technologies embedded in tactile art and design items can draw attention to tactile perception, as well as enhancing our experience of an object.

5.6.1 Touch screens

As has been discussed in 1.2 , the skin on the palms of our hands is covered with highly sensitive receptors which feed information to our brains about that which is being perceived or manipulated. Haptic technologies that have sensors embedded in them, such as touch screens, have been developed to respond to human touch. In addition, touch screens can align tactile, auditory and visual signals, as when sending a message on one's phone, one finds the app icon visually, presses it, types in the message, and when that message has sent, the phone emits a pre-determined sound. This integration of multisensory information aids the intuitive use of touch screens.

However, there is very little tactile feedback from touch screens and the surface interest from these devices is minimal. The hand is 'no longer the prehensile organ that focuses on effort: rather nothing more than the abstract sign of manipulability, to which buttons, handles and so on are all the better suited. The invention of touch screens, interactive monitors which dispenses with the keyboard and mouse, making computers easier to use than ever, would appear to bear out Baudrillard's theory that the increase of tactile experience in the media age has not necessarily produced an enrichment of sensory perception' (Jütte, 2005:239). The textiles that have been developed in this project resemble large, flexible, rather unsophisticated touch screens (in that the sensor used can only detect proximity of touch, not direction or pressure). However, the fabrics do have a great deal of surface interest. As the fabrics are woven with silver throughout the weft, there is no possibility of differentiating responses to the various textures. Each woven texture would have to be isolated (separated from the other conductive areas) and programmed separately, which would be very complex. The textiles are intended to be an antidote to the traditional smooth surfaces of touch activated electronic devices. Like a smart phone they utilise multisensory integration.

5.6.2 Capacitive sensing

The electronic sensors used in both touch screens and this project are known as capacitive sensors. These sense proximity by generating an electric field and then detecting whether this field has been disrupted. They can identify any conductive object. Sixty percent of the human body is made of water; the water contains electrolytes* which are conductive, meaning that capacitive sensors can detect human presence. The code for the sensors can be calibrated to detect distance from the sensors; for example, this can be set to be activated one metre from the sensor or through direct touch.

One notable project that has investigated the use of capacitive sensing in garments is Google's *Project Jacquard* (Poupyrev et al.) Google developed their own conductive yarns that have a copper core and are covered with braided yarn so that they look like normal yarns but are also solderable. After many fabric trials they decided to limit the capacitive sensing area to a small patch on the sleeve of garments. The conductive threads are woven on a 3D jacquard loom, floating through a pocket in a double layer fabric so that they can be isolated, then stripped and soldered to the components. The yarns on the top layer are woven in a grid, and like a touch screen can detect direction of touch. The bespoke electronics are connected via Bluetooth to the user's phone, different types of touch triggering different applications on the phone.

<u>5.6.3 Development of the electronics</u>

The characteristics of the conductive yarn have been crucial to this project also, and trials of different yarns were the first to be conducted. Through research into other projects, in particular Kobakant's 'How to Get What You Want' (Perner-Wilson and Satomi, 2019), it was possible to discover which yarns had proved to be the most successful in terms of conductivity. However, as most electronic textiles are sewn or embroidered, (including Kobakant's projects) and the yarns in this project were being woven, different properties were required. As stated in 5.5.1, several yarns were selected, some from Statex GmbH and some from Karl Grimm, both in Germany. The yarns from Statex are a very fine silver coated polymer, which are mainly intended for weaving, and are often used for radio frequency shielding* as well as medical and smart textiles. The yarns from Karl Grimm have a much thicker layer of silver and are solderable. They can be used in electronics, but in the past have been used for passementerie* and military braids and are very decorative.

Initial research into touch-activated textiles involved working with microcontrollers that can be used in sewn electronic circuits, such as Adafruit Flora and LilyPad Arduino. Both use the Arduino platform, an electronic prototyping system of hardware and software, where users can develop interactive creative projects. The first experiments with capacitive touch were set up so that the conductive area to be touched was isolated from the rest of the fabric (185-191). An LED illuminated when the touch sensor was triggered. However, individual spots of conductivity would not be suitable for this project as the aim is to hear what a large area of fabric with a 3D surface sounds like when touched. In addition, each area would need its own touch sensor. It was decided to abandon this approach and focus on developing fabrics where the conductive thread runs throughout the weft. It also became apparent that microcontrollers that are connected via sewn conductive thread are very temperamental as the combination of flexible fabric and thread creates unreliable connections, even when the thread is sewn tightly to the fabric.

It was then decided to use Teensy* hardware (which also uses the Arduino platform). These are bulkier than sewn hardware but can be soldered; the Teensy audio board also has a superior sound output to the sewn audio components. The audio components for the latter deliver a poor quality 'tinny' sound, not suitable for amplifying the very quiet sounds of textiles being touched. The Teensy would have to be placed in a small pouch or pocket in the garments, with soldered insulated wires coming from it and then being attached to the conductive fabric. Eventually the Teensy hardware was abandoned as it was felt that programming the audio interface to connect wirelessly to the speakers was beyond this researcher's capabilities.

Audio-engineer Chris Ball was employed to develop the interactive electronics and set up the components as follows: a capacitive touch board (MPR121) is connected to an Adafruit Feather 328P board (p.192). The touch board is also connected with a fine insulated wire to the fabric so that when the fabric is touched the capacitive sensor will be activated. This triggers the Feather board to send a message to a radio receiver, which is encased in a separate box (p. 193). The radio receiver is connected to a Wav (sound file) trigger board that has an SD card in it with the pre-recorded sounds of the textile being touched. The Wav trigger board can also be connected to speakers or headphones. When the message is received that the textile has been touched, it triggers the pre-recorded sound of that textile being touched.

One length of electronic fabric was exhibited at the IFFTI* conference (p. 210) in Manchester in 2019 (Haire, 2019), using the above set-up. It proved to be successful though very temperamental. The electronics were first tested at home on a small piece of the textile that was to be exhibited and there were no problems. However, when the full-length fabric was set up with accompanying electronics in the exhibition space, the capacitive sensing code had to be re-calibrated, as it was a larger piece of fabric in a larger space with metal strips in the flooring, so the capacitance* had changed and touch detection was weak. Moreover, when we returned the next morning, there were far more people in the building so the capacitance had changed again, and the sounds were being emitted one metre away from the fabric. The textile is not supposed to make a sound unless it detects direct contact. In addition, the sounds generated were not of the fabric, but an eerie very loud feedback*-type sound. The code was again re-calibrated and the textile worked successfully.

It is relatively simple to develop electronic textiles where an LED is illuminated or a sound triggered when an isolated conductive area is touched. It is far more complex to make a large area of conductive textile respond reliably to capacitive sensing due to the interference of surrounding conductive objects or bodies. The flexible nature of fabric can cause major problems with connectivity. Sewn circuits are not reliable, and ideally soldered wire should be used to connect components to each other and to the fabric. The wire also needs to be insulated to prevent short circuits*. In an electronic circuit, ‘touching’ can be both beneficial and a problem: if one conductive component touches another it can either complete a circuit or break it, depending on where and how the components touch. Electronic sensors that detect human touch can evidence the delicate nature of this faculty through interactivity, but the sensors themselves are also delicate, responding to both direct touch and the surrounding environment depending on how they are programmed.

6 Surface Sounds

6.1 Introduction

This research sits partially in the category of sound art, a contested space where fine art and art music intersect. In order to situate this project in an expanded field, this chapter briefly documents the changing attitudes to hearing natural and man-made sound since the period of the classical world, and the significance of audio technology that augments our capacity to listen. It will then describe how these changes led to the development of sound art, how and why the project is situated in this field, and where it identifies a gap in existing knowledge. The chapter goes on to investigate audio-tactile interactions in relation to textiles, the development of the fabric sound recordings, and the perception of the sounds of fabrics being touched.

6.2 Hearing

'We have no ear lids. We are condemned to listen. But this does not mean our ears are always open'. R. Murray Schafer

Hearing is arguably a more passive experience than looking or touching but listening is selective (Schafer, 1994:11). We can choose to focus on certain sounds yet disregard others as background noise. The sound of fabrics being touched would generally be regarded as the latter, but in this research the aim is to bring these background noises to the fore, to draw our attention to an element of the under-appreciated everyday sonic environment. Clothing is ubiquitous and we are rarely cognisant of the noise that it makes, partly because its sounds are generally quiet. As with most everyday sounds, they are also not valued. By elevating the sounds of fabrics to art, the value of those sounds is increased so that the experience becomes more multi-sensory.

The hierarchy of sounds exists within the hierarchy of the senses. In the classical system, hearing generally appears second, after sight but before the proximal senses of taste, touch and smell. It was valued in the mediaeval Christian and Jewish faiths, as it was the receiver of religious instruction and divine utterances (Jütte, 2005:66). The development of printing technology in the fifteenth century accelerated the move from hearing words to seeing them (Schmidt, 2003:42). Oral culture was transformed into one where the visual dominated and people became silent readers of texts rather than engaged social listeners (Schmidt, 2003:42). Modernism graded and individuated the senses further, sound being isolated from exterior experiences by hi-fi technology at home (acousmatic sound*) and the acoustically separate concert hall, in opposition to former social auditory experiences (Jones, 2005:408).

Advances in audio technology enabled the capture of sound in much greater detail. However, the technology was mostly reserved for recording music, high culture in particular. At the same time, the background noise of the modern urban world became problematic, New York forming a Noise Commission in 1930, where the aim was to reduce urban environmental sound. It became desirable to block out the sounds of the city through sound proofing. Acoustic sciences developed technology that reduced one type of sound whilst at the same time inscribing and amplifying others (Jones, 2005:401). However, despite the focus on musical sound, advances in audio-inscription have also enabled us to hear the extraordinary sounds of nature, such as in Sir David Attenborough's television programmes about the natural world. The wildlife sound recordist Chris Watson has contributed greatly to this field, including Attenborough's films (Watson, 2020). Through this technology and the amplification of sound it is possible to hear what had previously often been inaudible. This project would not have been achievable without these developments. The opportunity to hear very quiet or inaudible sounds through technology that augments the sensorium has influenced and informed this research. The domestic sonic environment, like the natural one, is frequently ignored. In order to bring these sonic phenomena to the fore, it is necessary to use high quality recording equipment alongside amplification.

The ’slow’ movement (Wikipedia, 2020) has also informed the project. This movement is a reaction to the fast pace and stress of modern life, encouraging us to slow down and pay more attention to the world around us. The BBC currently broadcasts ‘Slow Radio’ features, where one may listen to birdsong, or the sound of a dishwasher in action. Isolating everyday sounds draws attention to them, making us focus on what is usually in the background. There is a type of hearing loss associated with the modern world, where we listen to music, audiobooks or podcasts on headphones, cutting us off from the sonic world around us. Isolating sounds has its drawbacks and benefits. We are able to listen in a more focused manner but cannot hear the sonic layering of the wider soundscape. The textiles in this project were recorded in a sound-proofed music studio, where there was no extraneous sound. However, when the sounds are activated through touching the textiles, they are heard alongside whatever sound is being produced in the wider environment. The sounds are amplified so that they are raised above the environmental background sounds yet are still mingling with them. They mediate the conflict between environmental and inscribed sound, between background and foreground noise.

6.3 Art Music to Sound Art

The domestic sounds and songs that accompanied everyday life gradually developed to become the formalised, organised sound known as art music (Shaw-Miller, 2011:253), the pitch* and time duration of each note being documented by written notation. Around 1800, as the Industrial Revolution was gathering pace, music began to free itself from its context to become an autonomous, ‘absolute’ music (Shaw-Miller, 2011:253). Listening to absolute music in formal concerts became a quasi-religious experience, where extraneous environmental sound was removed and quiet contemplation was encouraged (Shaw-Miller, 2011:254).

The composer R. Murray Schafer (b.1933), stated: ‘Absolute music is disengaged from the external environment and its highest forms (the sonata, the quartet, the symphony) are conceived for indoor performance. Indeed, they seem to gain importance in direct ratio to man’s disenchantment with the external soundscape.

Music moves into concert halls when it can no longer be effectively heard out of doors. There, behind padded walls, concentrated listening becomes possible. That is to say, the string quartet and urban pandemonium are historically contemporaneous' (Schafer, 1994:103). Schafer also noted that concert halls and art galleries in urban environments had become a 'substitute for outdoor life' (Schafer, 1994:104), the sounds of a diminishing natural world being evoked in 'programmatic'* music at the same time that landscape painting developed as a genre in its own right.

There were several attempts in the twentieth century to introduce environmental sound as high culture, firstly by the Futurist, Luigi Russolo (1885-1947). He questioned the avoidance of environmental sound in his 1913 manifesto 'The Art of Noises'. He believed that musical sound was self-referential and did not reflect the soundscape of the modern world. His stated aim was to open up music to all sounds, whether those be rural nature-based sounds, or the cacophonous sounds of industry or the city. He developed noise-making devices named '*intonarumori'* to create his sounds (Kahn, 2011:30) , and categorised the types of noise to be created into 6 groups (Russolo, 1913) (p. 150). Most of the noises were created by audio-tactile interactions. The '*intonarumori*' were made from wooden boxes which had a variety of internal constructions. The sounds were activated by the performer via a handle attached to the boxes.

Musique Concrète continued this interest in environmental sound yet banished any imitation of it. Pierre Schafer (1910-1995) made recordings of sounds, which he then edited to remove the sounds from their referents, thus musicalising sound (Kelly, 2011:15).   John Cage (1912-1992) developed these ideas further by stating that all sound could be thought of as music. In his ground-breaking work *4'.33"* (1952), Cage's 'score' instructed the orchestra to remain silent for 4 minutes and 33 seconds, allowing the audience to listen to the environmental sound in the concert hall. He challenged the hierarchical distinction between art music and sound (Cage, 2009) and between high and low culture. The present research also challenges this hierarchy, by elevating everyday sound to the status of art.

Through his focus on ‘sounds in themselves’, Cage ‘bursts the seams of the musical framework so as to open onto the outside, reminding music what it is made from: sound’ (LaBelle, 2006:3). Not only that, he paved the way for what is now known as sound art, whereby sound becomes part of a new hybrid art form. A defining characteristic of sound art is that it is ‘between categories’ (Licht, 2007:210), not really fitting the labels of art music or fine art but being somewhere in between. The sound is not notated, as in music; it is digitally recorded or performed live, and generally is experienced in an art gallery setting or as an installation outdoors rather than in a concert hall. Sound art is less elitist than art music; it is ‘the ultimate destination for the removal of the performer/audience relationship. The person experiencing sound art already comes to it as an expert in as much as he or she has been hearing and listening every day of their lives’(Licht, 2007:216). The academic Kate Lacey writes ‘sound artists have long been driven by a mission not only to get people to listen to different things, but to listen differently – indeed to make listeners self-reflexively aware of themselves as *listeners*’ (Licht, 2019:6). It democratises sound and removes the distinctions between high and low culture. It can also enhance public awareness of the soundscape and open up the ears to the sounds of everyday life, making the familiar strange.

There are many definitions of sound art. The academic Alan Licht has defined thus the category in which I believe this project sits: ‘A visual artwork that also has a sound-producing function, such as sound sculpture’(Licht, 2019:6). My research output is in fact an audio-tactile-visual artwork, as it is the tactile interaction that creates the sound. The addition of tactility into the sound art enhances the experience of it, making it multi-sensory rather than just audio-visual. The ‘audience’ of this artwork are not just viewers or listeners, they are participants, as only they can activate the sound. This approach further democratises engagement with an artwork, in sharp contrast to the ‘hands-off’ Modernist attitude, where sight, sound and touch were to be kept at a distance. The engagement with the everyday domestic soundscape also refers back to the period before the dominance of art music, before organised notated sound prevailed.

6.4 Audio-tactile interactions

Almost all musical instruments require sensitive touch to activate their potential sounds. Sound is created by changes in air pressure (Taylor, 2000), and touch alters air pressure and causes vibration. Schafer states: 'Hearing is a way of touching at a distance' (Schafer, 1994:11), the vibration caused by touch becoming audible at about 20 – 30 Hertz*. Below 20 Hertz, vibration can only be felt, not heard. The number of vibrations per second dictates the pitch of the sound; the greater the vibration, the higher the pitch. The highest audible vibrations (for humans) are heard at about 20,000 Hz (Latham, 2003:6). Sound vibrates in the tube of air inside wind and brass instruments, it vibrates when strings are touched plucked or bowed, and when drum skins are touched. 'For musicians, the sense of touch defines physical experience of art: lips applied to reed, fingers pushing down keys or strings' (Sennett, 2003:481). Our ears sense the vibratory effects of the musician's touch.

The textiles in this project are audio-tactile interfaces, which bear a relationship to musical instruments. The aim has been to create as much friction as possible between the fabric and the person touching it. The greater the friction, the greater the vibration caused by the interaction between the hand and the fabric. The sounds created are not individual notes but contain a multiplicity of pitches due to the variety of surfaces within each textile creating different vibrations. It is noticeable, for example, when examining the spectrograms* of one of the sound files for the white rib fabric (below), the vibration triggered by dragging the fingers horizontally across the fabric produces a very wide spectrum of sound. There is a pulse-like rhythm which is the ribbed pattern being touched. The peaks of the ribs are the vertical bands which are fully red. In Fig. 22 below, there is even distribution across all frequencies and unusually it covers the full extent of average human listening. This suggests that the peak of the fabric rib being touched creates sound that is white noise*.

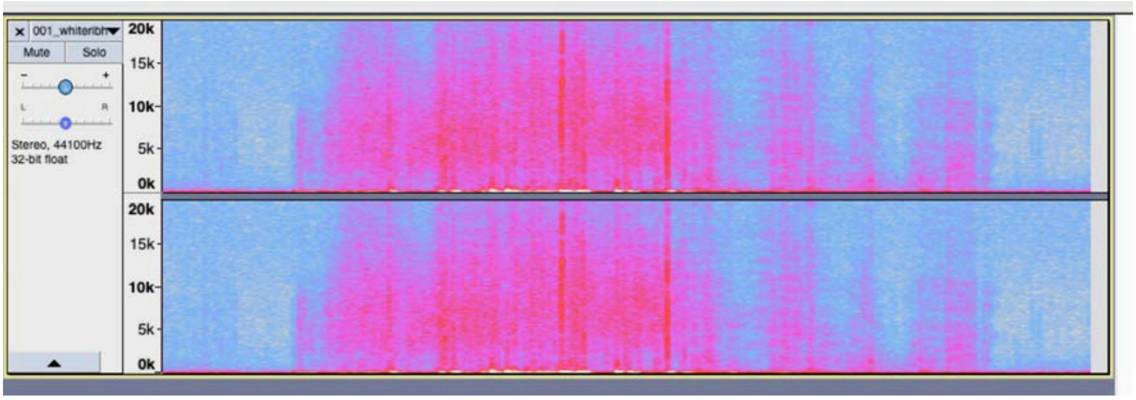

Fig. 22 Spectrogram of the white rib fabric, a finger dragged horizontally across the fabric.

6.4.1 Textile acoustics

There has been little research into what textiles sound like in the domains of art textiles and sound art. However, in the domain of textile technology and engineering a small amount of research has been conducted in order to understand what fabric sounds potential textile purchasers find pleasant or unpleasant (Cooper, 2014:164-183) (Na and Cho, 2003) (Yi et al., 2002) (Kim et al., 2002) (Cho et al., 2001). Research has also been conducted for the purposes of cloth modelling and simulation for virtual reality and computer graphics (Huang et al.). In general, the sounds generated were produced by rubbing a piece of fabric against the same fabric with specially designed technology, rather than skin to fabric contact. In most cases, ready-made fabrics have been used for tests, and where fabrics have been specially woven (Kim et al., 2002), they utilise conventional weave structures. None have developed bespoke fabrics that have a range of noise producing surfaces, as in the present research. Other research is mostly quantitative whereas mine is qualitative. The perception of the fabrics in this project has been assessed by questionnaires but is predominantly an arts-based enquiry.

The perception of textile comfort is not limited to touch; it is a multi-sensory experience, and auditory contributions form a part of this. One study states: 'Although many sensory studies have dealt with tactile and visual comfort factors, studies of acoustic comfort are rare. Acoustic energy through a fabric is caused by the oscillation of air molecules, and how much this oscillation is impeded by barriers governs the acoustic behaviour of the fabric, showing its high relationship to comfort properties. A fabric's sound is related significantly to its mechanical structure and fiber structure, which also affects the textile development process and even alters the purchasing preferences of consumers according to their physiological responses' (Na and Cho, 2003:837). The study examines the acoustic properties of several different fabrics and asks students to describe the sounds of the fabrics with 150 pre-selected adjectives that relate to sound type. A fabric sound generator recorded the frictional sounds of the fabrics, which were two types of wool, four polyesters, one silk and one flax. The students were not told what the fabrics were. Twenty-six of the students were American and thirty-two were Korean, seventeen of the latter having majored in music. Both subject groups felt that the sounds of flax and silk could be described as feeling good and those of polyester and wool as feeling bad (Na and Cho, 2003:842).

The findings of the above research correlate with research into the tactile response to fabrics in Chapter 5, (p.71) (Delong et al., 2007). Silk is invariably the most favoured in tests for tactile pleasantness and wool is usually the least favoured. Silk is generally considered to be smooth and soft but wool is perceived as being scratchy. When the sounds of these fabrics being touched are recorded and played back, the smoothness or scratchiness becomes evident. *How a fabric sounds gives an indication of how it feels.* Even within a range of woollen fabrics, from a soft lightweight tropical suiting to a thick melton*, the sound of the former is preferred to the latter (Yi et al., 2002). 'The brain does not perceive the comfort world as a series of independent sensory experiences, but instead, different sensory impressions mix to subtly alter and integrate sensory components' (Na and Cho, 2003:837). The sounds of textiles being touched contribute to our perception of those textiles, yet we rarely consciously take this into consideration. This project is intended to highlight multi-sensory textile perception by amplifying these under-appreciated sounds.

To create a noisy fabric, therefore, is to create an uncomfortable one. As silk is generally perceived to be comfortable, in order to make it uncomfortable and noisy, the weave setting and structures must create stiffness. This is confirmed by research by Kim et al. (Kim et al., 2002) into the sounds made by rubbing silk fabrics together, known as 'scrooping'*. Seven silk fabrics were woven to the same density with four basic weave structures – one plain weave*, two twills* and one satin*, using the same filament yarns. Three additional satin weaves were woven in the weft with silk noil*, spun and highly twisted silk. The conclusions indicated that the stiffest twill fabric had the highest loudness, but a soft and smooth traditional silk filament (satin weave) fabric had the lowest level of loudness and a more delicate sound. The fabric with the silk noil weft produced the sharpest sound. The research concluded: 'Yarn types, fabric structures, and finishes determine the mechanical properties of fabrics, while the weave structure affects both the luster and the sound of fabrics. In addition, the rustling sounds of general fabrics are related to their bending, shear*, and surface properties. Thus, fabric structure is regarded as an important factor affecting fabric sound; however, there have been very few studies on how structure can change the sound of a fabric, especially silk…..Based on these results, the structure of a fabric can be designed to have a loud sound by changing its weave. On the other hand, the most effective method of producing a fabric with a sharp sound is to change the yarn type' (Kim et al., 2002:559).

The fabrics in my research have been developed specifically to create a variety of sounds through experimentation with different types of yarn and different weave structures. The handwoven fabrics are not stiff but some use thick silver yarn in the weft which creates greater friction thus emitting more sound than pure silk . Weaving with a power loom enabled the creation of stiff fabrics because the silk filament warp contained far more threads per centimetre than the handloom and density of thread is one of the elements that dictates stiffness. The silver yarn used in the weft created raised areas; silver is rougher than silk and so creates more friction. The fabrics created on the power loom were more successful regarding sound production than the handwoven ones as they are stiffer and rougher, but also more uncomfortable next to the skin.

6.4.2 The development of the sound recordings

In order to evidence the sounds of the conductive fabrics being touched, it was necessary to record their sounds whilst they were being touched. The sound files were later put onto a micro SD card that slots into the audio interface. The first recordings of fabrics were conducted at home with a Roland Edirol R-09 sound recorder. They were not of sufficient quality to be useful for the final interactive garments but gave some indication of the sonic potential of the weave samples as they were woven (p. 198). It became apparent that it would be necessary to use specialist directional microphones. Sound tests were recorded with a home-made contact microphone* and a DPA 4060 Lavalier condenser microphone* in university. The latter were conducted in an office, where there was too much background noise for the recordings to be useful but did give an indication of sound quality (pp. 198-199). Finally, the textile sounds were recorded in a sound proofed music studio with DPA 4060 Lavalier microphones with a windshield and a Sennheiser 8060 mini-shotgun microphone*. The Lavalier was secured below the shotgun. These condenser microphones pick up different types of sound from different directions, ensuring that a range of vibration was recorded.

In recording the sounds of the fabrics, the aim was to create a variety of sounds, not just the noise of friction. I dragged my fingers across the fabrics in 3 different directions: down the fabric, across the fabric and in a circular type motion all over the fabric (pp. 199-202). For example, when recording one of the ribbed fabrics, the sounds were different across the rib to those down it. The ribs created a juddering undulated sound whereas following the rib down the fabric created a smoother sound as there was less friction due to reduced difference in the surfaces. It was important to not only evidence the surface materiality of the fabrics through sound, but to sonically reference the varying types of eczema that the fabrics represented. The fabrics overall make rather harsh, scratchy sounds, which is caused by a combination of the metal yarn, the woven structures used and the stiffness of the fabric. As an eczema sufferer, I feel that the sounds evoke the rough scratchy nature of broken eczematous skin In the following chapter I will report on an interview with another eczema sufferer, who made observations on the experience of wearing the fabrics based on eczema.

Initially the sounds were recorded with the fabrics lying on a table, but the sounds of pressure on the wood underneath them came through. I decided to drape the fabrics on my body whilst touching them and recording their sounds, but this meant that I also had to hold my breath whilst doing this as the sounds of my breathing integrated with the sounds of the fabric being touched. Although one of the aims of the project is to reference the links between textiles and embodiment, I felt it was undesirable to hear my breathing when I am not going to be the only person wearing the finished garments. It personalises the embodiment and distracts from the desired effect of focusing on the sounds of the fabrics.

The sounds of six fabrics were recorded (white rib, silver rib, black rib, black blob, MMU1924, MMU11silber4), four woven on the power jacquard and two woven on the hand jacquard. The latter two fabrics were not used in the final garments. Several recordings were made of each direction of touch for each fabric in order to get a range of results. The aim of creating the sound recordings was to create a factually accurate inscription of the sounds of the fabrics being touched, which complements the tactile and visual perception of the textiles. In sound design this is known as 'hyper-real', a sound that enhances or reinforces the salient features of an object/element. It is the user experience of wearing the textiles that is paramount. The accuracy of the sound is important to evidencing the materiality of the cloth. If the sounds had undergone audio-engineering or mixing they would not have been true to their source and would not have represented the multi-sensory perception of the textiles.

6.4.3 Analysis of the sound recordings

Ten undergraduate students of woven textile design were interviewed about their responses to the sounds of the four fabrics to be used for the garments. Six were from Year 2 of the course (level 5) and four were from Year 3 (level 6). The fabrics were rather unpoetically described (by me) as 'black blob' (fig.23), 'black rib' (fig.24), 'silver rib' (fig. 25), and 'white rib' (fig. 26). The two groups of students listened separately to the variety of sounds recorded from each fabric. Prior to the recordings they were informed of the background to the research, that the fabrics were based on the surface of eczema and that the sounds were intended to evidence the uneven surface of the cloth. The students were instructed to listen to the sounds whilst touching the fabrics in the same manner in which they were recorded (all over, horizontal, vertical) and give their opinions on which sounds best represented the feel of the fabrics.

Fig. 23 'black blob'fabric

Fig. 24 'black rib' fabric

Fig. 25 'silver rib' fabric   Fig. 26 'white rib' fabric

Most of the year 2 students gave the same response when questioned on the sounds of the fabrics, whereas the year 3 students gave a variety of responses. This could be because they were more experienced and more confident. It could also be because I gave a lecture about my research to them in 2018 so they knew more about my research than the year 2 students. Detailed results of the interviews can be found in the appendix (pp. 203-204). It was concluded that the recordings of the rib fabrics which were stroked horizontally best represented the feel of these fabrics. The sounds of friction where the finger went across the ribs could be heard clearly. The recordings of vertical stroking were deemed to make a more pleasant (smoother) sound but did not accurately reflect the nature of the fabrics. The year 3 students commented that recording 357 (silver rib all over) sounded harsher than it felt.

There was slightly less agreement with the 'black blob' fabric. The year 2 students unanimously agreed that the vertical recording of the fabric was preferable to all the others. However, three of the year 3 students preferred the vertical recording and one thought either the vertical or horizontal recordings would accurately represent how the fabric felt. In general, the students (although not requested to) commented on whether they liked the sounds as well as whether they thought the sounds best represented the feel of the fabrics. They disliked very abrasive sounds and preferred the smoother ones. The most abrasive ones were described as being like a storm and the smooth ones as being calm and like the sea. It is possible in some cases that the preference for smoother sounds was conflated with the preferred choice of sound that accurately represented the feel of the fabrics.

Following the students' comments , their preferred sound files were edited to reduce the file length. When recording the different types of fabric sound I repeated the stroking action several times, in order to obtain a range of sounds from the interaction with each fabric. It was noticeable in some recordings that the type of sound picked up from the fabric changed across the file, with some stroking actions producing less accurate representations of the fabric than others. Several stroking actions per recording were reduced to one. When the garments are worn on the body and the participant strokes the fabric it will trigger the sound recording. That recording needs to be of one action that is short in length so that the participant can pick up all or part of the recording of that action when stroking the garment. A recording of repeated actions would reduce the participant's control over how they interact with the garments as there is potential for the sound file to be activated at a point that does not reflect the specific surface of the fabric being interacted with.

6.4.4 Fabric sounds

The comments made by the students regarding the preference of smoother, calmer sounding fabrics are echoed In Cerise Cooper's doctoral research (Cooper, 2014), in which she investigated the acoustic perception of a range of textiles. She discovered that participants in the study did not value the sound of textiles highly in multi-sensory evaluations of a selection of fabrics. In a hierarchy of the senses relating to the perception of textiles, sound was generally positioned fourth, touch being first, sight second, and smell third. Below are some of the participants' comments relating to how they felt textiles should sound (Cooper, 2014:176-177) :

'...pure silence, as I move can I hear my cotton shirt. Unobtrusive, not interrupting. Background noise. Not at the fore front...'

‘...I think positive sounds would be no sound, or a flowing sound, doesn’t make a sound at all. A very low sound of a fabric would be good...’

‘...It shouldn’t have a sound. I went through the five senses and thought there shouldn’t be a sound, no rustling...’

‘...no, I don’t think you’d want a sound, if there is it means there is friction.’

All participants considered textiles making sounds as a negative attribute. Only the final comment suggests why this might be the case, which is that sound is equated with friction, which suggests discomfort.

These negative perceptions of textile sound are relatively recent. The change in attitude to the sounds of dress is contemporaneous to the abandonment of corsets (which acted as structures to support large skirts) in the early twentieth century and is related to female emancipation (Tortora, 2010). Prior to this time, people dressed for show rather than comfort, and the sound of a large quantity of silk entering a room announced the wealth of the wearer. Likewise, the beaded and fringed flapper dresses of the 1920’s were designed to be a sonic accompaniment to the jazz music of the era and it was believed that ‘the noisier the gown, the higher the cost’ (Lebing, 2013:91). There are very few references to the sounds of historic dress in books on the history of fashion (Tortora, 2010); most come from literature contemporaneous with a period, such as in Henry James’s ‘Daisy Miller’ in the late nineteenth century. He describes the Swiss resort of Vevey in June: ‘There is a flitting hither and thither of “elegant” young ladies, a rustling of muslin flounces, a rattle of dance music inside the morning hours, a sound of high pitched voices at all times’ (James, 1879:13).

However, in one particular area it is very important that clothing makes no sound, and that is during military reconnaissance. In a study by Jin et al. (2012) they stated ‘The noise of combat uniform is a key factor that affects auditory camouflage performance. That is, the importance of reducing noise of military clothing cannot be understated since soldiers can be discovered by the sense of hearing.’ They also commented that the coated water-repellent fabric used in many combat uniforms generates noise over 70 decibels, ‘which causes unpleasantness to wearers’ (Jin et al., 2012:595). In the general population, quiet dress has become the norm over the last century. Clothing that hangs close the body has become prevalent, which has been enabled by advances in textile technology, particularly the development of stretch fabrics (Tortora, 2010). This project goes against the trend for quieter fabrics by amplifying their sounds rather than seeking to reduce them.

Paradoxically, as noisy fabrics tend also to be uncomfortable ones, they are highly unsuitable for clothing for eczema sufferers, whose sensitive broken skin requires the softest and smoothest of fabrics to be worn next to it. However, the textiles that have been created in this project are not intended to be worn directly next to the skin by those with eczema (although the pure silk linings of the garments are suitable); they suggest the uneven surface of eczematous skin. The sounds suggest the friction created when the eczematous skin encounters the textiles worn next to it. Indeed, the sounds of textiles being touched would be a good indicator for eczema sufferers of what or what not to wear, the quietest fabrics being the most suitable and the noisiest the most unsuitable. The abrasive sounds of the textiles in this project reference the rough surface of eczematous skin, but at the same time indicate that these fabrics would not be suitable to be worn against it. The silk and silver fabrics suggest their potential to be developed for the treatment of eczema, but at the same time are not designed to be practical. They form part of an art study that offers new perspectives concerning the sensory perception of fabrics more widely.

7 Embodied Experience

7.1 Introduction

This chapter draws together the different aspects of the body's sensory perception of textiles outlined earlier in this thesis, in the creation of the multi-sensory garments. It addresses the historical neglect of certain aspects of the sensing body, its relationship with clothing, and the nature of dress as an embodied experience. The design development of the garments is discussed in this chapter, building on the previous research, with this focus on the interaction of cloth to the physical body, as well as the principles utilised in the design of the garments. This chapter discusses how the integration of electronics in a garment can extend our body's physical presence in the world and augment the awareness of our senses, and how integrating electronics with textiles can highlight new insights into the materiality of body and cloth. The manner in which the wearable garments can be animated through touch in order to create sound is referred to by the creation of a graphic score. This is intended to convey how the garments might be 'performed' like a musical instrument when worn and interacted by and with the body. A response to the garments by an eczema sufferer has been described in order to assess how effectively they convey the nature of eczema and the sufferer's relationship with clothing, and finally how the interactive garments might be exhibited is described. The theoretical components of this chapter have been drawn upon through an artistic approach. The chapter addresses the materiality of body and cloth and how the multi-sensory experience of wearing the interactive garments can enhance our perception of the embodied sensations of the material against the skin. The garments in this project aim to alter our awareness of our bodies and the proximity of clothes as part of the physical body by drawing attention to their materiality.

7.2 Embodied cloth

The historical privileging of mind over body in philosophy, and the suppression of the proximal senses in aesthetics has, until recently, led to a focus on art forms that are distanced from the body. This research, in which garments have been created which draw attention to the corporeal and the embodied nature of clothing, contests traditional hierarchies in aesthetics and the neglect of the body. In general, clothing has been designed to hide the body in order to suppress its animality and its connection to nature, particularly since the rise of Christianity and its repression of the 'sinful' drives and urges that might lead us away from the path to God (Negrin, 2013:142). For example, monks' and nuns' simple habits allow them to ignore the body and focus on the interior life of the spiritual mind (Negrin, 2013:146). Bodily disease was associated with demons in the mediaeval world, therefore disease needed to be cleansed and eradicated (Shephard, 2002:216). By basing the multi-sensory garments in this project on bodily disease they challenge this denial of the body and its afflictions.

This study draws upon fashion theory but the garments are not primarily intended as fashion clothing. To give a brief overview of clothing/fashion, we can see an emphasis on the visual, and impact of what we look like and who we interact with. The fashion theorist Joanne Entwistle states 'Dress is an embodied practice, a *situated bodily practice* which is embedded within the social world' (Entwistle et al., 2001:1-10). What we wear and how we wear it is affected by an engagement with the social world. Clothing is designed to be worn on the body, yet much western fashion design has been predicated on creating novel visual forms relating to images of the ideal body of the period rather than the actual physiognomy of real bodies (Negrin, 2013:144). The historian Anne Hollander noted that artistic depictions of nudes correspond to the prevailing fashions of that period (Entwistle, 2000:324), indicating that the nude is also impinged on by contemporary perceptions of fashionable dress. She also believed that fashion is a primarily visual art form where the focus has been on achieving a particular look (Negrin, 2013:145). Modernism, with its emphasis on abstraction, brought about an increasing focus on the visual aspects of fashion and divorced the body from its clothing. At the same time this approach enhanced the creative potential of fashion design, as shapes unrelated to the body became permissible (Negrin, 2013:145).

This suppression of the natural body and a focus on the visual aspects of dress is contested in this research through an emphasis on the multi-sensory embodied experience of clothing.   The body and each of its senses have equal agency and the garments contest the normative approach in which the design appeals primarily to sight. They are not conceived of as static visual forms but as dynamic garments that respond to the movement of the body, specifically the actions of touching the garments in order to trigger their sounds. The wearer has an organic relationship with the clothing, tactile cloth being loosely shaped around the body, not constraining its natural shape.

This approach draws upon the proposition by the philosopher Merleau-Ponty who contested de-corporealisation and the dominance of the mind by suggesting that the body also gains knowledge of the world around it through sensory perception. He stated that the body forms our perception of the world through its understanding of external space, the relationships between objects within that space and how the body navigates that space (Merleau-Ponty and Edie, 1964:5). The aim of his work *The Primacy of Perception* was to 're-establish the roots of the mind in its body and in its world, going against doctrines which treat perception as a simple result of the actions of external things on our body as well as against those which insist on the autonomy of consciousness' (Merleau-Ponty and Edie, 1964:3-4). New materialist thought also seeks to counter a dualistic approach by emphasising the awareness of the body's corporeal experience of the world and its relationship to that world. Clothing is an interface between our sensory body and the external environment, its liminality highlighting the symbiotic relationship between the two interconnected systems.

A garment, with its essential reference to a body, takes on the body's form and is shapeless without it. The body, writes Joanne Eicher, serves as 'an armature, a three-dimensional base for dress' (Eicher, J cited inHume, 2013: p1). The sari, for example, is not just a length of cloth, it is a '*lived* garment' (Banerjee and Miller, 2003:1). The manner in which the sari is draped and folded around the body, its precarious fixings, mean it can become undone quite easily. The wearer becomes very aware of the sari and its relationship with the body. The body moulds the cloth and gives it form. 'In its relationship with dress, the body is an eminently osmotic shell: when we adopt certain garments, we do not confine ourselves to knowing their qualities and attributes, since, through direct physical contact, we also assimilate them, we make them our flesh' (Warwick and Cavallaro, 2001:116). We become particularly aware of the body's relationship with clothes when they are uncomfortable. Umberto Eco talks of 'epidemic self-awareness' when wearing jeans that are too tight (Eco cited in Entwistle et al., 2001:33-58). The embodied nature of clothing affects how we interact with the world.

Pedro Almodovar's film *The Skin I Live In* (Almodovar, 2011) addresses the close relationship between bodies and clothing, and its theme has resonances with the present project. In this narrative the plastic surgeon Robert Ledgard becomes fixated with developing protective bodysuits made from a textile artificial skin after his wife suffers from horrific burns following a car crash. The film demonstrates the symbiotic interplay between the materiality of the corporeal and fabric/clothing, textiles acting as a literal and metaphorical replacement for skin.

Jean-Paul Gaultier's design for the flesh-coloured bodystocking looks like skin and is also very flexible. It highlights the embodied nature of clothing: the bodysuit would be a limp piece of fabric if it was not worn on the body. Although the garments in my project are not close-fitting bodysuits, they do refer to the embodied nature of clothing and its relationship with the skin. Like Ledgard, I have created a 'second skin' to be worn over the first one, although his concern is the replacement or protective covering of the skin, whereas this research suggests a different dynamic with damaged skin. Gaultier's bodystocking is made from lycra, a very elastic fabric that will stretch over the body like skin, and allows people to 'wear their own bodies' (O'Connor cited in Davies, 2017:69). The garments in this project are also partly made from lycra (also known as spandex) although for different reasons. The aim was not to make the garments skin-tight; it is the lycra in the silk weft yarn that shrinks once washed at high temperature to create the fabrics with 3D surfaces that resemble eczematous skin. Like skin, lycra can both stretch and shrink.

Almodovar has suggested that his film was influenced by the textile sculptures of Louise Bourgeois and some of her work was featured in the film. She roughly sewed flesh coloured fabric together to create sculptural human forms that interrogate the relationship between fabric and flesh, clothing and the body, her reasons for doing so being related to psychological trauma, the 'repaired' textile bodies being a metaphor for her attempts to repair her mental health (Morris et al., 2007:266). Her use of skin coloured fabric to suggest the embodied nature of cloth has also been influential to this project. I have avoided the colour of skin for reasons mentioned in Chapter 4 (p. 60) but have referred to the symbiotic relationship between the body, skin and fabric in the garments I have made to expose the materiality of the body**.** The academic Cath Davies describes Almodovar's film as being 'a study of textiles' function relating to somatic vulnerability' (Davies, 2017:78). This could also be said for my project as the somatic vulnerability created by eczema and its proneness to infection are referenced in the silk and silver garments. However, the vulnerability is reversed in order to attribute value and agency to distressed skin, and friction as a means to amplify and resonate the experience of sensation. Davies further comments: 'Fabric-as-material and corporeal materiality are sutured throughout this film' (Davies, 2017:78), a statement which could be similarly applied to this research, as it weaves together the materiality of the body with cloth. However, my skin-based garments take a somewhat perverse approach to the relationship between textiles and the aberrant body, by almost celebrating the skin's malfunction.

7.3 The Design of the Garments

The designs of the garments were based on traditional clothes that are cut from loom-width lengths of hand-woven cloth, such as the Japanese kimono or silk ikat coats from Central Asia (Anawalt, 2007: 144-145, 202-205). There were several reasons for this: a) it was undesirable to make the garments look futuristic, unlike many e-textile interactive garments. The aim was to update garments based on historic principles, but made from conductive cloth invisibly embedded with electronics; b) the garments are not intended to be fashion items; c) the simple unisex shapes arising from this method of pattern cutting importantly allow the garments to be worn by most shapes and sizes of body; d) little fabric would be wasted in the construction of the garments; e) the electronic components can be attached without compromise to the garments.

The design of clothing that is made from loom-width lengths of cloth sometimes involve no sewing, such as the toga, sari or sarong. Other types of garment, such as the poncho, kimono or European peasant blouse, are cut from a piece of fabric where there is no wastage after cutting due to the pieces being a series of rectangles arranged on the cloth so that there are no gaps in between. The rectangles are sewn together to create the garments. The types of loom available and their widths dictate the design of the clothes and the manner in which they are cut. This is in sharp contrast to modern European pattern cutting where many odd shaped pieces are cut from a length of fabric and there is much wastage of cloth in between the pieces.

High levels of craftsmanship have been employed in this project, partly because I value this aesthetic, but also to counteract the basic low-tech aesthetic of most DIY electronic textiles. Most DIY e-textiles seem to focus on quantity of production rather than quality of production. There are many examples of high levels of craftsmanship in interactive garment design, such as those by Cute Circuit (Circuit, 2020) and Hussein Chalayan (Mower, 2007). These include Cute Circuit's design for the Boston Museum of Fine Arts, made of black silk chiffon and embroidered with Svarovski crystals, that also featured illuminated Magic Fabric which showcased imagery inspired by artworks in the museum's collection (Circuit, 2020). The fashion theorist Anneke Smelik states: 'The artisanal qualities that are imbibed in craftsmanship bring the technologies within the grip of our hands, making the high-tech world more human and accessible' (Smelik, 2018). However, I would argue that the above designers' clothing is of the futuristic kind and can appear off-putting to the general public. My garments are intended to reject both the low-tech aesthetic of DIY e-textiles and the high-tech aesthetic of futuristic designs. In order for interactive garments to gain common currency I believe it is necessary for them to become more human and less machine. Traditional craftsmanship aids this transformation.

The ivory, grey and silver garment was designed and constructed by Elena Etheridge, a lecturer in the Manchester Fashion Institute at MMU. I advised her on technical design considerations when designing the garment regarding the functioning of the electronics, and we worked together to decide where each fabric should be placed on the garment. The black, grey and silver garment was designed and constructed by myself, using the same principles as described above. Much of the garment had to be hand sewn, or hand-sewn and machined afterwards very carefully, due to the stretchy undulating nature of the fabric. The edges of the garment – the edging panel, hem and sleeve edge – had to be faced* and hand-stitched with a bias-cut* fabric lining, in order to stabilise them and create a professional finish.

With both garments, the different fabrics employed in the designs had to be separated by strips of non-conductive fabric, so that the conductive fabrics did not touch each other. This ensured that each electronic circuit was isolated, and the sensors in each section of the garments did not pick up mixed signals and that the correct sounds were triggered when activated. Before the lining of the garments was completely stitched to the outer fabrics, strips of adhesive copper tape were attached to the back of the conductive areas that were intended for tactile interaction, perpendicular to the weft threads, so that the latter would be connected together and ensure an even distribution of conductivity down the cloth. Tests had shown that, without this intervention, the further touch was placed from the capacitive sensor, the weaker the signal was. A small pure silk bag was made for each of the garments which has been attached to the fabric at the back of the neck, into which the capacitive sensing components were placed.   Silk is not conductive so would protect the components from the silver yarn. The insulated wires soldered to these were soldered at the other end to a small piece of copper tape, which was attached to the longer strips of copper tape. However, it was discovered that the sleeves (made from the silver rib fabric) of the ivory, grey and silver garment should not be connected to the electronic circuit as their conductivity, when touching the body of the garment, interfered with the capacitive sensing of the front panels (made from the white rib fabric).

Prior to the assembly of the black, grey and silver garment, it was discovered that the two fabrics that were required to make up the garment (black blob and black rib) had oxidised* in places. All the other fabrics that had been woven were stable. The supplier of the silver yarn suggested that the possible cause was humidity. The two fabrics had been stored near an outside wall in my studio and it is possible that because of the prolonged rain of winter 2019/20 that the fabrics had reacted to this. The fabrics were tested for conductivity and it was ascertained that there had been little decrease in conductivity in the oxidised areas; about 1 or 2 ohms was usual. The yarn manufacturers considered that further degradation was unlikely as long as the fabrics were removed from the environment that had caused the damage.

This demonstrates that materials, like bodies, respond not only to each other but to the environment. The garments are involved in a chain of reactions and interactions. The textile surfaces are created from the interaction of structure and yarn, and the silk and spandex yarn with hot water. The textiles have subsequently reacted to water in the air and the plaster and bricks that were proximate, creating a chemical change in the silver. The garments respond to the conductivity of the body both through the hands touching the outside of garments, but also the conductivity of the body altering the electronic capacitance from the inside of the garments. Moreover, the conductivity of the environment alters capacitance from outside the body and garments. There is a paradox, in that the garments are not worn next to the skin directly as the conductivity of the body interferes with the electronic fabrics. In order for garments to function they must be physically separated from the body by non-conductive under-clothing as both they and the body are conductive. The sensors in the garments (our second skin) sense our touch, but there must be a barrier between this and our first skin.

Fig. 27 The interactive garments

7.4 Extending the sensory body

'*All media are extensions of some human faculty – psychic or physical. The wheel is an extension of the foot. The book is an extension of the eye…clothing an extension of the skin…electric circuitry, an extension of the central nervous system…Media, by altering the environment, evoke in us unique ratios of sense perceptions. The extension of any one sense alters the way we think and act – the way we perceive the world…When these ratios change, men change*.' Marshall McLuhan

A multi- sensory body does not have to end at the skin but can extend itself through electronic clothing. Ubiquitous computing enables technologies that 'weave themselves into the fabric of everyday life until they are indistinguishable from it' (Weiser cited in Schick and Malmborg, 2010:63-64). Our clothes are worn very close to our skin and are an ideal environment in which to place sensors that measure and respond to the body's functions. Interactive textiles can imitate the sensitivity and communicative abilities of the skin and the sensors in the fabric can provide feedback on the functions of the body and skin. The garments in this project abstract and reference the skin and at the same time are an extension of it. They do not gain information from the body as in some smart garments but they gain information from the conductivity and surface of the skin-based fabric via the capacitive sensors. They evidence the body's materiality through dynamic interactions, through a responsive relationship between the body and its extensions.

The garments address the dichotomy between the 'hard' technology of computer science and the 'soft' materiality of the body and textiles. Digital technology is generally associated with disembodiment and the virtual (Joseph et al., 2017:8), but it can also be used in a hybrid system of the digital and material. E-textiles combine the virtual (software) with physical electronic hardware as well as textiles (Joseph et al., 2017:7). The Maker Movement* has made electronics much more accessible, and the DIY ethos and online tutorials and forums have enabled artists, designers and musicians to develop projects that were previously only the domain of computer scientists. It has allowed the integration of micro-electronics into the material world of the designer-maker and the opportunity to enhance or highlight that very materiality. My project exemplifies this cross-disciplinary approach, combining technology with traditional craftsmanship to evidence the materiality of both the body and clothing.

New materialism proposes, in an ontological shift, that humans are not separate from the material world but part of it (Joseph et al., 2017:9). In a post-human* world there is great importance attached to the body, materiality and craftsmanship. This is partly the result of a reaction against the dematerialisation of virtual technology. The academic Anneke Smelik states 'there is no doubt that technological innovations will have a deep impact on the meaning and communication of clothes and fashion. If technologically enhanced clothes can measure temperatures, chemical processes or vital functions, sense movement and position, or have expressive qualities, they will change the relation of the wearers to themselves as well as transform the communication to and with others. The fact that the garments are worn on the body increases the urgency to take into account the body's materiality' (Smelik, 2018:457-8). The materiality of body is referenced in this research through the skin-based textiles and the electronic touch sensors that verify this materiality through sound.

7.5 Graphic scores

I have created graphic scores for the 'performance' of touching the fabrics whilst wearing the garments (pp. 205-209). Graphic scores are visual representations of sound, usually produced by composers to articulate to musicians the manner in which they want their musical compositions to be played, but by unconventional means (Sauer, 2009:10). They often employ images of musical notes, but not necessarily on stave lines*, as in normal musical notation. They denote the essence of a composition rather than an exact inscription of the notes to be played. My graphic scores have been influenced by a score created by R. Murray Schafer for his piece entitled *Snowforms* (Sauer, 2009:210-211). This work, created for children to perform, was inspired by the undulations of snow in winter seen from the window of his Ontario farmhouse. The image depicts a series of horizontal rows of curving lines, some short, some long, with the pitch* denoted just above them. The lines are to be sung (with no lyrics) as a chorus, the undulating sounds echoing the forms of the snowy landscape.

My graphic scores, on the other hand, are based on the landscape of the skin, but in fabric form. With eyes shut, I slowly drew a finger on my left hand across each fabric used in the garments, whilst simultaneously drawing what I felt with my right hand. The left hand traced the undulations of the fabrics whilst at the same time the right hand imitated what I felt by means of a line drawing. The recorded sounds of the fabrics being touched were also produced by drawing a finger across the fabrics in a particular direction. The scores are intended to correlate with these sounds. For example, if a finger is drawn across the black rib fabric, a juddering type sound is produced. This is because there are regular short gaps between the peaks and troughs of the fabric. Similarly, the graphic score for this fabric visualises the feel of the cloth through regular undulating lines.

A finger was drawn across each fabric in a number of different locations, all parallel to each other, and a line drawing was produced that correlated with the tactile impression. In the case of the rib fabrics, the resultant graphic scores suggest the encounters with the fabric at different points on its horizontal axis, as this direction produces the most pronounced tactile impressions. They also suggest the stave lines used in conventional musical notation. The drawings based on the black blob fabric were created from drawing a finger across the fabrics on both the horizontal and vertical axes, as the fabric has an allover pattern that has pronounced tactile impressions from any direction.

I initially attempted drawing with my eyes open, and although the drawings were more visually accurate than those that emanated solely from touch with my eyes closed, they were also more inhibited. It is much harder to create a drawing as a response to touching a surface than it is from looking at it, but the results are more intuitive. The scores are intended to intimate how one might interact with the conductive fabrics by demonstrating to the participant wearing the garment that they could imitate the directional lines in the scores whilst drawing fingers across the fabrics, in order to gain the most accurate multi-sensory response. The lines on the graphic scores imitate the actions that I employed when recording the sounds of the fabrics being touched.

Fig. 28 Graphic score for the fabric ‘black rib’, fingers drawn across the fabric horizontally.

7.6. A Response to the Garments

In order to gain responses to the interactive garments from the standpoint of someone who understands the skin condition eczema from a personal perspective, an interview (pp. 222-223) was conducted with Kelly Joseph, an eczema sufferer and member of staff at Manchester Fashion Institute (Manchester Metropolitan University). We originally intended to conduct the interview in person at university, but due to the Covid-19 pandemic we had to conduct it via video conferencing software. This meant that Joseph was not able to wear and interact with the garments. However, she had done so at the IFFTI conference exhibition in April 2019, so was able to give some observations on the garments from memory. I also touched the garments in order to activate their respective sounds during the video conference.

I asked her if she felt that the fabrics represented her experience of eczema. She replied that they looked and felt itchy and scratchy, which was her experience of the skin condition. The silver would scratch the skin if you touched it but it visually looked like it would too. She said the fabrics looked like her skin looked when it was eczematous and really dry. 'If you were to get a microscope on your skin, that's what it would look like, but for some reason when I look at the fabrics, I think "itchy"'. When I played the sound of the 'black blob' fabric, she responded that it sounded dry, like sandpaper, and it was the type of dry, scratchy sound that describes eczema and dry skin. When the sounds of the 'white rib' fabric were played, a similar response ensued, Joseph stating that the fabric also sounded sandpapery and dry. She also stated that white rib fabric best represented her own eczema in look and feel. I asked her if the sounds enhanced her perception of the fabrics. She replied that they definitely did; if you could't touch the fabrics, you could imagine what they would feel like because of the dry scratchy sounds. 'If you were touching them and hearing them, they would almost make you feel like they were more scratchy. If you couldn't touch them and you could see them, you could guess what they would feel like'.

This response to the garments, fabrics and sounds has evidenced their effectiveness in representing the experience of those suffering from eczema. Eczema's rough voice interrupts the flowing conversation between body and cloth, and proclaims its discomfort to the senses. It is this voice that I have attempted to amplify in this research, through translating its patterns and textures into cloth and then recording the sounds of these surfaces being touched. The touch-activated sounds represent the voice of eczema, their dry scratchiness evidencing both the materiality of the cloth and the eczematous body.

7.7 The Presentation of the Research

The intended audience for this research is mainly eczema sufferers and their carers/families. The dissemination includes the general public more widely, with the aim of generating discussion about eczema and its relationship with clothing tp deepen insight and understanding of this condition. The work is intended for exhibition in presentation directly related to eczema research, similar to Beverley Hood's (mentioned in the literature review) (ASCUS, 2017), or those aimed at creating awareness of eczema to the general public, similar to the *Beyond Skin* exhibition (Lifespace, 2017b) or Maria Fusco's *ECZEMA!* (Fusco, 2018).

The garments are not intended to be worn except for presentation and enacting the graphic scores, with accompanying film performance.   Handling samples of the interactive fabrics would be displayed for public interaction whilst listening to the sounds, either through headphones or speakers. My website (http://www.victoriahaire.com) gives indications of how the garments might be presented in the public domain. The element of public participation is not the primary function; the participation comes in discreet ways to experience the sonic/haptic sensations of the fabrics.

The rationale for the exhibitions is primarily to change perceptions of eczema through public engagement and create understanding and awareness about the skin condition. The presentation employs art textiles to open up conversations with the public about eczema in relation to subjects such as the embodied experience of clothing and skin, the sensitivity of eczema to the clothes worn next to it, how we engage with the material world, the sounds of textiles being touched, perceptions of beauty, and human sensory experience.

The garments in this research were created through a desire to highlight the multi-sensory embodied nature of dress and its relationship with the skin. They give agency to the 'fleshy, phenomenonological entity' that is the dressed body (Entwistle, 2000:327). Through close contact with the body, we assimilate clothing and combine with our flesh in a symbiotic relationship. The research has demonstrated how clothing can convey the similarities between the fleshy body and the skin-like qualities of fabric; the eczema-based textiles draw attention to this relationship through their materiality and the sounds of that materiality. McLuhan stated that clothing is 'an extension of the skin' and 'electric circuitry, an extension of the central nervous system', and that these extensions can alter our perception of the world by altering environments (McLuhan et al., 2001:26?) . The garments influence changes in perception regarding our relationship with textiles by evidencing the materiality of cloth through sound. This alters our perception of the textiles, makes us more aware of the surface textures of the fabrics, and more aware of the rough, scratchy nature of eczema. It is the interactive electronic nature of the textiles from which the garments are made that enables this altering of perception.

8 Conclusion

8.1 A summary of the research

This research aims to highlight the collaborative nature of sensory perception by the development of interactive garments made from woven e-textiles, that evidence their haptic and sonic relationship with the body as a site of transmission and reception. The thesis provides an account of this practice-based research. It has been supported by a theoretical and contextual framework that underpins the approach as an artistic and practice-based enquiry, which has been broad in its scope. It has drawn upon a number of areas in the arts, humanities and sciences and these have been referenced through the lens of textiles. This research can be situated in cross-disciplinary contexts and fields of practice and shows how this approach could offer new understandings towards the relationship between skin and textiles. Scientific research tends to offer evidence-based approaches to this relationship, whereas the arts and humanities can offer approaches that are related to cultural factors, such as references in literature to perceptions of wearing cloth. By referencing these different research methodologies and applying them to this research, new contributions to knowledge have evolved. A new contribution to knowledge has also arisen regarding the audience for the research. These contributions will be discussed further in section 8.2.

This thesis challenges the privileging of sight in sensory perception and the dominance of vision in the perception of art objects. It contests these long-held assumptions and promotes the non-hierarchical multi-sensory perception of artworks, in order to gain new insights into the appreciation of art objects.
The interactive artworks developed in this research have been approached as investigative vehicles for examining the complex multi-sensory relationship between textiles and skin. Eczema, as the basis for the textile designs, has been used as a conceptual prism for interrogating this relationship, the intention being to highlight the materiality of the skin and cloth, and the symbiotic relationship between these two membranes.

This research examined the similarities and synergies between textiles and skin and presents a case for a re-examination of the correlations between these two flexible coverings. Studies of the relationship between textiles and skin have generally been conducted within the fields of textile science and dermatology. By drawing on both the scientific and cultural aspects of the correlations between skin and textiles, this research has revealed both objective and subjective accounts of our experience of wearing textiles and how the reciprocal relationship between textiles and skin affects our perception of both. This sensory reciprocity is of particular importance to eczema sufferers, whose sensitivity to clothing worn next to the skin condition was the starting point for this research. The research has highlighted both the rough surface of eczematous skin, and the importance of the surface and composition of textiles worn by eczema sufferers. By creating textiles (woven from yarns that are used in the treatment of eczema) that imitate this rough surface, the sensory relationship between textiles and eczematous skin has been revealed. The sound of these interactive textiles being touched evidences the surface of the fabrics that imitate eczematous skin. The research has also revealed that human skin patterns have very rarely been used as the basis for textile designs.

There has been an historic neglect of touch in the appreciation of artworks, but this research seeks to actively promote this engagement. There has also been an historic neglect of touch in perception research, though recent studies have shown that touch, like other senses, does not operate in isolation, but in combination with other senses. An increased interest in the tactile and sensorial aspects of touching and making textiles has occurred in recent years, due to a focus on the significance of materiality. Most assessments of the tactile qualities of fabrics are conducted (by machines or computers) in the field of textile science, and although objective, tend not to include sensory responses from human interactions with textiles. This artistic study argues for a more integrated approach to tactile perception research. Art textiles are generally not intended to be touched; this research contests this narrative and actively advocates touching the 3D surface of the textiles from which the garments are made. The textiles bridge the divide between domestic and art textiles and contest the notion that art cannot be useful, and in particular, cannot be touched.

Most e-textiles are embroidered and do not have much surface texture, whereas this research has created woven e-textiles that have 3D surfaces. Weaving has been employed as the medium from which the fabrics are made as this allows for the creation of textile structures with 3D surfaces that are also conductive. The materiality of the fabrics facilitates the sonic response to touching the fabrics. There were limited types of yarn available for weaving the fabrics, due to restricting yarns only to silk and silver because of their associations with medical textiles employed in the treatment of eczema. These limitations, however, presented opportunities for experimentation and pushed me to be more inventive. The process-led methodology for the research allowed for many iterations to be woven with a narrow range of materials, each iteration producing a refinement of the options available. The colour palette also had to be restricted because of the yarns that were available. The use of CAD in the design process proved to be restrictive, in that it was difficult to visualise how the designs might translate from 2D photoshop image to a fabric with 3D surface. A hybrid practice of using a combination of handweaving and CAD techniques would have been more advantageous.

Textiles that are embedded with haptic technologies that facilitate interaction can draw attention to tactile perception and enhance our experience of the textiles. The textiles created in this research resemble large, flexible, unsophisticated touch screens, and they use the same type of electronic components– capacitive touch sensors. However, touch screens tend to be very smooth, whereas the textiles in this research have much surface interest and are intended to be an antidote to the lack of tactile feedback associated with conventional touch screen devices. Different types of component that detect capacitive touch were trialled. Sewn devices were abandoned in favour of those that were soldered, as these created more reliable connections and hence fewer problems with the electronic circuits. However, the technology can be very temperamental, as experienced when one of the interactive textiles was exhibited at the IFFTI conference in Manchester in 2019. It became apparent that the capacitive touch sensors would have to be re-calibrated to adapt to each new environment in which the textiles are exhibited, as they are sensitive not only to human touch, but also how conductive the surrounding environment is.

The sound of clothing being touched is background everyday sound and not valued. This research aims to bring it to the foreground and to elevate this sound to art. The thesis argues for listening to the sounds of fabric, and situates the research partially in the field of sound art. The sounds of textiles being touched have been examined in the domain of textile science, but rarely as an arts-based enquiry. In scientific research the aim is to assess how fabric sounds can affect perceptions of fabric comfort, whereas in this research the aim has been to draw attention to how the sounds evidence the surface textures of the cloth. The sound that a fabric emits when touched indicates how it feels, in a multi-sensory experience. The yarns and weave structures employed in the fabrics developed in this research have been chosen specifically to create textiles that emit a variety of noisy sounds. The sound recordings of the fabrics being touched were factually accurate inscriptions of these sounds. This truthfulness was necessary in order to evidence the actual materiality of the cloth. Noisy fabric sounds are generally perceived to be a negative attribute as they imply discomfort. This research actively seeks to create noisy fabrics that refer to the rough and uncomfortable surface of eczematous skin, in artworks that offer new perspectives on the multi-sensory perception of textiles.

The garments in this research were developed to highlight the corporeal and the embodied nature of clothing, rejecting the historical bias against the sensing body and contesting traditional hierarchies in aesthetics. The ‘second skin’ garments refer to a skin disease – eczema, the embodied nature of these artworks referencing the materiality of cloth and the corporeal. The design of the interactive garments is based on traditional clothing, the emphasis being on high levels of craftmanship using traditional techniques. This is in order to counteract the low-tech aesthetic of most e-textile projects, and conversely to reject the hi-tech futuristic designs from some fashion e-textile collections. The garments extend the sensing body through electronics, the sensors connected to the garments transmit data from touching the fabrics in a similar manner to the way in which our skin detects touch and send this information to the brain. The interactive electronics embedded in the garments verify the materiality of body and cloth through sound. A response to the garments from an eczema sufferer has concluded that they effectively convey the experience of those suffering from eczema. The garments alter our perception of textiles through the fabric sounds triggered by interactivity, and we become more aware of the textiles' surface and more aware of the rough nature of eczematous skin on which the textiles are based.

8.2 The contributions to knowledge

The inter-disciplinary approach to the research has revealed contributions to knowledge in two main areas: the relationship between eczema, skin pattern and textiles, and the sounds of fabrics being touched, which is linked to the first area, providing insight into the relationship between these symbiotic membranes, skin and textile. The research has drawn on the personal expertise of dermatologists, musicians, electronics engineers, a fashion pattern cutter and weave technicians, as well literature from a wide range of fields. By drawing on this broad spectrum of knowledge and applying the research to an artistic investigation, it has enabled the new knowledge described here.

The contributions to knowledge have evolved as the research has progressed. The original contribution concerned the development of a woven e-textile haptic interface that emits the sound of itself being touched in real time. However, as the research developed it became apparent that there were greater contributions to knowledge from other areas, as outlined above. I also realised that I was less interested in electronics themselves and more interested in how they could facilitate an interactive artwork that addressed the corporeal experience of textiles. Although the research has many technical aspects that are necessary for the development of the project, the focus has been on the creation of artworks that speak to how our senses experience the wearing of cloth.

Research into eczema and the clothing worn next to it is generally conducted in medical fields. This investigation into the relationship between eczema and textiles has brought into focus the importance of the composition and materiality of clothing for eczema sufferers and has been informed by medical science. However, rather than evidencing this through objective scientific trials, it has been revealed through an interactive artistic output which allows for the mutual and subjective interrelationship between sensory experiences to be explored. Using eczema as the basis for the textile designs and a conceptual prism for the research has thrown a light on the very delicate reciprocal relationship between body and cloth. Eczema, as a disruptive extension of the skin, sits in between the body and its clothing. Through its heightened sensitivity to any form of touch due to the broken and inflamed nature of its surface, it is an ideal source on which to base the touch-triggered interactive textiles with 3D surfaces. The eczema-based textiles confer agency to the skin disease and its sensitivity and materiality by drawing attention to its qualities, the sounds of the textiles being touched simulating these attributes. Although the textiles are not intended to be of medical benefit for eczema sufferers, this artistic presentation indicates how this skin condition can be managed through the textiles that are worn next to it. By basing textile designs on the surface of eczematous skin and embedding the designs with touch sensors that evidence the surface of these fabrics, we can become more aware of the significance of the symbiotic relationship between textiles and eczema. This contingency offers a deeper understanding of the embodied and lived experience of eczema, changing perceptions for the sufferer and non-sufferer. A further contribution to new knowledge is in the original use of human skin patterns to create woven textiles, similarly advancing understanding of the symbiotic relationship of skin and textiles as interlinked membranes.

Traditionally, research into the sounds of textiles being touched has taken place within the fields of psychology and textile science in order to assess the potential impacts of these sounds on customer preferences. This research has been informed by these arenas, but the output is an interactive textile artwork that emits textile sounds in order to draw attention to their materiality, rather than an assessment of the sounds of mass-produced textiles being touched. There have been very few attempts to address this area within sound art, e-textiles and art textiles. None have used textile sounds to evidence the tactile surfaces of woven textiles, the designs of which are based on the skin. This further contributes to new knowledge into the sensory experience of textiles and the connected eczematous body.

Public engagement projects created as a response to the experience of having eczema or as a response to eczema research have, until now, not taken the form of interactive textiles. This research uses interactive textiles in the form of garments that are based on the surface of eczema, and made from materials employed in the treatment of the disorder. This research contributes to new knowledge regarding audience perception of eczema and its sensory relationship with clothing. The research broaches specific discussions about eczema's sensitivity and surface, but also opens up wider discussions about the synergies between textiles and skin and our sensory encounters with the material world. It also promotes discussions about perceptions of skin beauty.

8.3 Future Directions

The suggestions below indicate how this research could be developed in the future and demonstrate its potential use in a range of environments that are related to my investigation. They focus on the materiality and multi-sensory perception of textiles, particularly relating to touch and sound. A professional website will be developed to promote the artistic research presented in this thesis and will be referred to in applications for funding in order to evidence work already completed.

Woven textile designs based on the surface of eczema could be further developed to imitate the flaking skin attributes of eczema. There is much scope for additional development of woven textiles that simulate skin diseases, including the skin disease psoriasis. Sufferers of this disease also have sensitive skin that is prone to infection, and they benefit from wearing silk and silver for the same reasons as for eczema sufferers.

Further development of interactive garments could also involve sufferers from eczema and psoriasis, engaging them in the creation of woven textile artworks that articulate their perception of the diseases in art workshops. Textiles offer an ideal medium to simulate the surface of the skin due to their similarities and are better suited for the purpose of creating skin-based artworks than conventional art mediums such as paint and paper. The art workshops propose creating e-textiles based on skin conditions. I taught e-textile workshops in Greater Manchester in 2016-17, organised by MADLAB (Madlab, 2020) during the MAKE STUFF events (Madlab, 2017). These could be developed and extended.

The research conducted in this investigation could also be applied to other arts and health contexts, including environments for people with sensory impairments such as dementia or autism. Interactive textiles could be developed for 'Snoezelen' rooms (controlled multi-sensory environments), that are commonplace in the United Kingdom in care homes and schools for children with special educational needs and disabilities. These rooms contain a range of therapeutic experiences and sensory stimuli, which can include tactile textures, aromas, sounds and fibre-optic lighting. These are intended to enhance the sensory experiences and learning processes of their users. Cathy Treadaway's research (Treadaway and Kenning, 2015), outlined in the Literature Review (p.32), has indicated that wearable interactive textiles can be of benefit to dementia sufferers, and my research could also be adapted for this purpose.

There is further potential to develop research into the sound of fabrics being touched. An expanded range of interactive fabrics could be created with the aim of developing a wider variety of sounds. This research has recorded the sounds of a narrow range of fabrics that have been specifically created for this investigation, and as a result the range of sounds produced is fairly limited. Having tested other mass-produced fabrics prior to creating the custom-made designs, it became apparent that all sounds of fabrics being touched with fingers are reminiscent (to varying degrees) of how one might imagine sandpaper to sound, even fabrics that feel soft. In order to develop the research further, it will be important to take this factor into account in the development of new designs.

This research has revealed the lack of information in fashion research regarding the sounds of clothes, particularly relating to historical dress. Most references to this subject appear in literature contemporaneous with a particular period; I have found none in fashion history textbooks and very few in academic papers. Changes in attitude to the sounds of dress over the last two to three hundred years, briefly documented in this thesis, could be further researched and analysed. This would involve mostly primary research due to the dearth of studies currently available. It could widen our understanding of the multi-sensory experience of wearing clothing, and add to new materialist discourses by indicating how the sounds of embodied clothes in motion can indicate the materiality of garments.

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Appendix

<u>Quatre Tapisseries pour la Châtelaine de Vergi</u>
(Four Tapestries for the Chatelaine of Vergi)

First tapestry

Un chat qui s'émerveille
une ombre l'ensorcelle
blanche comme une oreile

Le cri du bateleur et celui de la caille
une ombre l'ensorcelle
blanche comme une oreille

Une ombre qui sommeille
une herbe qui s'éveille
un pas qui m'émerveille

Second tapestry

Quand le jour a rouvert les brances du jardin
Un chat qui s'émerveille
Le cri du bateleur et celui de la caille
Une herbe qui s'éveille
Celui de la perdrix celui de ramoneur
Une ombre l'ensorcelle
Celui de l'arbre mort celui des bêtes prises

Au dire des merveilles
L'ombre en deux s'est déchirée

Third tapestry

Mille chevaux hors d'haleine
Mille chevaux noirs portent ma peine
J'entends leurs sabots sourds
Frapper la nuit an ventre
S'ils n'arrivent s'ils n'arrivent
Avant le jour ah la peine perdue

Le cri de la perdrix celui du ramoneur
au dire des merveilles une herbe qui s'eveille
celui de L'arbre mort celui des bêtes prises
Mille coqs hurlent ma peine

mille coqs blesses à mort
un à un à la lisière des faubourgs
pour batter le tambour de l'ombre
pour réveiller la mémoire des Chemins
pour appeler une à une
s'ils vivent s'ils vivent

mille étoiles toutes mes peines

Fourth tapestry

Dormez cette pâleur nous est venue de loin
le cri du bateleur et celui de la caille
dormez cette blancheur est chaque jour nouvelle
celui de la perdrix celui du ramoneur
ceux qui s'aiment heureux s'endorment aussi pâles
celui de l'arbre mort celui des bêtes prises

n'endormiront jamais cette chanons de peine
que d'autres ont repris d'autres la rependront

Jean-François Chabrun 1947

The Art of Noises

'Here are the *6 families of noises* of the Futurist orchestra which we will soon set in motion mechanically:

1	2	3	4	5	6
Rumbles	Whistles	Whispers	Screeches	Noises obtained	Voices of
Roars	Hisses	Murmurs	Creaks	by percussion	animals
Explosions	Snorts	Mumbles	Rumbles	metal, wood,	and men:
Crashes		Grumbles	Buzzes	skin, stone,	Shouts
Splashes		Gurgles	Crackles	terracotta, etc.	Screams
Booms			Scrapes		Groans
					Shrieks
					Howls
					Laughs
					Wheezes
					Sobs'

Luigi Russolo (1913)

Eczema photographs

Fig. 29 My own eczema

Fig. 30 Detail of my own eczema

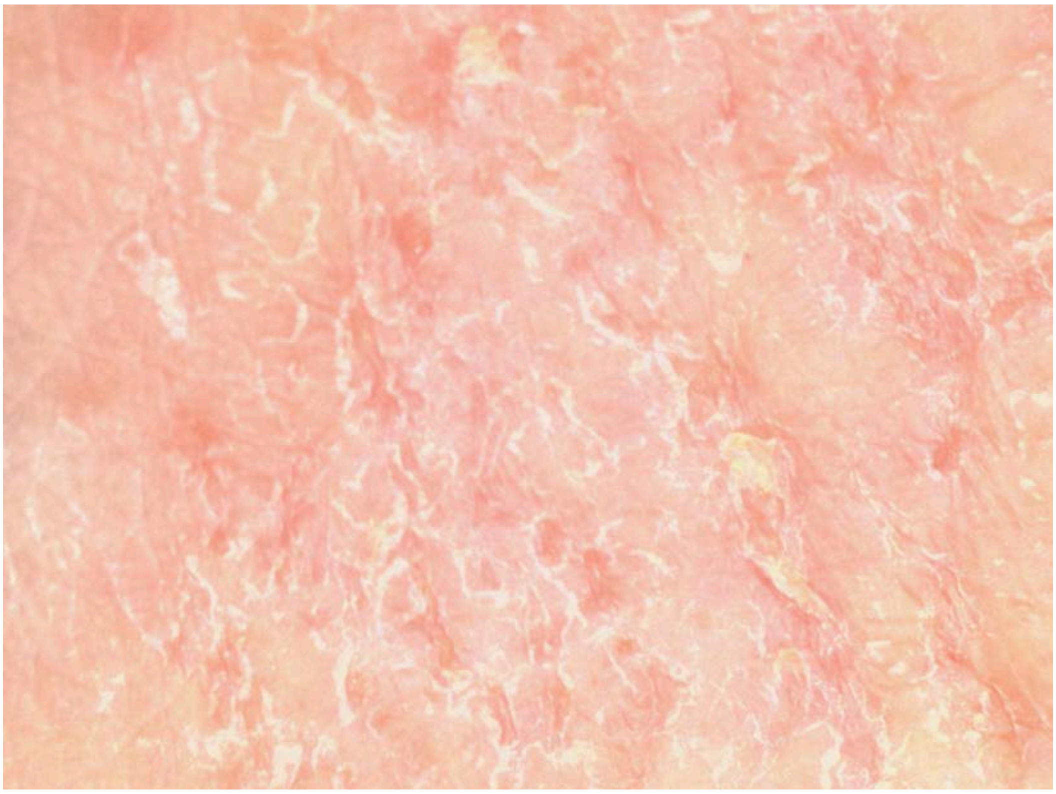


Fig. 31 My own eczema

Fig. 32 My own eczema

Photoshop files

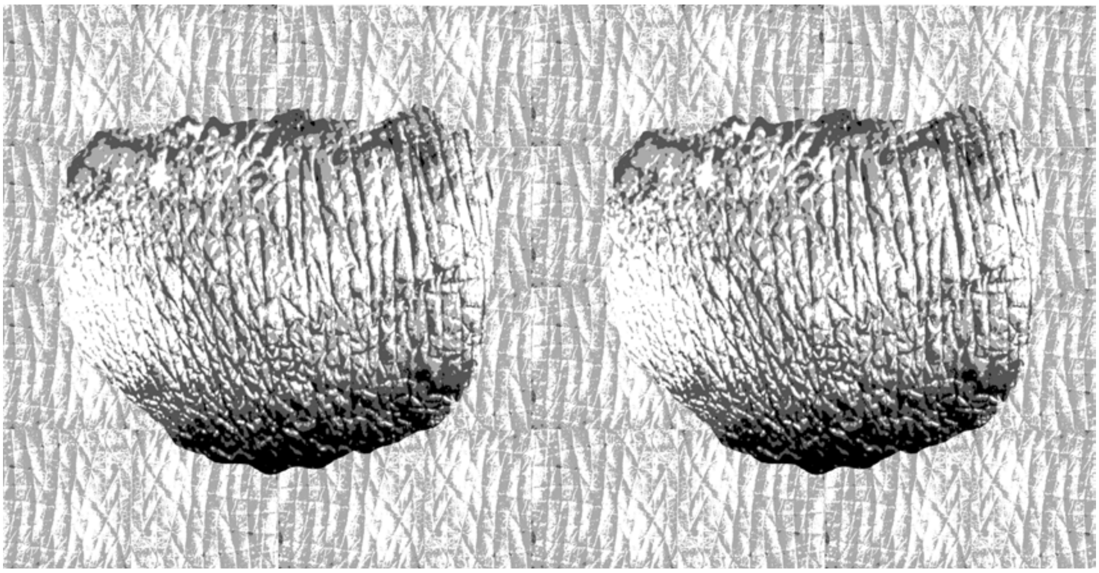


Fig. 33 ‘Puckered’ , development of fig. 7.

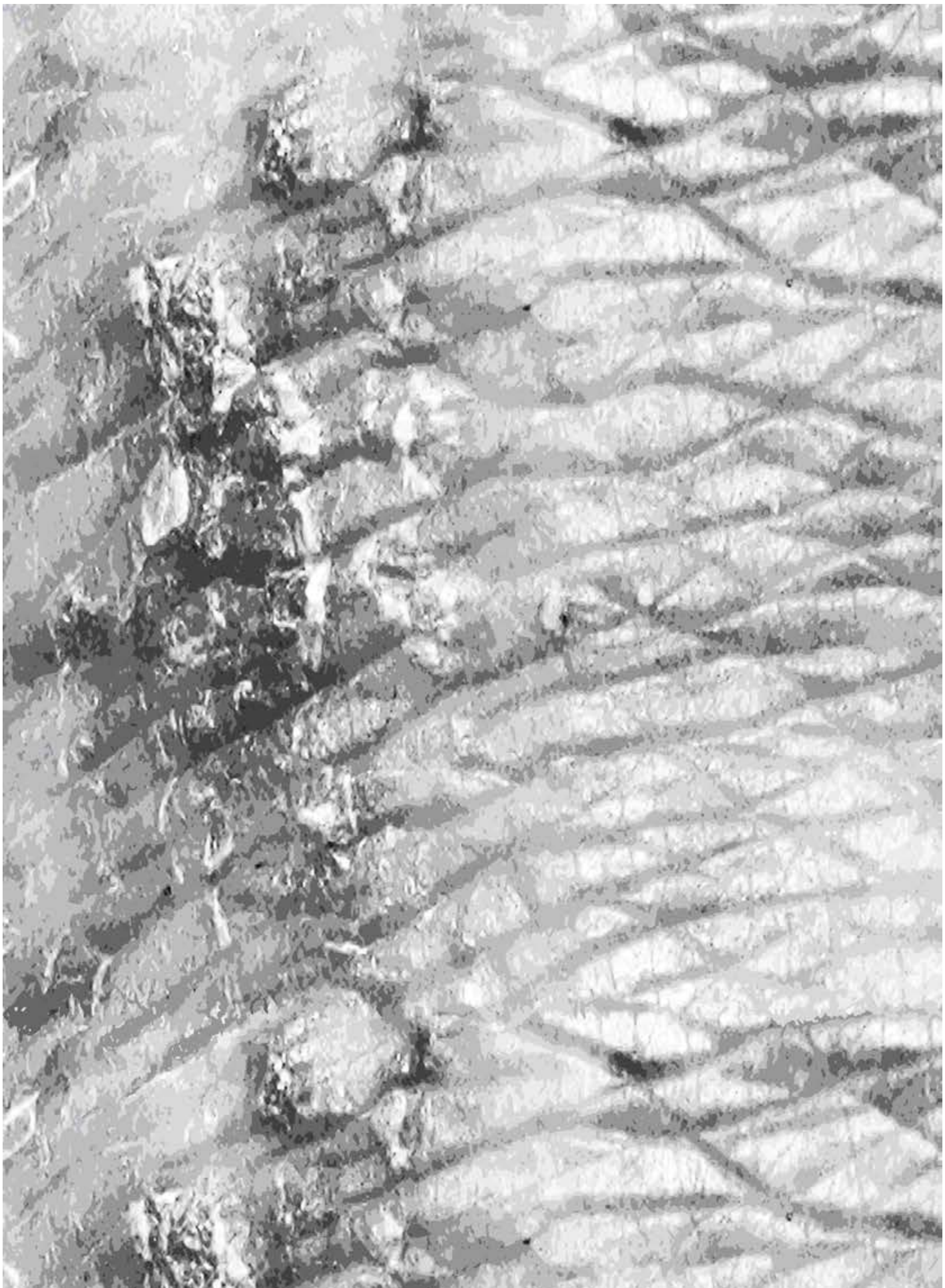


Fig. 34 ‘Myeczema’, development of fig. 32

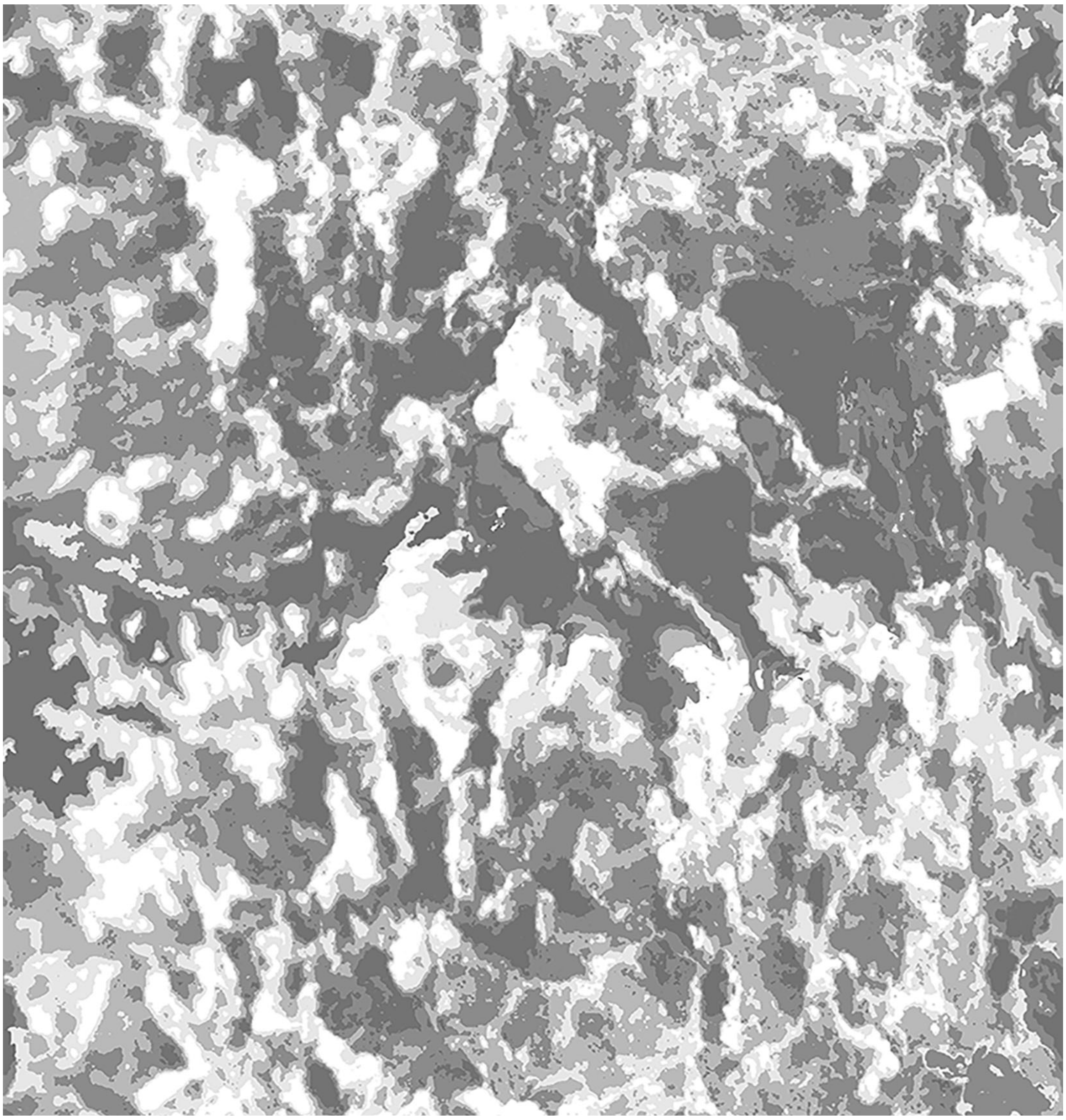


Fig. 35 ‘MMU11silber4’, development of figs. 29 and 30

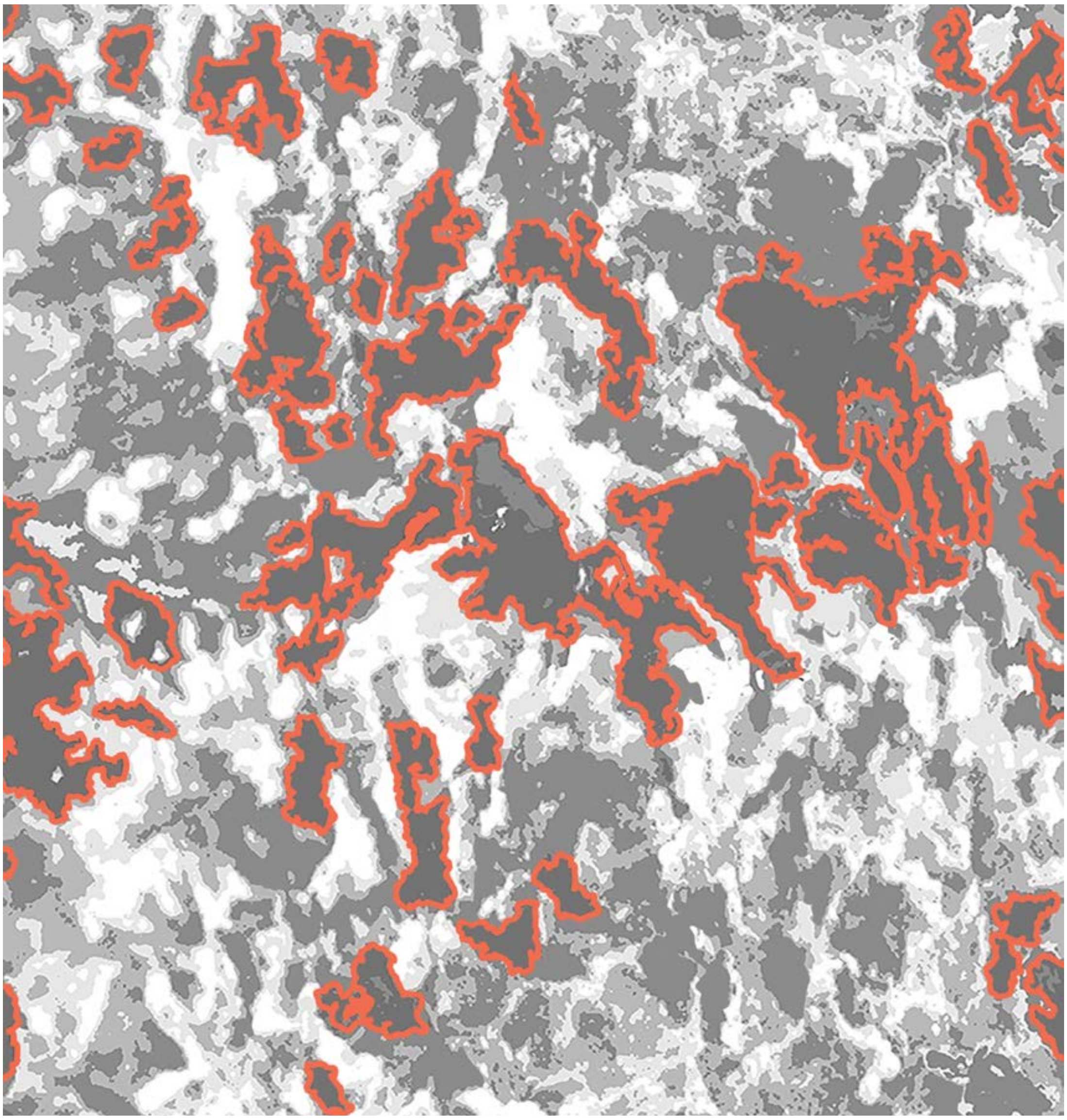


Fig. 36 Further development of ‘MMU11silber4’ design, with red areas highlighting the boundaries of the areas that are to be woven in silver.

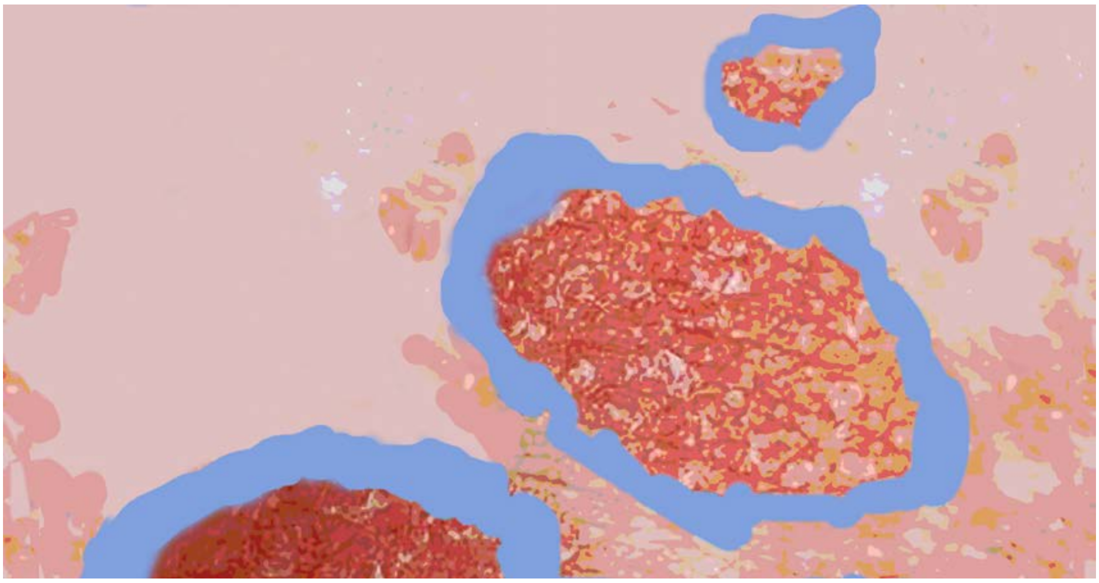


Fig. 37 Design for 'eczemaspl' trial, with compound extra-weft areas denoted in blue. Development of fig. 8.

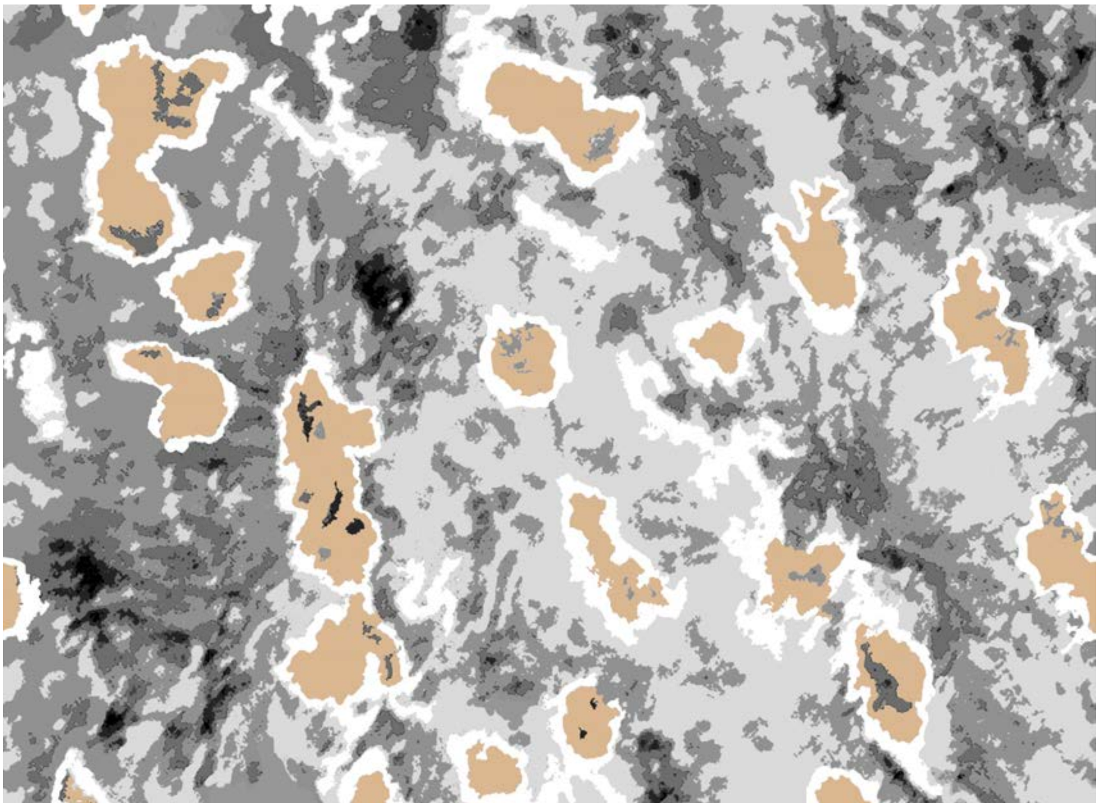


Fig. 38 'MMU1924' , development of fig. 31

Data Tables

Filename: Dobby trial	
Warp and EPI*	Eurestex 60/2 shantung silk 36 EPI
Weft and PPI*	Statex silver 78f 18 dtex z turns 40 PPI
Structures used	8 end* warp satin, 8 end weft sateen, plain weave
3D effectiveness	n/a
Resistance	1.5 ohms resistance in areas where silver is on the surface (8 end weft sateen); 2.5 ohms where silver is on the back of the fabric (8 end warp satin); 7 ohms where silk and silver and woven together equally (plain weave).
Sound quality	n/a
Comments	Sample to test relative conductivity of weave structures using Statex silver yarn on a dobby loom.

Fig. 39 Data table for dobby trial fabric

Filename: Jacquard trial (R.A.Smart)	
Warp and EPCM*	Ivory silk filament 104 EPCM
Weft and PPCM*	Statex silver 78f 18 dtex z turns 30 PPCM
Structures used	Warp satin and weft sateen
3D effectiveness	none
Resistance	3.5 ohms resistance where silver yarn is on the surface, 7 ohms where it is on the back.
Sound quality	n/a
Associated files	Jacquardtrial.wav, satin.wav
Comments	Sample to test conductivity of silver yarn on design based on skin print. Silver yarn was cut away at the back of the fabric to isolate conductive area. Woven at R.A.Smart.

Fig. 40 Data table for jacquard trial fabric (R.A. Smart)

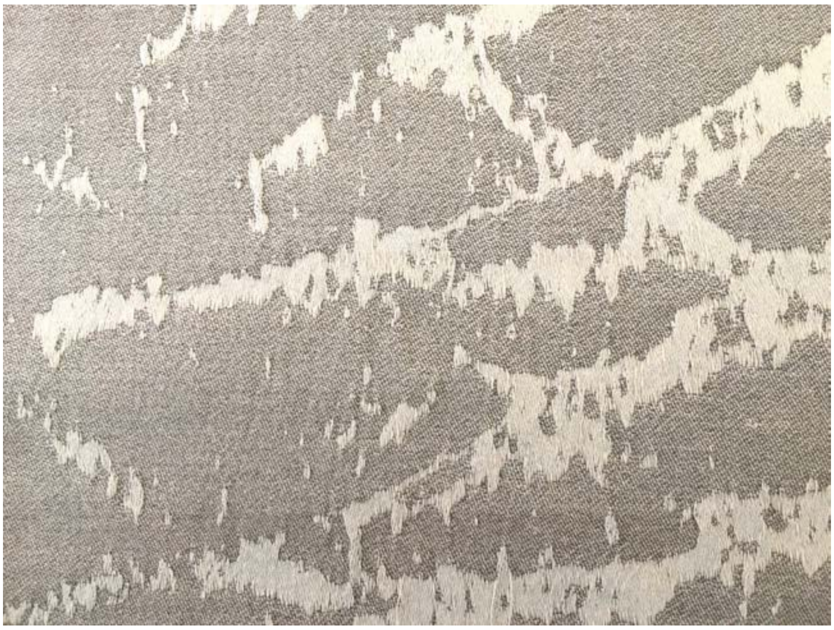
Filename: Skin1	
Warp and EPI	Cream polyester cotton 2/80 120 EPI
Weft and PPI	Statex 78f 18dtex z turns 32 PPI
Structures used	8 end warp satin and 8 end weft sateen
3D effectiveness	none
Resistance	16 ohms resistance where silver is on the surface
Sound quality	n/a
Associated files	Fig. 31 (eczema photo, cropped), Skin1.JQD

Fig. 41 Data table for Skin1 fabric

Filename: Skin2	
Warp and EPI	Cream polyester cotton 2/80 120 EPI
Weft and PPI	Statex silver 78f 18 dtex z turns 32 PPI
Structures used	8 end warp satin and 8 end weft sateen
3D effectiveness	none
Resistance	22 ohms resistance in areas where silver is on the surface
Sound quality	n/a
Associated files	Fig. 31 (eczema photo, cropped), Skin2.JQD, Skin2.Wav

Fig. 42 Data table for Skin2 fabric

Filename: discoid3	
Warp and EPI	Cream polyester cotton 2/80 120 EPI
Weft and PPI	1260 Ground – Handweaver's Studio black tram silk Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Double cloth sateen opp 2. Double cloth sateen opp 3. Double cloth sateen back to face 4. Double cloth sateen back to face 5. Double cloth sateen face to back 6. Double cloth sateen back to face 7. Double cloth sateen opp
3D effectiveness	No three-dimensionality
Resistance	12 ohms resistance where silver is on the surface
Sound quality	n/a
Associated files	Discoid3.JQD
Comments	Mock double cloth fabric – the fabric is double-sided with a pocket in the oval sections. By creating a fabric with 2 faces (one on the front of the fabric and the other on the back), I was attempting to get one face to shrink and the other to be static , thus creating raised and flat areas, but the experiment was unsuccessful.

Fig. 43 Data table for discoid3 fabric

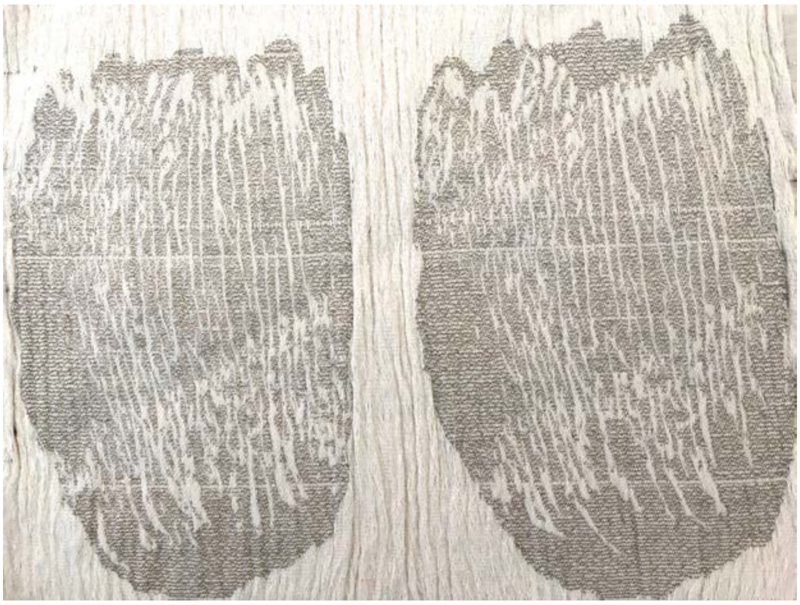
Filename: puckered	
Warp and EPI	Ivory polyester cotton 2/80 120 EPI
Weft and PPI	706 Ground – Habu ivory silk crepe z-twist Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Ground – hopsack A, extra – 8 end sateen 2. Cord warp 3. Buckskin weft 8s 4. 8 end sateen weft 5. Satinette warp 6. 8 end sateen warp
3D effectiveness	low
Resistance	13 ohms resistance in silver areas
Sound quality	low
Associated files	Fig. 6, fig. 32, puckered.JQD

Fig. 44 Data table for Puckered fabric

Filename: puckered2	
Warp and EPI	Ivory polyester cotton 2/80 120 EPI
Weft and PPI	470 Ground – Habu black silk crepe z-twist Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Ground – 8 end sateen warp, Extra – 8 end sateen weft 2. Cord warp 3. Buckskin warp 8s 4. 8 end Sateen weft 5. Satinette warp 6. 8 end Sateen warp
3D effectiveness	low
Resistance	11 ohms resistance in silver areas
Sound quality	low
Associated files	Fig. 6, fig. 32, puckered.JQD

Fig. 45 Data table for Puckered2 fabric

Filename: 2discoidb	
Warp and EPI	Ivory polyester cotton warp 2/80 120 EPI
Weft and PPI	529 picks Ground - Retractryl 60/2 nm Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Ground – compatible 8 end sateen, Extra – 8 end sateen 2. Buckskin weft 8s 3. Plain Weave 4. Cord warp 5. 8 end satin warp 6. 8 end sateen weft
3D effectiveness	Not effective, as the Retractryl yarn did not shrink as expected.
Resistance	9 ohms resistance
Sound quality	n/a
Associated files	2discoidb.JQD

Fig. 46 Data table for 2discoidb fabric

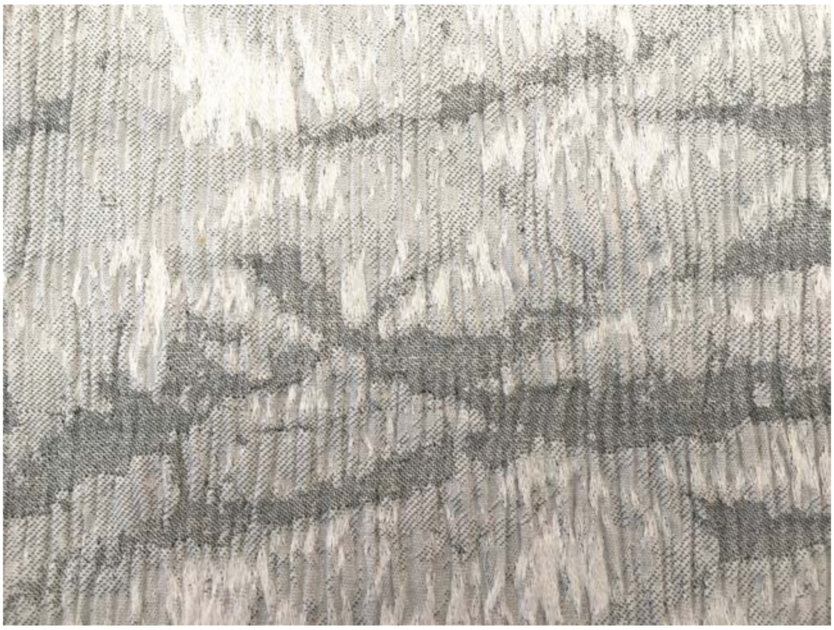
Filename: Skin3	
Warp and EPI	Ivory polyester cotton 2/80 120 EPI
Weft and PPI	1242 Ground – Habu black silk crepe z-twist, 32 PPI
Structures used	1. Crepe weft 8s 2. Plain weave 3. 8 end sateen warp 4. 8 end sateen weft
3D effectiveness	low
Resistance	n/a
Sound quality	low
Associated files	Fig. 31 (eczema photo, cropped), Skin3.JQD

Fig. 47 Data table for Skin3 fabric

Filename: myeczema	
Warp and EPI	Ivory polyester cotton 2/80 120 EPI
Weft and PPI	Ground – Habu black silk crepe z-twist, Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Cord warp 2. Buckskin weft 3. Plain weave 4. 8 end sateen weft 5. Ground – 8 end satin, extra – 8 end sateen 6. Compatible 8 end sateen
3D effectiveness	low
Resistance	8 ohms resistance
Sound quality	low
Associated files	Fig. 31, fig. 33

Fig. 48 Data table for Myeczema fabric

Filename: MMU11silber4	
Warp and EPI	Gaddum & Gaddum 120/2 ivory spun silk 120 EPI
Weft and PPI	Ground – Habu black silk crepe z-twist, Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	All compound weaves 1. 8 end sateen weft 2. Venetian weft 5 3. Compact 8 end satin and sateen 4. 8 end sateen warp 5. Extra weft plain weave 6. 1-2 twill right 7. 2-1 twill left 8. 8 end sateen warp
3D effectiveness	Medium
Resistance	3 ohms resistance
Sound quality	Low/medium
Associated files	Fig. 28, fig. 29, fig. 34, fig. 35, MMU11silber4.JQD, R09MMU11silber4.wav, R09MMU11silber4(2).wav

Fig. 49 Data table for MMU11Silber4

Filename: eczemaspl	
Warp and EPI	Gaddum & Gaddum 120/2 ivory spun silk 120 EPI
Weft and PPI	Ground – Bart & Francis ivory silk and spandex 85 den x 6 Extra – Statex silver 78f 18 dtex z turns 64 PPI
Structures used	1. Compound plain weave 2. 8 end warp satin 3. 8 end weft sateen 4. Ottoman
3D effectiveness	Medium
Resistance	5 ohms resistance
Sound quality	Low/medium
Associated files	Fig. 7, fig. 36, eczemaspl.JQD
Comments	First trial of weaving ground and extra weft together around silver areas.

Fig. 50 Data table for eczemaspl

Filename: MMU1924	
Warp and EPI	Gaddum & Gaddum 120/2 ivory spun silk 120 EPI
Weft and PPI	Ground – Habu black silk crepe z-twist, Extra – Karl Grimm High Flex silver 3981, 7x1 twist 64 PPI
Structures used	All compound weaves 1. 2-1 twill left 2. 1-2 twill right 3. Extra-weft plain weave 4. 8 end weft sateen 5. Compatible 8 end satin and sateen 6. 1-2 twill right 7. 8 end weft sateen
3D effectiveness	Medium/high
Resistance	2 ohms resistance
Sound quality	Medium
Associated files	Fig. 30, fig. 37, MMU1924.JQD R09 MMU1924.wav, R09 MMU1924.wav, MMU1924 contact.wav, MMU1924 8060.wav, MMU1924horizontal 362.wav, MMU1924horizontal 363.wav, MMU1924vertical 364.wav
Comments	Despite improved 3D effectiveness, the sound quality did not correlate compared to later samples, as the raised areas were quite soft. This resulted in little friction.

Fig. 51 Data table for MMU1924 fabric

Filename: MMU1924a	
Warp and EPI	Gaddum & Gaddum 120/2 ivory spun silk 120 EPI
Weft and PPI	Ground – Habu black silk crepe z-twist, Extra – Karl Grimm High Flex silver 3981, 7x1 twist 64 PPI
Structures used	1. Sateen weft 2. 1-2 twill right 3. Extra-weft plain weave 4. 8 end sateen warp 5. Compatible 8 end satin and sateen 6. 1-2 twill right 7. 8 end sateen warp
3D effectiveness	Medium/high
Resistance	3 ohms resistance
Sound quality	Medium
Associated files	Fig. 30, fig. 37, MMU1924a.JQD
Comments	Despite improved 3D effectiveness, the sound quality did not correlate compared to later samples, as the raised areas were quite soft. This resulted in little friction.

Fig. 52 Data table for MMU1924a

Filename: MMU1924a reverse	
Warp and EPI	Gaddum & Gaddum 120/2 ivory spun silk, 120 PPI
Weft and PPI	Ground – Habu black silk crepe z-twist, Extra – Karl Grimm High Flex silver 3981, 7x1 twist, 64 PPI
Structures used	8. Sateen weft 9. 1-2 twill right 10. Extra-weft plain weave 11. 8 end sateen warp 12. Compatible 8 end satin and sateen 13. 1-2 twill right 8 end sateen warp
3D effectiveness	Medium/high
Resistance	3 ohms resistance
Sound quality	Medium
Associated files	Fig. 30, fig. 37, MMU1924a.JQD
Comments	Back of previous fabric with silver weft cut away between spotty areas.

Fig. 53 Data table for MMU1924a (reverse of fabric)

Filename: Ivoryblock b	
Warp and EPCM	Ivory silk filament 104 EPCM
Weft and PPCM	Ground – Bart & Francis ivory silk and spandex 85 den Extra – Statex silver 78f 18 dtex z turns Various – 30-38 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	n/a
Resistance	5 ohms resistance
Sound quality	n/a
Associated files	Fig. 6, fig. 10, Ivoryblockb.EP
Comments	Trial to ascertain the maximum number of picks possible on the power jacquard loom. The more picks there are in the fabric, the stiffer (and therefore noisier) it will be.

Fig. 54 Data table for Ivoryblock b trial fabric

Filename: Ivoryblock b	
Warp and EPCM	Ivory silk filament 104 EPCM
Weft and PPCM	Ground – Bart & Francis ivory silk and spandex 85 den Extra – Statex silver 78f 18 dtex z turns 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	High
Resistance	5 ohms resistance where silver is on the surface
Sound quality	High
Associated files	Fig. 6, fig. 10, Ivoryblockb.EP, whiteribhorizontal1 370.wav, whiteribhorizontal2 371.wav, whiteribhorizontal3 372.wav, whiteribhorizontal4 373.wav, whiteriballover 374.wav, whiteriballover2 375.wav

Fig. 55 Data table for Ivoryblock b fabric

Filename: Ivoryblock c	
Warp and EPCM	Ivory silk filament 104 EPCM
Weft and PPCM	Ground – Bart & Francis ivory silk and spandex 85 den Extra – Statex silver 78f 18 dtex z turns 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	High
Resistance	5 ohms resistance where silver is on the surface
Sound quality	High
Associated files	Fig. 6, fig. 10, Ivoryblockc.EP, silverrib contact.wav, silverrib 8060.wav, silverriballover 357.wav, silverribhorizontal1 358.wav, silverribhorizontal 359.wav, silverribhorizontal 360.wav, silverribvertical 361.wav
Comments	This design emanated from the same weave file as the previous design, but with the weave structures allocated to different areas, resulting in the raised areas appearing in other locations.

Fig. 56 Data table for Ivoryblock c fabric

Filename: Blackblock	
Warp and EPCM	Black silk filament 112 EPCM
Weft and PPCM	Ground – Bart & Francis ivory silk and spandex 85 den Extra – Statex silver 78f 18 dtex z turns 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	Very good
Resistance	7 ohms resistance
Sound quality	Very good
Associated files	Fig. 6, fig. 9, Victoria.Blackblock.EP, blackrib contact.wav, blackrib 8060.wav, blackriballover 342.wav, blackribvertical1 343.wav, blackribhorizontal1 344.wav, blackribhorizontal2 345.wav, blackribhorizontal3 346.wav, blackribhorizontal4 347.wav, blackribhorizontal5 349.wav, blackribhorizontal6 350.wav, blackriballover2 348.wav

Fig. 57 Data table for Blackblock fabric

Filename: Eczemaspl 2c	
Warp and EPCM	Black silk filament 112 EPCM
Weft and PPCM	Ground – Bart & Francis ivory silk and spandex 85 den Extra – Statex silver 78f 18 dtex z turns 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	High
Resistance	7 ohms resistance in raised silver areas
Sound quality	High
Associated files	Fig. 7, fig. 11, Eczemaspl2c.EP, blackbloballover1 351.wav, blackbloballover2 352.wav, blackbloballover 353.wav, blackblobvertical1 354.wav, blackblobhorizontal1 355.wav, blackbloballover 356.wav

Fig. 58 Data table for Eczemaspl2c fabric

Filename: Ivory block b	
Warp and EPCM	Ivory silk filament 104 EPCM
Weft and PPCM	Ivory silk filament 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	n/a
Resistance	n/a
Sound quality	n/a
Associated files	Fig. 6, fig. 10, Ivoryblockb.EP
Comments	Pure silk lining fabric for ivory and silver garment

Fig. 59 Data table for Ivoryblock B fabric (pure silk)

Filename: Blackblock	
Warp and EPI	Black silk filament 112 EPCM
Weft and EPI	Pale grey silk filament 34 PPCM
Structures used	Compatible 8 end satin and sateen (compound weaves) Extra weft plain weave (compound weave)
3D effectiveness	n/a
Resistance	n/a
Sound quality	n/a
Associated files	Fig. 6, fig. 9, Victoria.Blackblock.EP, blackribflat contact.wav, blackribflat 8060.wav
Comments	Pure silk lining for black and silver garment

Fig. 60 Data table for Blackblock fabric (pure silk)

Yarns

Silk

Eurestex 60/2 NM Shantung silk

Gaddum and Gaddum 120/2 NM spun silk

Silk filament (R.A.Smart)

Habu ns-8 black silk crepe

Bart & Francis 85 den silk and spandex

Handweaver's Studio and Gallery 200/220 tram silk

Silver

Statex Shieldex®78/18dtex Z – turns

Karl Grimm 3981 High-Flex 7x1 twist silver14/ooo

Kitronik Electro-Fashion conductive thread

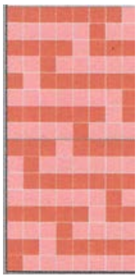
Other

Bart & Francis Retractryl 60/2 NM

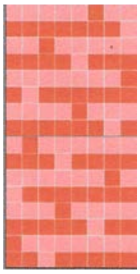
Somac polyester cotton thread 2/80's cc equivalent

Weave structures

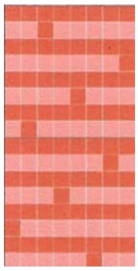
Compound weaves



compatible 8 end
sateen and satin

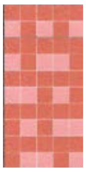


compatible 8 end
satin and sateen

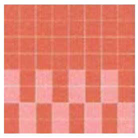


8 end sateen weft

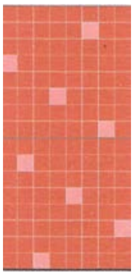
extra weft
plain weave



venetian weft
5's

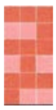


extra weft
ottoman



8 end sateen
Warp

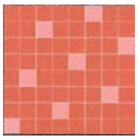
2-1 twill
left

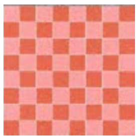


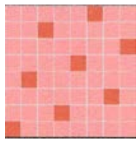
1-2 twill
right

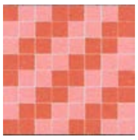
Fig. 61 Compound weave structures

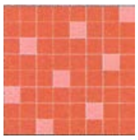
Non-compound weaves

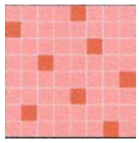

8 end satin


plain weave


8 end sateen


2 and 2 twill


compatible
8 end satin


8 end sateen

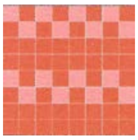

Ottoman

Fig. 62 Non-compound weave structures

The following weave structures are not currently available due to lack of access to the weave software because of Covid-19 restrictions:

hopsackA
cord warp
buckskin weft 8's
satinette warp
crepe weft 8's
double cloth sateen back to face
double cloth sateen opp
double cloth sateen face to back
double cloth sateen back to face

Jacquard weave files

The following files can only be read with the relevant software (Scotweave and Nedgraphics) and are available on a USB drive on request:

Scotweave

Skin1.JQD

Skin2.JQD

Skin3.JQD

2discoidb.JQD

Discoid3.JQD

Puckered.JQD

Puckered2.JQD

Myeczema.JQD

Mmu11silber4.JQD

eczemaspl.JQD

Mmu1924.JQD

Mmu1924a.JQD

Nedgraphics

Victoria.Blackblock.EP

Ivoryblockb.EP

Ivoryblockc.EP

Eczemaspl2c.EP

Capacitive Sensor Development

First test

Connect adafruit flora to piece of copper foil via alligator clips and 10m resistor.

D10 is sensor port

One end of clip 1 connected to D10 and other end to both one end of resistor and the copper foil. One end of clip 2 connected to D9 and other end to other end of resistor.

Upload CapacitiveSensorSketch3

Open serial monitor

When foil is touched the monitor numbers spike greatly – from 200 to 20000.

LED D7 illuminates when numbers go over 4000. Response time is slow though.

Second test

As above but using my silk and silver 'jacquard trial' fabric. The clip connected to D10 – other end pinches both one end of 10M resistor and silver area of fabric. D9 connected to other end of resistor.

Upload CapacitiveSensorSketch3

Open serial monitor

When silver area of fabric is touched the monitor numbers spike greatly

LED D7 illuminates when numbers go over 4000. Response time is slow though.

Third test

Using my silk and silver fabric, first clip connected to D10 – other end pinches both one end of 10M resistor and silver area of fabric. D9 connected via clip 2 to other end of resistor.

Flora RGB neopixel is connected to Flora with clips. VBATT on flora to + on neopixel, D6 on flora to inward-facing arrow on neopixel, GND on flora to – on neopixel.

Upload CapacitiveSensorSketch4

When silver area of fabric is touched the neopixel lights up red. It works if anywhere on the silver area connected to the circuit is touched, but not on the other silver areas on the fabric. Serial monitor also inspected to test number spike.

Fourth test

As third test but neopixel is sewn to flora at ports rather than connected with clips. Used Karl Grimm silver thread, high flex 7077 silver-coated kevlar 14/000. A video of this test can be accessed here:
https://vimeo.com/user4976678/review/441247927/9c011c0065

Fifth test

All connections are sewn – i.e. D10 on flora connected to one end of 10M resistor and silver area of fabric with silver Karl Grimm thread, high flex 7077 silver-coated kevlar 14/000. D9 on flora connected with silver thread to other end of 10M resistor. Flora connected with thread to neopixel as in fourth test.
When the silver area of fabric was touched there was no response. I concluded that a short circuit had occurred after testing with a multimeter.

Sixth test

Unpicked all sewing and started again, this time with a different thread. The Karl Grimm 7077 was quite difficult to sew with. It is fairly stiff and tends to knot itself. I replaced it with Kitronik electro-fashion conductive thread (made from spun stainless steel). Connections as in fifth test:
D10 on flora connected to one end of 10M resistor and silver area of fabric. D9 on flora connected to other end of 10M resistor. Flora connected with thread to neopixel: VBATT on flora to + on neopixel, D6 on flora to inward-facing arrow on neopixel, GND on flora to – on neopixel.
Uploaded CapacitiveSensorSketch4
When any part of the silver area on the fabric was touched the neopixel illuminated. I was particularly pleased that when a finger was drawn across the more 3D section of the silver area, the neopixel illuminated intermittently.

This would indicate that the sensor is sensitive enough to detect changes in surface texture.
A video of the this test can be accessed here:
https://vimeo.com/user4976678/review/441247702/4f562ae675

Capacitive sensor sketch 3

```
#include <CapacitiveSensor.h>

/*
 * CapitiveSense Library Demo Sketch
 * Paul Badger 2008
 * Uses a high value resistor e.g. 10M between send pin and receive pin
 * Resistor effects sensitivity, experiment with values, 50K - 50M. Larger resistor
values yield larger sensor values.
 * Receive pin is the sensor pin - try different amounts of foil/metal on this pin
 */


CapacitiveSensor   cs_9_10 = CapacitiveSensor(9,10);        // 1M resistor between
pins 9 & 10, pin 10 is sensor pin, add a wire and or foil if desired
CapacitiveSensor   cs_9_2 = CapacitiveSensor(9,2);        // 1M resistor between pins
9 & 2, pin 2 is sensor pin, add a wire and or foil
CapacitiveSensor   cs_4_8 = CapacitiveSensor(4,8);        // 1M resistor between pins
4 & 8, pin 8 is sensor pin, add a wire and or foil

void setup()
{
  cs_9_10.set_CS_AutocaL_Millis(0xFFFFFFFF);     // turn off autocalibrate on
channel 1 - just as an example
  Serial.begin(9600);
}

void loop()
{
   long start = millis();
   long total1 =  cs_9_10.capacitiveSensor(30);
```

```
  long total2 =  cs_9_2.capacitiveSensor(30);
  long total3 =  cs_4_8.capacitiveSensor(30);

  Serial.print(millis() - start);       // check on performance in milliseconds
  Serial.print("\t");                   // tab character for debug windown spacing

  Serial.print(total1);                 // print sensor output 1
  Serial.print("\t");
  Serial.print(total2);                 // print sensor output 2
  Serial.print("\t");
  Serial.println(total3);               // print sensor output 3

  delay(10);      // arbitrary delay to limit data to serial port


if (total1 > 4000){
 digitalWrite(7, HIGH);
}else{
 digitalWrite(7, LOW);

}

}
```

Capacitive sensor sketch 4

```
#include <CapacitiveSensor.h>
#include "Adafruit_FloraPixel.h"

/*
 * CapitiveSense Library Demo Sketch
 * Paul Badger 2008
 * Uses a high value resistor e.g. 10M between send pin and receive pin
 * Resistor effects sensitivity, experiment with values, 50K - 50M. Larger resistor
values yield larger sensor values.
 * Receive pin is the sensor pin - try different amounts of foil/metal on this pin
 */


CapacitiveSensor   cs_9_10 = CapacitiveSensor(9,10);        // 1M resistor between
pins 9 & 10, pin 10 is sensor pin, add a wire and or foil if desired
//CapacitiveSensor   cs_9_2 = CapacitiveSensor(9,2);        // 1M resistor between
pins 9 & 2, pin 2 is sensor pin, add a wire and or foil
//CapacitiveSensor   cs_4_8 = CapacitiveSensor(4,8);        // 1M resistor between
pins 4 & 8, pin 8 is sensor pin, add a wire and or foil
Adafruit_FloraPixel strip = Adafruit_FloraPixel(1);

void setup()
{
   cs_9_10.set_CS_AutocaL_Millis(0xFFFFFFFF);     // turn off autocalibrate on
channel 1 - just as an example
   Serial.begin(9600);
   strip.begin();
   strip.show();

}
```

```
void loop()
{
   long start = millis();
   long total1 =  cs_9_10.capacitiveSensor(30);
   //long total2 =  cs_9_2.capacitiveSensor(30);
   //long total3 =  cs_4_8.capacitiveSensor(30);

   if (total1 >4000){
     digitalWrite(7, HIGH);
     strip.setPixelColor(0, Color(0,255,0));
     strip.show();
   }else{
     strip.setPixelColor(0, Color(0,0,0));
     strip.show();
   }


  Serial.print(millis() - start);       //check on performance in milliseconds
  Serial.print("\t");                   //tab character for debug window spacing

  Serial.println(total1);               //print sensor output 1
  //Serial.print("\t");
  //Serial.println(total2);             //print sensor output 2
  //Serial.print("\t");
  //Serial.println(total3);             //print sensor output 3

  delay(10);                            // arbitrary delay to limit data to serial port
}

 //Create a 24 bit color value from R,G,B
 RGBPixel Color(byte r,byte g, byte b)
```

```
{
  RGBPixel p;

  p.red = r;
  p.green = g;
  p.blue = b;

  return p;

}
```

Components for the interactive garments

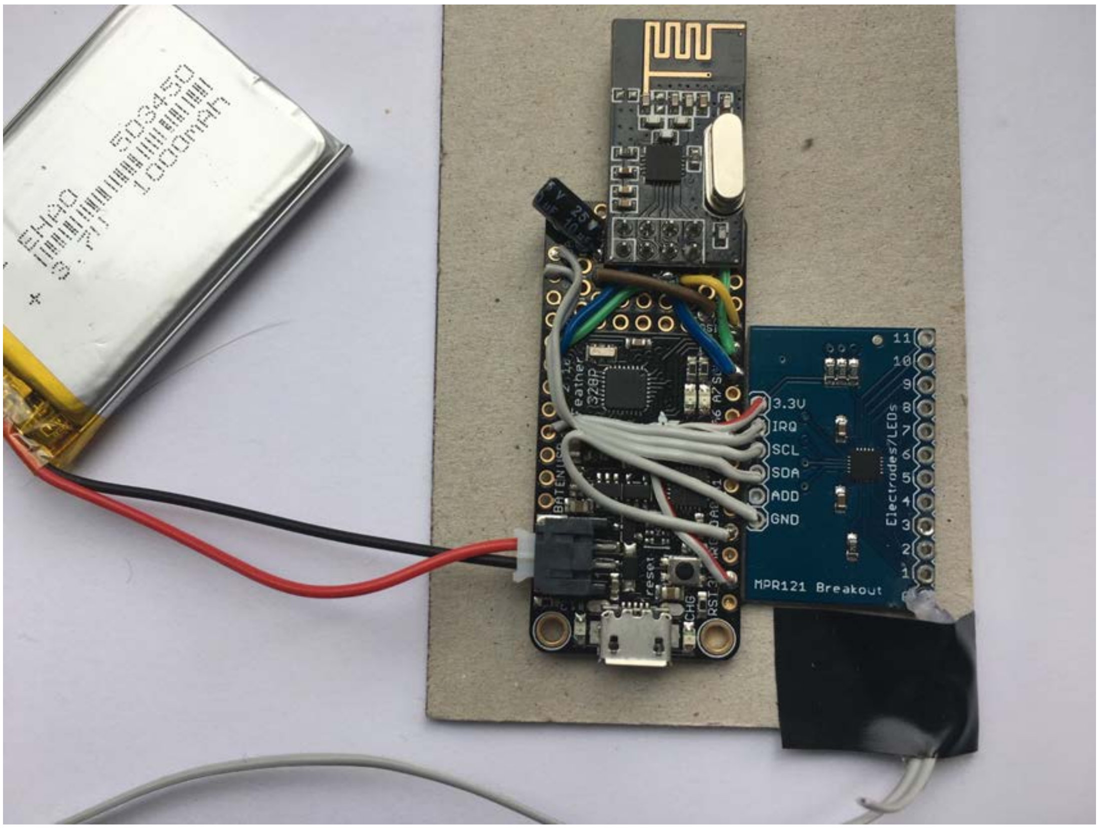


Fig. 63 MPR121 capacitive touch board connected to feather328 board and lithium battery. They have been glued to a piece of card to make the wiring more immobile, and placed in a silk bag attached to the inside collar of the garments.

Fig. 64 Box containing radio transceiver and wav trigger board

Fig. 65 Interior of box showing RF24 radio transceiver and wav trigger board

Basic code for the interactive garments

(this must be altered according to serial ports used and environmental factors)

```
#include <MPR121.h>
#include <Wire.h>

#include <RF24Network.h>
#include <RF24.h>
#include <SPI.h>

/* CONNECTIONS:
   FEATHER328 : MPR121
          4 : INT
         A4 : SDA
         A5 : SCL
       3.3V : 3.3V
        GND : GND

   FEATHER328 : NRF24L01
          9 : CE
         10 : CSN
         11 : MOSI
         12 : MISO
         13 : SCK
       3.3V : 3.3V
        GND : GND
*/

#define TOUCH_THRESHOLD 5
#define RELEASE_THRESHOLD 1

const int dress=1;
```

```
RF24 radio(9, 10);                // nRF24L01(+) radio attached using Getting Started
board
RF24Network network(radio);         // Network uses that radio

//const uint16_t this_node = 01;       // Address of our node in Octal format (this is
defined by dress number)
const uint16_t other_node = 00;      // Address of the other node in Octal format

const byte numElectrodes = 1;

struct payload_t {               // Structure of our payload
  byte message;
};

void setup(void)
{
  delay(5000);
  Serial.begin(115200);

  Serial.println(MPR121.begin(0x5A));
  MPR121.setInterruptPin(4);
  MPR121.setTouchThreshold(TOUCH_THRESHOLD);
  MPR121.setReleaseThreshold(RELEASE_THRESHOLD);
  MPR121.updateTouchData();

  SPI.begin();
  radio.begin();
  radio.setPALevel(RF24_PA_LOW);
  network.begin(103, dress+1);
}

void loop() {
```

```
  network.update();

  //if (MPR121.touchStatusChanged()) {
    MPR121.updateTouchData();
    MPR121.updateBaselineData();
    MPR121.updateFilteredData();

    for (int i = 0; i < numElectrodes; i++) {
      int b=MPR121.getBaselineData(i);
      int f=MPR121.getFilteredData(i);
      int d=b-f;
      if(i==0){

        Serial.println(d);
      }
      if (MPR121.isNewTouch(i)) {
        Serial.print("electrode ");
        Serial.print(i, DEC);
        Serial.println(" was just touched");
        sendMessage('T', i+dress*numElectrodes+1, 10);

      } else if (MPR121.isNewRelease(i)) {
        Serial.print("electrode ");
        Serial.print(i, DEC);
        Serial.println(" was just released");
        sendMessage('R', i+dress*numElectrodes+1, 10);
      }
    }
  //}
}

boolean sendMessage(char TYPE, byte PAYLOAD, byte MAX_ATTEMPTS) {
```

```
  Serial.print("Sending message...");
  byte attempts = 0;
  RF24NetworkHeader header(other_node, TYPE);
  payload_t payload = {PAYLOAD};
  boolean result = false;
  while (!result && attempts < MAX_ATTEMPTS) {
    result = network.write(header, &payload, sizeof(PAYLOAD));
    attempts++;
  }
  if (result) {
    Serial.print("success!");
  } else {
    Serial.print("failed.");
  }
  return result;
}
```

Sound files

1st recordings (recorded with a Roland Edirol R09 recorder)

R09 jaquardtrial

https://soundcloud.com/vjhaire/r09-satinhedgehogwav/s-3xGdNTOQRId

R09 satin

https://soundcloud.com/vjhaire/r09-satinwav/s-5shgcaPX5H6

R09 Skin2

https://soundcloud.com/vjhaire/r09-beigezwav/s-GICJTh6pL4G

R09 MMU11silber4

https://soundcloud.com/vjhaire/r09-crinkly3wav/s-Dy0JcscZCHF

R09 MMU11silber4(2)

https://soundcloud.com/vjhaire/r09-crinkly2wav/s-OpUiKvCt63R

R09 MMU1924

https://soundcloud.com/vjhaire/r09-silverblobwav/s-JKTv4LpX2KG

R09 MMU1924(2)

https://soundcloud.com/vjhaire/r09-silverblob2wav/s-WIJP7S1LuHx

2nd recordings

(files recorded separately with a Sennheiser 8060 condenser microphone and a home-made contact microphone)

Silverrib 8060

https://soundcloud.com/vjhaire/silver-rib-8060/s-5ze8VRehU9t

Silverrib contact

https://soundcloud.com/vjhaire/silver-rib-contact/s-pcl3jd9WGwa

MMU1924 8060

https://soundcloud.com/vjhaire/silver-bumpy-8060/s-tarjtQPJhBB

MMU1924 contact

https://soundcloud.com/vjhaire/silver-bumpy-contact/s-TAymyWrSTjA

Blackribflat 8060

https://soundcloud.com/vjhaire/black-rib-flat-8060/s-MJX9O52acON

Blackribflat contact

https://soundcloud.com/vjhaire/black-rib-flat-contact/s-gXDMrrYxPh2

Blackrib 8060

https://soundcloud.com/vjhaire/black-rib-8060/s-eLMRBzZ8S5t

Blackrib contact

https://soundcloud.com/vjhaire/black-rib-contact/s-CD3QcbYowgX

Black blob 8060

https://soundcloud.com/vjhaire/black-crinkly-8060/s-IOtpQOlpV8f

Black blob contact

https://soundcloud.com/vjhaire/black-crinkly-contact/s-WTQmDyWJVwl

3rd recordings

Black rib all over1 342

https://soundcloud.com/vjhaire/blackriballover1-342/s-5VGs8HOb3uS

Black rib vertical1 343

https://soundcloud.com/vjhaire/blackribvertical1-343/s-Ces3a4QlMqu

Black rib horizontal1 344

https://soundcloud.com/vjhaire/blackribhorizontal1-344/s-s3U1WXWfVKZ

Black rib horizontal2 345

https://soundcloud.com/vjhaire/blackribhorizontal2-345/s-v4bkdOtLO2S

Black rib horizontal3 346

https://soundcloud.com/vjhaire/blackribhorizontal3-346/s-Kyq1JTok7r3

Black rib horizontal4 347

https://soundcloud.com/vjhaire/blackribhorizontal4-347/s-pFe1vgBTzd4

Black rib all over 348

https://soundcloud.com/vjhaire/blackriballover2-348/s-wSIEFdGOzhq

Black rib horizontal5 349

https://soundcloud.com/vjhaire/blackribhorizontal5-349/s-JYgqsA8zkfH

Black rib horizontal6 350

https://soundcloud.com/vjhaire/blackribhorizontal6-350/s-I5xWM6YNJYC

Black blob all over1 351

https://soundcloud.com/vjhaire/blackbloballover1-351/s-OE0LUZGBjpw

Black blob all over2 352

https://soundcloud.com/vjhaire/blackbloballover2-352/s-T6aqDyvUNL5

Black blob all over3 353

https://soundcloud.com/vjhaire/blackbloballover3-353/s-ohrNajBrLWy

Black blob vertical1 354

https://soundcloud.com/vjhaire/blackblobvertical1-354/s-OxbmJrj0a6a

Black blob horizontal1 355

https://soundcloud.com/vjhaire/blackblobhorizontal1-355/s-YopIWvNTHiK

black blob all over4 356

https://soundcloud.com/vjhaire/blackbloballover4-356/s-sLfsyJN2XJU

Silver rib all over 357

https://soundcloud.com/vjhaire/silverriballover-357/s-rVGkHZChiFp

Silver rib horizontal1 358

https://soundcloud.com/vjhaire/silverribhorizontal1-358/s-JoVJjNQ8S0K

Silver rib horizontal2 359

https://soundcloud.com/vjhaire/silverribhorizontal2-359/s-Tx4FqqLRghj

Silver rib horizontal3 360

https://soundcloud.com/vjhaire/silverribhorizontal3-360/s-DXlcpHFNTGW

Silver rib vertical1 361

https://soundcloud.com/vjhaire/silverribvertical-361/s-rNEpbhqY1rm

MMU1924 horizontal 362

https://soundcloud.com/vjhaire/silverblob1-362/s-qdwsjuoroPA

MMU1924 horizontal 363

https://soundcloud.com/vjhaire/silverblobhorizontal-363/s-viMi6yplgob

MMU1924 vertical 364

https://soundcloud.com/vjhaire/silverblobvertical-364/s-u3fyemo5Ewm

MMU11silber4 vertical 365

https://soundcloud.com/vjhaire/greycrinklevertical-365/s-8SgqoLhZ9sf

MMU11silber4 all over 366

https://soundcloud.com/vjhaire/greycrinkleallover-366/s-8vLJgUSXASR

MMU11silber4 horizontal1 367

https://soundcloud.com/vjhaire/greycrinklehorizontal1-367/s-gYNMFhUaN7g

MMU11silber4 horizontal2 368

https://soundcloud.com/vjhaire/greycrinklehorizontal2-368/s-A54XHoZnlBI

White rib horizontal1 370

https://soundcloud.com/vjhaire/whiteribhorizontal1-370/s-SHN79OP5Trj

White rib horizontal2 371

https://soundcloud.com/vjhaire/whiteribhorizontal2-371/s-RAo0wQ4P0pj

White rib horizontal3 372

https://soundcloud.com/vjhaire/whiteribhorizontal3-372/s-DsYJ7nz539I

White rib horizontal4 373

https://soundcloud.com/vjhaire/whiteribhorizontal4-373/s-Zg1fVWBYcYr

White rib all over 374

https://soundcloud.com/vjhaire/whiteriballover-374/s-BXYkRHcNmlg

White rib all over2 375

https://soundcloud.com/vjhaire/whiteriballover2-375/s-6F8m6NHNXG8

Survey of student responses to the sound recordings

File name and number	**Comments of 6 x level 5 BA woven textile students**
Black blob all over 351 352 353 356	 352: All students thought there was too much background noise in this recording. 353: Same response as for 352. 356: All 6 students preferred this file and thought it most sounded like the fabric felt.
Black blob horizontal 355	All students preferred this file to 356.
Black blob vertical 354	Students said this file reminded them of the sea. They felt it was calmer and preferred this sound to all the other recordings of the black blob fabric.
Black rib all over 342 348	
Black rib horizontal 344 345 346 347 349 350	All students felt that the horizontal sounds represented the black rib fabrics best, as the sounds of friction on the rib could be heard. 346 was the favourite of all students.
Black rib vertical 343	Students felt this produced a constant noise which did not represent the fabrics accurately.
Silver rib all over 357	
Silver rib horizontal 358 359 360	 359 was the favourite silver rib sound for all students
Silver rib vertical 361	It was felt there was little variation in this sound and it did not represent the nature of the fabric.
White rib all over 374 375	
White rib horizontal 370 371 372 373	This was the favourite of the white rib fabric sounds for all students.
White rib vertical 369	Students said this file reminded them of the sea and was calming.

File name and number		Comments of 4 x level 6 BA woven textile students
Black blob all over	351	All 4 students preferred this recording of the black blob all over sounds.
	352	
	353	
	356	
Black blob horizontal	355	3 students thought the horizontal recording was preferable to the vertical one. 1 student thought either were suitable.
Black blob vertical	354	
Black rib all over	342	
	348	All students preferred this recording of the black rib all over sounds.
Black rib horizontal	344	2 students preferred this recording.
	345	1 student preferred this recording.
	346	
	347	
	349	1 student felt that 349 represented the bumpy areas of the fabrics well, but 345 represented the smoother areas better.
	350	
Black rib vertical	343	The students liked this recording but felt that the horizontal recordings better represented the nature of the fabrics.
Silver rib all over	357	The students felt that this sounded like rustling and that it sounds harsher than it feels.
Silver rib horizontal	358	
	359	1 student preferred this recording.
	360	3 students preferred this recording. The horizontal sounds were preferred to the all over ones.
Silver rib vertical	361	The students felt that this recording sounded like waves.
White rib all over	374	The students did not like this recording. They felt it sounded like a storm.
	375	All 4 students preferred this recording.
White rib horizontal	370	1 student preferred this recording.
	371	Two students preferred this recording.
	372	
	373	1 student preferred this recording.
White rib vertical	369	The students liked the sound of vertical recording better than the horizontal ones as it is calmer. However, they recognised that the horizontal ones represented the ribbed nature of the fabrics better.

Graphic scores

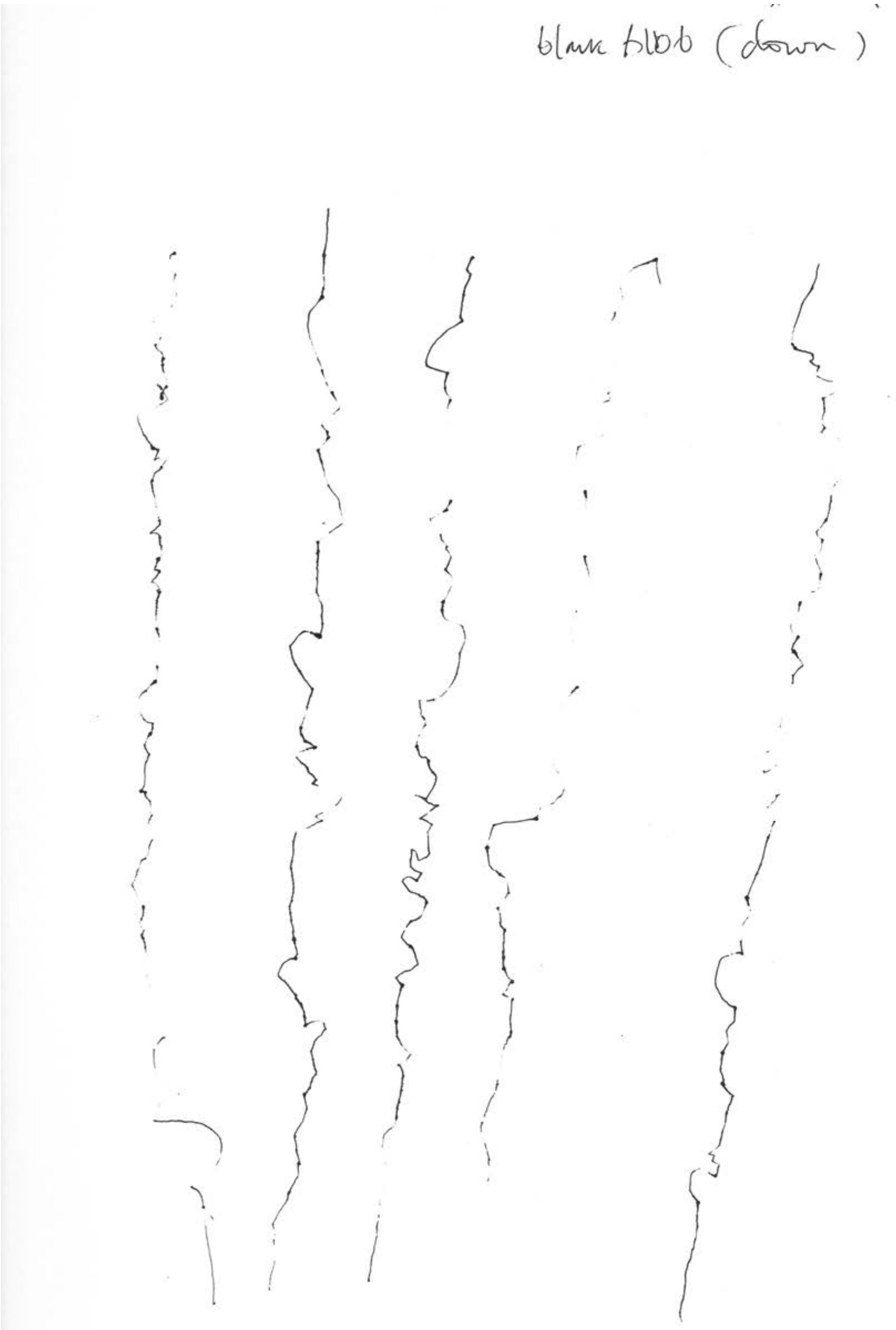


Fig. 66 Black blob down graphic score

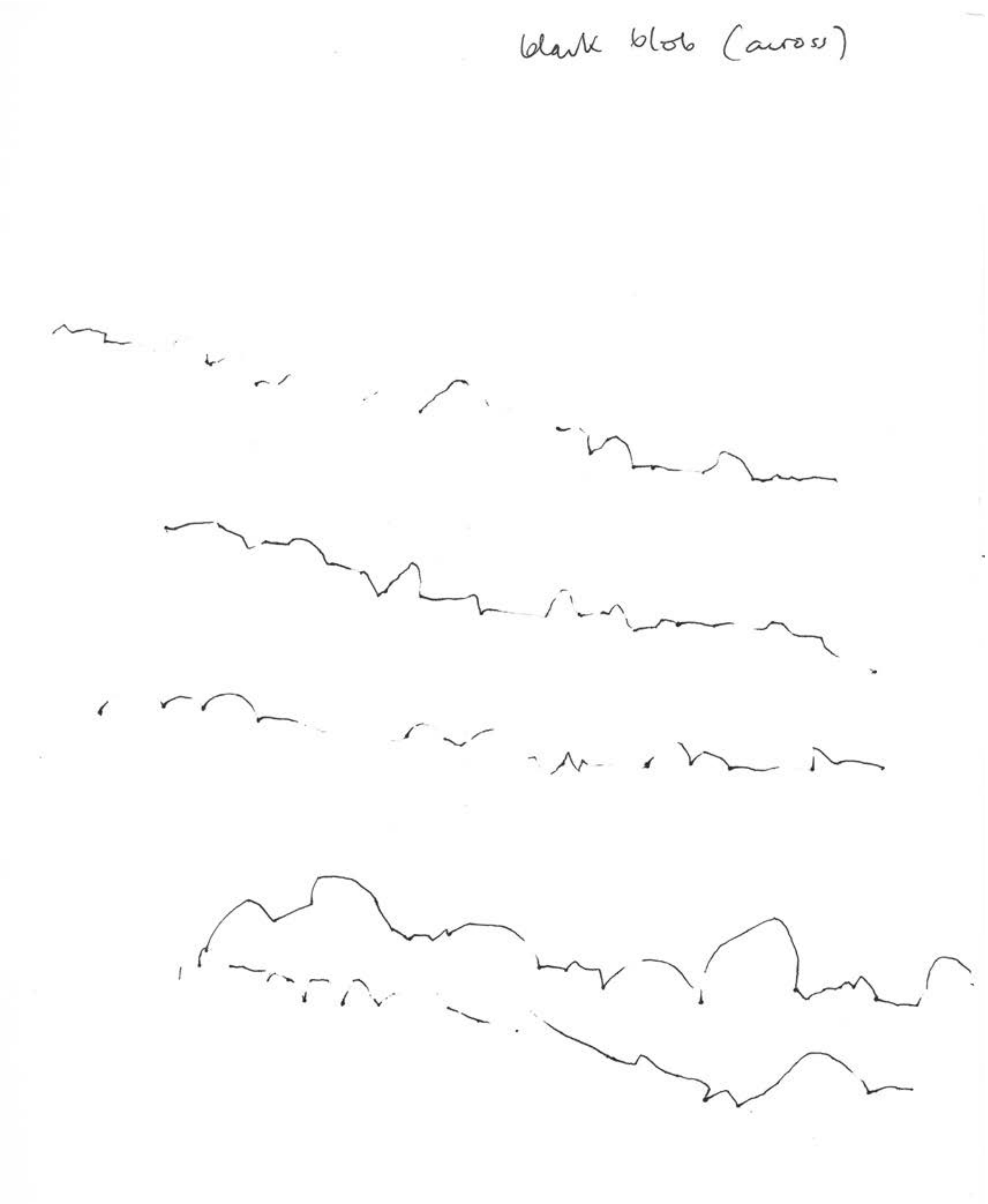


Fig. 67 Black blob across graphic score

Fig. 68 Black rib across graphic score

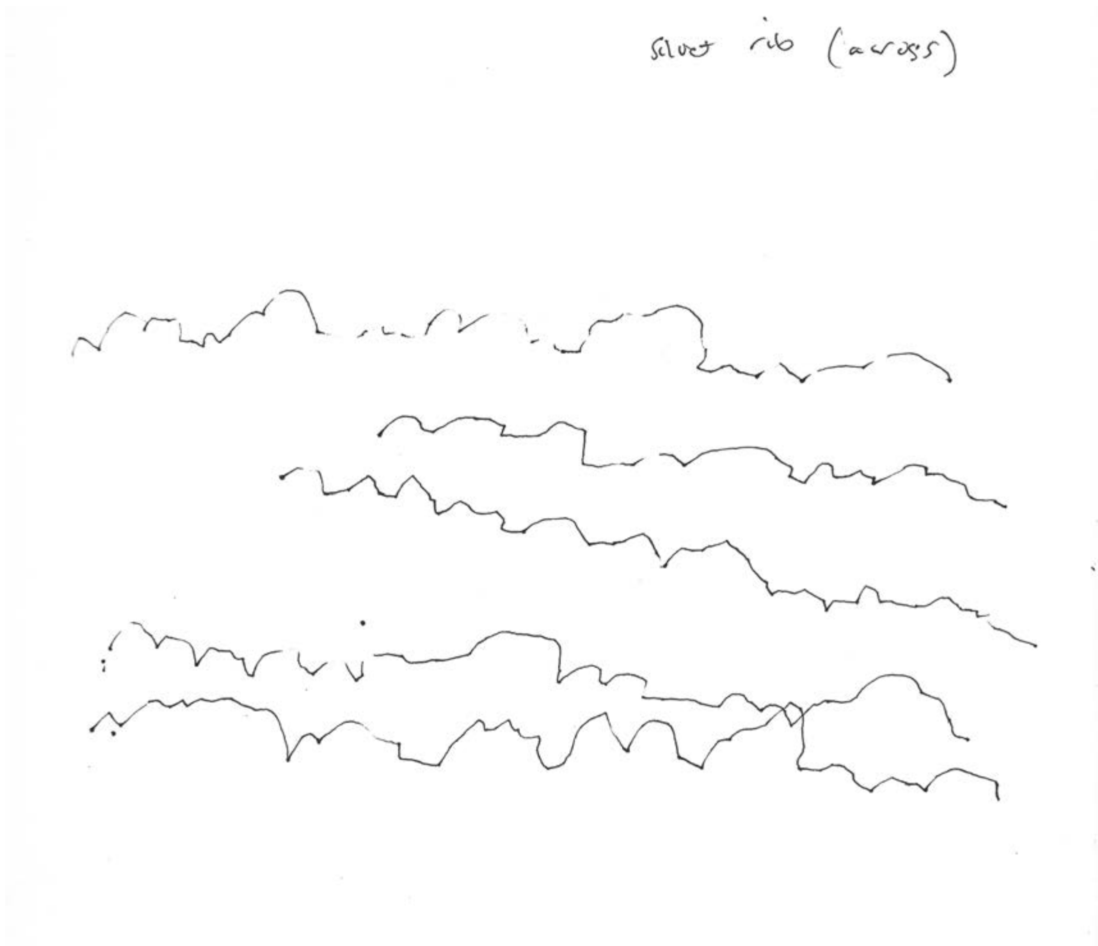


Fig. 69 Silver rib across graphic score

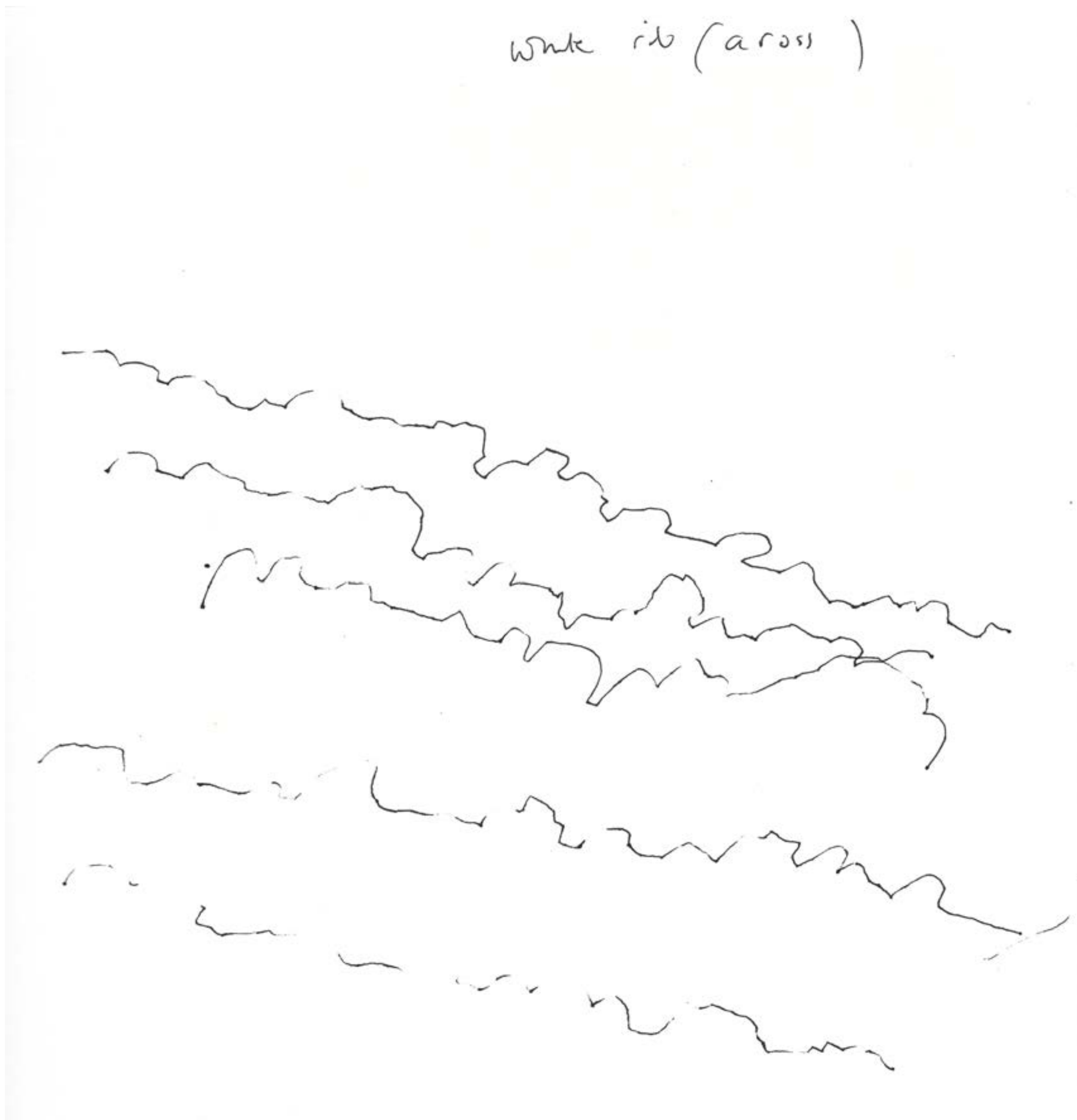


Fig. 70 White rib across graphic score

IFFTI 2019 (MANCHESTER)

Fig. 71 My exhibit at the IFFTI 2019 conference (a non-paper submission). It included the interactive 'blackblob' fabric, connected to the electronics in a silk bag (on the floor) and speakers, as well as one of the garments (not yet connected to the electronics).

Fig. 72 Conference delegates interacting with the ‘blackblob’ fabric.

A video of the fabric being interacted with can be accessed here:

https://vimeo.com/user4976678/review/441248161/fd2d6cd560

Photographs of the garments

A video of the garments being interacted with can be accessed here:
https://vimeo.com/440234804/697fa44c71

Fig. 73 The black and silver garment and the ivory and silver garment

Fig. 74 Front of the ivory and silver garment

Fig. 75 Detail of of the ivory and silver garment fabrics

Fig. 76 Side view of the ivory and silver garment

Fig. 77 Rear view of the ivory and silver garment

Fig. 78 The lining of the ivory and silver garment

Fig. 79 Front of the black and silver garment

Fig. 80 Side view of the black and silver garment

Fig. 81 Detail of the black and silver garment

Fig. 82 Rear of the black and silver garment

Interview with Kelly Joseph (Manchester Fashion Institute)

Victoria Haire: Do you think the fabrics have represented your experience of eczema?

Kelly Joseph: I feel like visually….erm from a tactile perspective…the fabric feels scratchy,..to me that is what my skin is always like, it's scratchy and itchy. To look at, it does sort of look like what my skin looks like, my skin up close especially when its really dry. I think it's because you've got that sort of metal, it looks like it would scratch you if you rubbed your arm against it, in some ways that kind of its more like more how it represents my eczema.

Victoria: So its' not the visual it's the tactile ….?

Kelly: Yeah visually it does as well, if you were to get a microscope on your skin that what it would look like, but for some reason when I look at that fabric, I think itchy.

Victoria: I'm going to play you some of the sounds now – Here are the Black blob sounds.

Victoria: The amplified sounds at the IFFTI exhibition were better.

(Black blob sounds were played)

Kelly: These sound dry, it's that dry sound like sandpaper, that dryness, the sort of words you would use to describe eczema, dry skin , the connection there is what I would say.

(White rib horizontal sounds were played).

Kelly: Again it almost sounds like when you're using sandpaper, when I'm thinking of eczema, connecting all that together, I know what its like when youre trying to scratch yourself with fabric, some fabrics I know you can't get good purchase on so that you can scratch yourself. If you've got jeans on its really hard to scratch yourself, whereas here I can use my jumper to scratch more easily. I know what fabrics you can bunch up under your hand and use to help scratch. Words for the sounds are dry, which kind of makes sense looking at the fabric.

(Black rib and silver rib sounds were played).

Victoria: Is there any particular fabric that represents your eczema better than others?

Kelly: The best was white rib. It's most similar to how I feel my skin would look.

Victoria: Do the sounds enhance your perception of the fabrics? And do the sounds make the fabrics appear to be more itchy or scratchy?

Kelly: Yes definitely, the sound is that sort of dry sound, if you couldn't touch the fabric, it helps you imagine what it would feel like.

Victoria: So the sound enhances it really?

Kelly: Yes definitely, if you were touching it and hearing it , it would almost make you feel like it was more scratchy, if you couldn't touch it and you could see it you could guess what it would feel like.

Victoria: So the fabrics have a multi-sensory effect?

Kelly: Yes it all works together to address the theme that you're exploring.