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Abstract

This project sets out to gain information about the handling of textiles that have been electronically enhanced through a sound response related to touch. By doing this it presents differences between the fabric hand of a traditional and a sound enhanced e-textile and suggests how an audio dimension can be integrated in the design process. The question of how to design towards a *mutable interaction* and *e-fabric hand* in textile design will be addressed, under consideration of traditional evaluation of the fabric hand. The overall aim is to explore the potential of fabrics as sound interfaces, not interposed between input and output, but as “coordinators between phenomena” (Dourish, 2001) of tactile and audio experience. A case study, informed by two pilot studies, has been conducted to detect types of touch when handling sound augmented fabrics. Results are presented in descriptions of commonalities and differences in touching behaviour, with four highlighted individual cases. Four touch types are identified as *stokers*, *scrunchers*, *sensor-focused* and *holistic*. Finally, ideas for further studies are introduced based on the results and a textile design-led approach. The practice-based study has been conducted by a researcher with a background in e-textile design, throughout a four months long project placement in Culture Lab at Newcastle University.

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Chapter 1

Introduction

Handling fabrics is a multi-sensory task.

In order to design towards a suitable fabric for specific context, textile designers need to have an understanding of evaluating materials applying cross-modal and tacit skills.

Textile designers make use of tacit competency that draws from a combination of sensory clues. Most of these indications are based on traditional evaluating in creative tasks, such as the narrowing of eyes to review colours for visual judgement, or the wrapping of fabrics onto dress forms to tell about drape for tactile clues. To identify the ingredients of a material, fibres are being burnt and recognised according to the smell of the burnt material¹.

Additionally, the manufacturing of the fabrics and materials require the meticulous training in operating an extensive set of mechanical tools, machines and materials.

Computers are being used for visual and two-dimensional designing², and numerous applications are able to represent the planned structure and pattern of the fabric. The designing of three-dimensional objects shifted into the two-dimensional domain of graphical interfaces and visual metaphors (Dourish, 2001).

With the development of electronically enhanced fabrics textile designers face new challenges. Additional practical technical knowledge is required such as the construction of electrical circuits, as well as the need to adapt the new requirements to the existing tools. With the shift from analogue to digital tools it is not only the loom or knitting machine that is driven by a computer but miniaturised computers are embedded in the fabric itself.

This means a general change in the designer's approach. A combination of all three skill sets is now required to turn a fabric into a temperature-, light-, smell-, sound-sensitive object that surrounds and supports humans and their close environment.

The development and wide distribution of soft 'smart' materials, as well as the easy access to digital tools and knowledge, boosts a high production of DIY and academic projects in the textile domain. The number of new university courses for smart textiles enormously increases. Smart textile conferences become numerous since 1997 when CMU, MIT, and Georgia Tech co-hosted the first International Symposium on Wearable Computers (ISWC). Bespoke applications can be found in specialised areas such as the medical or military sector. And consumer products built into fabrics and clothes promised to be an

1 <http://fabricstockexchange.com/blog/resources/fabric-identification/>

2 This excludes the machinery which is operated by technicians.

upcoming market (Starner, 2002).

Despite the promising predictions for wearables³ and e-textiles as being part of the ubiquitous computing future, the extensive implementation of electronically enhanced fabrics proves to be challenging (Edwards 2003, Amft, Lukowicz 2009). With the wide spread of smart mobile phones, e-textiles and their most prominent application in wearables became questionable.

In 2007 a panel with the title ‘The death of wearable computing’ was proposed for ISWC. And in July 2011 the longest running US governmental programme on wearable computing for situational awareness of soldiers, which was expected to enter service in 2013, has been put on hold and will be reconsidered in favour of handheld tablet similar to commercially available devices (Ackermann, 2011).

1.1 Motivation

From the view as a textile designer there is one aspect often disregarded in many of the e-textile and wearable applications. An e-textile has an imposed function which blends into intuitive fabric handling of a conventional textile. This can lead to an awkward interaction, such as pressing buttons on a worn device, which disregards the malleable qualities of the fabric as a material. The question that this imposes is, considering that the touch of conventional fabrics differs in its expression from that of a technologically enhanced fabric, how to design towards the twofold interaction?

In conventional textile and surface design the ‘fabric hand’ which is commonly called the handle of a fabric describes the tactile sensory response towards textiles. While Mäkinen and Luible (2006) relate the fabric hand to purely technical terms such as “flexibility, compressibility, elasticity, resilience, density, surface contour (roughness, smoothness), surface friction and thermal character”, Pan (2007) understands it as a more complex study that includes qualitative assessment of “physiological, perceptual and social factors”.

With electronically enhanced textiles there is a necessity in identifying and understanding the new demands towards fabrics. The evaluation of an *e-fabric hand* not only requires the identification of the handle of a fabric but also needs to consider its responsive qualities. How is the fabric being touched when it gives a sound feedback? Would it be poked, rather than stroked? Would it be stretched when the participant is aware that it contains highly sensitive microphones? How does the perception of the affordances change? How is the experience described?

This project explores creative interaction with a sound augmented fabric. Through user tests it is aimed to reveal ways of handling and perception of an e-textile as well as detecting differences to touching conventional fabrics. This means that through a categorization of touch behaviour certain types of touch can potentially be identified that suggest either a tangible interaction, which benefits from the malleability and flexibility of the fabric by

³ The term ‘wearables’ is widely used as an abbreviation for ‘wearable computer’. Please see glossary for definition and derivation.

such as folding, squeezing and stretching, or a GUI performance similar to the usage of a touchpad or screen such as tapping or stroking of the fabric. The user test intentionally neither presupposes towards certain types of touch nor will the test be task-based.

Recalcitrancy of the fabrics as an advantage – towards a *mutable interaction*

There is an important aspect to fabrics as interfaces which is based on the inherent qualities of textiles. Fabrics, traditionally defined as soft materials, are performing materials. Their advantages compared to most other materials are flexibility, stretchability and malleability. This opens up an unlimited variation of modifying and shaping a fabric when touching it. Despite being advanced in integrating circuits in fabrics, it is still a problem to manufacture reliable stability and coherent controllability of e-textiles that endure usage and handling. E-textiles are recalcitrant and often function differently from their intended response. For instance, shortcuts and unshielded connections can be a challenge when the fabric is touched due to the conductivity of the human skin.

This project aims to review this barrier and possibly reinterpret it in favour of a beneficial use. Integrated into the soft circuitry the interaction includes unpremeditated elements. This is hoped to lead to a personalised control of the interface. It is encouraged to understand the interaction as a *mutable* one, which means that through a vast number of possibilities to operate the interface it is possible to personalise the interaction and achieve the same outputs through different types of interaction. Furthermore, it will consider the aspect of “improvisation” as introduced by Dourish (2001).

In order to be able to design for these new challenges, textile designers need to understand how the tactile response and handling of e-textiles is different from the handling of traditional textiles, and if and how the performability of an e-textile could potentially be considered and applied.

This project set out to gain information about the the handling of fabrics that have been electronically enhanced through a sound response related to touch. By doing this it attempts to detect differences between the fabric hand of a traditional and a sound enhanced e-textile and show how an audio dimension can be integrated in the designing process. The question of how to design towards a mutable interaction in e-textile design will be addressed, under consideration of the fabric hand. The overall aim is to explore the potential of fabrics as sound interfaces, not interposed between input and output, but as “coordinators between phenomena” (Dourish, 2001) of tactile and audio experience.

The study has been conducted throughout a four months long project placement at Culture Lab at Newcastle University. Culture Lab is a place and space that supports interdisciplinary and trans-disciplinary research in the fields of HCI, media art and research, performance, music, psychology and sociology.

The interdisciplinary and creative atmosphere of the department meant that it was not only possible to gain information from different point of views but also very practically being

able to work and undertake instant prototyping and documentation throughout the project.

1.2 Structure

This project draws inspiration from a wide range of disciplines and chapter 2 seeks to locate the context of the work in relation to other relevant disciplines.

Literature from relevant research areas will be identified and discussed. These include a specification of the area of touch research relevant to this study, namely research in HCI and ubiquitous computing, interactive sonification and auditory displays, and e-textiles. Tactile textile and interaction design projects and prototypes will be introduced.

On the background of this outline chapter 3 describes the contextual design brief. A discussion about the choice for suitable methodologies will be included.

Chapter 4 is dedicated to the series of pre-studies and the design prototypes. Each study includes the partial objective, the practical design process and the results.

In Chapter 5 differences and commonalities during these design tests will be presented and discussed. It provides a summary of the tests and outcomes, and opens the discussion on how to carry the study further in forthcoming research.

Chapter 2

Literature Review

Two separate directions of research shall be reviewed and, in the third section, be brought together in the context of interaction.

First, it will be looked at the sense of touch and its place in Human Computer Interaction (HCI) research, and textiles as a special case for this as looked at in Baurley's article "Interactive and experiential design in smart textile products and applications" (2004).

'Fabric hand' will be defined and its both technical quantitative and qualitative evaluation methods introduced.

Second, the area of auditory displays, sonification and audification are presented. The two main sources for this are Gregory Kramer's book 'Auditory Displays' from 1994, which is still the only English-language book dedicated to auditory display and sonification, and the chapter about auditory displays in 'HCI beyond the GUI' edited by Philip Kortum. The aim of this section is to identify areas of sonification that show potential for analysing cross-modal haptic and audio interfaces.

In the third section, both areas are brought together in the context of human interaction, intentionally omitting the computer of HCI. Based on Bill Gaver's 'Technology Affordances' and Mark Weiser's 'Ubiquitous Computing', the section looks into tangible interfaces as understood by Dourish's 'Where the action is: The Foundations of Embodied Interaction' from 2001. E-textiles and wearables are treated as a specific case of this area of research as well as the field of sonic interaction design. Here, Herrman's and Hunt's approach will be introduced as well as the design led research by Karmen Franinovic and Yon Visell as part of the Sonic Interaction Design group Europe.

Finally, a few examples of HCI projects involving tactile interfaces are presented. This combines working projects, textile and wearable projects, and desirable but highly speculative conceptual designs.

2.1 Touch

“Why lie with an ear to the ground when one can connect to the internet?”
(Howes, 2005)

2.1.1 Touch technology in HCI

In the essay ‘Skinscapes. Embodiment, Culture, and Environment’ Howes constitutes the difference of the sense of touch to the sense of vision. While vision is focused, touch is diffuse and able to multi-task. Howes (2005) describes, “A person may be immersed in tactile sensations, enveloped by the wind or by the heat, yet at the same time register minute, local perceptions, the tickle of an insect or brush of a leaf. (If sight worked this way we could see the blue expanse of the sky, and at the same time be looking at grains of sand in the ground.)”

‘Multi’ in HCI has a different definition. On multi-touch surfaces more than one point of contact can be made at a time, which opens up possibilities of multi-tasking and use by multiple users in parallel (e.g. Han, 2005; Dietz & Leigh, 2001; Buxton, 2005).

A second characteristic is that the sense of touch has been traditionally categorised as a close-up sense as it requires a direct contact with an object in order to receive the sensual perception.

Through the development of touch-technology in HCI including remote touch and haptic feedback devices, efforts are being made to surmount the restrictive directness through haptic feedback devices (Brave, Ishii & Dahley, 1998; Strong & Gaver, 1996; Brave & Dahley, 1997).

2.1.2 Touch (and technology) in textile design

Baurley’s article ‘Interactive and experiential design in smart textile products and applications’ from 2004 provides an overview of the merging process of textile development and HCI. Baurley predicts that the synthesis of smart functionality and textile products will profoundly change traditional cultures of clothing and interior products. She says, because the relationship with these products of everyday life will radically change the design of the products and materials will be effected. In her view textile design will converge towards ubiquitous computing and HCI and consequently alter the role of the designers into “facilitators”. Their tasks and skill sets will be changed towards the ability to give “form to virtual content” (Baurley, 2004).

In the author’s opinion it is necessary to take advantage of present expertise in textile design and to use the established roles in everyday life that these product inherit as a starting point for expansion and augmentation. She points out that the twofold handling of e-textiles include both a conventional and a technologically driven interaction which need to be

compared and mapped onto each other to find out about forms of interactions and experiences. She proposes the extension of the textile “language” (Baurley, 2004) towards the new demands of experiential design.

Three concrete scenarios are presented which involve remote interpersonal communication, social interaction and social gaming, and tools for creativity and gaming. All three concepts build upon familiarity with textiles, be it of expressive or social nature in individualism, bondage, or differentiation through clothing.

For a methodological evaluation of the new types of textile products the article introduces psychophysics, a strand of psychology that investigates perceptual sensual processes capitalizing thresholds of stimuli, which according to Baurley are often applied to measure people’s experience when touching textiles⁴.

Based on her call for mapping of conventional and new interaction with fabrics, the following section looks at established evaluation methods of conventional fabrics.

The fabric hand

According to its use the fabric hand as explained in the introduction can be measured on an objective or a subjective basis.

A series of technically elaborated tests for mechanical properties are applied in the textile industry to deliver information about fabric hands in comparison. Several studies use the Kawabata evaluation system for fabrics (KES-F) (e.g. Mäkinen & Luible, 2004; Cho & Casali, Yi, 2001) which uses a set of machinery to measure fabric properties through for instance through bending, shearing and stretching. Other less time-consuming and machinery complex tests have been developed such as the “fabric extraction technique” in which the fabric is pulled through a hole (Pan, 2007).

However, it is believed that the clothing industry still mostly uses subjective evaluation with “professional trained handle experts” (Mäkinen & Luible, 2004) on the basis of individual experience. A subjective assessment of the fabric hand is dependant on the individually different responsiveness to tactile stimuli. Mäkinen and Luible define this as a “psychological reaction from the sense of touch as the tactile sensitivity of people varies according to age, skin hydration, cultural aspects or gender of the test person.”

⁴ This will be described in more detail in subsection 2.2.

2.2 Sound

2.2.3 Sonification and auditory displays

As one of the pioneers in audio display and sonification research, Kramer introduces the history of non-speech auditory display and sonification in the preface of his book 'Auditory Display' from 1994. By then, 1992, a very young field of research, ICAD (International Conference on Auditory Display) was initiated with 36 attendees. 20 years later, Kramer's book, based on the conference proceedings, is still the most referred publication in the field, as it brings together a wide overview not only of the field of sonification methods but also delivers the background information of how the human perception of sound can be beneficial in the field of HCI.

There still appears to be a lack of theoretical foundation and consensus about practical design, however, researchers discuss certain aspects which result from it being a novel field of research. An example for this is the difficulty of applying visual concepts onto the audio domain (Frauenberger et al., 2005). Arising from the EU funded 'COST Actions' on Sonic Interaction Design⁵ more publications discussing the theory and design process of auditory displays are expected within the next months.

In the introduction Kramer (1994) writes that sound is omnidirectional, hence, in contrast to the visual sense, provides the possibilities of monitoring "all directions simultaneously." This provides twofold information: While "all directions" refers to the immediate "perception of loudness, phase (time of arrival) and spectrum of the sound" and enables to localize the source of the sound, "simultaneously" could be understood in the sense that we can not only perceive several sounds at the same time as "detailed textures" (Kramer, 1994), but also that audio perception can take place in addition to other sensual happenings. For interaction design and audio displays this has advantages which Kramer list as; eyes free, rapid detection, alerting, orienting, backgrounding, parallel listening, acute temporal resolution, affective response, auditory gestalt information⁶.

There are several ways of how sound can be adopted for auditory displays. Kramer distinguishes two approaches; symbolic or analogic information representation. While a symbolic representation indicates the data being illustrated, an analogic representation directly displays correlations.

In the study 'Some Organizing Principles for Representing Data with Sound' (1994), Kramer characterises auditory displays in "different levels of directness". This refers to the differentiation of audification, a straightforward translation of a data waveform to an audio waveform, sonification, in which the sound does not necessarily have a direct translation, and audiation, which requires additional recall of the sonic experience.

⁵ http://www.cost.esf.org/domains_actions/ict/Actions/IC0601

⁶ See glossary.

Several studies are concerned with the perception and organisation of audio based on an underlying principle of gestalts (e.g. Bregman, 1994; Williams, 1994).

Williams' study 'Perceptual Principles in Sound Grouping' calls for an understanding of audio perception when hearing complex sounds. She introduces the term "Auditory Grouping" which she describes as the "perceptual process by which the listener separates out the information from an acoustic signal into individual meaningful sounds." (Williams, 1994). This is based on the assumption that auditory displays should be presented so the listener can detect the changes consistently as well as perceive them in the first place. Auditory grouping can be used either in a time stream, sequentially, or simultaneously, cross-spectral. Williams idea of "auditory gestalts" originates from gestalt psychology, which studies humans' disposition to recognise patterns and constellations. She proposes to apply the principles of "pragnanz", a term introduced by psychologist Max Wertheimer (Williams, 2004), which have been successfully applied in vision research, when multiple parameters are summed into one audio stream. Pragnanz, as in Williams study summarised, comprises of

- *Similarity*; Elements that share the same attributes are assumed to be related.
- *Proximity*; The closer two components are, the more likely they are to be related.
- *Continuation*; components that show smooth changeovers from one condition to another are perceived as related.
- *Habit or Familiarity*; Identification of known arrangements among possible sub components leads to grouping of these subcomponents.
- *Belongingness*; An attribute can only be part of one object at a time and is perceived as connected to the rest of the organisation to which it belongs. Inconsistency causes tensions which must be corrected to achieve stable conditions.
- *Common fate*; Attributes which experience similar changes at the same time are perceived as associated.
- *Closure*; incomplete figures are most likely being completed.

Bregman's theory described in 'Auditory scene analysis: the perceptual organization of sound' (2004) shows many similarities in the sense of understanding sound as "auditory streams and scenes" as principles of perceptual organisation.

Williams references a distinction between sensation, perception, and cognition described by psychologist Matlin in her book 'Sensation and Perception' (2009). While sensation is defined as "immediate and basic experiences generated by isolated, simple stimuli", perception "involves the interpretation of those sensations, giving them meaning and organisation". Cognition then also includes "the acquisition, storage, retrieval and use of knowledge." (Williams, 1994).

Just as Baurley, Williams also proposes psychophysics⁷ as a method to study sensual perceptions. Thresholds which refer to the perception of a stimulus at a certain perception of time are used in this methodology. To level differences in subjective perception, participants are

⁷ Also called Sensual Psychology.

usually asked to indicate their individual levels of hearing.

The chapter on audio and sonification in the book “HCI beyond the GUI” (Peres et al., 2008) provides an extensive reference system, as well a practical guides for designing auditory interfaces.

The authors state that “the effectiveness of an auditory display depends critically on how sensitive listeners are to changes along the dimensions used to represent the relevant information.” Pitch and frequency, loudness, timbre, temporal structure and spatial location are listed as perceptible for humans and regularly used in auditory displays.

A subsection talks about the Auditory Display Systems and names the advantages and disadvantages of the “front end” that appears as loudspeakers or headphones⁸. Speakers increase the listener’s mobility, but make the sound audible to everyone in the room. Headphones allow to make the audio only available to one person, but might isolate the user from ambient audio and potentially shift the focus onto other perceptual events.

Evaluation methodologies are presented that are based in task analysis while being pointed out that auditory interfaces might need adaptations and precise considerations in the development of the task study. The authors suggest to consider not only the users’ gender, age, experience with interaction technology but also to regard musical expertise and familiarity with auditory displays. According to them the kind of task that the user is required to fulfil needs to be very specific, and they suggest to identify the parameters of the interaction, including any kind of non-audio aspect of the task. Moreover, boundaries of the performance should be identified and named.

Regarding interaction, it should be clear if the test will be performed in a single user or shared space, if it will be one or more than one tasks, and if the presence of other sound than the one from the auditory display will need to be considered or even require eliminating ‘masking’, which is defined as the decrease of audibility of a sound due to the existence of another sound⁹.

In the last subsection Peres et al. give an overview of potential future trends in sonification and auditory display research. Following are listed as possibilities; sound as an input source, interactive sonification, multimodal interfaces involving audio, and the concept of adaptive auditory displays in dependency of the environment.

⁸ The usage of other audio output such as transducer speakers or fabric speakers are presented in chapter 5.3

⁹ Masking is one of a number of possible complex effects that can arise in the development of auditory displays.

2.3 Interaction

2.3.1 Ubiquitous computing, tangible interfaces and Embodied Interaction

Gaver's Affordances

A basis for the concept of ubiquitous computing and interesting for an understanding of fabric interfaces is Bill Gaver's publication 'Technology Affordances' from 1991. Gaver refers to the term "affordance" by psychologist J.J. Gibson and applies it to perception in interaction design.

"Affordances are properties of the world that are compatible with and relevant for people's interactions. When affordances are perceptible, they offer a direct link between perception and action [...] In focussing on everyday perception and action, the ecological perspective may offer a more succinct approach to the design of artifacts that suggest relevant and desirable actions in an immediate way. [...] In this account, affordances are the fundamental objects of perception. People perceive the environment directly in terms of its potentials for action, without significant intermediate stages involving memory or inferences. For instance, we perceive stairways in terms of their "climbability," a measurable property of the relationship between people and stairs."

Gaver (1991) introduces the difference of perceived, hidden and false affordances which can lead to rejection. He says in case no suggestion of an existing affordance, then it is hidden and can only be obtained from other evidence. A false affordance occurs when information gives the illusion about a nonexistent affordance, upon the user might try to respond to. If there is no evidence for an affordance, people won't usually think of acting.

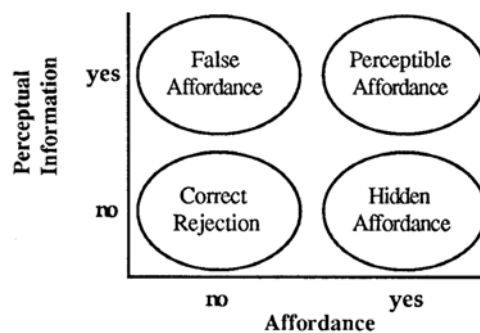


Fig.1: False, hidden and perceptible affordances, Graph from Gaver (1991)

Amongst other sensual perception, Gaver gives examples for tactile affordances.

"We can often feel what can be done with something – that it is hot enough to fry an egg, sharp enough to slice a tomato, and so on. Similarly, input devices may make use of tactile affordances."

Gaver's call for "transparent interfaces" leads to the concept of ubiquitous computing, first formulated by Mark Weiser in the article "The Computer for the 21st Century" (Weiser, 1991) in which Weiser develops the theory of "disappearing technologies".

Weiser's UbiComp

When Weiser drafted the idea of ubiquitous computing in 1991, personal computers were mostly desktop based, chunky and by no means ambient-aware.

Ubiquitous computing means the inclusion of information processing in everyday objects and actions, and therefore “getting computers out of the way” and making them “invisible” (Weiser, 1993). In practice this means that computers needed to be made transportable, networked and location-aware. While he indicates that this must be resolved by rethinking mostly the hardware rather than the software interface, he states that the challenge would be to recreate the relationship between people and computers, hence looking at the action of the user.

While ubiquitous computing can be now, 20 years later, mostly observed in the form of mobile communication and other ambient-aware devices, Dourish takes the idea further and develops the concept of “Embodied Interaction” which looks at the relationship of tangible interfaces and social computing from the perspective of interaction.

Dourish's tangible interfaces and embodied interaction

One of the aspects of what Dourish refers to as “tangible computing¹⁰” he describes as follows;

“A third topic of investigation in tangible computing is how these sorts of approaches can be harnessed to create environments for computational activity in which we interact directly through physical artifacts rather than traditional graphical interfaces such as mice. Mice provide only simple information about movement in two dimensions, while in the everyday world we can manipulate many objects at once, using both hands and three dimensions to arrange the environment for our purposes and the activities at hand. “ (2001)

Dourish points out that the interaction using tangible interfaces is distributed amongst multiple points of interaction, in contrast to single or few points of interaction. This can be even achieved “through a coordinated use of those artifacts” (Dourish, 2001). Furthermore, tangible interaction will be able to break up consecutive ordering in computation. Dourish explains that interaction will not occur in “parallel” to the physical world but the interaction will include unpredictable elements due to the vast possibilities to map the task onto the attributes of the environment. In tangible computing the physical properties of the artefact are what creates an “affordance” as described in Gaver's paper.

Dourish criticises the lack of a theoretical and design framework which must exist in order to understand tangible interaction. He asks: “Why does tangible interaction work? Which features are important, which are merely convenient and which are simply wrong? How does tangible computing mediate between the environment and the activity that unfolds it? (p. 52-53) The theory of Embodied Interaction lies upon the idea that interfaces can benefit from the “familiarity with the everyday world”. Dourish distinguishes between using the physical world as a metaphor or as a medium for interaction (p.102). But the crucial point

¹⁰ A term introduced by Hiroshi Ishii, head of the Tangible Media Group at MIT

is that embodied interaction is not based on the object for interaction, but based on the action, the making use of the interface. This action “is emerging out of everyday, mundane experience. [...] Embodiment is a participative status, a way of being, rather than a physical property.”

According to Dourish, an interface “can be simultaneously representation, object, and action, carrying different meanings, values, and consequences.” From a design point of view, he points to the possibility of inheriting multiple meanings in one object, according to the way they are used. (p.169) Also important for the design is the thoughts about space and the activities being carried out in it. This is related to the possibilities and constraints of body movement, as well as the adaptability of the space.

Crucial for this project is his statement about the role of designer. While, according to Dourish, in traditional interaction design the role of the designer controls the artefact and its use, with embodied interaction the designer is responsible for the object, but the user takes responsibility for its use. He introduces the term of “improvisation” into HCI.

“Obviously, artifacts must be designed with at least some expectations of their probable use. However, designers are continually surprised at the uses to which their artifacts are put, or the ways in which they are incorporated into the activities of users. [...] Improvisation draws on a variety of resources in the environment, including not only physical and social resources but also technological resources. So, how technology will feature as an aspect of working practice cannot be predetermined by the designer, but instead will emerge from the specific, situated activity in which the technology is incorporated.”

2.3.2 Sonic Interaction Design

In Hermann’s and Hunt’s publication (2005) a field of particular interest in sonification which includes the interactivity of the sound aspect is identified. “We define interactive sonification as the use of sound within a tightly closed human–computer interface where the auditory signal provides information about data under analysis, or about the interaction itself, which is useful for refining the activity” (Hermann & Hunt, 2005). Here, the relation to musical devices is mentioned as these provide a direct acoustic response and feed back into the coordination of the user’s activities. Hermann and Hunt point out that acoustic instruments need a constant input for a constant output. According to them it both engages the player, as well as it effects continuous transition of the sound as a reply to the intricate cross-modal interaction. The authors speculate if the often “choice-based inputs” (Hermann & Hunt, 2005) of computer systems such as menus and icons are the reason for an unsuccessful engagement as it happens with musical instruments.

They base their statement that interactive sonification is a special kind of virtual musical instrument also on the fact that the relation of the action in the physical world is close to the virtual response, as in hitting a piano key, which is louder when it gets hit harder. The difference however to a musical instrument is that it is primarily played to learn about the

data, rather than for musical engagement. Yet its form of interaction will benefit from the knowledge about developing and performing musical instruments.

In addition to the partially earlier introduced sonification methods using auditory event markers, audification and parameter mapping, the promising framework of model-based sonification (MBS) is described. In MBS the data is operating a virtual dynamic system setup, which causes the data structure to be sonified rather than the data itself.

Franinovic and Visell (2008) research in the field of sonic interaction design and sonification of everyday objects. They are arguing for a focus of research at the crossing of auditory display and sonic interaction design for products, such as for products that do not have a visual display. They base this call on similar reasoning as the ones in auditory display research, such as continuity, alternative to vision, and dynamic display.

In this study they adopt the design methodology of Basic Design, which originates from the Bauhaus tradition in the early 20th century and uses basic abstraction in relation to human perception, to sonic interaction. This means that the designs result from the interplay of the object's features, rather than upon an understanding of these as separate characteristics. The process included field recordings in a kitchen environment, sound analysis and description and action decomposition¹¹. The design process derived from basic exercises remixing the sonic features which has been identified and extracted before to the more complex design methodology using morphological design matrixes. A series of physical prototypes for interactive lamps were developed, such as the Sound Vessel which reacts to the movement and sound of pouring rice into a vessel with illumination.

¹¹ Separating and identifying movements

2.3.3 Examples of sound and /or textile projects

The last subsection of the literature review gives a few examples that had been influential for this project. The reasons for this are varied, and range from material and technical inspiration to sound interaction principles.

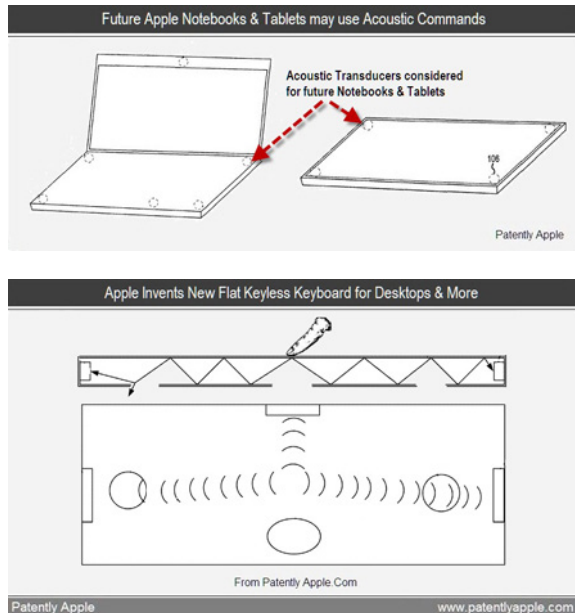


Fig.2: Apple patent for a key-less keyboard



Fig.3: Zamborlin's 'Gesture Follower' with acoustic transducer input, 2009

Both those projects rely on a precise and repeatable input source. The practicability in the context of textiles will be described further in chapter 4.3.1

As in February 2011 published, Apple patented a keyless keyboard that accepts acoustic demands. It uses transducer microphones (piezoelectric) embedded in the housing, coupled with a microprocessor that interprets the electrical charges triggered by the audio input.

Apple states that the interpretation will be based on aspects like type of the touch, such as stroking or tapping, the location of the touch, amplitude of the input and similar factors, which will form a “vocabulary of acoustic commands¹²”.

The gesture follower developed by Ircam, and developed further by Bruno Zamborlin as part of his joint Ircam/ Goldsmith College PhD in Media Arts, is an application developed in Max MSP. In the publication ‘Continuous Realtime Gesture Following and Recognition’ from 2009 Zamborlin et al. describe the real-time gesture following depending on time progression and likelihood.

Zamborlin developed a specific interface using sound input to transducers for a context in live performance.

¹² <http://www.patentlyapple.com/patently-apple/2011/02/future-apple-notebooks-tablets-may-use-acoustic-commands.html>

Highly speculative but interesting for its sensory aspect is Chris Wobken's project "New Sensual Interfaces" from 2007. Despite being rooted in the idea of biosensors and nanotechnology involving organic materials, this project is concerned about the sensorial aspect of computing. Replacing the keyboard, mouse or similar operating tools, seeds, or "smart dust", are used for "breaking, sharing, throwing away and mining data" on a personal computer. This project looks at integrated interaction and new forms of sensual computer interfaces.



Fig.4: Wobken's 'New Sensual Interface', 2007

A project conducted at Georgia Institute of Technology describes a Textile Interface Swatchbook. Gilliland et al. (2010) use embroidery with conductive thread to create a group of swatches that work like graphical user-interfaces. They see it applied in mobile devices and plan to develop it further and use it as a reference tool for textile interfaces.

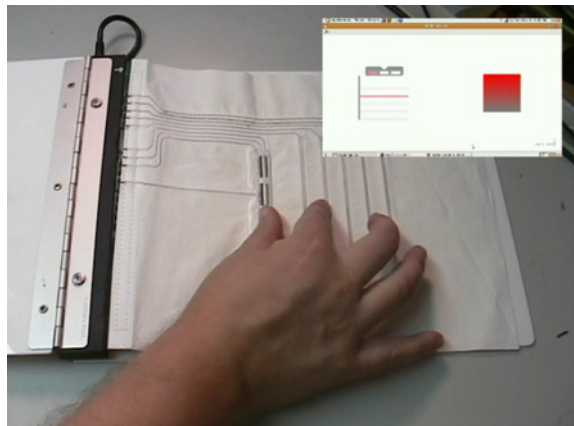


Fig.5: Embroidery Interface Swatchbook, 2010

There are only a few textile interfaces that are specifically designed for electronic sound.

Hannah Perner-Wilson, recently graduated from the High-Low Tech research group at MIT and a pioneer in Do-It-Yourself (DIY) textile electronics contributing and publishing on numerous websites, published her thesis 'A-kit-of-no-Parts' (2011), a work that is concerned with making electronic components out of ordinary craft materials and tools. This is an extensive material exploration which gives an insight into the culture of prototyping as it is understood in many textile and crafts fields. Based on Coelho's 'Transitive Materials' (2009) in which he explores electronics embedded into paper pulp already dur-



Fig.6: Perner-Wilson's seashell speakers, 2011

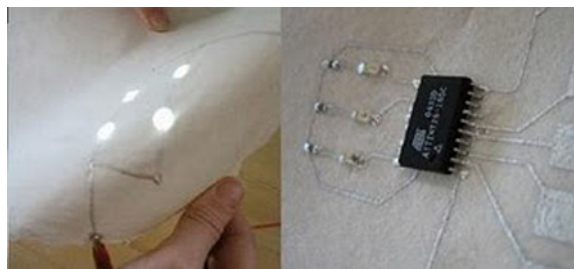


Fig.7: Coelho's Transitive Materials, 2009

ing making the paper, she worked on textile and other material speakers, that use coils in close proximity to a magnet.

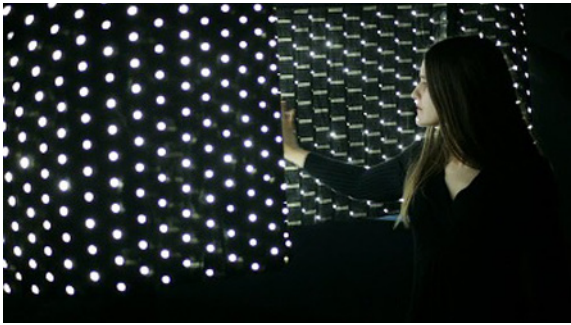


Fig.8: Berzina's 'e-static shadows', 2009

Zane Berzina's research project "e-static shadows" explores static electricity as a provider to drive a light pattern woven into a textile. The several meters large fabric measures the intensity of the charge being exposed to it, and translates them into visual and audio patterns.



Fig.9: Shenoy's speech-processing vest, 2003

In a master project conducted at Georgia Institute of Technology in 2003, Shenoy focused on the development of e-textiles for acoustic signal processing applications. It is concerned about arrays and placement of microphones as sensors being used in speech enhancement, source localization, source separation, speech-to-text translation, and

speech recognition applications (Shenoy, 2003). He developed a beamforming fabric and a speech-processing vest.

Chapter 3

Design and Methods

3.1 Design Brief

The design brief of developing an extensible audio augmentation of a textile material requires brings together two main fields of study.

The textile qualities need to be considered, aspects of the fabric hand, such as softness, smoothness or stiffness, be regarded and tested. This includes the material and the size of the sample, as well as the textile techniques that are used. In parallel the frame for the sound augmentation needs to be appraised. This study also questions the way that technology is implemented. Is an e-textile application to be preferred to an external installation with microphones?

Designing towards a fabric hand

Traditional testing for fabric hand of textiles in consumer products is a mixture of objective mechanical testing, and in cases where this is not sufficient, additional subjective testing. A typical set up for a test is described in chapter 3.2. Advanced machinery evaluation is beneficial for commercial purposes to help fabric retailers in categorising, and to simulate situations in which consumers are faced with a range of fabrics produced for the same purpose. Objective tests of the fabric hand unfold information about the technological quality of the material and is related to its market value and categorization.

However, these methods don't reveal information about variational perception of the fabric in a specific context, as well as the general difference of approaching fabrics in the first place.

To understand the relevance of fabric hand in electronic textiles, a definition of e-textiles and its difference to wearables is vital. Shenoy (2003) specifies: "The basic difference between an e-textile and other wearable computer applications is the presence of data and/or power distributing conductor's woven into an e-textile. Most of the wearable computer applications are stand-alone devices attached at specific locations on the body. Thus, the focus of wearable computers is on the development of applications or accessories. On the other hand, e-textile research focuses on providing an underlying platform, which can then be used to mount various devices or sensors."

This suggests that research and development of e-textiles is primarily concerned with the manufacturing process of fabrics that defines structure and texture of the fabric. It is coupled with a more basic research of the raw materials which addresses the chemical compo-

sition comprising mechanical, electrical and biological reactions.

Prototyping

Prototypes in both e-textiles and wearable and applied e-textile design are fragile. In the DIY community toy chips and prototyping platforms such as Arduino¹³ are adopted. But even in high profile projects such as the Emotion Sensing Dress Babelle made by Philips Design Probes as part of the SKIN project in 2006, one will find purely hand-constructed garments based on the traditional making of custom-fitted haute couture¹⁴. An accomplished crafting process for soft circuitry plays the vital role.

In electrical engineering the hardware and software modelling is highly developed, yet a tacit experience in smooth integration in the fabric is lacking. In few cases the prototypes are tested for washability and durability, but consideration of application-specific comfort and general handling of the fabric are less explored.

Sound in e-textiles

The deployment of sound has not yet been considered intensively from both the technological and the textile design side.

From an experiential point of view there are three reasons for that:

1. Sound needs vast technology and hardware to reach quality in sound
2. Lack of sound technological skills in textile design
3. A general disinterest in developing the quality of the sound (e-textiles still appear to be in the stage of “making it work”)

3.2 Methodologies

In order to analyse the participants’ touch behaviour and methods of describing the fabric touch experience, a combination of methodologies is deployed to allow for collecting a combination of different sensory aspects. It is aimed to go through an iterative design process to explore different aspects of interaction with sound augmented textiles.

Ongoing informal user tests are combined with more formal set ups, recruiting participants from Culture Lab. Video recordings would allow to observe the touch, while audio recordings focus on the terminology that the participants draw on to describe the experience.

In the analysis it was looked for cues and repetitions of certain types of touch. This will be summed up to classify touch behaviour.

Traditional and quantitative evaluation of fabric hand

Industrial evaluation of fabric hand is performed through a series of objective mechanical strength tests, analysing fabric properties related to tensile and shearing, bending, compression, surface properties at low stress, simulating the forces encountered when handling a

¹³ See glossary

¹⁴ See glossary

fabric (Pan, 2007). This test, and a couple of modifications of it, sets out to measure human perception of fabric hand in parallel to hand evaluation.

In hand evaluation tests individuals are recruited to rate and describe the presented fabrics with adjectives. A protocol on the website of the ‘Textile Protection and Comfort Centre’¹⁵ describes a typical test structure. Participants were asked to rate on a bi-polar rating scale in the categories of warm/cool, damp/dry, hard/soft, stiff/flexible, rough/smooth, clean/fuzzy, thick/thin, heavy/light, loose/dense, non-stretchy/very stretchy.

Additionally, this test also asked for comparison of fabrics, preferences or most suitable descriptions for a single fabric sample. The structure of a test is described as follows:

- “Conducted in an environmental chamber at temperature/ relative humidity conditions agreed upon and appropriate for the end use.
- Assembled swatch sets are conditioned for a minimum of two hours in the test environment prior to the test (handling).
- Test sessions are scheduled according to availability of qualified participants.
- Upon arrival, each evaluator washes and dries hands according to the required hand washing procedure.
- Evaluator enters the environmental chamber for a 30 minute conditioning and acclimatization period. Hands should be used minimally during the conditioning period.
- Each evaluator receives a swatch set with rating sheets for each sample. Samples are handled according to the specified handling procedure (illustrated pictorially in the environmental chamber). The test samples are evaluated, one at a time, on the selected bipolar terms and for any other items included on the response form. The ratings are recorded on the evaluation form.
- Ratings are averaged and analyzed for significant differences.
- Typically 30 - 40 participants are used in a study depending on whether the study is for males or females or a combination of both. Evaluators are primarily NCSU students between 18 and 35 years of age, who through a screening process are determined to be healthy, nonsmoking individuals with no dermal contact issues.”

Both mechanical and individual set ups are valuable for commercial purposes to support fabric retailers in categorising, and to simulate situations in which consumers are faced with a range of fabrics produced for the same purpose. Both objective and subjective tests of the fabric hand reveal information about the comparative quality of the material and is related to the market price.

However, these evaluation methods don’t reveal information about variational perception of the fabric in a specific context, as well as the general difference of approaching various fabrics in the first place. This reveals a reoccurring problem in data collection about comprehensive touch sensations: They don’t provide an objective scale of measurement towards

¹⁵ <http://www.tx.ncsu.edu/tpacc/comfort-performance/>

touch classification or rating of the human sensory response toward touch which reflects back on a lack of terminology. Other attempts have been more successful in this, such as the evaluation of cold and warmth (Pan, 2007). Here it can be relied on a physical scale called temperature and we can account and relate our subjective sense of coldness to it.

Hence, both technical and sociological researchers not only struggle to find a classification system for tactile experience but also to reveal repetitive mechanisms of cross-modal experience involving touch.

Therefore, in order to gain information about touch behaviour, this project moves away from the traditional quantitative and qualitative test set ups in determining fabric hand of textiles and pursue a combination of observations of touch behaviour in a broader field, based on design iterations.

The project will examine three stages:

1. Initial observation of people handling fabrics
2. Prototyping of sound-enhanced e-textiles
3. Observation of people handling the sound-enhanced e-textiles during a non-task based user test

Chapter 4

Studies

4.1 Pre-study 1: Conventional fabrics

To define a starting point and framework for the project, initial focussed meetings were held, aiming to reveal clues about both the hierarchy of senses being involved and the cross-modal interplay of senses when touching standard fabrics. Primarily, it was envisaged to identify evidence for the involvement of the sense of hearing.

The analysis is based on audio-recordings and informal observations.

The conversations happened during informal meetings between researcher and participant. This allowed to collect initial information about how fabrics are being examined when they are taken out of the applied context and are presented as samples. Fabric samples in textile design can be defined as prototypes to communicate the fabric hand and look of a prospect mass-fabricated textile. They usually have a size of between A4 and A2 when created by hand, and show at least one repeat if the pattern is planned as a repeat later, or a representative detail if the pattern is planned as a single placed image.

Four participants, recruited through an open email call at Culture Lab, were asked to touch eleven different samples of fabrics, each in the size of 20 x 30cm. Three participants were male and one female in the age range of 27-34 years, with backgrounds in computer science and media art.

The fabrics were chosen due to their range of variation and were made from cotton, wool, silk, leather, latex, with different finishings. Three pairs were similar in surface structure, the other four were very individually different fabrics with more unique tactile qualities. Seven of the fabric samples were plain white or off-white, five were green or grey. None of the textiles had a visual or tactile treatment.



Fig.10: Eleven textile samples for test 1 and 2.

The samples were laid out as a loose pile on a table. There was no sensory constrain during these meetings – participants were able to touch, see, hear, smell, and if they would have

liked to, taste the fabrics.

The conversations were set up as one to one sessions. Each participant could talk and stay as long as they felt necessary. The researcher took actively part in the conversation. As it was clear that touching samples was uncommon for most to the participants, the purpose and working methods of textile designers was explained to them. It was intentionally left up to them to describe their experience. When the participants were interested in background knowledge, the researcher would join the conversation to provide information from both from point of view as a textile designer, as well as a user.

The meetings have been audio recorded and transcribed. In parallel observations were made and notes being written down and after the meetings. The aim was to gain information about the ways in which the participants described the experience of touching the different samples. It was assumed that the participants would coin individual ways of describing and use of terminology, which was welcomed in this test.

Results

The experience and terminology by the four participants showed a great variation. The reasons for that are assumed to lie in divers cultural backgrounds as well as professional activities. However, there were commonalities in the methods that were used to grasp and explain an experience. The main similarity was the description of the tactile experience through drawing back on objects and events from the memory, as described in the examples below.

A great variety was observed when the textiles were being touched and examined.

The samples tapped on, stroked, pulled, stretched, scrunched, pressed, mostly with both hands. Without exception the samples were being lifted up and brought close to the eyes. In line with the liking or disliking the fabric samples were being handled for longer or shorter times. All four participants used mainly associations to communicate their experience.

Connections to objects or other tactile memories, bound in a narrative story, were the most prominent method to illustrate likes and dislikes.

Participant 1 chose an association with an object from his memory to express his dislike of latex.

P1: "It reminds me of eh, my band got a lot of props and equipment and costumes and things like that and one thing that my collaborator bought a while ago was a gas mask. A Russian one. And its the most horrible item in the world because of the touch of it. It's like, cause it's really grippy because of the rubber. You put it on your head and it sticks to your head and tries to pull your hair out when it seals around your face. Cause it grips so tightly obviously to seal out the gas, it's the most horrible claustrophobic nastily alive feeling"

An association with an experience from memory to express the dislike of silk and felt.

P1: "The felt and this stuff [silk] I always find quite unpleasant to handle cause I'm a guitarist and I've got callus at the end of my fingers so when you handle like lace and stuff it catches on your fingers. It's really weird because it's like, especially lace, you know like underwear is made out of

lace. And it's supposed to be attractive and it's supposed to be erotic and I find the most, like, you know like fingernails on a blackboard when your fingers are catching lace, its like, just thinking of it is making me like uah."

Three of the participants expressed the touch of fabric samples as an unfamiliar experience. Relations to potential applications for this material was common.

P3: This one is more kind of like, it still feels a bit harsh but it's more like, you could have a night cover made from it and it will be ok.

Visual associations following an initial tactile feeling were prominent.

P4: "Yeah I think I like this kind of silk which is very silky, very smooth. Of course it reminds me of Japan and some beautiful made outfits and things I would like to have because I have cheap versions in my house in black colour."

P2: "It feels very cheap and kind of old. When I looked at it I started to think of 18th century or 17th century and those people only dressed in that. Poor people from the working class from the village. And I was imagining very simple shirts made of that and very simple clothes, probably a bit dirty, yeah it's just this kind of thing"

P2: "It almost feels like it's starched. What is interesting about it is the forms that it makes when you crumple it up really remind me of the forms that you see in classic paintings like in Michelangelo paintings, the form that you see in cloth. Or in particular marble sculpture when they sculpture cloth, it kinda looks like that, it's more 'paintily'."

Summary and conclusion

In total it was observed and informed by the conversations that the sense of hearing did not play a discernible role in the description of the touch of fabric samples. While tactile experience was mostly only briefly mentioned by using adjectives, such as "smooth", or "cold", it was followed by a visual association and/or description.

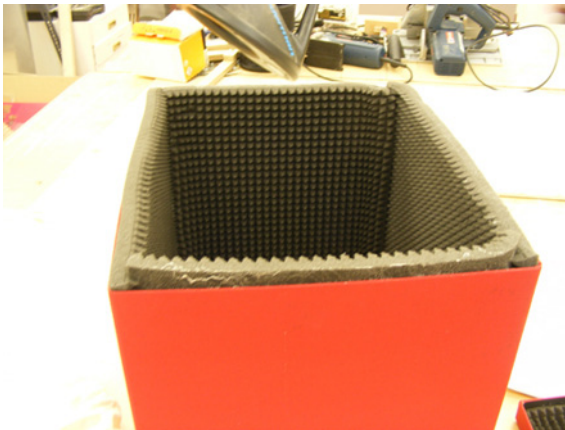
Although the participants sporadically referred to individual aspects of the tactile experience, such as temperature or smoothness of a material, this was embedded in a broader description that would revert to memory and associations from both tactile and visual experience.

All participants examined the fabrics using both hands, holding them closer to the eyes to see the texture, and touching them in a variety of ways including lifting up, pulling, scrunching, folding, pressing, and gliding it through their hands repeatedly.

This study indicated that the touch of fabrics, even if it is samples taken out of context, was both an intuitive and direct interaction that makes use of the malleable qualities of fabrics and that these often formed a strong trigger to feelings and associated memories of story and place. The sense of touch was closely connected to the visual sense, as it could be observed through bringing the samples close to the eyes and using visual descriptions and associations alongside with much shorter described and more rare tactile associations.

4.2 Pre-study 2: Sound proof Box, Touch only

In the second pre-study about touch of the fabric samples, the same participants were asked to touch the fabrics inside of a soundproof box. The aim of this study was to identify a possible role of sound when touching fabrics. It was decided to isolate the sense of touch in a way that would be as little obstructive to the sense of sight and hearing as possible. The disadvantages of creating an artificial situation in which the participants would be more focused on their sense of hearing, were carefully considered. It was decided that the construction of a box might provide a less constraining set up than blocking the senses of sight and hearing through blindfolding and headphones.



For this experiment a box was constructed that would allow the participant to put their hands through two holes and touch the samples inside without seeing and hearing them.

The box, being fabricated from a 50 x 60 x 75cm cardboard box lined with soundproof foam and a layer of fabric, had two holes on the long side for the participants to put their hands through.

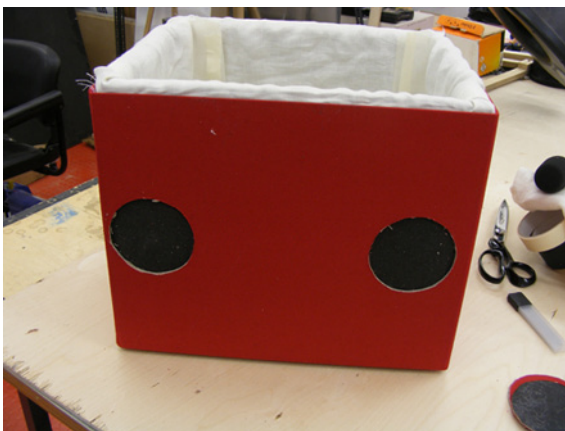


Fig.11: Construction of the sound proof box.

Again, the meetings were one-to-one and an informal conversation. The aims were to find out

what are the participants interested in in the first place when they can see and hear the fabric

and how they would describe their experience in case they would use a different terminology.

Additionally, this test set out to find out what they think about the box design as an obstructive tool.

Results

The disadvantages of the box as being an obstructive object for handling the fabrics were numerous. The box wasn't large enough for the participants to handle the fabrics freely inside. Furthermore, through the fitting inside the box with several layers of soundproof foam and fabrics, the temperature immediately rose when the participant put their hands through the holes. This, according to their own description, changed the feel of the fabrics. Participant 1 describes the influence of the warmer temperature inside the box:

P1: "I think I'm less aware of the temperature difference as well. I don't know if that's because the inside of the box has a kind of levelling effect of the heat in my hands, but remember the last time

when the leathery ones were a lot, felt a lot colder and now everything feels pretty much the same temperature of me.”

Although the sight of the textiles was obstructed, the sound of the textile still was not mentioned to play a role in the recognition of the fabrics. Participants relied on their tactile sensations, although a slight shift in the way of tactile exploration happened. While in the first pre-study the participants mostly focused on the texture of the fabric, in this study the form of it became important too. In the examination people were keen to find out the size and the framing of the samples.

Participant 2 describes:

P2: “Yeah you become very conscious about the edges as well. Like how it’s frayed around the edges which I didn’t notice that much when I could see it. Because I guess you kind of avoid noticing things like that. These are the details that I become, you know, I am noticing more than anything.”

During this test the participants did not use associations or story telling to describe the experience of the touch. As the view was obstructed the understanding of the fabric materiality became much more important. Understanding in this context means to being able to evaluate size, shape and material of the fabric. Adjectives were used to describe the experience.

P2: “And from what I can tell, it feels like the leather one because it’s got the glossy feel on one side and the suede on the other side.”

P1: “One side is very smooth. The other side is quite warm, not smooth.”

P3: “Hm, I wonder if that’s the same like last time. One side was harder one was softer. Now it feels harder.”

All participants focussed on recognising the fabrics from the first test. They were all successful in distinguishing leather and latex which have the two most differing grips.

P1: “This one is quite different, this one is the skin of animal. How do you call that?”

Researcher: Leather.

P1: Yeah this is leather. Obviously. Hm, it feels bit oily.”

P3: “Yeah again, there some of the textures that are really easy to discern. Like the leathery one is kind of, the difference is even more marked when I can’t see them.

Researcher: How would you describe it?”

P3: I describe it more like human skin, than anything else. It’s kind of, when I touch one hand with the other it’s that sort of sensation.”

Discussion

This study showed an major shift in the participants focus when being obstructed in their sense of sight. The conclusion in the context of this project was that the study of touch in a box was not useful. However, this led to the understanding that the senses are closely con-

nected and obstructing one or the other does not only mean removing a sensory perception, but also adding factors by effecting the perception of other senses.

For the purpose of this study this was important to be considered, but evaluated as diverting from the overall aim of augmentation of textiles through sound.

Therefore it was decided to take a different approach that would allow to emphasise the sound by augmenting it, instead of obstructing the sense of sight.

4.3 Augmented fabrics study

Addressing the overall objective of this project, this chapter describes the development of a sound-enhanced textile and its implementation in user tests.

4.3.1 Design

Soft hardware

In order to be able to study people's perception towards sound enhanced fabric, for this project it was important to design fabrics and/or a set up that would make it possible to touch in a way that is as little obstructive as possible. The choice, set up and embedment of hardware in an implementation of an e-textile were the vital steps in the design process. For this project it was essential that the sound augmented fabrics should be similar in handling and touch to conventional fabrics. Furthermore, based on the participants comments in earlier meetings, they should be visually and tactile stimulating to make participants interested in touching them.

The three iterations of design of the fabric prototype involved creating tactile and visually engaging textiles, prototyping a suitable audio hardware implementation, and fabricating the final prototype.

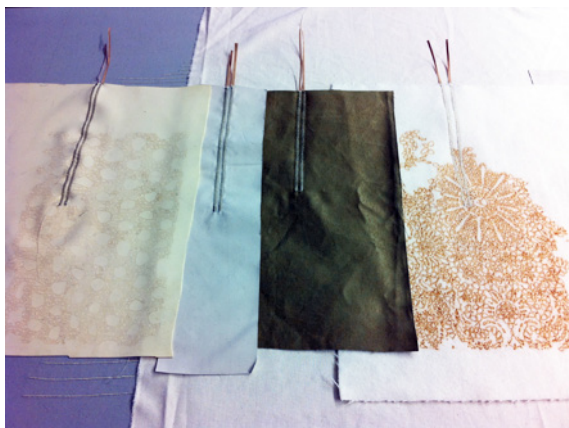


Fig.12: Sound-augmented textile prototypes.

The two established techniques in textile fabrication of digital embroidery and laser-etch have been applied to create visually and tactile interesting fabrics. In both cases hand drawings of grid patterns support an organic and flowing appearance.

a. Visual patterns have been added with laser etch. The technique also produces a tactile difference of the surface, which in some cases, such as wool, causes a bigger difference than in others, such as plain cotton.

b. Digital embroidery to create a more vivid tactile pattern. In some cases conductive thread

is used that would create both tactile and touch-sensitive textiles.

Sound set up

For this project it was important that the participant could relate to the sound as a feedback to his touch. That suggested that microphones as a direct audio input and real-time feedback would be a suitable solution. The decision for the microphone was made after a series of tests with microphones of different sizes and recording patterns.

In this set up the operating space of the hands is constrained to the space provided by the surrounding microphones. In this case that was a small space of about 50 x 50 x 30cm to get the most out of the microphone alignment. The microphones alignment defines the space in which the participant can touch the fabric. Furthermore, the sound input varies widely when the fabric moved closer or further away from the microphones. The recording of the ambient sound and ultimately the participants voice recordings appeared to be to discourage participants from talking through their experience.

Experiments with piezoelectric elements promised to be successful. Piezo transducers are available in small sizes and can be sewn into the fabric. They both allow to move with the fabric and keep the same place and distance to the fabric, and block out the acoustics in the room. Additionally they provide a certain intimacy of the sound feedback. Comments in user tests underlined the close-up of the sound: “Sounds like someone scratches inside my ear.”

Piezoelectric transducers are made from certain materials such as ceramics or crystals, that produce electric charge in response to mechanical force. There are several types of piezoelectric materials. For the reason of malleability and low impedance the highly flexible polymer PVDF¹⁶ was chosen for this project.

Although the piezo films, as they will be referred to in this report, are available in larger sizes from rolls up to 100cm width, but the high cost of the material limited the use within this project to the commercially available piezo sensors in the size of 20x10mm. The challenge within this project working with the piezo sensors was that the electrodes on the film are exposed and the sensor can be sensitive to electromagnetic radiation¹⁷.

Each fabric sample contains a piezo film in the centre on the back of the imaged sample. Embedding in this case means that the piezo mic and the connecting wires are as flexible as possible and would not get the full attention in the user tests.

The following paragraphs and images show the embedding of the sensors in the fabric samples.

¹⁶ See glossary.

¹⁷ Please see paragraph about shielding techniques in e-textiles.



Fig.13: Sewing the piezo film with silver thread.

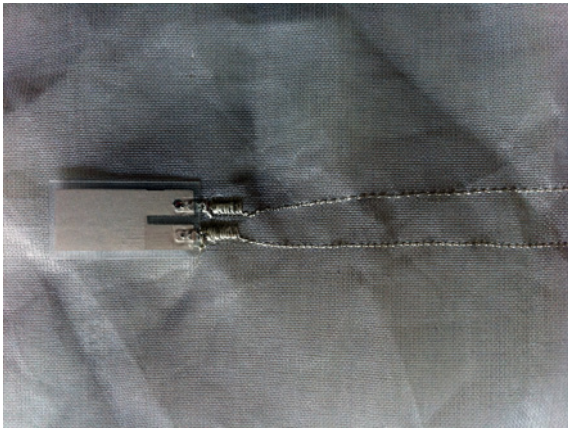


Fig.14: Sewing the piezo film with silver thread.



Fig.15: Wiring with copper tape.

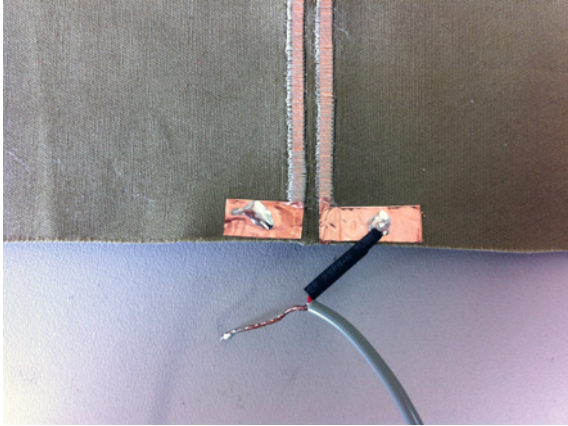


Fig.16: Connecting at the edges of the textiles.

Wiring

Several prototypes using conductive thread for the wiring showed that the yarn was not an ideal conductor for this purpose. While steel and copper thread frayed which caused constant changes in the resistance and short cuts in some cases, the silver thread wasn't conductive enough or broke easily when the fabric was moved.

The final design is made with sticky copper tape, which had the advantages of being highly conductive, easy to work with as well as being stable in its electric conductivity.

Shielding

The shielding of the cables and the connections of the microphones is important to consider. Again, in order to keep the fabric as soft and flexible as possible, compromises had to be made.

The copper tape has been covered with a layer of sewing thread to prevent connection through skin contact.

The contacts to the microphones are covered with a small piece of conductive shielding foam, and then sewn with conventional yarn on top. As this method already adds a fair amount of material on the surface which changes the tactility and flow of the fabric, in other samples the contacts have been left open.

The connecting point between the fabric and the wire that leads to the sound card is a critical spot. As it is on the edge of the fabric sample, a bigger amount of conductive foam had been sewn on top. This is not only to shield that spot but also to stabilise the contact to the cable when handling the fabric.

Hiding away the audio technology

As formerly discussed, the hardware is a weak point in e-textile design. While cables, resistors and sensors can be made from flexible materials, more complicated installations including chips or transducers are not possible to manufacture at this point.

In this project it was decided to hide the necessary technology of sound card, computer and speakers from the users' view. While computer and sound card are hidden in a table, the speakers are placed in the room, on the left and right hand side of the participant.

Sound design

The sonification process has been designed in Max MSP, a graphic programming application for interaction and sound. Simple patches take the audio as the input, process and play it back in real-time.

Several sound cards had to be tested to find one that had a time delay as small as possible as well as pre-amplifiers suitable for the low-input contact microphones. Regarding size, it needed to be small enough to be hidden away while having at least 4 pre-amplified inputs. Due to the exposed contacts and fabric shielding of the connections, noise was always something to be considered when both using the real audio and when analysing the incoming signal.

Input variations

In order to capture the type of touch and grasp the fine differences of for example weak and strong stroking of the fabric a range of measures were tested to analyse the incoming audio signal, including pitch estimation, brightness, noisiness and loudness of the sound input.

For instance, Ircam's Max MSP tool for gesture following promised to be a working tool to detect the differences in not only different types of touch, but also of touch of different fabrics. As demonstrated in their work (Bevilacqua et al., 2009) the tool can learn a series of behavioural patterns, and later recognise if these patterns are repeated based on *real-time progression and likelihood*.

When this tool is applied to the textile microphones it becomes clear that a very careful handling and fine-tuning in the touch of the fabric needs to be learned in order to get repeatable results. This led to very simple interaction with the fabric such as tapping or stroking and distracted from an aspired mutable interaction such as squeezing or stretching.

Additionally, the noise detected by the gesture following tool was strong and unstable.

The tool aims for precise following and it appeared to be unsuitable for the textile application in this project which aims for benefiting from malleability and somehow imprecision of the interface.

Non-repeatable reaction of e-textiles is a common occurrence. This is due to two facts: First, the materials are flexible and the handling is manually and exposed to very different types of handling. As a comparison: A key on a computer keyboard is always just an on/off

switch, disregarding how hard it is being hit. Second, the materials tend to be more exposed because shielding and hiding would add more material, hence flexibility would be less.

Both hardware and software in this project aim to explore these facts as characteristics rather than as issues. This addresses the question on how to take advantage of the fragility of both fabric and sound.

Sound interaction

To emphasise on the interaction with the fabric the sound response has been designed in a simple way. A MaxMSP patch uses an amplitude envelope and controls three sound samples applying granular synthesis. Peres et al. (2008) described the possible change in sound can be based on pitch and frequency, loudness, timbre, temporal structure and spatial location. In this project, where sound is used as input and output, the loudness of the input defines the temporal structure of the output. Or simply; The louder the touch, the longer would the sample loop play.

What appears to be a very simple algorithm in the first place, again proves to be different when involving fabrics. Two aspects need to be kept in mind. First, the same loudness can be achieved through different forms of touch. And second, it requires constant moving of the fabric to get a constant output. The sound patch is designed in a way that asks for different types of interaction. Furthermore, because the copper tape on the fabric was not entirely shielded, yet another type of touch can be applied to change the sound.

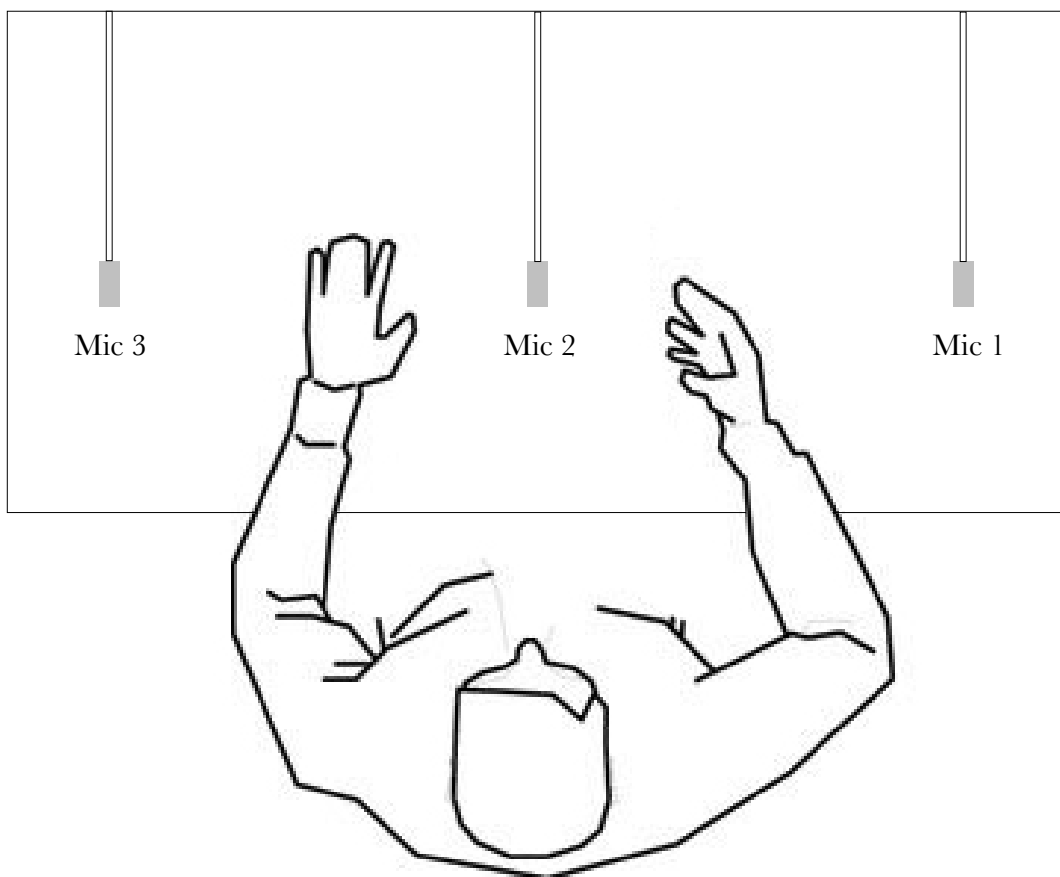


Fig.17: Distribution of the microphones.

The first sound set contains a constant rhythm as a background layer. The length of this rhythm can be shortened by influencing microphone 2. Another rhythm, initially silent, can be added with microphone 3. Both these microphones require a constant gain input and therefore a constant hand movement. This adds up to a delay of about 2 seconds in the repeated response, comparable to a wind up mechanism.

Microphone 1 adds a rumbling low noise when the hand is placed on the wiring. It has an instant response.

The second sound set starts with a tonal pulsing which can be stretched when microphone 2 receives input. This effect becomes dramatic when moved long enough. Microphone 3 is responsible for another tonal sound. This is triggered when moving around the microphone. Microphone 1 again adds noise by placing the hand on the wiring.

The third sound set starts with a rhythmical section. This can be silenced when the hand is placed on the wiring of microphone 2. Microphone 3 triggers another rhythmical section when moved. They both have a delay in their response due to the attack time of the sample. Microphone 1 triggers a sound in an instant response.

	Mic 1	Mic 2	Mic 3
Sound set 1	- adds rumbling low noise - rested hand - instant response	- shortens length of background rhythm - hand movement - delay of 2 seconds	- adds another rhythm - hand movement - delay of 2 seconds
Sound set 2	- adds noise - rested hand - instant response	- stretching tonal pulsing which becomes dramatic when stimulated for about 4 seconds - hand movement - delay (depending on the force up to 4 seconds)	- triggers tonal sound - hand movement -delay of up to 4 seconds
Sound set 3	- triggers loud noise (arcade game noise) - rested hand - instant response	- initial rhythmical section can be silenced - rested hand - delay of 1 second	- triggers another rhythmical section - hand movement - delay of 1 second

Fig.18: Touch and sound interaction

4.3.2 User tests

Aims

This test of the prototype with three embedded film piezo microphones sets out to gain information about the participants' approach towards tactile exploration that triggers a sound feedback. Through observation it attends to find out if and how the participants touch and interact with the fabric. Two days of testing were filmed and observed.

The analysis set out to detect and potentially classify *types of touch*¹⁸. This includes three aspects: The participants' interest in either creative expression or functionality, the use of the interface either benefiting from its malleability or understanding it as a GUI, and the interplay of the tactile and graphic experience in association with the three different sound sets. The discussion addresses two questions. Does an intuitive handling turn into a task-driven and interface-led handling of fabrics? For example, this could be expressed through tapping just on the sensors instead of scrunching the whole fabric. How do the participants react to the embedded sensors? Will they focus on the areas that are close to the sensors, or will they be using the fabric as a whole?

Installation

The test was set up at Culture Lab OnSite, a space for public engagement which is being used by researchers and artists as gallery, for user tests and workshops. The space is under the railway arches close to the train station in Newcastle. Every five minutes a train passes, which is reasonably loud in the space and could potentially distract, and possibly leads to

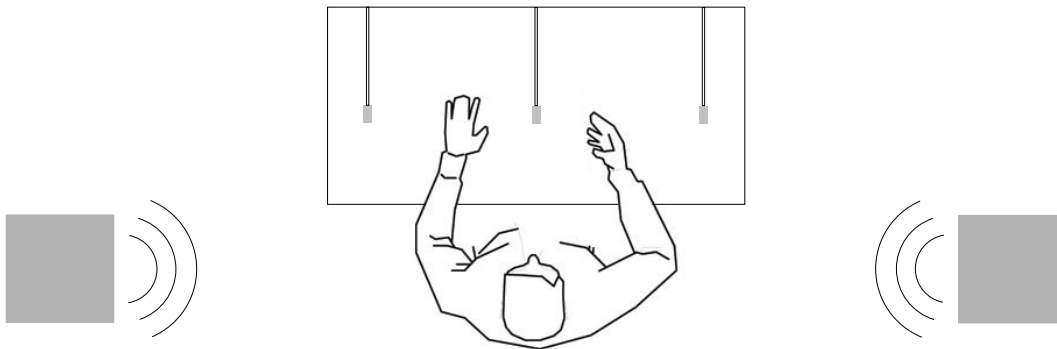


Fig.19: Speaker set up.

the phenomenon of masking (Peres et al, 2008). The room is about 20sqm large, with white metal panels on the walls and a concrete floor. The room has a considerable echo.

The set up in the room was perceived as an exhibition space. While the main fabric was placed in the middle of the room, flattened on a table with a smooth wooden surface. Two speakers were placed to the left and right of the table, directed towards the participant.



Fig.20: User test installation

The fabric is 80 x 45cm large, and is made of polyester which causes the laser etch to melt the surface instead of burning it. This means that there is no strongly noticeable burnt smell, which has shown to be distracting in former tests when using natural fibres.

The textile contains three microphones which are film PVDF piezoelectric microphones. They are sewn onto the fab-

¹⁸ Although there was an expectation towards depending on the individual, considering gender and professional and creative background (Peres et al, 2008), categories have not been considered in advance.

ric on the back. The conductors, although visible and tactile demonstrative, were visually integrated by being surrounded by the organic shape of the pattern.

Participants

Sixteen participants took part in this test, 25-60 years, eleven male and four female participants from diverse backgrounds in computer science, music, psychology, performance, economy, natural sciences, illustration and film, media art and curation. Thirteen participants were recruited from Culture Lab, three were associates. All participants were recruited through email invitation. Ten of them were aware that they would be making a user test with a sound-enhanced textile but haven't had seen the project before. Five participants were aware of the field and had seen the fabric before. One participant was unaware of what this test was about.

Structure

The test was set up as a non-task driven session. A short interview at the end of the test asked the participants which aspects of the fabric would be important and did engage them to start touch in the first place, if and how did the sound make them change their touch, and asked them to reflect on the three different sound sets, asking which they preferred or disliked and how this was related to the fabric.

The session started as a loose conversation about this project and one of the laser etch fabric samples was shown to the participant. The technique was explained and the participants encouraged to hold it in their hands. All 16 participants followed that encouragement.

After that the sound enhanced fabric was introduced and placed on the table.

Half of the participants know about the techniques of piezoelectric function beforehand.

The participant is initially introduced to the procedure of the test.

They would be played three different sound sets after another, while keeping the same fabric. They were made aware that this would not be a task-fulfilling test and that they would be left to themselves to play, test, figure out, or not figure out. It was important to not name the fabric in association with a function, so terminology such as interface, instrument or wearable have been deliberately avoided. The fabric has been called exclusively 'the textile'.

Observations



Fig.21: Fiddling before the test starts

were made, such as “It looks like a map.” Two people familiar with the process of laser cut were smelling on the fabric, expecting to smell it burnt. Immediately before the start of the first sound set, five participants either rolled up their sleeves, took off a watch, or switched off mobile phones.



Fig.22: Touch within three seconds

different parts of the fabric. The major part of people carried out a careful first contact and listened to what happened in the sound.

Immediate first response to sound feedback

If the sound was immediate and strongly responding at the first contact, people shied away but approached immediately again. Most of them were looking at the test facilitator with a look of surprise.

However, if this first contact seemed to be successful, people immediately approached the fabric again in the same way. Success in this case was constituted by an immediate sound change in response to a touch.

Before the sound starts

Ten participants touched the fabric before the sound started. Five of these participants fiddled also around with the corner or edges.

Five participants were not touching the fabric beforehand, but nearly all of these participants were placing their hands on the table. Five people asked for the techniques used for the samples and examined them more carefully (4 female, 1 male). Associations with the pattern

When the sound starts

Eight participants started immediately touching the fabric when the sound started.

All 16 participants started off touching carefully in the first three seconds, or were reassuring that they could also reshape the material.

These first touches included tipping with one finger on different parts of the graphic pattern and the sensors, as well as stroking with the fingers or palm over

Response within three seconds

Twelve participants noticed a change of sound and reaction from their touch within three seconds. Ten of them reacted by smiling, looking at the facilitator in surprise or immediate repeat of the same movement. Two participants noticed the change, indicated by a short moment of hesitation, but went on to explore other forms of touch or other areas of the fabric.

Change of type of touch throughout the test

After all participants started with tipping or stroking with the palm, twelve people changed the type of touch and started to fold, lift up and wave, or squash the fabric.

While the more elaborate actions that involved the malleability of the fabric such as folding or squashing the fabric, caused a bigger response, they were more difficult to repeat with the same sound result. Simpler actions, such as pulling the fabric from both sides or lifting it up with both hands, got a higher response and were simple to repeat.

Overall playing times

Participants spent between 1 minute and 15 minutes playing one sound set.

The first sound set has been played the longest duration with 4.11 minutes in average. The second sound set has been played 4.01 minutes, and the third 3.55 minutes.



Fig.23: Interaction with the textile.



Fig.24: Interaction with the textile.

Four examples of touch behaviour and the resulting sound feedback

In the following paragraph the test of four participants will be looked closer at. Their touch behaviour have been observed in more than one participant, however they have been chosen because they showed a more pronounced and concentrated form of touch in combination with sound feedback.

Examples

1. Participant A is female, 29 years. She is a research associate and computer scientist with a strong interest in fashion. She is experienced in pattern cutting as well as DIY e-textiles.

She is trained in classical music.

This participant approached the fabric immediately, lifted it up, hold against the light. She moved around the table even before the sound started and was interested in learning about the used techniques that have been applied to the fabric. She smelled on the fabric, expecting the burnt smell when natural fibres are being laser-cut.

When the sound starts she plays it with two fingertips for a second, but then immediately starts to scrunch the textile. She squeezes it with both hands, and lifts it up to get a better hold on it. She folds the fabric up and over. The fabric is being draped and sculpted, when she discovers the stiffness of the material and that it holds in place for a short while.

She is very interested in the malleability of the fabric, and what the textile can do in terms of its flexibility and softness. She folds it into three parts, as folding clothes, and unfolds it again. After 3.23 minutes she flattens it and asks for the next sound set.

When the second set starts she takes the fabric with both hands and wrings it like wet laundry. She flattens it out again, folds it over and plays it from both sides. She only approaches one sensor at a time when stroking the fabric, however influences all three of them when shaping the textile more rigidly.

She mostly uses both hands, and walks around the table to get a better grip of the fabric. She waves it over the table until it falls down on the floor. She picks it up and stops the second sound set. The second sound set was played for 3.47 minutes.

It seems that the sound did not influence her touch behaviour. Although being aware of the sound, she clearly was interested in the fabric properties rather than

In the third sound set she waits for a second, and then starts tapping with her fingers in the rhythm on the contacts at the edge of the fabric. She again squashes the fabric together and shakes it in the air. She places the sensors on top of each other by folding the fabric.

The third sound set is played for 3.45 minutes.

In a brief interview at the end of the test she explains that the sound made her “very cu-



Fig.25: Participant A.

rious” to touch the fabric. She explains that in the first set she was trying to “figure out what happens with the sound. The fabric is really delicate and I would have expected some more delicate music.”

The second set she said that “the sound seemed to be related to the amount of patterns”. When asked if the sound was influencing the way she touched, she replied that she was “playing around.” and that she couldn’t find out “what sort of touch does what sort of sound”.

However, she discovered that “the lines [the wiring] are reactive.”

When asked what part of the test did her encourage to touch the fabric she replied that “the sound made me spending so long. If it won’t sound, I wouldn’t touch it for so long. But it has a nice feel to it, so I probably would have spent some time in the shop too stroking it.”

Participant A made extensive use of the malleable and flexible properties of the fabric. She folded it, squeezed it, lifted, squashed, sculpted, shook, and waved it while holding it up. None of the movement was repeated, or attempted to be repeated, which could indicate that her behaviour was not influenced by the sound. Although she states that the sound made her touch the fabric for so long, and that “It was fun to move it around to see how it played”, she didn’t appear to be interested in gaining a control over the sound.

Participant B is male and 28 years old. He is a student in the Media Arts Master’s programme and has a background in electronic music and composition. He performances regularly.

When the first sound starts, he waits and listens for 3 seconds. He starts touching by sliding the fingertips deliberately along the microphones. He continues with sliding one finger across the patterns of the fabric. He tries to touch only the fabric parts that aren’t close to the microphones. He tests each microphone by itself, first running right hand over microphone 1, while resting the left hand, then playing with microphone 3 with the right hand while resting the left hand. He goes back to the right microphone and slides one finger back and forth in repetitive mode. He repeatedly slides one finger up and down each microphone. He pauses and asks for the sound to be louder. Again, he slides one finger along middle microphone in circles. The first sound set is played for 5.57 minutes.

When the second sound set starts he tests each mic to see the sound response by sliding a finger horizontally across the whole fabric. He moves the finger in waves motion between microphone 1 and 2. He slides the hand in waves to microphone 3 and then “scratches” it. With both hands he alternates in scratching microphones 1 and 3, and then move to play with microphone 3. He starts using both hands to play at different areas of the fabric and doing different touch manipulations. Such as, he puts two fingers on just the pattern on the right and scratches with the other hand on microphone 3. He again slides one finger around in circular motion, first slower and then faster. Sound set 2 is played for 5.08 minutes.

In sound set 3 he again starts with one microphone and one hand, to then move on to another microphone with the second hand. He includes the pattern on the whole fabric, and painstakingly plays different areas and details on the textile. He repeats making repetitive



Fig.26: Participant B

loops. He plays sound set 3 for 7:08 minutes.

When interviewed at the end of the test he replies that he felt “quite comfortable with the interface.” He describes that the graphical pattern was what engaged him to play it in certain ways. When asked about the different sound sets he replies that “I found it difficult in the first part. I tried to figure out specific positions and sounds and that wasn’t clear. In the beginning I was focused on pattern and try to figure out how to play the score.”

The second one he describes as “easy to play and comfortable. The three part division is easy to play with and easy way to break a musical phrase. [...] I found a beautiful movement in the second one by doing the repetitive movement.” He perceived the second set as being “more about touch”.

The third set he describes as a “mix between the first two. Sometimes I got lost. It was specific to each mic and you don’t know if patterns have an effect or not. It was more about going to find a sound you like.”

Participant B gained very much control over the sound response. He acted very patiently towards each microphone and repeated thoroughly his movements. He exclusively used it as a graphical interface by sliding fingers and hands in graphical patterns. He did neither pick up the fabric nor did he fold or squeeze it.

His movements were slow, detailed, repeated and elaborate.

It is worth mentioning that he carefully listened to the sound and appeared to be aware of details in change. He not only played to get a sound response in total, but carefully influenced the different layers of sound. He appeared to have found a few interactions to have control over the interface in certain waves, such as a circular movement across the fabric, or silencing a sound by placing his hand on the wiring.

Participant C is male, 25 years old and works as a computer scientist in HCI research. He describes himself as somebody who “likes technology and interested in how things work”.

In the first sound set he starts carefully with one hand tapping on the sensors. He gets an immediate sound response and starts playing with both hands, and massaging the fabric. He scrunches the textile. He is commenting that the sound has different layers and that the basic point for him is to find out what happens. He plays the first sound set for 3:33 minutes using both hands for repetitive massaging. He appears to be pleased when receiving an immediate sound feedback.

In sound set 2 he again receives an immediate response with his first touch. He approached the fabric in the same way again, but the sound doesn’t repeat. He pauses, smiles, and comments that he thought the fabric picked up his touch but that he “might have imagined it”. He tries more times and makes the repeated feedback work.

He lifts up one corner of the fabric and makes a smooth wave through the whole fabric. The sound response appears to match the wave movement and he waves again. His movements adapt to the rhythm of the sound. He manages to dramatise the sound by repeatedly waving the fabric in the same way, and speeding up the sound by speeding up the movement.

The second set is being played for 3.41 minutes.

Realising that the fabric always slides over the table when even only touching one corner and therefore triggering all three sensors, in sound set three he finds ways to block sensors. First he tries it by playing the hand on microphone 1 but notices that this triggers it rather than blocking it. He leans down on the table and places his forearm between two sensors which successfully makes microphone 1 stop. He plays sound set 3 for 3.16 minutes.

When interviewed, he points out that he was very interested in “what interaction did what. For example, what would waving do?” He said that he quickly “understood the mapping but [that] the fabric lets you do things that you couldn’t do otherwise”. He says that the mapping could be equally done with just three microphones in a row but then it would not be possible to wave through them.

Participant C was very interested in the matching of the movement with the sound, and he refers to the example of building up the loudness which occurred while playing set 2: “Would be great if it would go more and more intense so I have to stop before I break the windows”.

Participant C approaches the textile in a playful and inventive way to explore the malleability of the fabric through waving and massaging. His movements are short and repetitive, and he manages to receive a constant sound feedback.

He is successful in finding his own ways of operating the interface. He appears to be interested in how the electronic works, but is not blocked by his knowledge of the sensors. He tries to find tex-



Fig.27: Participant C

tile ways of operating the fabric and the sound feedback seems to match his movement speed. For example, if he wants louder or longer sound, he moves longer or more rigid varies with speed. His moves the fabric rhythmically.

Participant D is a female, 27 years old research assistant with a background in natural sciences.

She approaches the fabric immediately, and leans over the table to get a closer view of the embedded sensor. She examines microphone 3 with her fingernail, scratches and pushes firmly on it. After repeating this for 2 minutes, she moves to the microphone 2 and 3 to repeat these actions. While receiving big changes in the sound, they do not appear to repeat nor does she seem interested in making it repeat. She plays the first sound set for 5.19 minutes.

In the second sound starts she repeats the close-up examining and starts folding the sensor, and squeezing it between two fingertips. Again, she solely focuses on one sensor at a time. As the movements are quick the delay prevents the sound to repeat. This sound set is played

for 2.51 minutes.

In sound set 3 she scrunches the fabric with both hands, again with a strong focus on the sensors. She makes marching movements with her fingers. She also discovers the reaction when placing her fingers on the wiring and again scratches and folds those firmly. The sound gets silent, but again she doesn't appear to be aiming for a repeated reaction. She plays the third sound set for 2.24 minutes.

Participant D focuses mainly on the sensors and is intensely and rigidly folding, pushing and scratching them. She only plays one sensor at a time. The sound response is high, but despite being interested in the quantity of change, she appeared to not being interested in



Fig.28: Participant D

repeating it or finding a steady control. When interviewed she replies that the feel and look of the fabric made her engage with it. She points out that “It doesn't look and feel like a usually decorated fabric.” When asked about the sound response, she explains her procedure of examining: “I just started with the microphones, folding, tapping, the distance and how hard you press it. And then I discovered the lines, and depending on where you touch it what would it do to the music.”

Discussion

Four main behaviours have been identified.

Most participants applied a combination of all of them.

1. *Stroker*

Two out of sixteen participants exclusively used the fabric as a flat and graphical interface. Though they both discovered and interpreted the embedded microphones and their wiring quickly, they included the pattern in their exploration with finger tipping and stroking with the palm.

Both these participants came from a musical background, using mixing desks and graphical interfaces for their work and performance.

2. *Scruncher*

The Scrunchers are the participants that used the malleable qualities of the fabric to explore sound and the potential of the material handling. Scrunching includes every type of handling including for example folding, scrunching, shaking, squeezing and massaging. There are more or less extensive and inventive types of scrunching and increments in the way that participants applied those techniques. As this seemed to have differ due to various

reasons, the Scrunchers are summed up in one group.

The Scrunchers were participants from all backgrounds, however there appeared to be a more decisive approach to scrunching when participants worked with textiles before.

3. Sensor-focused

In different degrees most participants utilised the microphones and their wiring to explore the sound. These interactions do not solely focus on the use of the flatten material but show a strong focus on influencing the microphones and their direct surrounding areas.

All participants were familiar with embedded electronics in textiles and sought for them.

4. Holistic

Most participants explored the potential of the whole fabric, regardless of the knowledge about the microphones and wiring. In a broader sense this included the table on which the fabric was placed on.

Based on the collected information and the definition of touch types in can be concluded that within this project most participants employed a touch behaviour that is based on their various ideas of how an interface should look like:

Busy pattern areas are more likely to be active

Participants thought the pattern to be more active. One participant expressed his expectation of being able to intrinsically play each detail of the pattern by itself. Three participants pre-assumed that the pattern was applied with conductive material and therefore more reactive. Another participant summed it up as “You have less faith in the blank spaces.” In the sense of Dourish’s (2001) theory, the patterns could be labelled as “false affordance”, and therefore misleading to the participant.

Immediate response or delayed sound response

This was indicated by the immediacy of approaching the interface again, after receiving an instant sound response. As only some of the interactions were designed for immediate response, there was an element of uncertainty in this. In general, the participants reacted with smiling, or directly repeating the movement.

In general a delay in response was accepted when more fluid movements were performed for instance stroking in circles, massaging and waving.

Chapter 5

Discussion

5.1 Discussion

The three different studies conducted throughout this project revealed several differences in handling conventional and sound enhanced fabrics. Overall it was observed that an e-textile that is augmented through sound made the participants approach the handling differently.

While a conventional fabric, even if only as a sample taken out of context, is touched, it happens in a less task-driven way that caused the participants to squeeze, lift and stretch them in immediate ways.

The sound augmented fabrics were additionally approached as interfaces with a handling that appears to result from both the knowledge about sensor design, and the usage of touch sensitive interfaces such as touch screens. This is presumably rather characteristic of the particular population of participants who are technology centred, but would need to be examined in another study with less technologically focused participants.

It appears that the wide spread development of touch technology in recent years has widened the knowledge about sensory based interaction design and that most participants expected the interface to behave in a certain way. The action that is taken was mostly tapping and stroking the fabric. This suggests that the “affordance” (Dourish, 2001) has changed as people’s expectations towards a fabric has changed.

However, due to the rather slow and unexpected response of the fabric, the participants appeared to take into account the malleability of the material and started to experiment with the flexible qualities of the fabric. This suggests, that an intuitive reaction when using fabric as interfaces, could be assumed when designing e-textiles but would need to be carefully designed in conjunction with the interaction.

Considering the problems that the field of e-textiles faces in HCI, which is mostly the competition and more successful design of handheld devices (Amft & Lukowicz, 2009), the design towards interaction with sound enhanced e-textiles needs to be reconsidered.

Two potential ways of approaching this are following:

If the e-textile shall be part of ubiquitous computing and is viewed in its application context then the interface should be applied in situations that are familiar and embedded in everyday actions.

If the textile is seen as mostly from a material perspective with inherent qualities that distinguishes it from solid materials, then the design of it should suggest a use of malleability and

flexibility, and go towards a style of interaction that is very open and amenable to personalization, encouraging individualistic exploration by each user. While in the first case, the use of the fabric product can cause confusion about what this object might represent, in the second case the application is clearly distinguished from the materiality of the fabric. Here, purely the characteristics of a material is being utilised while its application is open to the user. While the fabric could be operated like a computer, or what we understand as operating a computer in the year 2011, it can also be customised in its use and being integrated in other parts of everyday life.

The response comes out of experimentation with fabric qualities, rather than from imposing a new interaction onto a familiar object. Rather than the fabric representing an object, the fabric becomes the object itself. Solely, its materiality is the starting point for interaction. In the sense of the “technology affordance” described by Gaver (1991), the suggested interaction is described by the potential of the material, rather than by the object in conjunction with the object’s function. Considering the different fabric qualities of such as softness of wool, stretchiness of lycra, or strength durability of cotton, this opens up a very wide and flexible room for interaction affordances.

5.2 Summary

In this project placement at Culture Lab Newcastle a textile sound interface was developed and tested to gain information about the impact of aspects of the fabric hand when developing interaction with e-textiles. Considerations about an e-textile hand not only include the conventional perception of the materiality of fabrics, but should also question the handling of and interaction with a fabric that is enhanced with a sound response.

The literature review addressed intersections of the fields of textile design, HCI and sound interaction design, and aimed to find intersections and potential for cross-applying approaches. A discussion of possible qualitative evaluation methods which would consider a broader understanding of fabric hand is presented.

Three user studies tested three different approaches towards touching fabrics. Study one as a pre-study observed behaviour when touching conventional fabrics. This was to introduce the idea of samples, and testing the possibility of having fabric interfaces out of an object context.

Four meetings with participants informed the researcher about different ways and methods of perceiving and describing the touch of fabric samples.

The second study tested whether an obstruction of the sense of sight and sense of hearing when touching the same samples would bring out hints of the involvement and importance of sound when touching samples. For this a sound proof box was constructed in which the participants put their hands in through holes to touch the fabrics inside. It was hoped that through the box which still allows the participants to hear and see normally everything else but the fabric touch, would be less intrusive than obstructing it through closed headphones

and blindfolding or darkening the room. However, the box proved to cause other issues around interaction, such as the obstruction of hand movement and the change of temperature in the box. Study two, which was an example for the separation of fabrics and technology, led to the decision of embedding the technology in order to support an less restrained interaction with the textile.

For the sound-enhanced textile prototyping film piezo microphones have been used. The prototype has been iterated with different conductive materials till the microphones were embedded in a way that would distract as little as possible while interacting with the fabric. A sound feedback was designed that, based on a simple algorithm, allows the participants to explore different types of interaction and develop their own type of interaction. The sound response is based on granular synthesis.

The participants then were presented with three variant sound sets that required different types of interactions, some of which were responding to dynamic input while others required a static input. Through observation results are presented that classifies different types of touch interaction and identifies differences and commonalities in the participants' interactions.

5.3 Future work

While this study explored approaches in touch when operating a fabric sound interface to map out the potential of malleable e-textiles, a continuation of this exploration and an in-depth study of more refines aspects could support developing guidelines for the designing of sound-enhanced e-textile interfaces.

In a further development a specific context for the fabric interface would be defined.

Possible applications depend on the aspect of interest.

The user tests revealed the potential to use fabrics for developing musical interfaces. While the sound feedback in this case was fairly restricted, the possibilities of interactions to reach the same output were vast. This allows the user to discover their individual ways of operating and ultimately customising the interaction. The test also showed potential for a visually engaging performance in which the audience could clearly follow the actions of folding, stretching and massaging the fabric that the performer is carrying out.

A discussed approach in chapter 5.1, but not yet conducted study, is the evaluation of e-textiles in everyday context. How are they bound into everyday life when they are applied in everyday domestic procedures? Pink (2009) conducted ethnographic studies in people's homes, which observe the process and accomplishment of household activities such as doing the laundry. . How would these activities change when e-textiles turned the home into a responsive organism? In this study the fabrics would be bound to applications, such as electricity visualisation as in for example Marcq's work that utilises wallpaper to indicate

electricity consumption¹⁹, and objects of use, such as the ‘Sensual Interface’ inspired by futuristically applied nano-technology (Wuebken, 2007).

Probably best based on a textile design-led approach, fabrics could be developed that work as input and output devices simultaneously. An example for this is a fabric that is both microphone and speaker deploying piezoelectric materials such as commercially applied ceramic lead zirconate titanate or Polyvinylidene fluoride (PVDF). Other materials showing piezoelectric properties such as crystals or organic materials could be tested for this purpose. Textile design has seen the introduction of shape changing materials when exposed to heat. The so called shape-memory alloys (SMA) are usually made of compounds of aluminium, nickel, zinc, copper, titanium, or zinc, copper, gold and iron. In e-textiles they mostly replace functions executed by motors. SMA embedded into fabrics can effect the fabric in its larger form.

Looking into the construction of material and turning the fabric into a both sensing and responding device, it could go a step towards Dourish’s call for embodied interfaces being the “coordinators between phenomena” (Dourish, 2001), borrow from the notion of everyday improvisation, and lead towards a mutable interaction with e-textiles.

¹⁹ http://www.celinemarcq.com/?page_id=60

Glossary

[3] Wearables

Steve Mann, an early researcher in the field of wearables defines 1998 “A wearable computer is a computer that is subsumed into the personal space of the user, controlled by the user, and has both operational and interactional constancy, i.e. is always on and always accessible.”

In the book ‘Fashionable Technology’ (Seymour, 2008) following definition is available: “The term ‘wearable technologies’ refers particularly to the electrical engineering, physical computing, and wireless communication networks that make fashionable wearable functional.”

And Shenoy’s (2003) definition, in contrary to e-textiles, is: “Wearable computer is a term used to describe any integrated device or a network of distributed electronic components placed on the human body. One of the sub-classes of this broad field is e-textiles. The design of an application involves issues relating to both the textile as well as those of the electronics industry. The basic difference between an e-textile and other wearable computer applications is the presence of data and/or power distributing conductor’s woven into an e-textile. Most of the wearable computer applications are stand-alone devices attached at specific locations on the body. Thus, the focus of wearable computers is on the development of applications or accessories.”

[6] acute temporal resolution, affective response, auditory gestalt information

Kramer (1994) defines:

Acute temporal resolution: Time-sequenced data; broad dynamic range (milliseconds to several thousand milliseconds)

Affective response: Ease of learning; engagement; convey subtle qualitative information.

Auditory gestalt formation: Discerning overall relationships or trends in data; picking out meaningful events or states in a stream of data.” (p.6)

[13] Arduino

Arduino is an open-source microcontroller developed in 2005 as a device that would enable experts and non-experts to design interaction projects less expensively than other systems available at the time. It has been extremely successful and boosted a high production in DIY electronics design. There is a series of different models, with the LilyPad as the device designed for wearable and e-textiles applications.

[14] Haute Couture

Shaeffer (2001) defines:

“Literally translated, the French phrase haute couture means “sewing at a high level”, but a better translation might be the “finest high-fashion sewing”. Although the haute couture designs shown on runways in Paris, Rome, London and New York are too expensive for most pocketbooks, their influence on styles, colors and accessories echoes throughout the women’s clothing industry worldwide. [...] Originating in mid-19th-century Paris with the designs of an Englishman named Charles Frederick Worth, haute couture represents an archaic tradition of creating garments by hand with painstaking care and precision. In an elaborate process that’s very much the same today as it was in the 1850s, each couture garment is a custom fit, fitted and even frequently redesigned to suit a particular individual.

[16] PVDF

In 1969 the very high piezo-activity in the polarized fluoropolymer, polyvinylidene fluoride (PVDF) was discovered by Kawai, as referenced in the technical manual by Measurement Specialities (1999). Besides the flexibility piezo film also has the advantage of having a lower acoustic impedance than piezo ceramic material. In PVDF it is closer to that of water, human tissue and other organic materials. For example, the acoustic impedance of piezo film is 2.6 times that of water, whereas piezo ceramics are typically 11 times greater. A close impedance match permits more efficient transduction of acoustic signals in water and tissue.

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Appendix

A detailed research diary including weekly reports is available at <http://internshipnotes.tumblr.com/>.

The transcriptions of the meetings from the pre-studies are available at <http://internshipnotes.tumblr.com/prestudy1> and <http://internshipnotes.tumblr.com/prestudy2>.

The video and sound files taken at the pilot study are available