E-textiles for Self-Expression: Participatory Making with Blind and Visually Impaired People

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E-textiles for Self-Expression: Participatory Making with Blind and Visually Impaired People

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Abstract

This research explores how blind and visually impaired (VI) people can engage with e-textiles in creative and tactile ways, by making interactive e-textile art pieces to tell their own stories. Touch, gestures used to interact with textiles and e-textiles, and association of meaning with objects are central concerns of the work, in the context of how different materials can evoke and be used in self-expression. The research focuses on how VI participants can design and make their own e-textile objects, bringing in ideas of empowerment and agency, and drawing attention to what characterises an effective 'participatory making' environment.

Three studies are reported. The first study observed practices at two schools for blind and VI children/young people to establish how 'objects of reference' are used within the classroom environment, and what other sensory stimulation is important. The second study involved two series of hands-on e-textile making workshops, at a charity for VI people, and at a contemporary art gallery, to explore how visually impaired participants can design and make personal e-textile objects. The third, a laboratory study, investigated what associations and gestures visually impaired participants used with e-textile sensors that had different textures and functioned in different ways. The research explored the potential of participatory making of e-textiles in terms of touch, personal association, accessibility, and creativity.

The research identifies some effective practices for participatory making of e-textiles with visually impaired people, including a modular approach to circuit-making. It highlights the importance of ownership of the process for the participants. It demonstrates that, although there is 'no common language of gesture' for touch-based interaction with e-textiles, conventions can be established through example or consistent use. It outlines the 'lessons learned' in working with blind and visually impaired people, which can inform other researchers, designers, or artists interested in participatory making.

For my daughter Aoife and son Arlo.

Acknowledgements

The first thank you has to go to my wonderful supervisors, Prof. Janet van der Linden and Prof. Marian Petre. Without their guidance, conversations, and support, this PhD journey would have been very different. We have come a long way together since Janet lured me into applying for a PhD studentship at the OU, and for that I will be eternity grateful.

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Publications

Giles, E., van der Linden, J., and Petre, M. (2018) ‘Weaving Lighthouses and Stitching Stories: Blind and Visually Impaired People Designing E-textiles’. In: *Proceedings of the 2018 SIGCHI Conference on Human Factors in Computing Systems (CHI’18)*, Montréal, QC, 21-26 April, New York, NY, ACM, Paper No. 470.

Giles, E. (2017) ‘Touch, E-textiles and Participation: Using E-textiles to Facilitate Hands-On Making Workshops with Blind and Visually-Impaired People’. *In: Proceedings of the 2017 Conference on Designing Interactive Systems (DIS’17)*, Edinburgh, UK, 10-14 May, New York, NY, ACM, pp. 384-385.

Both papers were written and published during the PhD process, reporting on important aspects of the research.

Included in this dissertation’s references are two papers (Giles, E. and van der Linden J., 2014, 2015) which were also influential to the research undertaken, and that I worked on before the PhD.

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1 INTRODUCTION

1.1 Problem space

Interaction is no longer solely about screen-based applications, but about using other senses as well, such as touch and hearing. This is particularly important for people who are blind and visually impaired (VI), for whom technology that embraces the use of non-visual senses holds considerable potential. Rogow (1988: 71) says that touch is important for children who are blind and visually impaired for them to *“achieve intimate and direct contact with the physical world”*. For blind and visually impaired people, touch is used for reading, through the use of Braille or Moon; for communication via special objects; and also to appreciate creativity - through events such as touch tours at galleries and museums, or through carefully planned tangible making activities. But it is also much more than that; touch is something we use every day, whether we are sighted or non-sighted, to connect with others and to express ourselves.

Technology that is designed for blind and visually impaired (VI) people often focuses on touch. For example, researchers have been designing technology that helps blind people find their way (Heuten, et al., 2008), that translates hand-touch-based communication into digital text (Gollner et al., 2012), and that helps blind people read diagrams (Swaminathan et al. 2016). These designs are about functionality, with the technology aiming to address the issue of visual impairment, compensating for the lack of sight at a practical level. However, there is less focus on technology for blind and visually impaired people which has an emphasis on creativity and self-expression. There is literature that does exploit the use of touch for creativity in VI users, such as the research of Metatla et al. (2015) and Tanaka et al. (2016) on haptic interfaces for audio. Metatla et al. chose to use a participatory prototyping approach with their users, however there were some challenges as participants were not always able to carry out the hands-on making approach. Many of the maker sessions turned into discussions around problems, rather than participants working on prototypes themselves. This highlights a challenge in VI participants designing and creating their own pieces of creative technology.

The research presented in this dissertation aimed to explore how visually impaired people can make their own creative technology using electronic textiles (e-textiles), and to explore the potential of using ‘soft’ sensors and switches for interaction. The research aligns itself with third-wave Human-Computer Interaction (HCI), as discussed by Bødker (2006, 2015), which is centred largely around emotions and experiences, in contrast to second-wave technology designs that are ‘functional’ and ‘purposeful’. This relates to non-work-related settings such as leisure activities or the home, as opposed to the second wave's focus on purposefulness and work-related settings. It also aligns itself with a post-modern approach to disability (Mankoff 2010), taking the view that each person's experience is different, their abilities but also how this is shaped through life experience as well. This contrasts with work around technology for impaired users where the medical model is often focused on, aiming to 'fix' the issue of the impairment.

E-textiles are a medium that intersects the disciplines of computer science, design, fine art, and fashion. E-textiles consist of yarns, threads, fibres, and fabrics which are both soft and able to conduct electricity (see Figure 1.1). The term 'soft circuits' is sometimes used to refer to circuits made from conductive thread, but the term also includes circuits which are made from soft conductive materials such as conductive paint or copper tape. In this dissertation, the term is used to refer to the former.

Figure 1.1: Conductive threads, yarn, fibre, and fabrics which can be used in e-textiles.

These materials can be connected to microcontrollers that can be programmed to allow for interactivity, controlling components which have been embedded into the garment or object (see Figure 1.2).

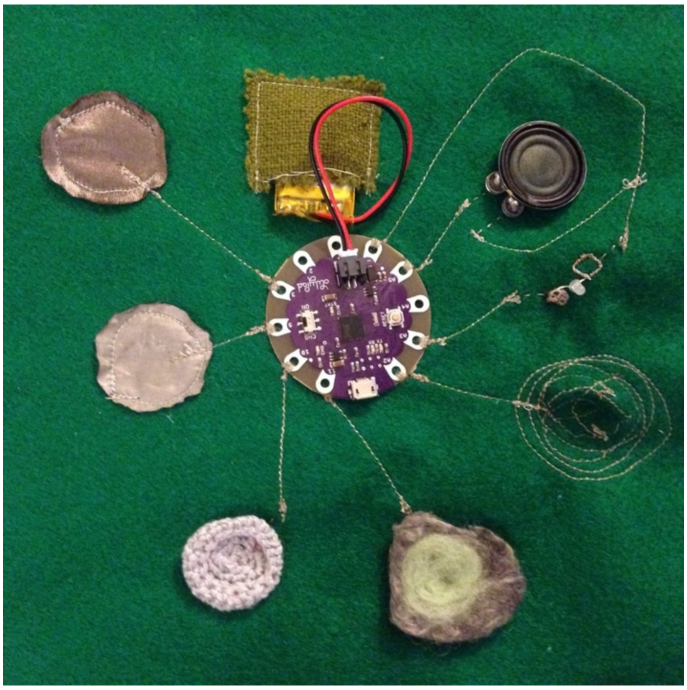


Figure 1.2: Lilypad Arduino connected to e-textile touch sensors along with an LED and speaker.

As e-textile materials can be crafted into sensors, this enables interaction through touch, such as pulling, stretching, or squeezing. However, within e-textile projects it is often the visual design of an object that takes priority, rather than touch, such as LEDs (light-emitting diodes) embedded into fashion items, or textiles that change colour (see Figure 1.3).

Figure 1.3: Galaxy Dress (Cute Circuit, 2009) which contains 24,000 micro LEDs.
Image used with permission.

The research discussed focuses on working directly with users who are blind and visually impaired: designing *with* people, not just *for* them, using a 'participatory making' approach. The research embraces creativity, self-expression, and empowerment, working with participants to create their own touch-interactive e-textile objects, using hands-on making techniques such as weaving, felting, and finger knitting. Throughout the dissertation, 'self-expression' is used broadly, and is reflected in a variety of related terms, including personal 'narratives' or 'stories' - all relating to the users' communication of their own sense of identity, goals, and experiences.

1.2 Personal research motivation

I have many years of professional experience running creative technology workshops for a wide range of participants: adults, children, and young people - both with impairments and without impairments. Within these workshops, the aim is to let people shape their own creative projects, and I have found that in such settings not only do the participants learn from me, but I also learn from them, resulting in an exchange of knowledge. Within participatory design, this is called *"Mutual Learning"* (Bratteteig, 1997: 1). As an example, I might be teaching a participant how to program a microcontroller, but then, when it comes to sewing a circuit, they might share a crafting technique such as how to tie off a knot in a clever way. Although there has been an increase in e-textile activities being facilitated for people with impairments or disabilities, there is still a gap in mainstream workshops for people to access. On a personal, practice-based level, over the years I have aimed to address this through collaborations with Wac Arts (*Wac Arts Interactive*, 2020) in London and Project Ability (*Create Programme*, 2020) in Glasgow. Yet I wanted to explore this gap on a deeper level, and make a contribution on which other practitioners and researchers could build. Hence, I began to work with The Open University in 2014, a collaboration which resulted in two publications about working with visually impaired people and e-textiles (Giles and van der Linden 2014, 2015). The PhD was an opportunity to continue this research and build on it. As well as making academic contributions, the research also aims to guide and inspire other practitioners who want to work with e-textiles with groups that might often feel excluded from creative technology activities.

Within the dissertation, I refer to myself as the 'researcher', the 'lead researcher', or 'I' when discussing from a personal perspective, or when elements of the research have been carried out just by me. When discussing elements worked on with my supervisors, I refer to the 'research team' or the 'researcher and her supervisors'. This convention is introduced for clarity. Although I have worked closely with my supervisors throughout the research, I carried out the design, analysis, and reflection, as the PhD researcher.

1.3 Research question

The overall research question driving the research that addresses the concerns outlined above is:

How can blind and visually impaired people design and make e-textiles for tactile interaction, to both foster and evoke self-expression?

This question concerns (a) the act of making, (b) how the e-textile products can be used for gestural interaction, and (c) whether the makers feel empowered and able to express themselves. In order to answer this question, several key sub-questions were identified, to unpick the elements of the main question, and to investigate touch and tactility in this context. These evolved throughout the preliminary research process, as discussed in Chapter 3, as the focus and framing were refined. The main question remained throughout. The sub-questions were as follows:

i. **What emotional associations do users have with the texture and appearance of materials which can be used in e-textile interaction?**

Can the feel of the fabrics and yarns be used in e-textiles to reflect personal associations and emotions of the makers? For those with some vision, can the appearance of these materials evoke something in the participants as well? Can these tactile and visual qualities then be used in the design and implementation of the objects' interaction? An example might be a fluffy fabric to represent a cat, which when stroked can purr. This question is explored in Study 2, an e-textile workshop series, and Study 3, a lab-based study.

ii. **What objects, materials and techniques are practical for use by blind and visually impaired people making e-textiles?**

The research needed to explore how visually impaired people use objects - what these are and how they are used. It also needed to explore making: craft-based making, circuit making, and their combination. Many textile crafting techniques such as sewing or knitting can be quite challenging, with the makers needing to be able to see what they are doing quite clearly. The same applies for making circuits; usually it requires soldering, or sewing if an e-textile circuit is being made. For blind and visually impaired participants, these techniques can be a challenge, and certain materials can be fiddly to work with. The research should enable participants to explore how they can make interactive textile objects using techniques which are accessible to them, and using materials that are suited for technical circuit elements, construction of a piece, and decoration. This question is explored in the first observational study in two schools for children with sensory needs and/or visual impairment, and in Study 2.

iii. **Can visually impaired makers express themselves through e-textiles?**

What evidence might there be of visually impaired makers expressing themselves using e-textiles? Does the act of making and the materials evoke personal memories in participants? Are they able to express identity, memories, emotions, and/or narratives using e-textiles? Do they demonstrate creative thinking in e-textile workshops? What design decisions do they take into account? How might design decisions 'come alive', and how might visually impaired makers use interactivity and electronic outputs such as sound in a circuit? This question is addressed in the second and third studies.

iv. **What are the challenges and opportunities for blind and visually impaired people in an e-textile participatory making environment?**

How can visually impaired people be empowered to design and make their own e-textiles? How can these participants have agency in design and making? A challenge for this research is the tension between the approach being as participatory and flexible as possible, whilst also ensuring that the participants have a working, interactive, e-textile object by the end of the workshops. The participants should feel empowered in making choices about the technology used, and so the research should explore how participants can inform technical choices as well as creative ones. The participants' role in the research should be as co-designers, being designed with, *not* for. Being in a social environment can also pose its own challenges; does being in a social environment linked with crafting encourage people to open up as they make, and feel part of something? The literature suggests that the crafting circle creates a sense of community through social contact. Strohmayer and Meissner (2017) found this in their e-textile quilting research with people engaged in sex work, as did Vogelpoel and Jarrold (2014) in their art and craft making activities with deaf-blind participants. The second study addresses this question.

v. **How do blind and visually impaired people interact with textiles (and e-textiles) using touch?**

E-textile sensors and switches are often designed with a particular interaction in mind for their use. How can this design process be more human-centred and be informed by potential users? It was necessary to explore how visually impaired people use their hands to handle and explore materials and textures: is there a common repertoire of gestures associated with this? Similarly, it was necessary to explore how visually impaired people use their hands for handling and interacting with objects (both interactive and non-interactive). Is there a language of tactile interaction? All three studies address this research question.

1.4 Research approach

The research spans different studies which used different research methods, which are introduced in turn.

Chapter 3 discusses a two-part observational study conducted in schools in East London, one which specialises in education for children with neurological, cognitive, and physical disabilities, and the other for children who are blind or visually impaired or on the autism spectrum. As the research took place in the children's environment and involved vulnerable children, it was decided that an unobtrusive approach should be taken, and contextual inquiry was chosen. Contextual inquiry is described by Holtzblatt and Beyer (2015) as designers *"going out into the field and talking with people about their work and life while observing them"* (p. 11).

Chapters 4 and **5** discuss two series of e-textile hands-on making workshops, facilitated in a community centre and a contemporary art gallery. This study used a mixed-methods approach, including a creative methods approach (Gauntlett, 2007) through the hands-on-making, observations, contextual inquiry, group discussions, and storytelling. As discussed by Rogers (2011), people interacting with technology in the 'real world' can be 'messy', and a carefully planned lab study cannot always be mapped onto other environments.

Chapter 6 discusses a lab study exploring gestural interaction and interactive storytelling, which invited visually impaired participants to participate individually in activities using e-textile sensors and switches. The research team wanted to observe what the participants would do spontaneously, rather than instructing them how to interact with the sensors, and so a contextual inquiry approach was taken again. Storytelling was used as well, with participants invited both to retell a popular fairy tale and to tell a story of their own, using the sensors and switches as props.

The research took place with the support of collaborating institutions: the schools that hosted the observational studies, and the visually impaired charity and the contemporary art gallery that provided facilities for the hands-on making workshops. The lab study took place at The Open University. All participants in Studies 2 and 3, and most in the preliminary study, were blind or visually impaired. The participants' particular condition was not discussed, unless they themselves offered that information. This was for ethical reasons, and to ensure that the disability was not the focus, as this can be disempowering. Across all studies, an information sheet about the research was read to each participant, who either signed a consent form – or in the case of the children, had a parent or guardian do it on their behalf (see Appendix A). The studies were approved by the Human Research Ethics Committee at The Open University.

Throughout the process, the research team considered the ethical implications of the research. With the schools and the children, the research was explained to the teaching assistants and the children by the teacher or head teacher. The lead researcher was introduced to everyone, with an explanation about how she would be observing the classroom.

In the e-textile hands-on making workshops, the research team was transparent with the participants about the purpose, duration, and outputs of the workshop series. The team also explained that the participants would be able to take everything they made in the sessions away with them, including the technology. All aspects of this were thought out in a careful and ethical way, with decisions being made around the users (as discussed in Chapter 4).

Regardless of the methods, the research team was mindful of its handling of personal and sensitive information which might arise in discussions. This is referred to by Guillemin and Gillam (2004) as *"ethics in practice"* (p. 262), and concerns the *"day-to-day ethical issues"* (p.264) which may arise during the research process. The process might bring up emotions, memories or situations experienced by a participant that might not be pleasant for them to deal with – these being *"ethically important moments"* (Guillemin and Gillam (2004: 265), in which the research team's responses may have ethical consequences.

1.5 Document structure

Chapter 1: Introduction

This chapter has contextualised the research in the problem space, discussed the motivation for conducting it, and introduced the research questions and methods.

Chapter 2: Literature review

This review brings together different areas of research to contextualise the work in the dissertation and to ground the research in terms of key literature which is built on through the research. First, e-textiles and their fabrication are introduced, to give an overview of what sub-areas are within the field and also how researchers and designers are exploring their potential technically. Then, how e-textiles are being used for interaction with HCI is discussed. This leads into a discussion of designing with people, including participatory design and an approach which involves more hands-on making, which this research refers to as 'participatory making'. The review then explores examples of this within e-textile literature. Touch is discussed next, including literature from both psychology and textiles. Objects and association is the next section of the literature review, ending with how objects and storytelling have been used together.

Chapter 3: Preliminary observations in schools

This chapter discusses a two-part observational study that took place in schools during the first 1.5 years of the research. The first observations were conducted at Brookfield House School, an academy which offers a bespoke curriculum to young people from 2 to 19 with complex needs, with some visually impaired students. The second set of observations took place at Joseph Clarke School, an academy which specialises in working with both visually impaired young people, and those with autism. The study provided insight into how tactile objects are used within the classroom environment for communication and for sensory and playful activities, as well as how they are handled. Music, storytelling, and sensory environments also play an important role in activities and emotional engagement with the young people in these schools.

Chapter 4: E-textile making workshops with VI participants

This chapter discusses preparation and planning for the two series of hands-on making workshops which took place as part of the research. It describes the preparations with the collaborating organisations: Bucks Vision, the blind and visually impaired charity with whom the research team collaborated with on delivering the first set of workshops; and MK Gallery, which hosted the second series with a local visually impaired art group, Eye for Art. After meeting collaborators, some observations took place of workshops that contained potential participants within the art group, including a special workshop to introduce Bucks Vision service users to e-textiles to gauge their interest in taking part. The prototyping for planning the workshops and to test potential making techniques is discussed next, along with how two visually impaired ‘experts’ fed into the process. The chapter ends by describing the hands-on making workshops and their delivery.

Chapter 5: E-textile making workshop findings

This chapter reports and discusses findings from the workshops, including how participants engaged with the hands-on making process, their creative choices in making their pieces, and the themes that emerged around the work created. The methods for collecting and analysing data from the workshops, and the contributions and limitations of the study, are discussed.

Chapter 6: Storytelling with e-textile objects

This chapter reports a lab study in which visually impaired participants were asked to interact individually with pre-made e-textile sensors and switches, connected to a microcontroller. The motivations behind this study are discussed, as is the process of making the objects. The study design is described, including the activities within the study, and the analysis of the data. The findings of the study are then presented and discussed, including how participants used gestures in interacting with the objects, what associations they had with each sensor and switch, and how they used the sensors and switches in storytelling.

Chapter 7: Conclusions and future work

The conclusion reflects on the research carried out and on its overall findings. Also discussed is how the research can be built on and what the next steps might be in order to do that.

2 Literature review

2.1 Introduction

This thesis is situated within human-computer interaction (HCI) - which is inherently interdisciplinary - with a focus on the use of electronic textiles (e-textiles). Therefore, this review will discuss a diverse range of literature including:

- **E-textiles**: Fabrication, and how e-textiles have been used as a medium within HCI;
- **Designing for and with people:** Participatory design, the maker movement, creative research methods, and participatory making through e-textiles;
- **The sense of touch:** Using touch to engage with objects; touch, objects, and meaning.

Figure 2.1 shows key literature in this review, much of which crosses between the three areas:

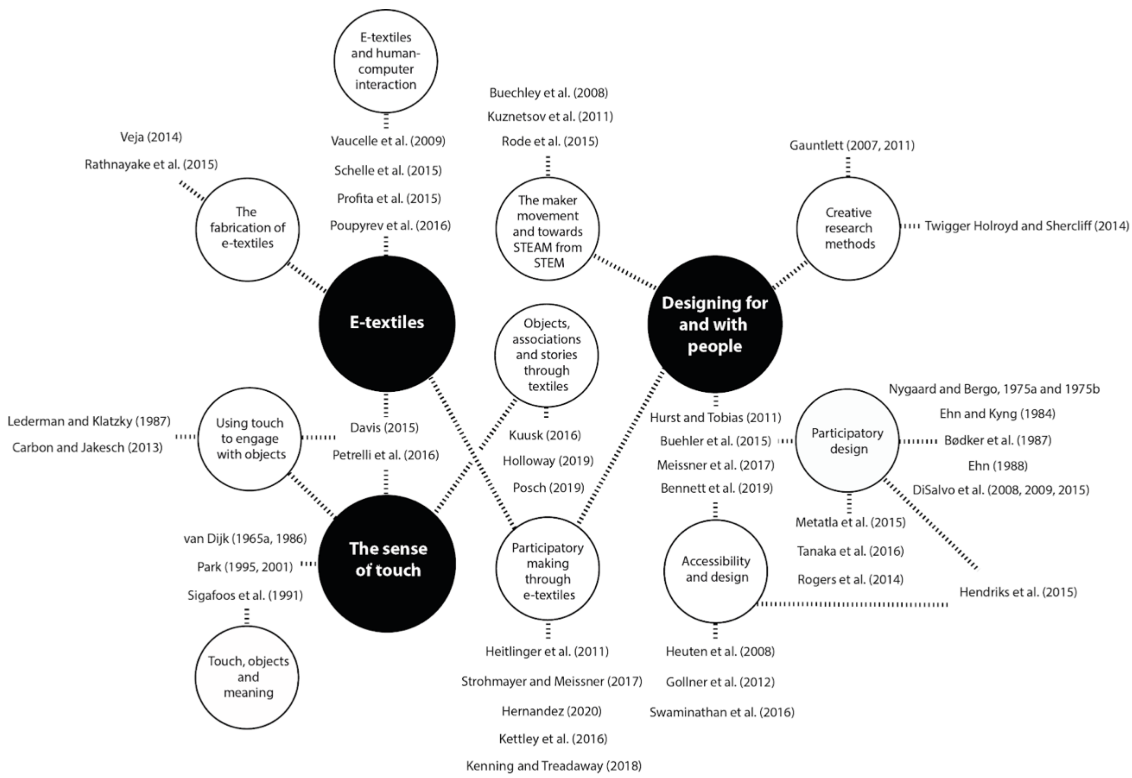


Figure 2.1: Diagram of areas discussed and key authors in the literature review.

2.2 Electronic textiles (e-textiles)

E-textiles cover a range of disciplines, including: engineering, visual design, textile design, wearable technology, digital arts, and medical devices. This review will not discuss all of these areas but will focus on those that are key to the research. It will also provide an overview of innovations within e-textile engineering and design, to set the context for the technology used in the research. Fabrication of e-textiles will be discussed in brief, but the main discussion will concern how these materials are used within HCI, and how e-textiles are being introduced to potential users.

2.2.1 The fabrication of e-textiles

In their most accessible and easy-to-find form, e-textile materials can be acquired from many a hobbyist electronics retailer. Conductive thread can be used to sew a simple, soft, LED circuit, and conductive yarn can be knitted or crocheted into sensors. The results are often seen at Maker Faires and in DIY technology workshops, particularly for teaching children about electronics and programming. Increasingly, e-textiles are incorporated into garments and upholstery, using industrial digital embroidery and knitting machines to include conductive yarns and threads into a structure including micro-components, with the technology becoming smaller and more hidden. This moves e-textiles and wearables toward ubiquity.

As discussed by Rogers (2011), over the last 30 years there has been a shift within human-computer interaction from designing for the desktop to designing *"beyond the desktop"* (p.58). Mark Weiser stated that: *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."* (1991:94). Although Weiser was using 'fabric' metaphorically (rather than referring literally to e-textiles), it can be argued that this vision of ubiquity could be realised through e-textiles and is already becoming reality, for example through the research of Veja (2014) who embeds components into woven structures, and of Rathnayake et al. (2015) whose conductive yarns also contain micro-components. Projects turned into products, such as *Project Jacquard* by Google (Poupyrev et al., 2016) combined with Levi's *Trucker Jacket* (Google, 2016), show how it is becoming more viable commercially to produce such products on a bigger scale, allowing members of the public to buy this technology and wear it, rather than just viewing it at exhibitions.

Veja (2014) researched the potential of integrating electronics into fabric by creating woven e-textiles (see Figure 2.2). Her practice-based approach focused both on creative crafting methods and technical aspects, and so explored both the functionality and the creative design of the work. Veja experimented with how components such as LEDs, soft resistors, switches, and battery holders can be woven into fabric, and with designing and making her own flexible circuit boards.

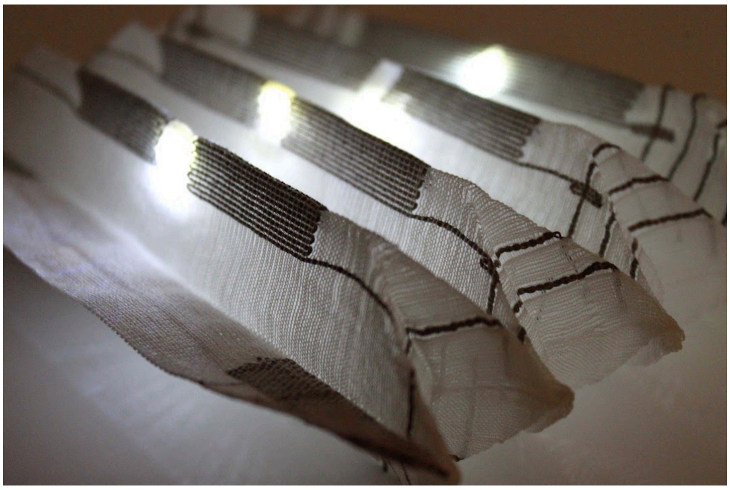


Figure 2.2: ‘cpledV2’ (Veja, 2014): e-textile piece hand woven on a dobby loom. Image used with permission.

The idea of embedding components into fabric is manifest differently in research carried out by Rathnayake et al. (2015), which produced conductive yarns that have micro-components such as RFID tags, LEDs and temperature sensors embedded within them. These micro-components are insulated using a non-conductive outer layer, which is placed around the conductive core and components using a braiding machine. This is a device that interlaces three or more strands of yarn, or other rope-like material or wire, into a continuous covering.

Project Jacquard (Poupyrev et al., 2016) uses conductive yarns in the fabrication of woven structures. The first commercial output was a partnership with Levis to create the *Trucker Jacket* (Google, 2016). The yarn used consists of a thin copper core, insulated with a non-conductive protective outer layer constructed through braiding, similar to the work of Rathnayake et al. (2015) This material is then woven into sensors, which are used as capacitive touch grids to trigger an output. Their promotional video for the jacket and the technology shows a person cycling, swiping their arm with their fingers to answer their phone, making the technology an addition to the body, and realising multitasking through a wearable.

All of this research into the creation of e-textile-based materials and structures is pushing the boundaries of how e-textiles can be used and integrated more effectively or less obtrusively. *Project Jacquard* (Poupyrev et al., 2016) builds on research by people such as Veja (2014) and Rathnayake et al. (2015), and shows the potential for how the technology can be worn, and for how everyday people might interact with this wearable technology in their day-to-day lives - primarily as something which interfaces with their mobile phones.

The next section considers how the use of e-textiles is being explored, and which interactions and experiences are being created by designers and researchers.

2.2.2 E-textiles and human-computer interaction

The use of e-textiles and wearables within HCI is currently particularly prevalent in research that explores health and wellbeing, including design for issues such as mental health and dementia. A user-centered approach is often taken for this. The three principles that are core to a user-centered approach, as discussed by Gould and Lewis (1985), are:

- Early focus on users and tasks (understanding who the uses are and observing them in their day-to-day tasks);
- Empirical measurement (observing, recording, and analysing these users interacting with prototypes early on in the design process);
- Iterative design (iterating the design based on the findings, following a cycle of: design, test, measure and re-design).

Vaucelle et al. (2009) created a series of four haptic wearable pieces to be used by patients with mental health issues with the support of their doctor or therapist:

- **Squeeze Me**: A piece for therapeutic holding, simulating the sensation of being held close and tightly by someone;
- **Touch Me:** Giving vibrotactile feedback to a user as they embrace the piece;
- **Hurt Me**: Giving controlled pain to the user through rubber spikes, worn as a bracelet that inflates and deflates to control the intensity;
- **Cool Me Down**: A cool wrap which administers a sudden change in temperature, grounding the senses.

The devices were used on clinicians for 'ideation' purposes during focus group sessions. A user-centered approach is particularly important with vulnerable users, because of the potentially sensitive nature of the design problem; it is sometimes necessary to test devices with carers or family members before approaching users directly, especially when working with sensitive issues. In contrast, through *Tactile Dialogues,* Schelle et al. (2015) worked directly with their users, creating a textile pillow for use in interactions between dementia patients and their carers or family. The pillow reacts to touch and activates vibrotactile stimuli with which the participants can play. It also acts as an interesting object to prompt conversations between the user and their carer or family member. The researchers spent time introducing the prototype to the users, and personalised the interaction for them. Profita et al. (2015) also took a user-centred approach in their research on wearable light therapy through *Lightwear*, collecting data from over 100 individuals online about their experience of having Seasonal Affective Disorder, and then using this information to inform their wearable designs.

These projects are all focused on designing *for* the user. An alternative approach is to design *with* the user - giving users a more active voice and engagement in the design process. This can be quite challenging when designing and making technologies for people which require a specific fabrication technique - in the cases discussed, professional textile fabrication.

2.2.3 Reflecting on the literature

Whether it is research which integrates micro components into yarns, or a scarf that gives the user light therapy, it is clear that designers and researchers are increasingly exploring ways that e-textiles as a soft material and technology can be more streamlined within our clothing, personal objects and daily routines, as opposed to technology which is more separate from our person and feels more machine-like.

Within the projects discussed, the potential for gesture and actuation - exploiting the sense of touch, for example, the swiping of the jacket for *Project Jacquard* (Poupyrev et al., 2016), and the feeling of vibration motors in *Tactile Dialogues* (Schelle et al., 2015) - is brought into focus. Many e-textile projects focus on the visual rather than the tactile, and it is interesting and encouraging to observe tactility becoming an increasingly-explored area, particularly concerning users for whom vision is limited. Given its potential importance for visually impaired people, this idea of using touch in interaction will be explored in more detail in Section 2.4.

What has not been discussed yet is the use of these technologies within projects in which users design and make their own e-textile objects; that will be explored later within the context of ‘the maker movement’.

2.3 Designing for and with people

2.3.1 Accessibility and design

It is important to contextualise what the common approach is for designing for individuals with disabilities. Focusing on visual impairment, technology designed for this user group often uses the potential of tactile interaction or actuation as an alternative to sight. Examples range from tactile wayfinding belts (Heuten et al., 2008), to gloves that translate hand-touch-based communication into digital text (Gollner et al., 2012), and technology that helps VI people read tactile diagrams (Swaminathan et al., 2016). This research and set of technologies is valuable in helping VI people to undertake everyday activities and retain their independence. However, by and large this is technology designed *for* VI users rather than *with* them. Across technology designs for people with other impairments and disabilities, this approach is also common, e.g., an application to assist with communication for people with motor disabilities (Zhang et al., 2017) and a smartwatch application to assist students with cognitive and developmental disorders (Zheng and Motti, 2018). Interestingly, there seems to be more input from participants in projects which use a more ‘physical’ piece of technology rather than an app - such as the work by Kirk et al. (2016) on using digital music instruments in the home for stroke rehabilitation, or Bennett et al.’s (2016) work on 3D printed prosthetics. These projects still do not necessarily include co-designing sessions with participants, but perhaps it is important to acknowledge that, with any dissemination of research, elements of the project story may be omitted. Regarding publications on technology and accessibility/disability, many of the narratives discuss the technology itself, omitting the processes used when designing it or iterating with users - and their input.

Mankoff et al. (2010) discussed how, by taking insight from disability studies, assistive technology as a field can shift to involve the user more in the design process. They argued for communities to be involved, supporting empowerment through the use of technology. There has certainly been a shift to more researchers inviting potential users to become part of the design process, that is, to become collaborators in the design and making of technology objects. This gap is being addressed increasingly within HCI, with researchers exploring how people with disabilities can be empowered in designing and making their own technologies. Hurst and Tobias (2011) discussed the strengths of custom-built and DIY assistive technology and how it can empower users. By having control over the design elements of the technology, users are able to control the aesthetics, can fix it themselves, and can also construct something which is less costly.

The ability to custom build something for oneself not only satisfies one’s sense of creativity, but also enables independence. Buehler et al. (2015) worked on a series of 3D printing workshops for a mixed group of undergraduate students and young adults with intellectual disabilities, also collaborating with an intern with intellectual disabilities on the workshop planning. This close collaboration led to the creation of personalised learning materials which were used in follow-on collaborative making sessions with the wider group. Being an active partner in the production of these learning materials gave a strong sense of empowerment and ownership to the intern. Meissner et al. (2017) ran a qualitative study, exploring the potential of DIY-AT (Do It Yourself Assistive Technology) in the context of users designing and making their own objects using a range of skills including 3D printing, laser cutting, and physical computing. The authors worked with a variety of participants with disabilities to create their own objects in a makerspace environment. The participants not only took on the identity of ‘makers’ but also shaped a form of empowerment personal to them through their projects. Bennett et al. (2019) worked with visually impaired hobbyists over a series of hands-on making physical computing workshops to make Arduino-based voltmeters. Two of the researchers involved were also visually impaired, with one of them specialising in nonvisual tutorials for programming and electronics.

This approach of co-design or prototyping with users who have a disability or impairment requires an open approach and the ability of researchers and facilitators to adapt in co-ordinating and running the sessions. Using techniques and methods that can be embraced by the individual participant instead of pre-defining the skills needed is an important part of this. The idea of creating a dedicated co-design approach has been discussed within communities of researchers and designers that work with participants who have a cognitive or sensory impairment. Reflecting on a series of academic workshops, Hendriks et al. (2015) concluded that individually adapting co-design methods is more appropriate for working with people who have an impairment, as users are diverse in their needs. They also explored the potential of a 'methods stories' approach when bringing academics and designers together in workshops: sharing stories about working with different users, in order to learn approaches from one another. The concept of 'methods stories' was coined by Lee (2012) as an approach that focuses not just on the data which is collected through a method, but also on what designers actually think about and feel when working with their methods (Lee, 2013).

This approach of designing objects or technologies *with* people instead of *for* them is of course not new, and has a large history rooted in participatory design. It is useful to discuss the background of this and how it has been manifesting itself in maker projects.

2.3.2 Participatory design

Participatory design involves users in the design process, traditionally in the workplace where employees have been involved with designing tools and technologies to improve their work environment. As discussed by Kensing and Greenbaum (2013), the approach came out of two situations linked to politics in the workplace. The first was a widespread management strategy across many countries whereby workers were being de-skilled and their tasks automated, leading to lower wages and a more-controlled workforce. The second situation was specific to Scandinavia, where changes to workplace agreements in the 1960s and 1970s meant that workers gained more rights with regard to decision making and their working conditions - but they were not always informed about the management's plans concerning technology. This was something they wanted to change.

Two of the most well-known participatory design projects are the Norwegian Iron and Metal Workers Union (NJMF) project (Nygaard and Bergo, 1975a and 1975b) and the UTOPIA project (Ehn and Kyng, 1984, Bødker et al. 1987, Ehn, 1988). The NJMF project was influential for future work, because it used a 'learning cycle' involving both the union and the researchers (Kensing and Greenbaum, 2013); the work also took an 'action research' approach. The UTOPIA project was significant because it took the participants involved further than any previous participatory design project through the use of prototyping. The participants themselves were actively involved and were taken out of their work environment and into a technology laboratory.

Kensing and Greenbaum (2013: 33) discuss the principles embedded in participatory design:

- Equalising power relations;
- Democratic practices;
- Situation-based actions;
- Mutual learning;
- Tools and techniques;
- Alternative visions about technology.

Both the NJMF and UTOPIA projects exhibit these principles and have been influential in the field of participatory design. The projects have been important in shaping the process of designing with people and not just for them. The approach of working with the participants in a hands-on way, using physical prototypes and encouraging them to re-imagine technologies, is an element of the UTOPIA project which has been carried forward through the work of other researchers who use a participatory or co-design approach.

Community participatory design differs from workplace participatory design in that it is not rooted in the same social constructs or organisational constraints (DiSalvo et al., 2015). An example is the *Neighbourhood Networks* project (DiSalvo et al., 2008, 2009), in which members of the public engaged with creative exploration of robotics and sensors in a neighbourhood activism context, through workshops.

There are also more creative examples of the use of participatory design, specifically with people with impairments, that could be classed as a more community-based approach. Metatla et al. (2015) worked with visually impaired people who experience issues in using visual interfaces in their work as sound engineers and audio producers. They collaborated with them to develop low-fi mock-ups using materials such as foam paper tags combined with basic audio equipment. Higher-level technical prototypes that could be re-programmed quickly were also used, so that the researchers could amend them according to participant feedback during their sessions with them. The researchers did find that participants discarded the hands-on making in favour of verbal exchange, because they weren't able to see what they were doing. This potentially highlights a problem that there are currently not enough hands-on making techniques available for people who are blind or visually impaired, so that they can rely on touch instead of sight for construction. The output of the co-designing process was a device called the Haptic Wave, which maps audio onto haptics (Tanaka et al., 2016). What is also special about this project is that the designers and researchers are not trying to fix the 'issue' of a lack of sight, but they are inventing something for users which is creative. This contrasts with the projects mentioned earlier such as the wayfinding belt (Heuten et al., 2008), or the gloves that translate hand-touch- based communication into digital text (Gollner et al., 2012). As useful as these projects are, there is a need for more creative uses of technology to be developed for people with impairments and disabilities. This aligns with Bødker's concept of third-wave HCI (2006), with technologies focusing more on personal experience and emotion, rather than just functionality.

The idea of functionality over creativity for certain users is challenged by the work of Rogers et al. (2014) through a project which explores aging, creativity, and technology. The researchers successfully incorporated hands-on making using *Makey Makey* (2020) in a participatory design project with elderly people, with an aim to challenge the idea that technology for older people should just be functional and deal with 'aging'. They explored the use of *Makey Makey* in a series of workshops with the participants, inviting them to imagine new technologies from their creative experience. The participants worked together to create musical instruments from conductive objects such as fruit and *Play-doh*, and their confidence in using the technology grew as they gained hands-on experience with it. The project saw them have fun together, collaborate, and explore creatively. This approach of hands-on making with creativity, and for users to be making their own technology, can certainly be used more in projects that involve people with impairments.

There is a difference between participatory design which invites stakeholders to become part of the process and work with the designers using design thinking, and participatory design which involves participants actively *making* objects - for which this dissertation uses the term 'participatory making'.

2.3.3 The maker movement and toward STEAM from STEM

Over recent years, the 'maker movement' has been growing increasingly, incorporating many different areas and activities. Arguably, shared making has been foundational to human society long before 'DIY culture' with activities such as knitting circles being recorded back to the 1700s (Rutt, 1987). Not only does making give us a sense of joy in working on and completing a project, but it also brings people closer together via a mutual interest, who share a passion for creative making. As Gauntlett (2011:222) wrote:

> *"The process of making is enjoyed for its own sake…but there is also a desire to connect and communicate with others…to be an active participant in dialogues and communities."*

In his book *Making is Connecting,* Gauntlett outlined the history of DIY culture - from home-improvements, to creative elements such as 'zines', to punk culture. Crafting and DIY, it could be argued, are very much connected, as are other forms of making. Through maker spaces/hack spaces, Fab Labs (Fablabs.io, 2020), the Transition movement (TransitionNetwork.org, 2020), arts festivals, and Womens' Institute groups, there are many opportunities for people to become involved with a community and create something physical. E-textiles have played a role in STEM education, where they are being used to encourage more young people to take an interest in electronics and programming. Within HCI, there has been a focus on this more educational approach with e-textiles. Buechley et al. (2008), using the Arduino Lilypad, found that linking programming and electronics to a design activity is important in engaging young people in engineering. This is reinforced in research by Rode el al. (2015) who argued for Arts to have a place in technology-related practice (phrased in terms of 'putting an A into STEM'). The creative approach is different in the two research projects; in Buechley et al.'s study, the young people integrated the electronics into a piece of clothing that they already owned, whereas the young people in Rode et al.'s study created an interactive soft toy.

This field of research is important in working toward children and young people gaining a better understanding of how they can make creative and interactive projects. However, perhaps because the focus is on acquiring competence rather than on designing products, the research by both Buechley et al. (2008) and Rode el al. (2015) appears to omit spending time with the participants and discussing with them what it is they want to make. The objects were pre-decided by the researcher (a wearable, or an interactive toy), whereas possibly the participants might want to work on something more personally designed. Another possible issue is the lack of diversity of participants. Kuznetsov et al. (2011), discussing their e-textile STEM research with 'at-risk' young women, commented that work with at-risk communities is conducted less within HCI due to the challenges that might come with this, such as initial lack of enthusiasm by the participants. Similar to the at-risk communities from a lower socio-economic background, people with disabilities are also often excluded from HCI research and maker culture. Using e-textiles as part of maker culture is rarely seen with these harder-to-reach user groups.

Many HCI researchers running hands-on making workshops use 'creative methods' - as discussed by Gauntlett (2007). His research is situated more in sociology than in computing, but it is useful to explore how 'creative methods' have been defined and how other humanities-based researchers are using them.

2.3.4 Creative research methods

Gauntlett (2007:25) described "creative methods" as those in which "...people express themselves in non-traditional (non-verbal) ways, through making something." Using hands-on making methods to empower people and involve them in the design and making process gives participants knowledge about these practices and allows the practices to be used more authentically in a research context.

Gauntlett discussed his own experience of conducting a user study with a group of young people, not just collecting data through interviews or focus groups, but also asking them to film things. Gauntlett wanted to explore the children's interests with respect to environmental issues, as part of broader research about whether the media of that time had prompted greater interest in environmental issues among young people. By choosing a DIY approach, and giving the participants a simple 'point and shoot' camera, he found there was an *"immediacy and easiness"* with this approach (2007: 94). This idea of ease and lack of formality is also relevant for participatory textile research, which uses what can be understood as 'creative methods'.

Twigger Holroyd and Shercliff (2014) discussed how, within textiles, there is a lack of documentation about making-with-others as a research method, and so they share their own experiences of running embroidery and knitting workshops with different groups of people as a method of research. Twigger Holroyd ran drop-in knitting workshops at festivals, and asked participants about their opinions on wearing home-made clothes. She noted participant conversations and asked them to write their 'knitted memories' on little tags, which she collected afterward. Shercliff took a more ethnographic approach, becoming part of a local embroidery group close to home, and joining in with their activities as she observed and became part of the group's dynamic. Her goal was to find out what personal reasons people had for participating in such a group. In discussing their work, the researchers used the term 'participatory making methods' as well as referencing Gauntlett's 'creative methods'.

'Participatory making' can perhaps be used to describe projects which do not necessarily fit within the traditional definitions of 'participatory design', as the latter is often more about design thinking and working toward quite a focused design challenge, often a product or service for users. The term 'participatory design' often has multiple interpretations attached to it, depending on discipline, and so to distinguish the context of something being much more focused on the 'hands-on making' process, 'participatory making' seems more appropriate for this research.

As discussed by the researchers, this method of working with others in collaborative hands-on making can help to support open and constructive discussions. Twigger Holroyd and Shercliff observe how making can slow down the pace of discussion, giving time for thought - in contrast to interviews, in which the format can put pressure on participants to answer, as discussed by Gauntlett (2007).

This idea of 'creative methods' as a way to collect data and to allow participants to express themselves fits well with Hendrik's (2015) assertion that individually adapting co-design methods is appropriate for working with people who have an impairment or disability, due to everyone's individual needs. These approaches to research are both more flexible than many traditional methods, and also allow more agency for the users.

Within e-textiles, there is an increasing body of work that addresses working with participants to make their own objects, particularly in the context of projects that call for reflection or that aim to explore the potential of knowledge exchange between practitioners/researchers and people who might not always have access to e-textile maker activities. Within this literature, some researchers have also been exploring how personalised sensory objects can be created *for* vulnerable people, while also working *with* vulnerable people to design and make their *own* e-textile pieces. This move toward a more open, exploratory approach within e-textiles is something that can be traced to the increasing openness of e-textiles as a field, with artists and designers coming together to share skills and practice with one another, and the e-textile community itself increasingly supportive of its members.

2.3.5 Participatory making through e-textiles

It is important to discuss how e-textiles as a tool and way of working - combining traditional textile skills with electronics and computer programming - has perhaps become so popular and is being embraced increasingly by researchers, designers, artists, and engineers as well as hobbyists. As mentioned previously, there are manifestations of e-textiles which sit more in engineering and design, and others which are more related to maker culture. However, the gap between these is diminishing gradually, as designers become increasingly open about their work and contribute to the open source movement. A champion of this is the collective Kobakant, formed and led by Hannah Perner-Wilson and Mika Satomi. Their blog *How To Get What You Want* (Perner-Wilson and Satomi, 2020) documents many of their e-textile projects, from exhibition pieces to small tinkerings which they just wanted to share. This documentation includes the testing of conductive materials, how to make soft components, sharing workshop content, and crafting techniques. They also instigated the annual E-textile Summer Camp (Etextile Summer Camp, 2019) in collaboration with Les Moulins de Paillard in France - a residency attended by all sorts of practitioners and researchers in the area of e-textiles, in which participants teach one another techniques and approaches in workshops, create projects together, and eat and cook together. This is the epitome of maker culture.

Another designer who has been opening up her work for others to explore and adapt is Irene Posch, with *Tools for Electronic Textile Crafts* (2014 - 2018). She has been adapting existing tools for electronics and crafting, to be useful specifically for e-textiles, for example: a multimeter which has a crochet hook attached, pin probes which can connect an Arduino Uno to a pin cushion, and conductive clips designed to be gentler on fabric. She has also run workshops, teaching other makers to do this, thus feeding her knowledge and inventions - which cannot be bought in an electronics shop or haberdashery - back into the community.

There are also many online resources available, such as Instructables (Autodesk, 2020), YouTube videos (YouTube, 2020) and Adafruit (Adafruit Industries, 2020), along with in-person workshops all over the world. For example, in London this has included MzTEK (MzTEK, 2020), who ran workshops, talks, and exhibitions for a number of years, aiming to encourage more women to learn and practice creative technology skills; Codasign (Codasign, 2017), which worked primarily with museums and galleries to teach children and young people how to use programming and electronics to make personalised projects, often related to a cultural theme; and E-Stitches London (E-Stitches, 2020), an e-textile meetup group giving a platform for artists, researchers, and designers using this medium to showcase their work through talks and practical workshops.

2.3.5.1 Working with communities

Because of researchers' openness and enthusiasm to explore different techniques, e-textiles have been used increasingly by researchers to explore how they can and might be used by different users in participatory contexts. Community, wellbeing, and empowerment have been a focus, driven (in common with the work of both Metatla, Rogers, Meissner, and others) by a desire to include people in the design process who might normally be excluded from mainstream activities.

Some of the research projects that incorporate e-textiles are with long-established communities; the researchers become part of the group, and work with participants to create collective works. Some of these projects could be described as tactile oral histories, containing personal stories or sounds which reflect an interest or life event of the participant. Heitlinger et al. (2012) brought participants' stories to life in their research with a community-led city farm in East London, by using touch and audio as the trigger for storytelling (see Figure 2.3). The interactive *Talking Quilt* was made by over 80 staff members, volunteers, and visitors and contains oral histories from 50 different participants. Each participant's story is connected to a patch in the quilt that they made themselves. When the patch is touched, their audio file is triggered. The stories are of personal details, such as life events, favourite foods, or where they are from.

Figure 2.3: User interacting with the community-made interactive quilt, The Talking Quilt (Heitlinger et al., 2012), at Spitalfields City Farm. Image used with permission.

Strohmayer and Meissner (2017) collaborated with a local charity to run an e-textile quilting project with people engaged in sex work. The space they created gave people a chance to come together, tell stories to one another, and feel a sense of pride in creating an interactive quilt collaboratively.

In her project *Textile Voices* (2020), artist and researcher Lucie Hernandez collaborated with a community group to make a soft sonic interface, using e-textiles and hand crafting such as felting and embroidery. The project aimed both to help participants build their creative skills and imaginations by co-creating the work, and to introduce the technology and make it less intimidating through the process. Each participant made a personalised e-textile element, associated with a recording of their personal oral history, to include in the larger piece. Social cohesion and wellbeing through e-textiles are a key focus of Hernandez's work, with craft, storytelling, and social exchange all coming together along with the technology elements. Her workshops have been conducted in rural areas, enabling participants who might not normally get access to these activities to engage with them.

Working with participants who have health or wellbeing needs has also been a focus in recent e-textile research, with participants (or their carers) making objects that are personal to them as users. Kettley et al. (2016) used e-textiles making workshops with users of the mental health charity, Mind, to encourage self-reflection during the making of a soft interactive object. One of their aims was to create a therapeutic space in which the workshops are delivered. The researchers have been working toward a framework to use when conducting participatory design, informed by psychotherapy approaches, and have proposed combining a Person-Centred Approach with the method of Interpersonal Process Recall. The researchers saw behavioural change in their participants; for example, one gentleman, who normally would be taking frequent cigarette breaks, relaxed into the activity, becoming so engaged that he had only one break during the sessions. The project has produced both academic publications and practical toolkit resources which provide guidance on working with participants on beginners' e-textile projects as well as information on the Person-Centered Approach.

Kenning and Treadaway (2018) worked with dementia patients and their family members and carers to create e-textile sensory objects, including interactive blankets for patients to touch and in some cases listen to. These objects contain tactile elements intended to evoke playful and sensory experiences 'in the moment'. The tactile elements were things such as textile birds and plants for a user with a love of nature, or a pocket reminiscent of a participant's old work apron. These tactile elements became switches which triggered sounds familiar to the users, e.g., their favourite music or woodland sounds, using the Bare Conductive Touchboard. Family members found that the blankets were a way to share an activity with their loved one, and a basis for conversation between themselves, carers, and other residents of the care unit. The wife of a patient, Bill, for whom a blanket was created (see Figure 2.4), used it as a means to connect with her husband, to reflect on special memories of things they did together over the years. The researchers reflected that dementia care often focuses on clinical and medical care, rather than emotional care. These e-textile, sensory objects enabled patients to connect socially with their loved ones and engage in pleasurable and meaningful experiences.

Figure 2.4: Bill's Blanket - part of Sensor e-Textiles, funded by Cardiff Met University, photo by Professor Cathy Treadaway, (2016). Image used with permission.

Within the 'participatory' e-textile research discussed, vulnerable groups are indeed included: people with dementia, with mental health issues, and involved in sex work. Other projects work with volunteers and community members of a city farm and local craft groups. Yet there is a gap in working with people who have a sensory impairment; can the tactile elements of e-textiles be exploited to engage with such groups?

2.3.6 Reflecting on the literature

All of the literature discussed in this section falls under the category of 'working with people': accessibility and design; participatory design; the maker movement and its integration into STEM and STEAM; creative research methods; participatory textile making, and working with communities.

There is certainly overlap among areas - with HCI researchers conducting STEM/STEAM workshops using 'creative research methods' and 'participatory making methods' - but this is not being used as terminology for discussing them within the HCI field. The same could be said for literature which sees participants with a disability or impairment for whom technology is often designed *for*, actually becoming the designers and makers *themselves* (Meissner et al., 2017; Bennett et al., 2019). ʻCreative research methods' and ʻparticipatory making methods' are integral to this, and so perhaps there is an argument for more HCI research to focus on these methods, building on the research by Gauntlett (2007) and Twigger Holroyd and Shercliff (2014).

Another research gap is the exploration of how people with sensory impairments, such as a visual impairment, can engage with e-textiles. There is literature which explores participatory work using e-textiles, such as that of Kettley et al. (2016) and Kenning and Treadaway (2018) who worked with vulnerable adults, but in their cases people with mental health issues and people with dementia. Perhaps there is a gap in using e-textile methods with people who have a visual impairment due to a concern that the visual is needed – but, as will be discussed, the sense of touch is incredibly important as well when working with textiles.

2.4 The sense of touch

Touch seems to be the sense which we most take for granted. We use it every day when eating food, when greeting friends, when taking part in activities, and so on. In their book *Learning Through Touch* (2002), McLinden and McCall presented a world in which we have lost our sense of touch:

> *"Imagine a world where tennis players have ʻno touch', doctors cannot feel for lumps...A world where you can't feel the wind on your face, the sun on your back or the good earth under your feet. In short, a world where you would experience your life as if you were watching a film...a very strange world indeed." (2002: 3)*

Textiles and touch are known to be important; Philippe et al. (2003) discussed how *"expert evaluation"* (p. 237) is carried out through touch. They described the *"reaction of the sense of touch"* (p. 237) when we hold a fabric in our hands as the *"hand"* of the fabric (p. 237). The way in which a fabric performs as we hold it - its feel, how it drapes, its aesthetic value - is what gives the fabric its character and can be assessed by handling it.

For blind and visually impaired people, touch can be particularly important, whether for example locating the TV remote, or assessing something's shape or size. This section will discuss the role that touch plays as a sense and how it is used with objects. This includes how users engage with objects, how meaning is linked to them, and how textile objects have been used as tools for storytelling.

2.4.1 Using touch to engage with objects

Gibson (1962) differentiated between 'active' and 'passive' touch. Active touch refers to a person touching something, whereas passive touch refers to a person being touched by something. He also described *"touching movements of the fingers"* (1962: 477) as being like *"movements of the eyes"* (1962: 477). Carbon and Jakesch (2013) discussed our desire to touch objects, and how certain aspects - such as an object's shape or surface - invite us to touch it. Drawing on existing research on haptics, they argued that retailers benefit by allowing consumers to handle objects, as well as look at them. Carbon and Jakesch developed a functional model for 'haptic aesthetics', consisting of different processing stages that people go through when exploring an object (see Figure 2.5).

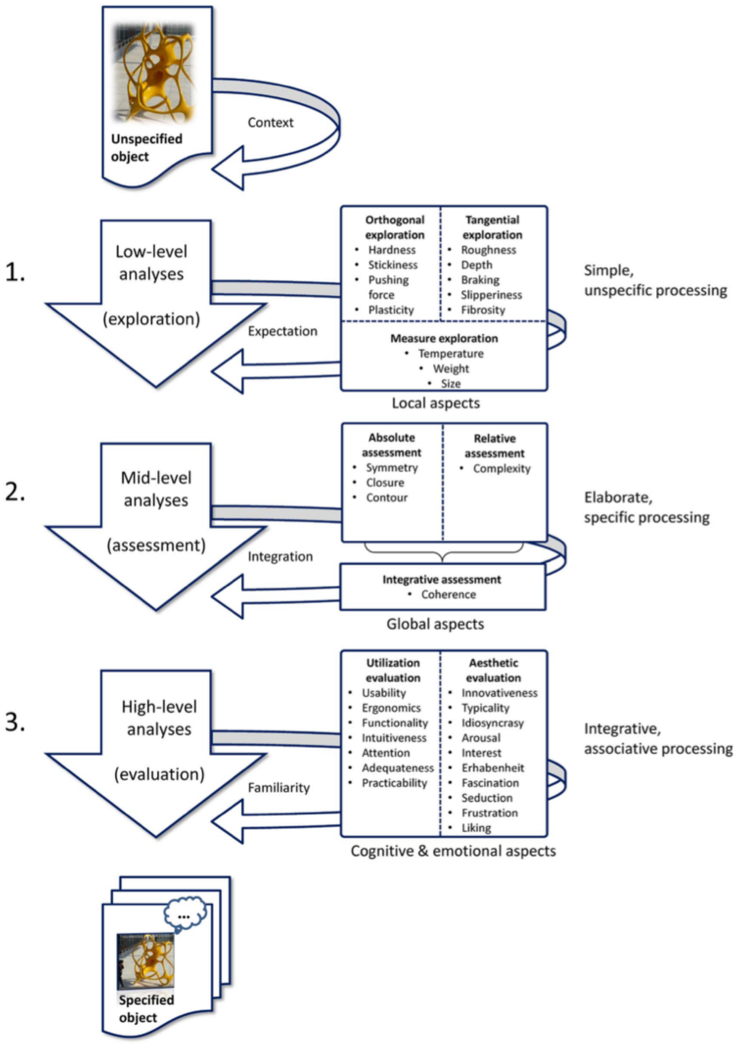


Figure 2.5: "The functional model of haptic aesthetics" © [2013] IEEE, reproduced from (Carbon and Jakesch, 2013). Image used with permission.

Their work built on that of Lederman and Klatzky (1987), who proposed the term *"exploratory procedures"* (p. 342) or *"EPs"* (p. 344) to define a framework for what a user might do in order to find out about the quality of an object. For example, if one wants to find out how hard an object is, one might apply pressure on it with a finger. Lederman and Klatzky identified patterns in the way that people handle objects during exploration which they call *"procedures"* (1987: 342). They commented that:

> *"Hand movements can serve as 'windows', through which it is possible to learn about the underlying representation of objects in memory and the processes by which such representations are derived and utilized." (1987: 342)*

Lederman and Klatzky linked exploratory procedures with *"object based knowledge"* (1987: 345), broken down into different properties (Table 2.1).

Knowledge about object	Exploratory procedure
Substance-related properties	
Texture	Lateral motion
Hardness	Pressure
Temperature	Static contact
Weight	Unsupported holding
Structure-related properties	
Weight	Unsupported holding
Volume	Enclosure, contour following
Global shape	Enclosure
Exact shape	Contour following
Functional properties	
Part motion	Part motion test
Specific function	Function test

Table 2.1: "Postulated links between knowledge about objects and EPs", Reprinted from Cognitive Psychology, Vol. 19, No.3., Lederman, S. and Klatzky, R., Hand Movements: A Window into Haptic Object Recognition, Pages 342-368, Copyright (1987), with permission from Elsevier.

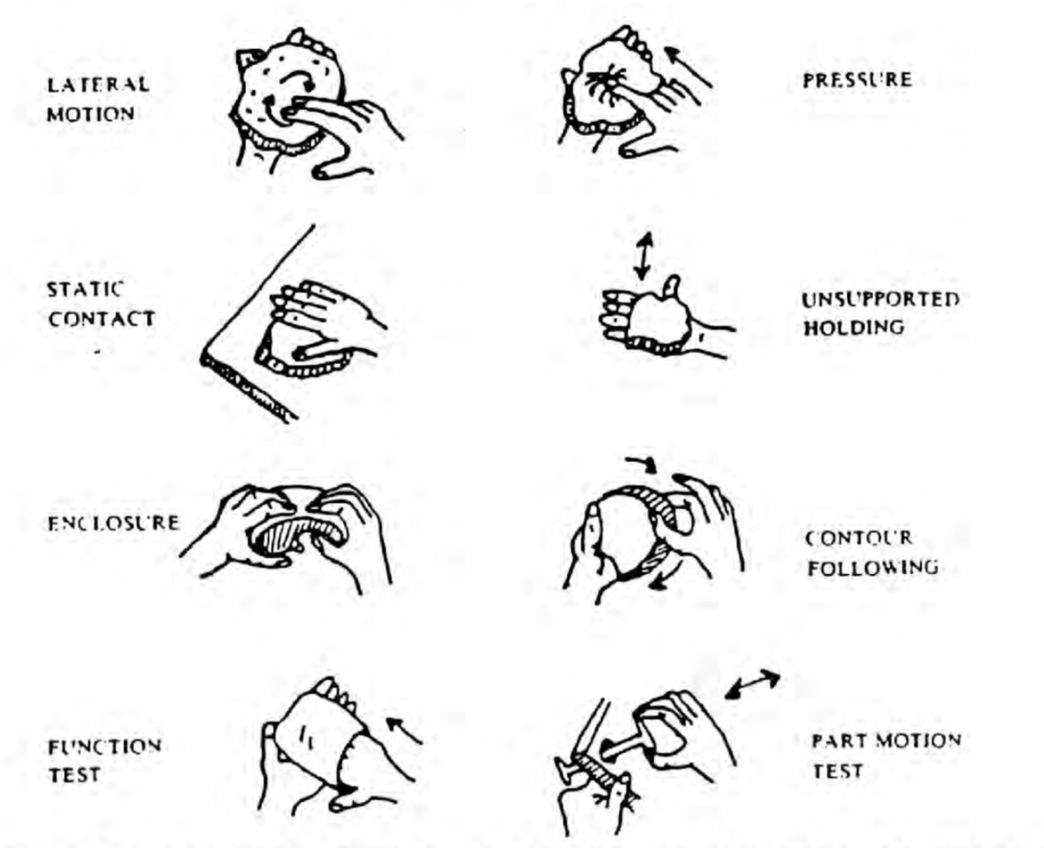


Figure 2.6: "Typical movement pattern for each of the exploratory procedures", Reprinted from Cognitive Psychology, Vol. 19, No.3., Lederman, S. and Klatzky, R., Hand Movements: A Window into Haptic Object Recognition, Pages 342-368, Copyright (1987), with permission from Elsevier.

Lederman and Klatzky discussed how, with one glimpse of the eye, a person can take in a lot of information. However, with a *"haptic glance"* (1987: 366) perhaps one object is accessible, and even that requires movement of the hands, rather than just one touch. Linking this back to exploratory procedures, the movements of the hand depend on what properties of the object are being explored.

Many interactive e-textile objects invite active touch, on a user's own terms. This is particularly important to promote empowerment and engagement for visually impaired users, who are often recipients of passive touch as part of everyday experiences, for example: being led across a room by their arm, being touched on the hand for tactile sign language if they use it, or being tapped on the shoulder when someone approaches them. The literature includes several projects that emphasise settings in which blind and visually impaired people control their own touch experiences. For example, an immersive theatre production of the book *Flatland* (2012, 2015), set in the dark, and designed for both sighted and non-sighted audiences, allowed audience members to move at their own pace around the space and interact with technology they encountered, giving them a sense of control over the theatre experience. (Barker et al. 2016, Wiseman et al. 2017).

The importance of touch has also been highlighted in recent lab studies involving objects enhanced with physical computing, some using textiles. Davis (2015) investigated people's preferences and emotional associations for e-textile objects, some static, and others dynamic. These textiles were mounted on the wall and designed to resemble animal skin, fur, or feathers. Participants were invited to look at and touch the objects. Davis found that touch can override visual feedback, and that a moving texture, whether seen or touched, was preferred to a still one. Findings indicated that an array of emotions may be linked to different textile objects, but across participants there was some consistency in how the objects explored were given emotional labels such as 'excited', 'happy', or 'OK'. Petrelli et al. (2016) also explored participant choices for objects, but in terms of regular shapes, such as small or large cubes or spheres, rather than Davis's (2015) animal textures. These were not e-textiles but 'hybrid objects': they were either coated in fabric or plastic, and were still, lit up, or vibrating. Petrelli et al. asked participants to associate words with the objects, collecting adjectives such as 'playful', 'relaxing', and 'surprising'. They found that people's preference was for spherical objects with a textile texture that vibrated. The researchers commented:

> *"It is of particular interest from the perspective of tangible interaction that digitally enhanced objects were preferred to those with no embedded behaviours. The precise reasons for this are unclear from the current findings and so this needs to be examined further in future research. We may speculate though that the digitally enhanced objects are preferred as we feel some psychological connection to them because of their immediate reaction to our touch." (2016: 106)*

This preference by participants for something that vibrates links to the assertion by Carbon and Jakesch (2013) that when we touch something we are actually also being touched (building on what Sonneveld et al. (2008) discuss about a child's first tactile experience). They discussed how interlinked touching and being touched are, and that this shapes our strong personal experiences linked to touching; if an object reacts to our touch, this gives us a stronger connection to it. But connected to this, is it important *how* a user touches an object? Currently, an object's form, what associations a user has to it, and how a user touches it seem to be disconnected.

2.4.2 Touch, objects and meaning

An area of therapy and education which sees everyday use of association through touch for useful actions, playful engagement, and communication is the use of 'objects of reference', often used with people with SEN (special educational needs) and VI children. As discussed by Park (2001), the term 'objects of reference' describes a way to communicate with deafblind people, often where the condition is congenital. The objects used in this approach are pre-made and are assigned a meaning by the facilitator in preparation for the user's interaction with it. For example, a spoon which can be given to someone who is deafblind and has learning disabilities, may help to communicate that it is time for lunch, or a ball can be used to communicate ‘it is time to put our coats on to play outside’.

Both active and passive touch play a part in the use of objects of reference, for example with carers presenting items to a user when it’s time to start a new activity, or when a user picks up an object to communicate that he or she wants something. The relationship between object and meaning, as well as object and use, is studied in semiotics (the study of signs and symbols, of meaning-making). Saussure defines two components of semiotics: the *“signifier”, or “signification”* - the physical manifestation of the sign, such as a sound, a symbol, or an object; and the *“signified*” or *“signal”* (Saussure, eds. Harris, 2019: 75-78) - the concept or mental image which is associated with the signifier. For example, if one reads the word ‘pillow’, one might think of sleep. Objects of reference are an example of how semiotics can be used deliberately in practice.

Objects of reference are used to bridge between a situation and the user’s understanding of it, often with people who are autistic, visually impaired, and/or have multiple and profound learning needs. Bloom (1990) described six categories of objects of reference:

- To represent an event;
- Linked to an associated object;
- Being a miniature version of a real object;
- Being ‘a partial object’;
- As an object with one shared feature;
- As an arbitrary object.

Taking this further, and expanding on what these objects might be used for, Ockelford (1992) described objects of reference as having three main uses:

- As an aid to memory;
- To help understanding of something;
- For communication.

Although in practice the use of objects of reference in schools is well established, Park (1995) identified a gap in the literature concerned with their use and evaluation. There are accounts of objects of reference used in practice, such as the work by Sigafoos et al. (1991) and van Dijk (1986), but not much evidence about their long-term effects with users. However, there are cases in which they have been found to be successful. For example, Sigafoos et al. (1991) found that, over time, one learner with profound and multiple learning needs was able to request a packet of crisps by just pointing to the logo from the packet. At first the learner only recognised the crisps when seeing the full packet, but as the object was cut down and re-used, the learner’s reference to it developed into something abstract. This showed that, through reinforcement and constant use, a user is able to make an association with a symbol which, although it is abstract, begins to represent something real for that person. van Dijk (1986) describes the use of a ‘memory box’ which contained objects that a deaf-blind child associated with situations on different days. These objects would be rotated depending on what day it was. For example, on Tuesdays, the box would become the ‘Tuesday box’ and contained swimming trunks, as swimming was the highlight activity to happen on that day. In this way using the objects built up a consistency with the user who then knew what to expect. A box with different objects was used to help this particular user overcome a separation anxiety linked to the user’s parents, where the objects were associated with the idea of going home and being reunited with the parents. Different objects mean different things and are associated with different memories and therefore different narratives for everyone, which is the next point of discussion.

2.4.3 Objects, associations and stories through textiles

In her book *Evocative Objects* (2007), Turkle observed:

> *“We find it familiar to consider objects as useful or aesthetic, as necessities or vain indulgences. We are on less familiar ground when we consider objects as companions to our emotional lives or as provocations to thought.” (2007:5)*

She discussed that objects are used not only for functionality, but also for reflection and creativity, inviting researchers, writers, and artists to discuss their relationships to these evocative objects. In Turkle’s book, Carol Strohecker discussed a project called *Knot Lab*, in which she taught children about knot tying. Not only did they learn about the hands-on process of tying knots and develop verbal and graphical representations of this, they also developed critical reflection and skills in collaborating with one another. One of the key observations from the project was how the space also acted as an environment for self-reflection, with the young people opening up with stories about personal experiences as they tied their knots. One particular child spoke about her parent’s divorce and seemed to use physical making as a way to ground herself, working through her personal problems as she created different knots.

Historically, spaces of making have often not only given people physical space in which to work but also space for thought and reflection; crafting circles have always been an important part of this. Price (2015: 84) discussed how knitting allows for *“thoughtful creativity”* as well as *“richer social relations”*. The group environment encourages reflection, not only on crafting but also on personal relationships. As discussed by Gauntlett (2011), there is much to be enjoyed about being an active participant in a community. How have researchers, artists, or designers attempted to capture stories, memories, self-reflection, and emotion, particularly through textiles?

Artist Sayraphin Lothian's project *A Moment in Yarn* (2012) captured people's happy memories by crocheting them into a granny square. She worked one-on-one with participants and translated their stories into physical objects that they could keep, with their memories being transformed into a soft, crocheted form. However, the artist made the object for, but not with the participant; does this object therefore really represent the memory, or does it represent someone else's interpretation of it?

Narrative through e-textiles or smart textiles has been linked in various ways, for example: a range of sustainable smart bed linen, which interfaces with an app to bring AR characters to life based on the textile patterns on the linen (Kuusk, 2016); interactive soft books for children, based on the researcher's own storytelling soft book she had as a child (Posch, 2019); and workshops to co-design and make tactile interactive books, designed for visually impaired children (Holloway et al., 2019). Posch's piece *The Book my Grandmother Might Have Made (*2019) explored how soft tactile storytelling books for children can be enhanced using electronics, with elements such as LEDs activating as users trigger switches embedded in the e-textile (see Figure 2.7). Holloway et al. (2019) worked with several participants - including those who had experience in working with children with a visual impairment - to create interactive e-textile books with an aim to encourage tactile engagement by people with a visual impairment. Whilst it is important to encourage potential facilitators to learn the skills to work with the VI community, one could argue that working with the end users so that they can make the books themselves is also important, putting them *in control* of the objects with which they are to engage. Alternatively, the researchers could have matched sighted and non-sighted participants to design the books *together*, building on approaches by researchers such as Buehler et al. (2015) that paired people with mixed abilities, an increasingly important approach in HCI to ensure that the user is involved.

Figure 2.7: A user triggering an LED in Irini Posch's The Book my Grandmother Might Have Made (2019). Image used with permission.

Kuusk (2016), in her PhD work called *Textales*, explored sustainability and smart textiles in the context of storytelling, creating woven bed linen which contains patterns that can be read by an augmented reality app on smartphones and tablet devices. Using an app to look at the textile through a smartphone or tablet, the user can see an illustrated computer image superimposed on the textile's surface. These images are characters from a narrative, for example those from *Little Red Riding Hood*. The idea is that parents and carers can use the application to tell stories to their children, with the textiles being treated in a more sustainable way, being reused by family members again and again, prompted by this digital engagement. It would be interesting for the participants to create their own woven objects which can trigger personal memories or stories on the application; however, this is not something that the research explored.

These examples demonstrate that e-textiles are being used increasingly to enhance and assist with creative expression of both published and personal narratives. They utilise tactility, as the objects are for handling; however, they are mainly for use by people for whom sight is a primary sense. The textural qualities of materials, and how these can relate to self-expression, stories, and memories, merits further investigation, as does the users' crafting of their *own* narratives. Kenning and Treadaway's (2018) research tackled the idea of personalisation, but this topic can be investigated even further.

2.4.4 Reflecting on the literature

This section has discussed literature on touch, including the importance of fabric and touch; how we use gestures to discover certain qualities of objects; active vs. passive touch; and how important it is for visually impaired users to have control over their touch experiences. Objects, association, and touch have also been explored, through users' preferences for certain objects; communicating through objects of reference; and how tangible objects have been used to convey narratives through textiles. This literature is vast and sits in different fields, but a common thread is the importance of the tactile and how people use it.

Gesture and touch are not something that is always considered within e-textiles, with designers and researchers assuming what gestures users will use. The potential of exploring objects and association - particularly for communication (as objects of reference are meant to do), or for narrative (such as the textile examples outlined) - is certainly another area to build on. The gap in the e-textile examples reviewed is a lack of participants creating their *own* narratives.

Another gap is researching what associations users make along with what gestures they use when touching an object. Davis (2015) and Petrelli et al. (2016) have both explored what associations people make with objects, including when they touch them, whilst Lederman and Klatzsky (1987) and Carbon and

Jakesch (2013) explored what specific gestures users choose when establishing tactile information from an object. Pulling these two areas together would address the gap.

2.5 Summary

The chapter has discussed literature spanning e-textiles, designing for and with people, and the sense of touch. It has explored how technology integrated with textiles is increasingly becoming associated with the body - in projects such as *Project Jacquard* (Poupyrev et al., 2016) - with tactility and gestures used for interaction with e-textiles.

Accessibility in design has traditionally been approached more commonly by designers making *for* people, rather than *with* them - but this is changing. This aligns with the argument by Mankoff et al. (2010) for users to be more involved in the process, taking input from disability studies for working on assistive technology.

Participatory design has been touched on, with the observation that moving toward using the term 'participatory making methods' (Twigger Holroyd and Shercliff, 2014) might be more appropriate for projects that involve the actual hands-on making process.

As STEM subjects move toward STEAM, with 'art' becoming increasingly important as a way to encourage participants to engage in science and technology fields, a more hands-on making approach with participants is gaining importance. However, participants who are considered more challenging are often excluded from activities, an exception being work by researchers such as Kuznetsov et al. (2011). This can be built on by a similar approach to working with people with disabilities and impairments becoming more common as well.

The importance of touch has been discussed, in how people handle objects, depending on what information they want about them (Lederman and Klatzky,1987), as well as what associations and emotions people make with objects (Davis, 2015 and Petrelli et al., 2016). How touch, association, and objects might be used with SEN users has been highlighted through objects of reference, along with how artists and researchers have used soft objects with storytelling.

Gaps have been identified in the literature that the research in this dissertation aims to address, including:

- A lack of literature addressing the use and evaluation of objects of reference;

- A lack of literature focusing on hands-on participatory making methods using e-textiles with people who have impairments or disabilities - more specifically with people who have visual impairment;
- The idea that a sense of touch can be linked to an object and used to engage with narratives or encourage interaction;
- An exploration into what gestures might be used when handling objects - as well as what associations might accompany them.

By addressing these gaps, this research contributes knowledge about *how* e-textiles can be used for interaction design by blind and visually impaired people – particularly in an environment which can be considered ‘participatory’. The research disseminates guidance about how participatory making workshops can be facilitated in order to give participants a platform for self-expression using e-textile technology linked with crafting. It demonstrates how e-textile sensors can be used as objects for storytelling, and how users associate gestures with such e-textile sensors.

3 Preliminary observations in schools

3.1 Introduction

As discussed in the literature review, tactility as a sense is often taken for granted. However, touch is particularly important for people with sensory needs, including those with complex needs, visual impairment, or neurodivergence. In order to prepare for the overall research, preliminary observations were conducted in specialised schools for young people with such sensory needs. This would be informative for the studies as well as providing a practical understanding of the role of objects of reference (OOR) within a real-life environment.

This chapter will outline how visually impaired people can use objects for sensory stimulation, relaxation, or exploration, and the role of objects of reference. The observations in the schools also helped to inform decisions about participant groups for the subsequent studies.

3.2 Aims

This preliminary research had the following aims:

- To establish why objects of reference are used;
- To observe how objects of reference are used.

As discussed, within the literature, there is a lack of evidence for the efficacy of objects of reference (Park, 1995). Jones et al. (2002) addressed this gap in their research with 13 adults with PMLD (profound and multiple learning disabilities), finding that the use of the OOR over a 20-week training period with the adults and their carers was successful. But it was important to observe *why* the objects are used in the settings in which this study takes place. It was also important to establish *how* they are used; are they used in a similar way to tactile signing (such as Lorm) or sign language (for example British Sign

Language), where an established non-verbal method of communication is understood by a range of people?

Three further aims were identified:

- To establish whether other objects are used and how, both inside and outside the school environment.

Apart from objects of reference, are other objects used with the young people, and for which purposes? Is it for communication, sensory stimulation or relaxation, or creativity? Does this occur both inside and outside the school environment?

- To find out what other sensory based stimulation plays a role in the young people's lives?

Are there key activities during the school day which are important? Are these open or more structured in how they are facilitated? Do the young people use senses apart from touch, such as listening or seeing? How do these play a role in the young people's lives?

- To reflect on how these objects or sensory experiences link to the proposed research with e-textiles.

Can e-textile technologies play a role in an environment where sensory objects and activities and objects of reference are relevant? What do the educators in these environments think about the potential of e-textile technologies?

3.3 Research questions

The research questions that these observations addressed were:

- What objects, materials, and techniques are practical for use by blind and visually impaired people making e-textiles?
- How do blind and visually impaired people interact with textiles (and e-textiles) using touch?

To fit the context of observing the young people in their daily lives in their school environment, the first question was adapted:

- What objects, materials, and techniques are practical for use by blind and visually impaired people when making?

It was important to observe what sort of objects the young people and children can use, want to use, or not want to use practically in their daily lives. Ultimately the purpose was to inform design decisions regarding the e-textile technology designed or imagined in this thesis. It was also important to establish what materials are possible to use by the visually impaired people - particularly in the context of a creative activity, for example making or storytelling. In the context of making, what techniques can participants use?

The second research question was also adapted:

- How do blind and visually impaired people interact with objects using touch?

Is there a specific way that the young people use their hands for interacting with objects? Not just objects which might be classed as 'interactive' but also objects which might have interesting tactile qualities, or have an interesting shape - this might be a favourite toy or just an everyday object of which they are fond.

3.4 Method

The two-part observational study discussed in this chapter investigates how sensory objects - particularly objects of reference - are used within two schools for young people with complex needs, autism, and visual impairment. The observations took place in the school building itself, in the playground, and in a local shopping centre as part of a field trip. The research was practice-based and open in its approach.

For the first part of the study, the observations were conducted in a school for children with profound and multiple learning difficulties. This took place over a 6.5 hour period on three consecutive Mondays - 19.5 hours in total. The second part of the study took place in a school which specialises in working with children who are autistic and/or have a visual impairment. This took place over two consecutive Mondays, with 6 hours for each session - 12 hours in total. Both took place in London.

The method of contextual inquiry was used, as this would allow unobtrusive observation of the young people in the context of their everyday lives. Further, it would also allow the observer to ask the participants about tasks which they were performing.

As part of this process, the lead researcher followed the lead of the educational staff - joining in with tasks when invited but primarily holding back and observing as the young people went about their school day. The researcher asked the young people about their activities and what they were doing if the opportunity arose, and went around the room during free play to gain an understanding of each child.

3.5 Data collection

To collect data, the observer used a simple notebook and pen to make notes when observing the children. As discussed by Druin, who also worked with young children, the use of video cameras can make young participants "freeze" (Druin 1999: 594) or "perform" (Druin 1999: 594, Druin et al. 1999: 3), and so note taking is preferred, particularly with this age group. The other approach to collecting data which is common within contextual inquiry is for the researchers to be 'in the moment', to immerse themselves in what is happening and then make notes at the end of the study. If the notes are written soon after, a lot can be remembered. This approach helps the researcher to observe and take a mental note of what is actually happening, as opposed to what they *think* is happening. If one is busy scribbling notes continuously, there is the danger of missing certain moments. In addition to this, specific objects that were believed to be of importance were photographed or sketched at the end of each session, in order to have a record of what had been used.

3.6 Participants

Six participants took part in the first part of the study (Group 1) and seven in the second (Group 2). They ranged in abilities, some having multiple learning needs, neurological disabilities, or autism. Some participants from Group 1 and all participants from Group 2 were visually impaired or blind. As part of their daily school activities they all interacted with sensory objects like soft toys or tactile books, took part in messy play, like playing with leaves, water or sand, and participated in art activities like painting or collage. Table 3.1 describes the participants.

Participant	Profile	Interests
Group 1 - aged between 15 and 16		
YP1	Wheelchair user; can crawl around but not straighten legs; has a learning disability.	Loves soft Teletubby Barney toys and wearing purple.
YP2	Has tunnel vision and learning disability.	Enjoys music - seems to find it calming.
YP3	Wheelchair user and has a learning disability.	Loves food/drink including bubble tea; watching sensory objects, such as a bubble tube, glitter in water; and tactile books. Enjoys messy play or tactility.

YP4	Has a learning disability and is epileptic. Needs support socks and splints for walking. Sometimes uses wheelchair. Can say occasional word and understands most things said.	Enjoys music, singing, and art activities such as collage. Likes animal puppets. Also enjoys watching naughty behaviour!
YP5	Understands simple sentences. Has learning disability and visual impairment.	Likes meeting new people and tactile books.
YP6	Wheelchair user, is epileptic, and has a learning disability.	Enjoys music - seems to find it calming.
Group 2 - aged between 3 and 5		
P1	Has visual impairment and is wheelchair user. Possibly has a learning disability as well.	Enjoys listening to sounds and feeling objects - enjoys soft ones like pom poms.
P2	Has a visual impairment.	Loves running around or zooming around in a toy car.
P3	Has a visual impairment.	Enjoys make-believe play.
P4	Visually impaired and learning disability.	Enjoys singing and throwing objects.
P5	Is autistic and visually impaired.	Enjoys dancing and engaging with friends.
P6	Has a visual impairment and possibly a learning disability.	Enjoys listening to songs.
P7	Is autistic and has a visual impairment.	Likes soft play and interacting with objects.

Table 3.1: Participants who took part in the observational study.

3.7 Analysis

As this study was intended as preliminary work, a light touch was given to the analysis, identifying themes across the two observations, and particularly focusing on what was observed regarding the use of objects of reference and the use of touch. As the method for recording data and reflections was restricted to handwritten notes and limited photographs or sketches, due to the sensitive environment, no video or audio data was available, as might normally be gathered in user studies. Although preliminary work, the observations helped to steer the direction of the subsequent research.

3.8 Findings

3.8.1 Observational study part one

The findings of the first observations span insights regarding the use of objects of reference, sensory objects for interaction within musical activities, and exploring sensory objects in the 'outside' world.

3.8.1.1 Examples of using objects of reference

Figure 3.1: Examples of objects of reference - physical objects and cards - that are used within the classroom.

It was observed how objects of reference were used with the young people to communicate that an event or activity was about to occur. Each physical object lived in a plastic folder, with an image of a similar item - or the place where an activity might occur - to accompany it on a card (see Figure 3.1). For example, before going on a shopping trip, a teaching assistant (TA) would show each person a photograph of a supermarket, and give each a toy shopping trolley and plastic bag to hold. The TA then said the word *"shopping"*. If the young person did not take the object, then the TA would press the young person's hand against it.

Objects of reference were also used to assist with communication. Every morning, the students all sit in a circle in the classroom. A big red button is carried around by one of the TAs each day for the young people to press, triggering the device to play a voice saying *"Good morning"*. For the first two weeks of observations, the TAs waited for the young people to press it using their hands (active touch) - something that the lead researcher was told is a sign of them engaging with the greeting. However, in the third week, a different TA instead took the young people's hands and pressed the button with them (passive touch), not waiting for the young people to execute the action themselves. The group was due to go out that day, and so perhaps time was short, but there appeared to be some inconsistency in how different members of staff were using the objects.

Bodily needs or functions were also managed through objects of reference, in particular using a nappy to tell students when it was time to be changed. The nappy was shown to them, after which they were offered it to hold, and then they would be led to the changing room. Another object which has an important purpose is a tactile fabric patch. These are placed on walls around the classroom to help the students find their way around. YP5 in particular used them, notably the one that was outside the toilet on the wall so she could easily locate it. The lunchtime object of reference – a plastic spoon and accompanying card - was also used on a daily basis. Along with showing the card to the young people, the teacher would play a CD of the song *Food Glorious Food*, and all staff would sing along to it as it played. This created an atmosphere of anticipation for lunch.

In a discussion with the teacher, she explained that staff are aware of how to use the objects of reference and that there are a set procedures for using them. For example, there is a progression from physical objects, to photographs (the cards), and then to symbols (the young people in this class would always be reliant on the physical objects). The students would start working with objects of reference from nursery age. Young people whose disabilities are less severe would begin to rely on the objects less. The teacher explained that, by age 16, if the students have not gone beyond using the physical objects it is assumed that they will not.

According to the teacher, objects of reference within this group are used particularly to support speech. Therefore, when showing the object or photograph to the young people, the staff also say out loud what it is represented. The teacher described this as a trial-and-error process in which staff had developed a way of assessing how a young person might engage with an object. Initially they look to see if there is eye movement toward an object, and if there is none then there is no understanding of it. They then check whether the young person goes on to touch the object. Lastly, they try to assess whether the person is making a choice out of two objects. If they reliably go to the same object two out of three times, then they are deemed to be making a choice. The young people will go from needing a physical prompt, to a verbal one, to being independent. The young people observed in the study will always need some kind of visual prompt. The teacher admitted that sometimes they use slightly different objects to their colleagues in other classes. They also use different images for the cards that go with the objects, and for sensory engagement such as ‘smell of the day’, e.g., coffee, herbs - these vary as well. To manage this better, the school does buy in bulk and tries to get objects as near as possible to ones used in the past.

3.8.1.2 Objects for interaction within musical activities

Figure 3.2: Objects used in the Tac Pac activity and puppets and book from The Animal Boogie.

From the observations it was clear that music is an important part of the young people's lives. Every day, songs were played to give sensory relaxation time. Disney songs were played the most. P4 in particular would get very excited when the music began, clapping his hands and shaking his head.

Another activity involving music was something called *Tac Pac* (see Figure 3.2). This is a specialised activity designed for sensory stimulation and relaxation which involves music, instructions for a facilitator to follow, and different objects - some for stimulation and some for relaxation. For example, there is a fan in the activity bag, and when the female voice on the audio says *"fan"*, the facilitator has to fan the young person with whom the facilitator is paired. Facilitators can also bring their own objects into this activity. In the observed example, the staff used hand cream to give the young people a hand massage upon hearing the instruction *"relax"*. The researcher was paired with YP4 for the activity, and during the relaxation section observed very affectionate behaviour from the young person. At one point YP4 took the researcher's hands and clapped them together gently, soon after taking her hand to his cheek and kissing it. This was apparently something YP4 always did with his friend, who wasn't there that day. Other young people also appeared to enjoy the activity, with P3 smiling to herself whilst her hands were being massaged.

Following *Tac Pac*, the group moved onto listening to an audio story called *The Animal Boogie*, sung to music by a man's voice on a CD. One TA sang along to it, whilst another was in charge of puppets (see Figure 3.2). The young person with whom the researcher had been paired previously (YP4) particularly loved a bear-like puppet, as well as one of a leopard, grabbing a puppet and shaking his head. Given that YP4 was non-verbal most of the time, it was a pleasant surprise to hear him say the lyric *"Sway"* from the song after he had heard it a number of times. YP3 continued to smile through this activity, seeming to be enjoying it, whereas YP1 found it very stimulating and exciting, grabbing at the puppets multiple times.

3.8.1.3 Exploring sensory objects in the 'outside' world

Figure 3.3: Different activities and objects which the young people engaged with on their day out: playing with glittery soapy water in LUSH, a rubber spikey ball from Hawkins bazaar and bubble tea from Bubbleology.

The last session with the young people was spent visiting a shopping centre in East London (see Figure 3.3). The purpose was to give the students a day out in the wider world and experience different sensory objects not found in the classroom.

It was observed that various items within the shops were of interest to the young people. When visiting LUSH, the handmade cosmetics shop, the staff demonstrated how different coloured, glittery bath bubbles could be mixed together, creating different coloured soapy water. The young people were fascinated by this, particularly YP3, who has a love for the bubble tube in the school classroom. The young people also smelled the soapy water

In Hawkin's Bazaar, a novelty gift and toy shop, the teacher bought a squishy-rubber, spikey ball, covered in a net, for the young people to play with. She thought that it would be good as a sensory object due to its texture and tactility. In fact, YP1 held it in his hands for 30 minutes, something quite rare for him to do.

The visit ended with a trip to Bubbleology - a bubble tea shop - to buy the young people a drink to try. YP4 was not so keen on it, but YP1, YP2, and YP3 enjoyed it - especially YP3, who twitched and shook her hands when drinking it, a sign that she is enjoying something.

3.8.1.4 Interaction with others and themselves

Along with the observations discussed above regarding objects of reference, objects for interaction within musical activities, and sensory objects in the 'real world', some other observations emerged based on the young peoples' interaction with other people or themselves.

The first observation was that human contact is clearly important for the young people, whether it is holding hands or getting a person's attention. There were multiple instances in which the importance for the young people of physical contact or human interaction was apparent. As described above, YP4 appeared to enjoy the song-based activities, and the physical contact which accompanied them. YP1 displayed a number of gestures and actions to try to get people's attention over the days observed. On the first day, he had one of his favourite toys present - a purple 'Barney' dinosaur. Soon after arriving into the classroom, he began to throw it in front of him, and continued to do so after the researcher brought it back to him. A TA told me that he does this on purpose, so that it gets brought back to him.

Another action that was observed from YP1 was grabbing. When out and about on a trip to a local supermarket and coffee shop, he began grabbing at the TAs as well as YP5 - this was a sign of him becoming impatient and bored. He also displayed both the throwing of his toy and the grabbing gesture whilst taking part in an art activity - working on a collage with the assistance of the researcher. This resulted in the imposition of some 'time out', after which he repeated the behaviour, resulting in the researcher finishing the collage for him. On the second day of observations, the grabbing continued, but he also reached out repeatedly for people as well, including the researcher.

YP5 appeared to have a desire for more intimate contact: wanting to hold hands or hug people. She reached out to hold the researcher's hand on the trip to the supermarket on day one of observations, and on day two she hugged one of the TAs who was helping with lunch - which created a reaction of pleasant surprise in the other TAs, as this was something new for her.

Another observation was that the young people often engage in self-monitoring and stimulation, biting their hands when frustrated. YP2 and YP4 both displayed evidence of biting their hands, something also seen in young toddlers when they are frustrated. YP2 did this often during the first observation session; the teacher explained this as being linked to proprioception, the student self-monitoring.

3.8.2 Observational study part two

The findings of the second observation sessions span insights regarding the children's use of textures, the use of their hands, and learning to communicate through touching objects; they also include the role of sound and their social interaction. Sound, social interaction, and play are important elements of the day-to-day learning environment; however, the main focus with the visually impaired children was touch and its exploration as a sense.

3.8.2.1 No objects of reference

On the first day of observation, the teacher was asked about objects of reference and their use in the classroom with her students. She said that, at this stage, the children come in not needing them - objects of reference are more for children or young people at an earlier level of development. For the children in her class, objects were used more to aid vocabulary. Mostly this was facilitated through activities and songs, such as picking a toy star from a box and singing *Twinkle Twinkle Little Star*, or a toy banana from a box and singing *Bananas in Pajamas*.

3.8.2.2 Learning to recognise textures

Figure 3.4: Tactile matching activities that the visually impaired young people do to learn about texture.

The classroom has objects to teach the children about recognising textures, and to assist them with learning to choose things based on their sense of touch (see Figure 3.4). One of the objects consisted of seven small cylinder shapes with a textured top, that match seven textured circles on a rectangular wooden base; another was a set of six hand shapes, each with a different texture, relating to a textured hand shape at the bottom of a wooden box; the third object was a series of nine textures on wooden shapes that have matching ones to accompany them. With all the objects, the challenge was for the user to match textures by feeling them with their fingers.

P3 worked with a TA with the cylinder and the hand shapes. The method the TA used to help P3 get an idea of textures was to take her hand, and touch her fingers on each surface one by one. She would then touch two different textures with her fingers and ask her to compare, deciding if they matched. If P3 answered incorrectly, the TA asked her to feel them again one by one.

3.8.2.3 Preparing to learn Braille

Figure 3.5: Tactile activities that the visually impaired young people do for learning to read Braille.

Some activities which aid the preparation of learning Braille were observed, all of which revolve around learning to harness a sense of touch. These activities are part of the 'pre-Braille checklist' and included activities such as counting or threading (see bobbins in Figure 3.5) as well as learning to 'feel' things.

One of the TAs worked with P3 to use a shape-sorting cube with 3D shapes such as triangles, squares, and stars (see sketch in Figure 3.5). When attempting to push a shape into an incorrect hole, P3 was visibly frustrated, trying to push it in harder instead of turning it around. The TA told her to try to turn it or insert it more slowly. However, as P3 became more impatient, she would exclaim the TA's name - who patiently again told her to slow down. When trying to decide which shape to fit in the hole, the TA also encouraged P3 to count the sides in order to establish which one it would fit. When P3 got it right, the TA clapped, leading the participant to do so as well. It seemed quite apparent that it was a challenge for P3 to sort the shapes, something that sighted children can do from a young age.

On each day, the teacher or TAs read out the day of the week to the children, and following this took the index finger of each visually impaired child to run over a day of the week card from left to right. The card also had Braille on it (see Figure 3.5), which, although the children were unable to read it just yet, familiarised them with it and so supported them in learning *how* to do so once they learned the system.

3.8.2.4 Encouraging touch and exploration

Figure 3.6: Objects placed around the classroom for the children to explore.

For visually impaired children, there is more likelihood of being *tactile defensive* toward objects, that is, to have a dislike of touching certain objects or textures. *Tactile defensiveness* is defined by Royeen and Lane (1991:112) as:

> *"Observable aversive or negative behavioral responses to certain types of tactile stimuli that most people would find to be non-noxious (nonpainful). Simply stated, tactile defensiveness is the inability to interpret appropriately the affective (rather than perceptual) meaning of touch or touch experiences within the context of the situation and in a way meaningful for use by the organism."*

In order to help a child address this, and perhaps move on from the aversion, activities such as messy play (such as painting, using bubbles, playing with cereal, etc.) take place in the classroom, to encourage tactile interaction and the exploration of different textures and sensations. Along with this, objects made from a host of different materials and of different shapes are placed in different areas of the classroom. For example, in a circle of three buckets were fluffy toys, pine cones, and leaves; on another table were differently-shaped plastic toys (see Figure 3.6). One challenge for the teacher is making the space interesting enough to encourage the VI children to explore and find things to touch, whilst also not having too many things out and about to distract the children with autism. With two very different sensory needs, the facilitation of such a space can be difficult.

3.8.2.5 The importance of learning to sit and listen

The teacher praised the children for listening well during activities; the lead researcher was told that this is an important part of their development. The teacher took the two children with autism (P5 and P7) into a separate room for an activity which encourages focus, something which can be challenging for them. The model used is called Attention Autism (*The Attention Autism Programme*, 2013 - 2020) and was developed by Gina Davis, a speech and language therapist. This helps to engage attention, increases verbal and non-verbal communication, and builds vocabulary.

For the activity observed, the teacher used an opaque bucket, in which she had placed some objects. She began by drawing a simple illustration of a bucket, and, when asked what it was, P7 answered with *"Bucket!"*. She used the words *"There's something in my bucket, in my bucket, in my bucket, there's something in my bucket…"* to introduce each object, saying what it was after she pulled it out. Upon revealing it, she would say the name of the object as well as making a sound effect for it, moving it around at the same time. An example of this was a Slinky. For this, the teacher said: *"Boing, boing and stop...and go! It's jumping, isn't it?!"* The teacher carried this on for another two times, during which P5 reached for it. She finished the activity each time by stating what the object was and the word *"finished"*, for example *"And* *slinky has finished"*, upon which the object would go back into the bucket. After doing this, the teacher drew a cross through the illustration of the bucket.

During this activity, the two students participating showed focus and interest in the activity. P5 reached out for the objects but was not given them; this did not seem to affect his enjoyment of the activity. The teacher praised them after finishing, saying their names along with *"Good sitting, good listening"*.

3.8.2.6 Introducing activities through song

Throughout the two days observing the children, many activities involved music and singing as a key part of their facilitation. An activity where the children would take it in turn to take objects out of a box was carried out alongside the teacher singing the song *'Zoodio'*, an African-American street song and game. Traditionally, the participants stand in two lines facing each other, and take it in turn to dance or walk down between their peers. However, in the version used in the observed school, the teacher used this song as a way to facilitate each student taking a turn to take an object from the box. Later in the morning, another song was played to the children as they took it in turns to choose items from a box, this time with the teacher playing a guitar and singing the lyrics *"What's in the box?"*. Depending on the object chosen, another song would be played afterward. For example, P6 chose a star from the box, and so *Twinkle Twinkle Little Star* was then played on the guitar, sung along to by the teacher. The following week, this activity was run again. Before even choosing a toy of 'Humpty Dumpty', P4 began to sing the song; he then picked up the toy as he did this. P3 also showed signs of anticipating a specific toy by starting to sing a song before choosing it. She had been playing on a toy rocking boat during both mornings of the observations (see Figure 3.6), and when it was her turn to pick an object out of the box she began to sing *"Row, row, row your boat…"*. She followed this by picking a bottle out of the box containing a small boat. The teacher then sang *Row, Row, Row Your Boat* and played it on the guitar.

Singing is also used to welcome everyone at the beginning of the day. The teacher asked the children *"What shall we sing?",* upon which P2 and P7 said *"Hello!"*. The teacher then began a 'Hello Song', everyone's name being said along with a 'hello' greeting to them. P4 smiled upon hearing his name, whilst P7 anticipated P3's name being sung, shouting it out beforehand. P3 responded by saying hello to him. Upon his own name being sung, P7 began singing it to himself. P4 acknowledged his name with a little glance toward the teacher, and P3 very quietly said a little *"Hello"*.

Before starting a food-based activity, singing was also used: "We're waking up our hands, we're waking up our hands. Give it a rub, give it a squeeze, we're waking up our hands". The song moved on to "We're waking up our jaws…". Last year they focused on dry food groups in the classroom. This year the focus was on both wet and dry combined, in this case, jelly, custard, Weetabix, and sponge fingers, all placed on trays in front of the children. Upon being told what the food was, P2 asked "Not biscuit and custard?!", followed by "I like custard".

The activity began with the children stomping toy animals on the food, before exploring it with spoons and their hands. The children also used the sponge fingers for dipping into the custard. The teacher mentioned that the sponge fingers were provided in case the children did not want to dip their fingers in the custard. Visually impaired children can find self-feeding challenging, and so using spoons for this activity provided good practice. Apparently this activity should always be child initiated; as a facilitator, it is important never to put food in the children's mouths. Enthusiasm can be shown, with an *"Ooooh!"* sound as food is poured onto the tray, but whether they want to touch it must be on the children's own terms. The activity ended by the teacher saying *"Finished, all finished"*.

3.8.2.7 Make-believe play and child development

During the second day of observations, the class moved from the classroom to the school hall for a more active play session. Soft play shapes were taken out from a cupboard for them to climb on, as well as balls and some toy vehicles. P2 immediately took one of the toy vehicles and proceeded to zoom around on it. The teacher said that, despite being a visually impaired child, P2 is fearless and has been known to hurt herself in the past by running around and falling.

There was a moment when P3 was sitting on a piece of the soft play by herself, and the TA who had been helping her with the tactile activity earlier asked her *"What are you up to?"*, to which P3 replied *"I'm in the car"*. The TA asked, *"Shall we go shopping or to the seaside?"* - P3 replied *"seaside"*. The TA then asked if they should pack a picnic, which P3 agreed to, and the TA asked her to choose two things. After this exchange was finished, the TA advised that it is very encouraging for a child who has a visual impairment to be engaging in make-believe play, as it is something that they find challenging. It is something that they are looking out for the child to do as a sign of development.

3.9 Discussion

Whilst the groups of children observed in both schools had different sensory needs and learning abilities within each class, it was informative to observe how objects and sensory activities are used for communication, enrichment, and play.

3.9.1 Objects of reference

One of the main aims of this study was to establish how and why objects of reference are used by and for children and young people with profound and multiple learning needs, or by those who have a visual impairment.

The second part of the study found that they are not really used at all with children who are older and at a higher learning ability. In the first part of the study, objects of reference were used, but there appeared to be some inconsistency in how these objects were actually used in practice with the young people (active touch vs. passive touch). They were also used to represent different objects in each classroom. Regarding active and passive touch, the lead researcher was told that it is important that the young people touch the button themselves related to the 'good morning' greeting - however this was compromised by a TA touching the young people's hands on it (passive touch). There was also inconsistency in the images that accompanied the objects.

One motivation for the observations was to better understand whether these objects act in a similar way to tactile or sign languages, wherein a consistent meaning is shared by individuals for an assigned gesture; this does not seem to be the case with objects of reference. As discussed by Park (1995), there is a lack of literature which discusses the success of the use of objects of reference; does this impact on practical guidance about the use of objects, leading to the inconsistency? Within the literature there is some discussion about whether to personalise objects of reference for the user or not, due to challenges with time and resources; however, if users were able to make these objects themselves could this be more achievable?

3.9.2 The importance of sound and music

Across both observations, sound and music appeared to be important - within part one of the study, in sensory activities involving stimulation and relaxation - and within part two of the study, in activities encouraging the handling of objects. Could sound play a role within tactile objects made by visually impaired people? Both groups also appeared to benefit from social interaction and enjoyed being around other people. This was observed through a hug or a light touch, play, and positive visible emotions. For the visually impaired children, the act of interacting socially with other people (as well as their environment) seemed to be something which requires much patience and gradual coaxing; tactile defensiveness also played a role, as did a difficulty in understanding abstract concepts (e.g., a toy elephant vs. a real one) due to the visual impairment. Could a tactile object, which is personalised to their sensory preferences, and which invites interaction - through touch but also through sparking conversation - assist with this? It appeared that the children enjoyed partaking in activities which required multiple people to engage in them at one time (such as playing on a rocking boat together), but perhaps this sense of cooperative engagement could be used alongside tactile objects as well, in an activity.

3.9.3 Focusing the studies

Another purpose of these observations was to establish whether these children and young people could be potential participants in further studies, involving making with e-textiles and using e-textiles as sensory objects to enhance storytelling. This was inspired by the literature around objects of reference as well as from discussions with various practitioners and educational facilitators, who were keen on the idea of e-textiles being used by the children and young people. In addition, there was also a personal motivation to gauge whether they could potentially become participants within later studies, one aim being to make hands-on making more accessible for hard-to-reach groups who often don't receive the opportunity to do such activities. However, the observations demonstrated that these school groups may be challenging to include in future studies for a number of reasons:

- All of the students are still in the stage of learning about tactility - ideally participants are needed who can make design decisions around touch in order to create an interactive object or story - so that we are making objects *with* them not *for* them.
- Many of the young people observed in the study are non-verbal. Without the ability to speak with participants, it would be difficult to explore the tools and materials fully or to gain insight into how visually impaired people can work with e-textiles.
- It is very challenging to gain access to a school group, even for two or three days as in our case. Hands-on making workshops especially require participants who can commit to ongoing sessions for a certain number of hours in order to fully explore the materials and create an interactive object.
- There are ethical implications. Although the young people seemed comfortable in the researcher’s presence, the project is highly experimental, requiring much time and personal input, and they could not give the consent themselves, instead it would have to be offered on their behalf. It would be preferable to find users who can give informed consent.

Having discussed all of these considerations, it seemed that there were some clear needs when looking for participants for future studies:

- To find people who are already familiar with using their sense of touch;

- To work with participants who can discuss vocally their experiences as they work with e-textile materials and tools;
- To collaborate with participants who can commit to a number of sessions;
- To include people who can fully consent to participating.

The children and young people discussed within this chapter were wonderful participants with whom to work and have helped to inform further decisions about the direction of this research. However, they were not the correct fit for the overall aims of the work outlined for this thesis, and working with them to answer the research questions would have gone beyond the scope of this project. Therefore, it was decided to work with adults with a visual impairment, as discussed in Chapter 4.

3.10 Summary

A two-part observational study has been discussed, with an aim to learn more about the use of objects within the lives of young people with visual impairment and other sensory needs. Objects of reference were an important element of investigation, to establish what their use might be in the field (school environments, in this case) and to begin to see if they could contribute to a tactile language. Other sensory forms of engagement were observed as well - such as the use of sound and textures. The other purpose of the observations was to establish whether these young people could be potential participants in user studies in the form of e-textile hands-on making workshops.

Whilst use of objects of reference has been observed, there is a lack of evidence (and indeed some counter-evidence) regarding the consistency of their use, and thus it can be concluded that they do not represent a solid tactile language on which to draw. However, the observations have shown the importance of the general use of objects with the young people and the importance of sound - something from which both groups appeared to derive considerable enjoyment.

The observations have helped to focus future studies discussed in subsequent chapters, and clarified the characteristics needed from participants, regarding their use of touch, the ability to articulate ideas, the ability to commit to a number of workshop sessions, and the ability to give informed consent.

4 E-TEXTILE MAKING WORKSHOPS WITH VI PARTICIPANTS

4.1 Introduction

This chapter introduces a longitudinal study design to explore the overall research question:

- How can blind and visually impaired people design and make with e-textiles for tactile interaction, to both foster and evoke self-expression?

This question includes four key elements which need to be addressed empirically:

- The use of e-textiles (materials and techniques);
- Tactile interaction (perception and use of touch);
- Use by visually impaired users: empowerment, engagement, agency;
- Effectiveness in enabling a participant's self-expression (storytelling and creativity).

Chapter 3 focussed on: (a) the use of objects of reference within learning environments for children with significant learning needs and/or visual impairment, and (b) how they learn to use touch. In considering the relationship between the use of tactile objects and a participant's association with them, some inconsistency was observed:

- There was no clear evidence of a 'tactile language' through objects of reference;
- The objects and their meaning were chosen by the facilitators, rather than by the participants themselves.

The study in this chapter takes lessons and questions from the use of objects of reference for concrete communication, but shifts the context to objects designed by visually impaired people to communicate their own stories or messages. It carries some of the questions into this new context, such as whether there is a common 'tactile language' and how people associate meanings with objects. However, it shifts attention (as discussed in Chapter 2) from ‘designing/making for’ to ‘designing/making with’ the visually impaired users, and it shifts from the sort of practical communication associated with objects of reference to self-expression and communication of personal stories.

The idea of objects with personal associations relates to the research by Kenning and Treadaway with late stage dementia patients (some of whom had a visual impairment) in which they co-designed tactile and interactive blankets with family members for their loved ones (2018). These pieces held personal reference meanings to the dementia patient in order to trigger an emotional response from them and to create an object for co-engagement with their family member. That research demonstrated one way an object of reference could be personally designed and made for a user. The study reported in this chapter explores how to enable visually impaired people to design and make their own objects with personal associations and hence to express their own stories.

The study outlined engaged with blind and visually impaired people. It was important to establish what would work *for them* in terms of their individual preferences (as opposed to having something imposed on them), in order to engage them in the making process, and hence to study the association between touch and meaning.

The sub-questions for this next stage were:

- What emotional associations do users have with the textures and appearance of materials which can be used in e-textile interaction?

What would the participants' initial reactions to fabrics be? Would there be any common associations with textures and textiles for individual participants but also across the groups? How would the participants tell stories with the fabric? How would participants use specific fabrics for interaction design?

Participants would need some time to familiarise themselves with different materials - yarns, fabrics, decorative elements and the electronics - and to reflect on what could be used for their designs, and how. The activities should encourage them to discuss the materials and what sort of associations they have with them.

- What objects, materials and techniques are practical for use by blind and visually impaired people making e-textiles?

What are the practicalities of rendering e-textiles accessible? This question concerns the soft materials (yarns and fabrics), the electronics (the boards themselves, the techniques and materials for circuit making), and the construction methods for the piece (attaching e-textile buttons together, constructing the circuits and adding decorative elements to the work).

For example, are there specific materials (fabric, yarn, etc.) which are more practical to work with? What crafting techniques and tools do the participants find accessible - and creatively engaging - to use? How important is prior experience of arts and crafts? Can the construction of soft circuits be simplified? What are the challenges and opportunities of e-textile making? Would the participants understand soft circuits?

- Can visually impaired makers express themselves through e-textiles?

How would the participants execute their design decisions? What evidence would there be of creative thinking throughout a making process? How would the pieces ‘come alive’ with the use of e-textiles and interactivity? Would the ability to express themselves and their stories create a sense of ownership over the work for the participants?

Learning the crafting and technical skills would provide a challenge *but also* an opportunity for everyone to potentially gain confidence in their own abilities and utilise new-found techniques within their work, but also on future making projects.

- What are the challenges and opportunities for blind and visually impaired people in an e-textile participatory making environment?

One of the biggest elements to perhaps answering this question would be the workshop setting itself, and how the participants would respond to working in it with other participants around them, and how the social side of the sessions would impact on their execution. How can the making environment be structured to support participatory making - especially for these visually impaired participants? Would the participants engage with and help each other, or just focus on their own work? And would they want to discuss their work with one another and collaborate on the making and thinking? How should facilitators behave, in order to support/assist participants, without taking over? What are VI participants able or not able to do? Are there typical challenges that can be eased?

- How do blind and visually impaired people interact with textiles (and e-textiles) using touch?

How would the participants handle fabric? How would they interact with e-textile sensors? Would the participants show a sense of identity through fabrics and touch? More broadly, is a gestural language shared among the participants? How might participants handle their own or others’ interactive e-textile pieces once completed?

In order to gather rich evidence which would address the questions, the study was conducted *“in the wild”* (Rogers et al., 2011: 440) in a hands-on-making workshop over a number of weeks, in which participants were invited to create their own, personalised, e-textile object. This context addressed key considerations: participatory making in a supportive social environment, time and support to gain confidence in using e-textile materials and tools, time to reflect on ideas and progress, and opportunities for the researchers to observe unobtrusively.

Based on my own experience of running creative technology workshops over the years, I knew that this type of environment can be more supportive and stimulating for participants than working individually. The workshop environment can provide an opportunity for participants to share and discuss ideas and learn from each other, consistent with Bratteteig's concept of *"Mutual Learning"* (1997:1). Similarly, participants can share reflections and stories, similar to a craft circle - which as discussed by Price can lead to "*richer social relations"* (2015: 84). The workshops were organised in a community space, so that they would feel genuine to the participants. Although it was framed to provide evidence relevant to the research questions, the study was expected to be exploratory, and the design acknowledged the likely need to improvise slightly. The intention was to collect rich data for qualitative analysis, including thematic analysis targeted at the research questions.

The chapter is organised in two main sections: one that provides a detailed account of the study design process and rationale (4.2 Preparation steps), and one that describes the resultant study design (4.3). The preparation was iterative, involving:

1) Engaging with communities (in order to recruit participants - 4.2.1);
2) Researching and prototyping with materials (4.2.2);
3) Prototyping conclusions leading to the project brief (4.2.3); and
4) Piloting the project (4.2.4).

The study design is reported in terms of:

1) Workshop series structure (4.3.1);
2) Project brief (4.3.2);
3) Volunteers and their role (4.3.3);
4) Skills/making elements (4.3.4);
5) Data collection (4.3.5);
6) Execution (4.3.6); and
7) Data analysis (4.3.8);
8) Summary (4.4).

The results of the study are reported in Chapter 5.

4.2 Preparation steps

4.2.1 Preparation step 1: engaging with communities

Finding blind and visually participants who would like to take part in the study was not just a matter of ‘finding participants’, but also building a relationship with appropriate community groups, establishing trust, understanding people’s needs and wishes, and making sure they would get something out of the collaboration. It took approximately 12 months to find appropriate groups who were willing to take part.

Various national charities that work with blind, visually impaired and deafblind people were approached, including Sense, The Royal National Institute of Blind People (RNIB) and the Royal London Society for Blind People (RLSB), as well as more locally-based charities such as Bucks Vision and Eye for Art, both based in and around Milton Keynes. Although none of the national charities were able to join in with the work, the two local charities were excited to participate.

4.2.1.1 Community group 1 - Bucks Vision

Bucks Vision has offices and a community space in Aylesbury. A volunteer coordinator, who is visually impaired herself, runs arts sessions once a week, for example making Christmas cards, or working with clay to make pots. Occasionally art facilitators had run workshops, but not always successfully, as they found it challenging to work with the participants. The volunteer coordinator was very keen to introduce members of the group to e-textiles, but was also cautious. She indicated that any activity that took place would have to be extremely tactile, as the participants’ sight could not be relied on at all, and anything like cutting with scissors or sewing with a needle would not be possible; in contrast, an activity such as gluing pre-cut elements might be more successful.

To help prepare for the workshops, and become more familiar with this user group, several meetings were organised with the group. The first was a coffee afternoon, bringing along some e-textile objects and materials for everyone to handle. A variety of e-textile objects were passed around, including a piece with light-up eyes using LEDs, and an interactive vibrating glove. Participants were generally very excited by the prospect that they would be making such interactive objects. In particular, they hoped that with this collaboration they could enter into the local arts competition for visually impaired artists and stand a good chance of winning. A second session introduced them to sound (rather than light or vibration) based interactive objects, including an interactive pompom connected to SuperCollider (SuperCollider, 2008), which made a variety of sounds when handled. It also included hands-on e-textile weaving, again producing sounds, in order to give people a taste of the type of practical activity they might be doing as part of the e-textile research workshops (see Figure 4.1).

Figure 4.1: From left to right: A participant weaving their piece, woven sensor, and interacting to make sound.

Meeting the participants, introducing them to e-textiles and running an e-textile weaving workshop gave the research team a good insight into the participants' approach to handling materials and what their crafting skills were. It also created an opportunity for introducing them to the project, with conversations over the multiple visits. From these meetings and from speaking to the coordinator for Bucks Vision, the research team reflected on some considerations for the workshops:

- The participants' sight could not be relied on at all. In order to be as accessible as possible for all, the making process had to be touch- based, rather than relying on vision;
- Sound was suggested as an appropriate and engaging output medium, so that the technology was accessible and could be experienced regardless of the level of vision;
- The participants should focus on the creative making of the object, its interaction design and circuit making. Programming on top of this would be too much for a short project and would give a different focus;
- Ideally, participants would feel ownership of the making process, and be involved in it as much as possible, with support where needed but feeling in control. Linked to this sense of ownership, they should also be able to take the object home afterward. This meant that the object had to be relatively low-cost and usable without the researchers present;
- There had to be explicit support for the participants to come to terms with the technology, and to create something within a safe structure;
- No knowledge of computing or electronics should be assumed. Therefore, the technology should not be complicated;
- Many VI people struggle with fine stitching or using scissors. Therefore, construction should involve materials such as fabric glue and pre-cut parts, or, participants could cut with some assistance;

Many e-textiles projects do not work because the conductive threads short circuit. Therefore, constructing methods that would prevent short circuits would be required.

4.2.1.2 Community group 2 - Eye for Art

The second community group was Eye for Art, which runs monthly arts and crafts activities for its members. In this group, members contribute financially to the sessions for materials and occasionally for an artist fee. Again, the research team visited and attended some of their sessions, observing how they organise their activities, and watching them make intricate textile objects involving sticks and colourful yarn weaving (see Figure 4.2). The topic of e-textiles was again introduced, and members were offered the possibility of handling a variety of e-textile objects and experiencing their interactivity. Overall, the idea of working with such materials was met with great enthusiasm.

Figure 4.2: Stick weavings created by visually impaired participants at Eye for Art.

Several more sessions were attended in order to keep in touch with the group, to gauge interest in the activity, and to discuss the topic of e-textiles more extensively. From observing what sort of crafts the group were doing, and from finding out their abilities - both vision and making - the following additional considerations were identified:

- Participants found the concept of e-textiles very abstract until they could get their hands on the materials - therefore, keeping explanations as tangible as possible, and having physical examples present seemed essential;
- The idea that circuitry could be incorporated into crafting created surprise amongst the participants when the e-textiles were demonstrated to them, but also made the thought of participating in the workshops more approachable;
- The participants in the second group seemed open to experimentation and 'to enjoy a challenge'. Therefore, they wanted to have input into the design brief, and they wanted a relatively open task, albeit with enough structure to help them learn and engage with the unfamiliar technology.

In addition, contact was made with a local art gallery, MK Gallery. The art gallery was interested in expanding their accessible arts offering and to collaborate by offering their project space. The gallery proposed to host a small exhibition at the end of the project of whatever objects had been created in the workshops.

There were a number of benefits to holding the workshops at MK gallery:

- The gallery was happy to give the use of its project space;
- The members of the Eye for Art group were excited by the prospect of making their work in an arts environment, including having the opportunity to exhibit there afterwards;
- Practically, the space was perfect, with a kitchen area and a large, well-lit room for people to work in.

4.2.1.3 Reflections - informing the design task

Different group profiles

Members of the two groups varied in their abilities and confidence, in terms of both sight and crafting skills. With the first group, the emphasis was on making the workshops a non-threatening activity - while still giving people agency and input - whereas the second group appeared to be more advanced in their making abilities, and portrayed themselves more as a group of artists. The participants' profiles needed to inform the design of the task. The task also needed to be grounded in the reality of working with the organisations involved - Bucks Vision, Eye for Art and MK Gallery - in order to adapt to their needs and collaborate.

Creating something to share

One common thread was the desire to create something which the participants would be proud of and could share with friends and family. The idea of an exhibition at the end of the project appealed to both groups. Therefore, framing the project as making an 'interactive textile art object' would give a focus for something which could be exhibited. The first group was particularly excited about the possibility of entering their work into an annual exhibition and competition organised by Bucks Vision. This framing also fit the context for the second group, for whom both the workshops and the exhibition would be held in a contemporary art gallery space. For an exhibition, the work would need to be able to be displayed in a clear way - either hung up, or placed on a table/plinth.

Scaffolding the activity - providing an accessible core

As the participants varied in their abilities, the workshops should teach basic skills and techniques for both crafting and e-textile circuit making, ensuring that the sessions were accessible for all. A certain amount of structure to the workshop sessions would be useful, but with an openness in approach to accompany it.

Along the same lines as retaining structure, but giving openness, is the idea of limiting the degrees of freedom when making decisions, or embracing creativity from constraints. Stokes discusses how famous artists have done this in their work - from Matisse's saturated colours, to Rothko's compositions - these are constraints in the form of 'task', being materials or working methods. As discussed by Stokes, these constraints can *"...generate great novelty and surprise."* (2006:53). The well-known educational approach of scaffolding (Wood et al., 1976) is also relevant here, whereby an educator introduces a task, facilitates the learning of it bit by bit so as to consolidate already learned elements, and build on knowledge.

Output from electronics upon interaction

Due to its accessibility for all involved, an electronic e-textile circuit with audio capabilities seemed to be the best option for inclusion in the art pieces; a sound board would need to be sourced for this.

Ownership

Most importantly the participants should feel a sense of ownership over their work and be able to bring the fully functioning piece home with them at the end of the project. There is a real danger with projects which incorporate arts and technology - especially when using e-textiles - for technical elements to not get completed, leading to the piece not being interactive and therefore participants feeling disempowered. It was essential that this did not happen with the project.

4.2.2 Preparation step 2: researching and prototyping with materials

The decision to run hands-on workshops in which visually impaired participants would design and make their own e-textile art objects was driven by the overall research question, with its attention to tactile interaction, supporting visually impaired people to design and make e-textiles, and exploring the potential of participant making for self-expression and storytelling. The engagement with appropriate community groups and potential participants identified a number of project requirements. In order to establish what materials and techniques would be suitable to use in the workshops, prototypes were built and evaluated in terms of the project requirements identified. Prototyping allowed the researchers to explore design options and to inform judgments about how to open up creative options without overwhelming participants.

The prototyping itself would need to include the following elements in order to scaffold the participants' making:

- Choosing a circuit board for the workshops;
- How to create a soft circuit to attach to it;
- What sort of trigger should create the interaction;
- What materials (yarns, fabrics or embellishments) should be included;
- Which crafting techniques could work for the participants.

These five things would inform how the workshops should be structured: order of activities (to promote engagement and learning) and appropriate reduction of the degrees of freedom (to make the task feasible and un-daunting, while allowing creativity and self-expression).

4.2.2.1 Circuit boards

There are many simple input/output circuit boards and microcontrollers that can be used within e-textile electronics. The choice depends on the functionality required and the context of use.

For the workshops, given that the participants would be blind and visually impaired, and given the emphasis on storytelling, it was decided that audio output would be preferable to light (using LEDs). Music, atmospheric sound, and spoken word all seemed like powerful ways for the participants to bring their work to life. This draws on influences of oral history, described by Thompson and Bormat (2017) as being a recording of a past memory. The board would need to be interactive, accessible, and able to trigger sound. The following criteria were identified as important for the choice of circuit board:

- That it should be able to store sound files in some way;
- It should accept multiple switches and sensors to trigger them;
- A function of interaction to trigger the sound should be easily programmable on the board, or be part of its existing functionality;
- The board must be small enough to fit inside a crafting project;
- It must be easy to power, preferably chargeable, to avoid the need to connect to mains power;
- It must not be expensive, to ensure that participants could keep their art pieces;
- Ideally, the board would be accessible to buy and not from a niche electronics shop or website, to enable participants to purchase more in the future.

Various microcontrollers and sound boards were tested or considered including: boards by Adafruit (Adafruit Industries, 2020), the Lilypad Arduino (Arduino, 2020), as well as some less-known electronics, such as re-recordable devices. Capacitive sensing boards by Bare Conductive (Bare Conductive, 2020) were also considered. Several prototypes were made to assess them against the requirements. Table C.1 in Appendix C compares key features across all the boards considered.

Uploading sound files

One aspect that was explored logistically was how to upload sound files onto a board while also trying to navigate a busy workshop environment. Having experienced how much time this can take when trying to facilitate a workshop, we knew that a board that would allow for this task to be streamlined would be of benefit, so as not to distract from the focal workshop activity. For the Adafruit and Bare Conductive products, a computer was needed for the transfer of MP3 files, whereas the re-recordable devices could capture sounds from a microphone independently.

Activation mechanism

Another consideration was how the sound device could be activated - through capacitive touch or push buttons/switches. In previous research workshops run by the research team, both an Arduino board with capacitive sensing code on it, and a Bare Conductive Touchboard, were used (Giles et al., 2015). Both of these had touch sensors attached to them; when touched by a human hand (which is conductive) the sensors would trigger an output. The advantage of the Bare Conductive Touchboard is that no computer is required to trigger sound, as it has a port for a small speaker to be attached. However, the way that the board is programmed to work with sound is just on/off, which does not allow for a wide range of gestures to be explored; the way in which a user utilises gesture when interacting with a sensor attached to it does not affect the way in which the sound is outputted.

The Arduino board setup required a laptop with the sound software, SuperCollider, installed on it. This more ‘complicated’ setup allowed for richer sounds to be used, and for gestures to influence this output in a more varied way through capacitive touch. However, it would not be practical to introduce the participants to something in the workshop which required a laptop, and therefore would not be practical for them to take home; the setup was just too fiddly and also out of budget.

Simple e-textile push buttons or switches were an alternative to capacitive touch sensing - another option for the research team to use in order for participants to trigger an output from a circuit board. These do not require a laptop to function. They can be constructed simply, by placing two layers of conductive fabric on either side of a larger piece of packing foam containing a hole, and with an area bigger than the conductive fabric so that these two pieces only make a connection when pressed at the hole.

Cost

Cost was another challenge in the context of multiple workshops and a limited budget. The Bare Conductive Touchboard is approximately £65, but an external power supply and a speaker would need to be purchased as well. The Adafruit products would also need speakers and a power supply. As stated in the aims, it was important that the participants should feel ownership over their work, and so there was a need for them to be able to take whatever they created home, in working order.

Usability

The usability of the technology, including the ease with which sound recordings could be made, the batteries could be changed, etc. needed to be considered.

Programming

A challenge of working with beginners, visually impaired or not, is whether to include programming in a workshop series. Previous workshop experiences have shown that participants can become overwhelmed when they are asked not only to design an aesthetically pleasing and personal interactive object, but to build the circuitry and program the circuit board as well. A decision was made that, although boards could be used that required programming, it might be better to have these prepared in advance for participants.

Table C.1 Appendix C shows a comparison of all the circuit boards considered for the project. Some of these allow for programming, and some are just simple re-recordable devices or simple sound boards which are pre-programmed to perform an action. The boards consisted of:

1. A re-recordable device from Rapid Electronics;
2. A re-recordable device from Ebay;
3. A re-recordable device from Amazon;
4. The Touchboard Pi Cap shield with Raspberry Pi Zero;
5. The Bare Conductive Touchboard;
6. An Adafruit Audio FX Mini Sound Board - WAV/OGG Trigger (no amp or headphones;
7. An Adafruit Audio FX Sound Board - WAV/OGG Trigger - with headphone jack;
8. An Adafruit Audio FX Sound Board - WAV/OGG Trigger - with stereo amp;
9. An dafruit VS1053 Codec + MicroSD Breakout - MP3/WAV/MIDI/OGG Play and Record;
10. A SquareWear board.

Balancing the various considerations, it became clear that a) keeping costs down, b) being easy to power, and c) working with sound in an accessible way, were the main considerations. This meant that boards 1, 2, 3, 6 and, 7 from the table were selected to explore further through prototyping. Given the various considerations outlined in Table C.1 in Appendix C, some of the circuit boards were discounted. It was decided that the Adafruit FX soundboards and the re-recordable devices would be tested for the prototypes. Due to issues with stock levels, boards 8 and 9 could not be purchased.

4.2.2.2 E-textile/soft circuit construction

Sewn circuits - also called e-textile circuits or soft circuits - can be fiddly and time consuming to construct. Errors can be made easily, for example if the negative and positive sides are not kept separate, thus creating a short circuit. The thread can fray, with the result that small fibres, that are hard to see, can touch when sewn close together. The metallic properties of some conductive threads can prove unruly to work with, making the thread slippery and lose grip with knotting, or feel heavy to work with - hence making sewing challenging; this is more common in threads which contain a higher percentage of materials such as steel or silver. Along with these difficulties, in general sewing takes time to master, and may prove tricky for beginners. Conversations with the community groups conveyed that the VI participants might feel uncomfortable using needles and undertaking fine stitching. Therefore, prototyping included a range of construction techniques, including:

- Sewing;
- Gluing;
- Sticking with double-sided tape;
- Sticking with heat-activated bonding tape (ironing on);
- Attaching press-studs;
- Insulating within a tube structure.

Whatever was used would have to be robust for the circuit making, switch/sensor making, and attaching buttons/sensors to the circuit.

Another aspect of the e-textile circuit construction to consider was the approach to building it. Some tinker and hobbyist kits have a modular approach whereby components can be moved around and have a more plug-and-play way of construction. An example of this is Little Bits (Sphoro, 2020), whereby different elements of a circuit whether that be switches, actuators or wires can be ‘snapped’ together using magnets that are part of these elements. These can be interchanged and so can be flexible in their construction. This way of working also compliments a scaffold approach as learning can be built on part-by-part. For the e-textile making in the workshops it was thought that a similar approach could work well, but using the press-studs as opposed to magnets due to their use in textiles.

4.2.2.3 Crafting methods

A range of crafting methods was considered for making the textile elements of the ‘art pieces’:

- Weaving;

- Finger knitting;
- Wet felting;
- Appliqué (potentially with some help cutting).

Participants would be encouraged to try out these crafting methods in the workshops, but would not have to should they choose not to. With the exception of applique, the methods identified were thought to be tactile and not reliant on sight. As found in previous research, simple weaving on small looms can be effective and is accessible for VI participants (Giles and van der Linden, 2014), as they can 'feel' the threading (warp) through which they are working (weft). Facilitators working with the deafblind charity Sense have found that finger knitting was accessible for their participants, some of whom had multiple sensory needs (Sense blog, 2015). Wet felting is listed as an accessible activity on the website of the Reading Association for the Blind (2020) as well as again being used by Sense facilitators in previous projects (Sense blog, 2015). Finally, although applique is not the most accessible technique, it becomes more so if the fabric pieces are attached using glue or tape instead of sewing. These various approaches would be offered in the workshops to allow people to experience and select among different methods, and use them in their creative process.

4.2.2.4 Building the prototypes

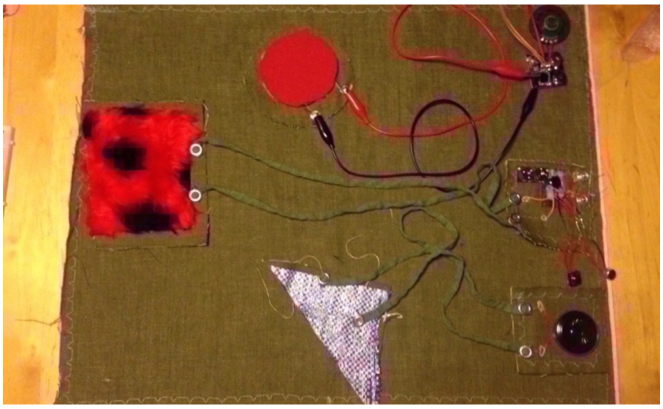
It was essential to test out some of the concepts and technologies in order to evaluate:

- Which board might be the best option for the workshops;
- What range of textured materials might be useful for construction;
- How the e-textile soft circuit would be made;
- How e-textile actuators should be made;
- Whether multiple actuators worked well together or not;
- Would matching associations with the materials and audio work?

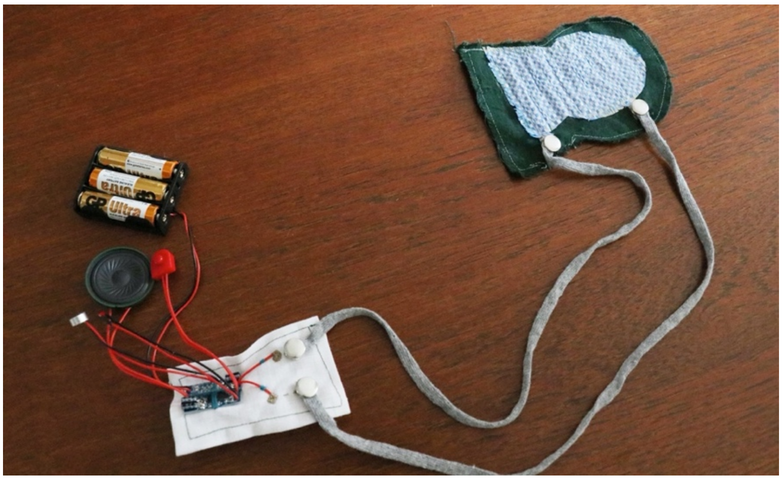
All of these elements were tested through the construction of different prototypes - made by the research team - shown in Table 4.1. Testing the circuit boards and the possible circuit construction techniques was especially important, to ensure that nothing chosen was too complicated or fiddly for the participants to use. It was important for the research team to test out the making, to take a user-centred approach and embrace reflection-in-action (Schön, 1983). Making prototypes themselves allowed the researchers to reflect on the designs and spend time playing with them to establish whether or not they might be suitable for participants. Table C.2 in Appendix C then contrasts the different components and construction methods of the prototypes.

<table>
<tr><td colspan="2">Prototypes created and tested</td></tr>
<tr><td colspan="2">Prototype 1: Fabric textures</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Focus</td><td>The first prototype tested how a variety of different fabric textures could be incorporated into an e-textile art piece - how could they be attached to a background, and what size should they be?</td></tr>
<tr><td>Description</td><td>Four fabrics were selected that varied in their tactility: velour, chiffon, faux fur, and a novelty bobbly yarn scrunched up. The four elements were attached to the background using double-sided fabric tape.</td></tr>
<tr><td>Key decisions</td><td>Fabric tape worked well, was simple to use, and could be managed by touch;
Patches of roughly 10 X 7cm or 10 cm in diameter were appropriate to fit over e-textile sensors or soft buttons;
The use of different textures seemed to work well as a concept.</td></tr>
<tr><td colspan="2">Prototype 2: Yellow felt tubes</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Focus	The second prototype tested the electronics and a modular approach to circuit construction.
Description	Having excluded the Bare conductive boards due to cost, this prototype used the Adafruit Audio FX Mini Sound Board - WAV/OGG Trigger (board 6 in Table C.1 in Appendix C with a small 8ohm speaker attached to it). Circuit construction used press-studs to connect felt tubes that were insulating conductive thread wires. The Sound Board was sewn onto a textile 'soft shield', to make it easy to attach press-studs. This introduced the idea of a 'plug and play' or 'modular' approach, meaning that the different elements of the circuit could be moved around even after construction. The sound had to be uploaded via a computer onto the board using USB. These sounds were triggered using basic, stitched, e-textile switches. The board could be powered with a USB hub, through mains power or a laptop.
Key decisions	• Insulating the conductive thread using felt worked well, although it was fiddly to sew; • The press-studs worked well for modular construction; • The e-textile switch seemed like an accessible way to trigger sounds; • Sewing was fiddly.
Prototype 3: Three-switch sea sounds	
	
Focus	The third prototype tested the link between fabric textures, association, and sound.
Description	This prototype used the Adafruit Audio FX Sound Board - WAV/OGG Trigger - with headphone jack (board 7) to be used with headphones or a speaker. As the plan was to make interactive e-textile art pieces - which could be displayed - it was decided that a

	small speaker would be more appropriate than headphones for use with the board. This board also puts out more sound than the one used in prototype 2, as it has an internal amplifier. Again, sounds needed to be uploaded using a computer, and the board could be powered with a USB hub, through mains power or a laptop. Three e-textile switches were constructed using different textured fabrics on the surface to represent a trip to the seaside. Sounds were recorded and uploaded onto the circuit board: a ‘crunching sand’ sound associated with the coarse fabric; a water sound associated with the blue satin fabric; and a seagull sound associated with the green fabric that had a texture ‘like a fluffy cloud’. The circuit and switches were sewn for speed of construction (compared to the felt tubes). The insulating layer in the switches was a bit too thick, making the switch difficult to trigger.
Key decisions	• The linking of different textured fabrics to associated sounds seemed to work; • Sewing was too fiddly and took too much time; • Being able to output sound was important.
Prototype 4: Ladybird re-recordable device	
	
Focus	The fourth prototype tested the use of two small re-recordable devices, which both use a small coin cell battery for power and have all the electronics required within the printed circuit boards (PCBs).
Description	The modular approach was taken again. Two re-recordable devices were evaluated. These were hacked: the playback switches were removed to incorporate e-textile switches instead, and one of the speakers was removed to allow for the movement of components on the piece. Tubular yarn was used to insulate the conductive thread , which could be drawn through the middle using a weaving needle 2. The wires were

<table>
<tr><td></td><td>made longer to allow for more experimentation with the composition. Press-studs were used for the connections. E-textile buttons were used again, but with a thinner insulating foam to allow for easier triggering. Double-sided fabric tape was used where possible to replace stitching.

The re-recordable devices allowed for 10 seconds of audio to be recorded, and the use of voice was explored by talking into the microphones. The boards were powered by coin cell batteries, but these were difficult to replace, resulting in damage to their casing.</td></tr>
<tr><td>Key decisions</td><td>The tube yarn was much easier to use as an insulator for the conductive thread than the felt sewn tubes, and faster than sewn circuits;
Fabric tape simplified switch construction;
The modular approach worked well again, but this time the wires were longer, allowing for more experimentation with the composition;
Recording straight onto a sound board was useful and simpler;
A thinner layer of insulating foam in the switch allowed easier triggering.</td></tr>
<tr><td colspan="2">Prototype 5: Single fish circuit</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Focus</td><td>The fifth prototype tested the use of a more robust re-recordable device, and refinement of the modular approach.</td></tr>
<tr><td>Description</td><td>A re-recordable device from Rapid Electronics (Rapid, 2020) was used (board 1), which allowed for 20 seconds of audio to be recorded and played back. It also used AA</td></tr>
</table>

<table>
<tr><td></td><td>batteries for power; these were more convenient in some ways than the coin cells, and easier to change in the battery pack. This prototype used recorded sounds from a computer (playing the sound on the computer and then pressing the device's 'record' button to capture the sound onto the device).

The modular approach was refined, using the soft shield, tube yarn wires, and press-studs, producing a more polished appearance. The switch was constructed with double-sided fabric tape, rather than sewing.

The prototype was designed to represent the lead researcher's memories of trout fishing with her dad. The switch, cut into the shape of a fish, had a woven plastic feel. A bubbling noise was used to communicate the idea of fish in water.</td></tr>
<tr><td>Key decisions</td><td>The more robust re-recordable device allowed for batteries to be changed easier and a longer sound recording to be put on the board;
A more refined overall making approach created a more professional looking set-up and object;
The re-recordable device, like the Adafruit board used in Prototype 2 worked well on a soft shield.</td></tr>
<tr><td colspan="2">Prototype 6: Three-switch fishing expedition (final prototype)</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Focus</td><td>The sixth prototype brought all the design decisions together to test the whole construction pattern for the art pieces: using the modular approach with three (hacked) re-recordable devices and e-textile switches on a fabric background with pockets to store the circuit boards and speakers accessibly.</td></tr>
<tr><td>Description</td><td>This piece was an expansion of prototype 5, with more e-textile switches and re-recordable devices. The addition of the background fabric provided an unobtrusive but</td></tr>
</table>

	accessible storage space for the re-recordable devices, and provided a backdrop for the e-textile composition. The switch construction relied on fabric tape and press-studs, rather than sewing. The prototype repeated the trout fishing theme: a dark blue background to represent deep water; the shiny, plastic fish switch from prototype 5; a shiny, green switch to resemble shimmery water, triggering the sound of water running into a lake; and fluffy fabric cut to resemble a hooded fleece that the researcher would often wear when out catching fish, triggering her voice saying "I love to wear my fleecy jumper when I'm fishing, it keeps me nice and warm". The combination of switches and background gave a more complete narrative and made the work more interesting to interact with.
Key decisions	• A more complete narrative with the three re-recordable devices and e-textile switches; • A background to help showcase the work and store electronics so that they would be accessible but unobtrusive.

Table 4.1: A table outlining the 6 different prototypes in terms of the focus, their construction, and key decisions that each contributed.

As the research team wanted the participants to focus on the feel of materials, their associations, and how they might interact with the objects, it seemed that the simple, re-recordable devices would be better to use than a complicated micro-controller. The board used with the fifth and sixth prototypes seemed to fit the criteria better than other boards considered or used for prototyping:

- It allowed for sounds to be quickly and easily recorded onto it through a 'record button' being present;
- The board was able to hold enough data for recordings to be up to 20 seconds long;
- The board was easily 'hackable', with a soft circuit button easily replacing the existing plastic one;
- The board was affordable and easy to buy via Rapid Electronics;
- The size of the electronics (circuit board and battery holder) was small enough to fit in pockets;
- To power the board, AA batteries were used, something easily bought by the participants for use after the project.

As with prototype 3, expressing a story element by choosing a textured fabric and sound based on personal association worked well.

The modular approach to circuit construction - using tube yarn for insulating the conductive thread, press-studs for circuit connections, fabric tape to secure the textured fabric button coverings, and discreet pockets in the background to make the circuit board accessible - overcame the potential barriers associated with stitching, and allowed each important element to be constructed separately and to be moveable during construction. This would allow participants to vary and experiment with the composition.

4.2.3 Preparation Step 3: Prototyping conclusions leading to the project brief

Table C.3 in Appendix C outlines how the prototypes gave input to design considerations moving forward for the project brief and workshop design. This included:

- **Textiles, general crafting context and textures:** ensuring that a range of materials were available, and introducing crafting skills to participants, to give the potential for personal associations with textures within the pieces;
- **Circuit board and sound I/O:** using the Rapid Electronics re-recordable device due to its length of recording time, ease of use with batteries and physical durability. The boards were hacked to support easy connections, by:
    - sewing them to an e-textile shield,
    - removing the switch; and
    - attaching the wires from the switch to press-stud connectors, so that an e-textile switch could be connected easily (see Figure 4.3 of an un-hacked and hacked board).
- **Soft circuit connections:** tube yarn 'wires' containing conductive thread and connected with press-studs to minimise sewing;
- **The triggers/actuations and their textile covering:** use thin packing foam, fabric tape and fabric glue for e-textile switch construction;
- **Workshop structure:** tasks, technology introduction and narrative design:
    - The complexity of producing even a simple interactive piece led to the decision to focus more on designing and constructing the interactive object, reserving programming for a later project or workshop.
    - The circuit-making would be simplified to ensure that participants could focus on the creative and interaction design process. Participants would make their own tube yarn e-textile wires, attach the connection and make the circuits. Facilitators would hack the board and prepare the e-textile shield;

- All of the prototypes demonstrated how the making of the pieces could be fiddly: facilitators would provide support as needed (but only as needed), framed as ‘functional help’, so that participants could focus on the creative design and construction of the work (the composition) as well as the creative thinking.

Each of the prototypes had contributed something to be taken forward for the next stage of prototyping the project - either by introducing a certain element or confirming that it worked when used again. The prototyping inspired a ‘modular approach’ to e-textile workshops, allowing ease of handling and experimentation, and allowing the creation of ‘plug and play’ circuits. This approach was supported by particular decisions about which technology would be used in the workshops, how the circuits would be made, and how they would be triggered.

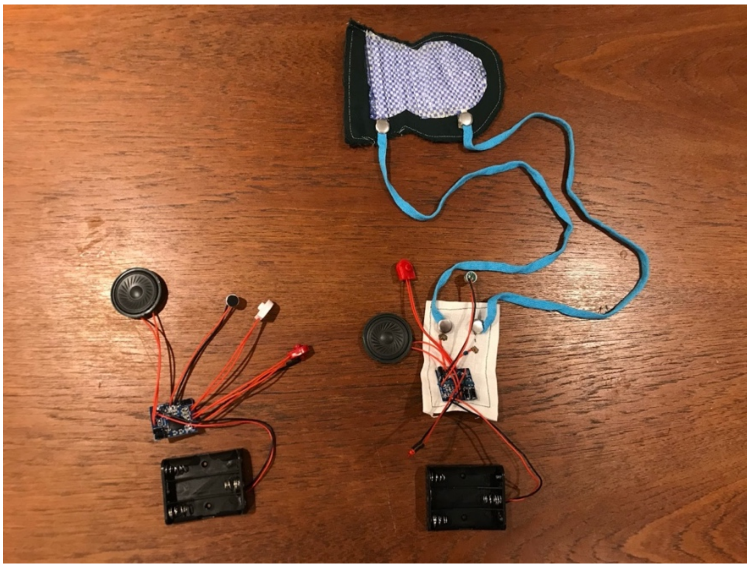


Figure 4.3: The re-recordable device used in the study before being hacked to use with e-textiles.

The surface of each of the e-textile switches would be material selected by the participant - whether a piece of fabric or a woven or knitted object. Not only would this covering complete the switch, but it would also be a way for the maker’s personal story or association to be reflected in a physical object, through shape, texture, or appearance. The story or association might also be reflected in the sound the switch would activate.

One of the main challenges of the workshops would be achieving the balance between respecting the participants’ ownership of the project, and protecting them from fiddly elements (mainly sewing circuits or hemming). It was decided that the background fabric containing the pockets for the circuit boards would be sewn for participants, unless they asked to do this themselves. Everything else - design and composition, e-textile switch making, e-textile tube yarn wire construction, the sticking down of fabrics etc. - they would do themselves. The workshops would be structured to scaffold independence. Everything would happen step-by-step, not being rushed and being repeated if necessarily. The modular approach would contribute to the scaffolding. An open approach would be encouraged, with participants being free to ask questions, give their opinions, choose their activities, and vary the brief (as opposed to a top-down classroom approach).

4.2.3.1 Structuring the project

The structure of the workshop was constrained by time and budget. Participants taking part could not be expected to attend sessions for longer than six weeks, due to other commitments. It was decided, in consultation with the community groups, that five or six sessions of a full afternoon of making would be appropriate. It was necessary however to ensure that all participants could complete their pieces in that given time, meaning that a schedule would need to be planned carefully, with open making time as part of the process. To ensure that everyone had a focus and a frame within which to work, it was decided that some creative boundaries should be set:

- Participants would be encouraged to focus on the feel of the work, the shape of physical elements on it, and the sounds of their interactive elements;
- The project would be framed as an 'interactive wall hanging', (but other objects could be chosen if desired);
- Up to three e-textile switches could be incorporated in a piece;
- Any of the crafting techniques explored could be used to cover e-textile switches and to decorate the piece of work;
- The pieces should reflect a personal story or association.

These boundaries were flexible, depending on what the participants wanted to make.

Due to the limited time for workshop delivery it was decided that the researchers would hem or help build the fabric backgrounds, including making the pockets for the circuit boards and speakers. This process would be carried out collaboratively with participants, with them choosing fabric, and planning sizes and any variations. The researchers assisting with the backgrounds could be looked upon as being like a framer providing a frame for a painting; something that is created to 'hold' the work. Most of the time, the artist is not expected to do this, instead focusing on the work itself. If participants wanted to do their own hemming or pocket making, this of course would be supported.

Overall, the prototyping phase was about understanding what compromises had to be made. The main driver was accessibility: keeping the participants in control and allowing them to complete something in the available time. It was about deciding where to offer them the flexibility to work on their own design, without making this process painfully frustrating and technically overwhelming. The project structure was thus designed to allow a number of degrees of freedom, while avoiding known practical traps. For the researchers, this became the core of achieving a participatory process.

4.2.4 Preparation Step 4: Piloting the project

The next step was to test the final prototype with a user as well as carrying out the making process planned for the workshop. The users who took part in these pilots were:

1) A visually impaired artist known to the researchers, who had previously partaken in making sessions with them; his own practice specialises in sculpture. He often runs workshops at galleries such as the Royal Academy as part of their 'touch tours' for VI visitors;
2) A visually impaired neighbour who has previously handled e-textile artefacts made by the researcher and who is slowly losing her sight. To manage this, she is trying to establish coping mechanisms. She loves making but does not always have the time or confidence to do so.

It was important to find out how visually impaired users might interact with the prototype - to assess if it was intuitive in its design and to explore what their interpretation of it was. It was also vital to evaluate the suitability of the making process - was it accessible in terms of the circuit making, the materials and tools used and the overall approach? Linked to this, was the concept of expressing a personal story through e-textiles effective? These pilots considered all three aspects of the proposed workshops: the materials, process, and the final product.

The pilot sessions lasted between three and four hours with the participants and provided some evidence that the users engaged with the prototype and responded to the associations.

4.2.4.1 Evaluating the user experience of the prototype

An afternoon was spent with the artist with the plan being to discuss art from a VI artist's perspective, for him to test out the prototype, and then should time allow, for him to construct his own personal interactive art piece using the e-textiles.

The visually impaired artist engaged actively with the prototype, triggering and experimenting with the circuits: pressing the switches in different combinations, triggering them on and off to try to get what he called an *"orchestration"* (see Figure 4.4). As he pressed the shiny plastic button, he joked about how *"It's* *really getting very wet"*, due to the sound of water. As well as interacting with the prototype, he discussed the concept of colours and space. The researcher was careful not to tell him what colour the different elements were until some initial explorations had taken place, not wanting to bias his perception of the piece. The concept of 'colour' was brought up in conversation, with him saying that the fluffy jacket shape was white. The researcher told him that in fact it was a red and black ladybird print fabric, to which he replied that if he thought it was white then in fact it *was* white. He was implying that the same perceptions of colour do not necessarily apply to blind and visually impaired people.

Figure 4.4: Visually impaired artist interacting with prototype.

Also discussed was the concept of sides of the prototype. The researcher explained that the circuit boards and speakers had been placed within pockets on the background fabric, to store them somewhere but also with the idea that by placing them inside the piece, they would become 'invisible' to the audience members. The participant replied that for him, his lack of sight meant that objects did not have a top part and an underneath/inside part and so he also wanted to put his hands into the pockets of the piece. This was something to consider; it would have to be expected that other people exploring the interactive objects might also want to put their hands in the pockets.

So much time was spent with this participant discussing the prototype and his insights into the art world that time ran out before there was a chance to do any making. This was unfortunate but demonstrated that enough time would need to be scheduled in the workshops for dialogue *and* making.

4.2.4.2 Making with a neighbour

The time with the second VI participant was focused on making her own interactive art piece. She created a very personal e-textile piece, based on one of her favourite songs, and an exhibition she was planning to attend that was also linked to a strong emotion and personal acquaintance. She chose to record a song by

Bob Dylan - *Shelter From The Storm* - onto the re-recordable device from YouTube. She felt nostalgic, as this song reminded her of an ex-partner from whom she had recently separated. She wanted to make a heart-shaped fabric shape out of ladybird-print furry fabric, because she loves this pattern and it relates to a comfort object on her fridge that helps her with anxiety. She touches this object when she needs reassurance.

The making of the participant's object linked her feelings toward her ex-partner with her own sense of confidence, and also her hopes for the future. It seemed to give her an opportunity to reflect on all of this. At the time of participating in the activity, it had just been Valentine's Day, and she and her ex-partner were planning to meet at an exhibition at the Design Museum in London entitled *Fear and Love.* As she carried out her making, she spoke about her fear of meeting him, but along with this, also her fear of taking part in the activity and crafting due to her worsening vision.

The participant grasped the activity very well - passing her conductive thread through the tubular yarn with no issues to create the insulated conductive thread wires for the piece, and using the press-stud tool to attach press-studs for the ends (see Figure 4.5). She cut out her heart-shaped fabric without any assistance and followed the steps for making a soft circuit button, sticking it together with glue with the guidance of the researcher - but again, doing it physically herself. The researcher provided a hacked re-recordable device to which the fabric wires and soft circuit button could be attached, and it seemed that the participant did not mind that this element had been pre-prepped. The reasons for doing this were discussed.

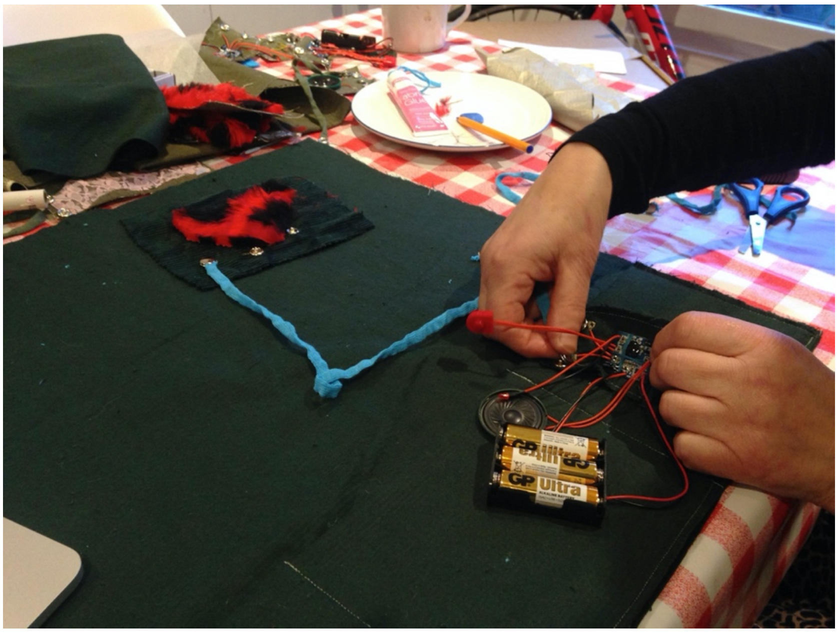


Figure 4.5: Visually impaired neighbour making her interactive art piece.

As parts of the making happened step-by-step, the researcher discussed the participant's views on them and whether she would prefer them to be delivered a different way. One example was the recording of the song onto the re-recordable device. The researcher demonstrated how to record sound by simply pressing the record button, with the participant copying. When asked how she found this process, she described it as being simple to do. Also discussed was how the making could be more accessible for her; she requested a bowl to contain all of her elements for the piece, as well as tools, such as needles. One thing she struggles with at home is finding day-to-day objects, which causes her anxiety. To cope, she places objects such as the TV controller into a basket on her coffee table, finding this technique for storing things useful. She also commented on how the choice of tablecloth placed underneath the tools and materials was not helpful, the one chosen being covered in little red and white squares, with the thought that something bright might help contrast the tools and materials. However, the pattern on it was disruptive for the participant due to her sight; she suggested that a plain one would have been better. This would need to be considered for the workshops.

At the end of the making session, when testing her piece for the first time, the participant was delighted with the result, becoming overwhelmed with joy. She was incredibly proud of herself and could not quite believe that she had created it. She clearly felt a sense of ownership over her work.

4.2.4.3 Reflections

The pilot sessions provided valuable feedback about the materials and the approach to be taken for the workshops. The session that focussed on making demonstrated some key findings:

- Hacking the circuit board to enable an e-textile button and soft wires worked and did not seem to disempower the participant;
- Giving the participant large enough pieces of fabric to work with was important;
- The participant was able to make the tube yarn wires - by threading conductive thread through it and attaching press-studs to the end;
- The participant was able to use glue to stick the e-textile switch together;
- With some help, the participant could use scissors effectively;
- The participant found it simple to record the audio by pressing the record button on the re-recordable device;
- A plain background on the making table should be used to help create contrast with the materials and tools - however this would need to be discussed with the visually impaired charity as well as to what they thought might be needed;
- The participant enjoyed and succeeded in meeting the brief of making an interactive piece that was personal to the maker and incorporated sound and a tactile element.

The modular approach to creating e-textiles was successful, and carrying out the session with the neighbour using this approach confirmed that:

- It made e-textile circuits easier to construct step-by-step;
- It overcame some issues of working with conductive thread - including short-circuiting;
- It reduced technical distractions, so that the participant could focus on design and self-expression.

The practical stages to making the piece - the choice of materials, the tools, and the step-by-step approach - worked well. Running the pilot session and explaining the technology and process to someone who had not made e-textiles before helped refine the explanations. There were a few elements to be mindful of and alter for the workshops but overall the pilot session of making with the VI neighbour was a success.

The interaction with the VI artist produced some important insights as well:

- The buttons seemed intriguing to touch, with the participant going back and forward between them;
- The triggering of the sound with the switch worked well, with the participant working out how to do this intuitively;
- He found a meaning in the work, associating it with water, and referring to it as an 'orchestration', seeming to enjoy all the sounds together;
- Some VI participants might not view the pockets containing the electronics as something to be 'out of bounds', but rather, like the VI artist, might be intrigued as to what is in them and decide to feel inside.

Although the intention was also to do some making with the VI artist, the unexpected focus of the interaction with the prototype was in fact very useful.

4.3 Study design

The study was designed to take the form of two series of workshops, in community spaces external to the university. These spaces worked well; as their purpose is to be available for community projects, the partner organisations were enthusiastic about hosting the workshops, and participants were all familiar with the spaces.

The research uses participatory making methods' (Twigger Holroyd and Shercliff, 2014), as discussed in Chapter 2. That is, participants actively making objects is a method for data collection. Twigger Holroyd and Shercliff discuss participatory making methods as having some key strengths (paraphrased and reformatted from Twigger Holroyd and Shercliff, 2014):

- Making opens up constructive conversation, which helps to elicit the experiences of participants;
- It slows conversation, giving room for reflection (rather than suggesting pressured to answer, as interviews might);
- It allows the researcher to hear a participant's thoughts first hand whilst making, rather than retrospectively;
- It allows for knowledge embodied in practical skills to show through and be observed;
- It helps show knowledge which comes to light 'in the moment', and also shows changes in perception from participants over the process.

Contextual inquiry would also be used to observe the participants during their making, and also to ask them questions as they work. However, a making environment can be hectic, and it is difficult to observe everything which is happening (both making and conversation), so video and still cameras would also be needed, rather than an observer with a notebook. The research team would be leading the making and facilitation in the workshops, as well as observing the sessions and documenting.

If possible, interviews would be conducted with the participants after the workshops in their own homes, in order to see what they did with the interactive art pieces and to be able to discuss their making experiences in a comfortable environment. It would also provide an opportunity to verify or contradict observations. For some people, it would take some effort to come to the workshop spaces every week, so the research team wanted to save them the trouble of this for the interviews.

4.3.1 Workshop series structure

The workshops were designed as six weekly sessions of four hours for the first group, and as five weekly sessions of 4.5 hours for the second group. The intention was that participants would learn skills and techniques, gradually developing their own ideas and confidence. This was both to create their own interactive e-textile art pieces, and to create a space where they could discuss stories and thoughts important to them and to have a chance to reflect on personal experiences.

The workshops would 'scaffold' skill development by breaking tasks into digestible chunks that accumulated into an overall understanding of e-textile making. For example, participants were given time to 'play' with the circuit boards, before receiving simple step-by-step instructions of how to build an e-textile circuit. They then would help each other test their circuits. The intention was to give them the knowledge to build these themselves when making their final pieces, and hence to be more in control of the technical process. Creative expression through any art or craft medium can be challenging and requires much thought and reflection. To be asked suddenly to come up with a narrative, and express it through textiles and electronics would perhaps feel slightly daunting. Therefore, some activities were planned to scaffold this thought process:

- Sharing with the rest of the group a personal fabric item which has a narrative attached to it, and discussing what that narrative or association is;
- Inventing a narrative or telling an existing one simply based on inspiration from a set of pre-cut fabric swatches of different texture and appearance;
- Choosing fabrics or making a fabric (by knitting, weaving, etc.) to become elements of their personal e-textile piece;
- Thinking about how the participants might want to use their e-textile switches for interaction, to communicate the theme of their work;
- Recording sounds (whether found or created) or recording their own narrative to be triggered by their switches.

The sessions were also structured to incorporate difficult elements in each session (the schedules for each week can be found in Appendix B). The sessions included the following:

- Associations with materials;
- Sharing personal textile artefacts;
- Different crafting techniques;
- Introduction to e-textiles/soft circuits;
- Project planning and execution;
- Sharing ideas and showcasing work;
- Reflection.

The structure and the activities were suggested, not imposed. Participants had the choice to 'take or leave' any of the activities. The overall structure was designed to give participants input and opportunity, to enable them to express themselves or their stories through e-textiles.

4.3.1.1 Project brief

The project brief was an 'interactive art piece' in the form of a wall hanging incorporating up to three e-textile switches that would trigger sounds. The materials used, and audio recorded, should relate to a personal memory or narrative which is important to the maker; the interactive e-textile art pieces would represent that memory or narrative. The re-recordable devices and battery packs would be placed in open pockets, allowing access without attracting undue attention.

To ensure a sense of agency, the participants would make all the design choices and take the lead on all construction, with help available on request. Throughout the workshops, the participants were encouraged to reflect on the feel of materials, and what their personal associations were with them - and they were encouraged to draw on these reflections when they made their own art pieces.

4.3.1.2 Volunteers and their role

It was important to provide necessary assistance while respecting and promoting participants' agency. On one hand, it was necessary to ensure that participants had enough volunteers in the room to assist with practical elements as needed, such as finding tools, re-positioning yarns if they got tangled, helping with cutting or gluing, or identifying the colour of a fabric. This assistance should be as unobtrusive as possible, and available on request, rather than being imposed.

4.3.1.3 Different crafting techniques

Participants were invited to learn a range of hand crafting techniques (see Figure 4.6) that they may not have used before, including:

- Finger knitting;
- Weaving;
- Felting;
- Threading;
- Appliqué.

Each of the 1st, 2nd and 3rd workshops dedicated one to two hours for participants to try finger knitting, weaving, and felting in turn. Following this, the participants could choose whether or not to use these techniques for making textile elements for their e-textile switches in the later workshops. Threading was introduced for the soft wire construction, and appliqué was introduced for e-textile switch construction; hence these were not optional.

Figure 4.6: Different crafting techniques tried by participants (from left to right): Weaving, finger knitting and wet felting.

4.3.1.4 Associations with materials

To give participants a palette of tactile materials from which they could choose materials for their own projects, fabrics which had a range of textures, weights and appearances were introduced from the first session. Time was scheduled in to discuss the tactile qualities of fabrics, and to discuss the ideas, thoughts, and associations that these might evoke.

Figure 4.7: Participants exploring different fabrics with their hands and discussing associations linked to them.

4.3.1.5 Sharing personal textile artefacts

Participants were regularly invited to share their ideas and work with one another. Participants were also encouraged to bring things from home that they wanted to share, particularly fabric objects that were meaningful to them and had a story attached (see Figure 4.8). The purpose was to open up a dialogue about memories and associations related to a physical item that were important to them. It can be intimidating to talk about personal aspects of one's life to a room of people who may or may not be known to the speaker. It was important for participants to have time to become familiar with one another, before being asked to create a piece of work personal to them and to discuss it.

Figure 4.8: Personal fabric items brought in by participants (clockwise from left to right): A scarf given by a friend, a participant's birthday dress, and a fabric cast linked to an injury which contributed to a loss of sight diagnosis.

4.3.1.6 Introduction to e-textiles/soft circuits

The e-textile circuits and components were introduced step-by-step (see Figure 4.9). In the first session, and to begin the circuit making process, participants were shown how to make a basic circuit using crocodile clips, a coin-cell battery and an LED or small vibration motor. Then they were shown how to make ‘soft wires’ with press-stud connectors, and each was given the task of making some which would be used later in the circuits for their e-textiles. They were able to test their soft wires on the basic circuit, and this helped their understanding of how e-textile circuits work.

During the 3rd session, the participants spent time experimenting with the sound boards. At this point the board had not yet been hacked, so the interaction was through the inbuilt push button. This was to ensure that they understood how the circuit board worked before it was hacked. During this session participants also started to make their e-textile switches.

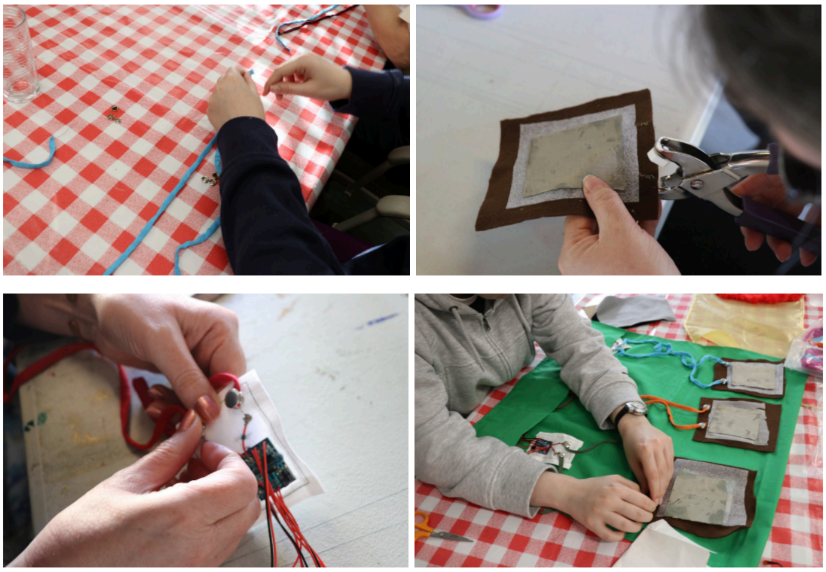


Figure 4.9: Participants making their e-textile circuits (clockwise from left to right): Threading conductive thread through tubular yarn for insulation; attaching press-studs for circuit connections; attaching a tube yarn wire onto a press-stud connection on a soft shield for a soundboard; and attaching a tube yarn wire onto an e-textile switch using press-studs.

4.3.1.7 Project planning and execution

Throughout the workshops, participants were encouraged to think about their own projects. Each crafting technique was explored as an option for fabrication, and the participants were encouraged to reflect on each session, and how they might want to steer their work. Phone conversations and emails with participants were used not only as data collection but also to help them with their project planning.

Participants were encouraged to plan the appearance and physical layout of their piece. The knowledge that elements could be moved if needed, allowed them to experiment and to defer decisions such as how many buttons they wanted to be part of the work. Through the sessions they made small piles of fabrics that they might want to include in the final piece, in order to aid with their tactile and visual design, and to ensure that no detail was lost.

Participants worked independently or with individual support to execute their pieces - they were also encouraged to assist each other when needed. Volunteers put themselves forward to help with the sessions, not only to make tea and cake, but also to be a helping hand if required.

4.3.1.8 Tools and Materials

Tools and materials used during the workshops by participants and the research team were pre-decided, but also customised over the the sessions, depending on what participants requested and required. Table C.4 in Appendix C shows the materials and tools provided initially for the sessions by the research team, consisting of fabrics, yarns, embellishments and crafting tools for construction, deconstruction and connecting, as well as additions during the workshops.

4.3.1.9 Sharing ideas and showcasing work

The workshops were designed to be a safe space where everyone could feel comfortable, an opportunity for enjoyment in company, a chance to learn about e-textiles and tell personal stories. People with impairments or disabilities can feel isolated, especially when elderly, so the social dimension of the sessions was important, as found by Vogelpoel and Jarrold (2014).

At the beginning of each session, time was scheduled for participants to have lunch, or a cup of tea and cake. This was to catch up on news and to discuss project ideas and progression: How were project themes and ideas coming along for each person? Had they decided which fabric or sounds they would like to use? How did they feel about taking part in the work? Or just how were they feeling that week? Tea breaks were also planned throughout the workshops, the facilitators ensuring to keep the atmosphere relaxed and friendly. Along with time at the end of activities for discussion and reflection, this relaxed time was intended to create an atmosphere of openness and informality and provide opportunities for conversation.

A public exhibition was scheduled for a number of weeks after each of the workshops finished. This was to offer the participants the opportunity to showcase their work to friends and family, as well as for the research team to show Bucks Vision and MK Gallery what had been created in their spaces. Again, this was to give participants the chance to have some fun, but also to feel empowered and show-off what they had learned, being able to refer to themselves as artists. After the exhibitions all participants would take their pieces of work home.

4.3.2 Data collection

It was decided that, due to the exploratory nature of the research, a selection of tools should be used for capturing data, to enrich the understanding about what had happened during the workshops. The positioning of these can be seen in Figure 4.10.

4.3.2.1 Video, photography and audio recordings of workshop sessions

Sound

Given the 'busy' nature of the workshop environment, a number of media devices were set up to capture images and sound during the sessions. With multiple participants, it would not be possible to be present for every conversation. Being a facilitator as well as assisting with the making made it likely that the researchers would miss some conversations and other interaction. The audio recorders would help to capture conversations around the table in a rich way.

Video

The main purpose of the video recordings would be to have a linear record of the running of the workshops, which the research team could come back to in order to re-observe what had happened during the sessions; this would be recorded on two stationary video cameras. The lead researcher would also use a digital SLR camera to record some video with more-tightly-framed shots to capture key elements during the sessions, for example: ways in which participants are using tools and materials for crafting or making their circuits; gestures they are using to interact with e-textiles; or the participants describing ideas and reflections that provide insights about their work.

Still photos

Still photographs would also be taken using the digital SLR camera, to capture key elements during the sessions. These would provide images of what each person produced, for documentation purposes and to be used for analysis.

Some of the audio and video would be transcribed, specifically for quotes from participants.

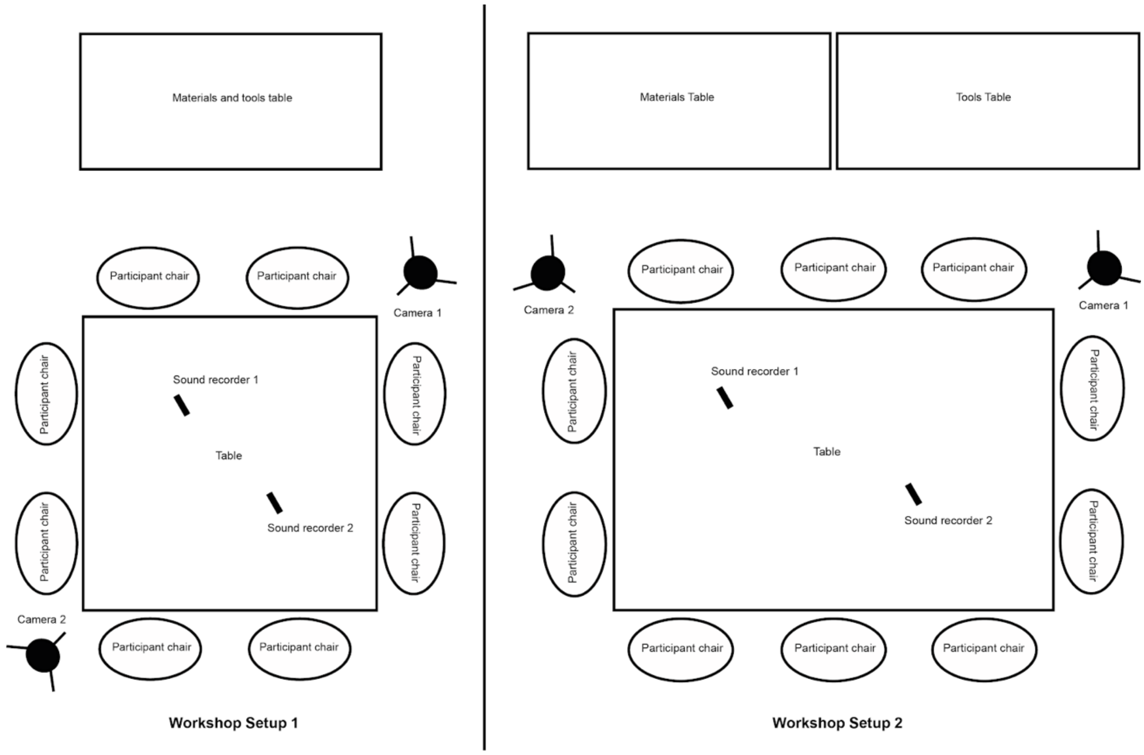


Figure 4.10: Left: Setup for first workshop; Right: Setup for second workshop series - including stationary video camera and audio recorder setup.

4.3.2.2 Facilitator notes

As discussed in Chapter 3, hand-written notes can be useful when trying to capture data but not be too intrusive, because participants sometimes 'freeze' when video cameras are used (Druin 1999, Druin et al. 1999). For the first workshop, hand-written notes would be used as the main approach for data capturing, due to the need for the research team to familiarise themselves with the participants and vice-versa before too many cameras were introduced. As the workshops progressed, hand-written notes would also be useful for noting key things people said, and to help the research team reflect on the sessions.

After each session, the plan was for the research team to discuss their notes with one another - to ensure that everyone had a clear understanding of what had happened and been observed. These would be typed up by the lead researcher for referring back to during analysis.

4.3.2.3 Emails/Phone calls/Audio Diaries/Interviews with participants

To ensure that participants were happy and were given support between the workshops, it was decided that they should be contacted each week via email or a phone call, to ask how they found the previous session, their personal projects and ideas, and how they had found the technical processes of learning crafting and circuit making skills.

Participants would also be interviewed sometime after the sessions to give them a chance to reflect on the process and give their feedback. With the permission of the participants, this would happen in their homes, partly to investigate where they had placed their e-textile creation and whether they were still interacting with it.

4.4 Execution

The workshops took place as planned with two different groups taking part in the study. They happened over a number of weeks with each group having an exhibition afterwards.

4.4.1 Workshop participants

The participants who took part in the workshops were recruited through Bucks Vision and the Eye for Art group. The participants varied in age and ability, having different levels of sight, and varied experience with hands-on making. A total of 18 people participated over the two-workshop series, with 8 in the first series and 10 in the second. Some of these people did not attend all of the sessions and did not create a final piece, but the majority did. However, all of them gained some crafting and circuit-making experience. Table 4.5 summarises who participated. Volunteers assisted with the sessions, ensuring that the participants had help when needed – whether that be to collect certain materials or be a second pair of hands when making something for the work. The two volunteers for the first workshop were new to Bucks Vision and so had not worked with the participants before. The three volunteers for the second workshop series knew the Eye for Art group well – also being volunteers for their regular meet-up sessions that take place every month. It was obvious that they had a comfortable rapport with the participants, knowing when to offer help and when to be there more as a friendly ear to discuss the making with.

Participants	Age	Level of Sight and Experience of Crafting	Sessions Attended
First Workshop Series			
Hailey	50 - 55	Partially sighted - sometimes attends Bucks Vision activities and does crafting in spare time.	6/6
Karen	30-35	Blind - frequently takes part in activities ran by Bucks Vision and has won awards for art pieces through charity.	6/6
Louise	50 - 55	Partially sighted - has a strong background in hobbyist knitting and sewing.	2/6
Ewan	30 - 35	Blind - has never done crafting before.	5/6
Jim	50 - 60	Partially sighted - used to do small amounts of crafting with grandma as a child.	5/6
Uma	70 - 80	Partially sighted in left eye and blind in right eye - does not do much crafting but used to work in textiles when younger.	5/6
Sonja	80 - 85	Partially sighted in right eye and has replacement left eye - has a strong hobbyist background in making art pieces, from textiles, to paper collages to painting. Has won awards for art pieces through charity.	6/6
Kat	50 - 55	Partially sighted in right eye and blind in left eye - makes a lot of hobbyist arts and crafts to keep stress down.	1/6
Second Workshop Series			
Jane	55 - 65	Partially sighted - Member of arts and crafts group.	5/5
Kelly	55 - 65	Partially sighted - Member of arts and crafts group.	5/5

Pam	55 - 65	Partially sighted - Co-leads art and craft group.	4/5
Mark	20 - 30	Partially sighted - Member of arts and crafts group.	1/5
Jacob	45 - 55	Partially sighted - No crafting experience but is a talented poet.	5/5
Carrie	55 - 65	Partially sighted - Member of arts and crafts group.	1/5
Susie	45 - 55	Partially sighted - Member of arts and crafts group.	1/5
Verity	55 - 65	Partially sighted - Co-leads art and craft group.	4/5
Patricia	75 - 85	Partially sighted - Member of arts and crafts group.	5/5
Evie	75 - 85	Partially sighted - Member of arts and crafts group.	2/5

Table 4.2: Participants who took part in the e-textile workshops, listed with pseudonyms.

4.4.2 Workshop settings

The workshops took part in the two settings as planned: the first series in the Bucks Vision community workshop space and the second in the MK Gallery project space. Both spaces were large enough to accommodate everyone comfortably, were well lit, and had large, configurable tables (see Figures 4.11 and 4.12). Both had accessible kitchen and toilet facilities.

Figure 4.11: First workshop setup in the Bucks Vision community space.

Figure 4.12: Second workshop setup in the MK Gallery project space.

The first workshop series took place between February and March 2017 with an exhibition in April 2017. The second workshop series took place between June and July 2017 with an exhibition in August 2017.

The second series of workshops could be organised and prepared for while the first series was underway, providing the opportunity to make any alterations suggested by the first series. This included:

- Ensuring that there was enough time to run all activities, as some were missed in the first workshops;

- Getting to the hands-on making with crafting slightly faster as some participants (Sonja) in the first workshops were keen to move onto the creative side quicker;
- Having a conversation with the volunteers earlier on about their role and how perhaps help could be given.

4.4.3 Data analysis

The workshops were analysed from different perspectives, to address the research questions and also to reflect the richness of the data collected. An inductive thematic analysis approach was taken (Braun and Clarke, 2006), in which the lead researcher let themes emerge as they explored the data, exploring these with the research team.

The analysis was an iterative process. The researchers discussed initial thoughts about observations and themes after each session, based on their hand-written notes and recollections. These discussions were particularly valuable due to the messiness of working in-the-wild. It helped to record events and to consider what emotions and reactions the participants had been displaying when taking part in activities.

The data obtained through emails and phone calls with participants between sessions – along with the interviews carried out in their homes afterwards was used as a way to verify or contradict what had happened in the sessions. These also fed into the process of allowing themes to emerge.

The lead researcher was the primary coder for the data, but discussed themes and findings with the rest of the research team (her supervisors). This ensured that a dialogue happened around the process, providing scrutiny and discussion.

4.5 Summary

This chapter has described the process of planning and prototyping a two-part study, focusing on how visually impaired participants could take part in hands-on making workshops with e-textiles. This discussion has considered a number of aspects:

- Building relationships with organisations and the participants;
- Early activities run with potential participants to generate interest in the project;
- The role of the researchers and the participants;
- The importance of the making environment and social aspect of the project;
- Providing a chance for reflection;

- The planning process, including prototyping materials and technology;
- The evaluation of the modular approach with VI experts to ensure its suitability;
- The study design, including the planned workshop structure and proposed methods for data collection and analysis.

The findings from the study are discussed in Chapter 5.

5 E-TEXTILE MAKING WORKSHOP FINDINGS

5.1 Introduction

The workshops were deemed to be successful, by the researchers, the participants, and also the organisations that had collaborated. All of the participants who were able to attend the majority of the sessions created an interactive art project, to their own design, and engaged in the e-textile crafting and the telling of a story (presented in Table 5.1 below). They explored a range of materials and reflected on touch and sensory engagement. All of the participants took part in group conversations and activities, thereby engaging actively in the participatory making environment.

This chapter presents and discusses the evidence leading to this overall assessment of success (Section 2), and presents the evidence from the workshops that addresses each of the research questions (Section 5.3, as follows):

1) What emotional associations do users have with textures and appearance of materials which can be used in e-textile interaction? (Section 5.3.1).
2) What objects, materials and techniques are practical for use by blind and visually impaired people making e-textiles? (Section 5.3.2).
3) Can visually impaired makers express themselves through e-textiles? (Section 5.3.3).
4) What are the challenges and opportunities for blind and visually impaired people in an e-textile participatory making environment? (Section 5.3.4).
5) How do blind and visually impaired people interact with textiles (and e-textiles) using touch? (Section 5.3.5).

Finally, the evidence is discussed in Section 5.4, including the limitations of the work, and a summary of observations is presented in Section 5.5.

5.2 Assessment of the success of the workshops

5.2.1 Participant work

The 13 participants who completed the workshops told their stories through fabric and sound in the construction of their final work. They conveyed these narratives through the textures and appearance of the fabric. They also curated the soundscapes with much thought, relating these to the e-textile buttons on their work.

Table 5.1 below shows the final output from each participant: what their work was, their choice of materials, and what the work represented.

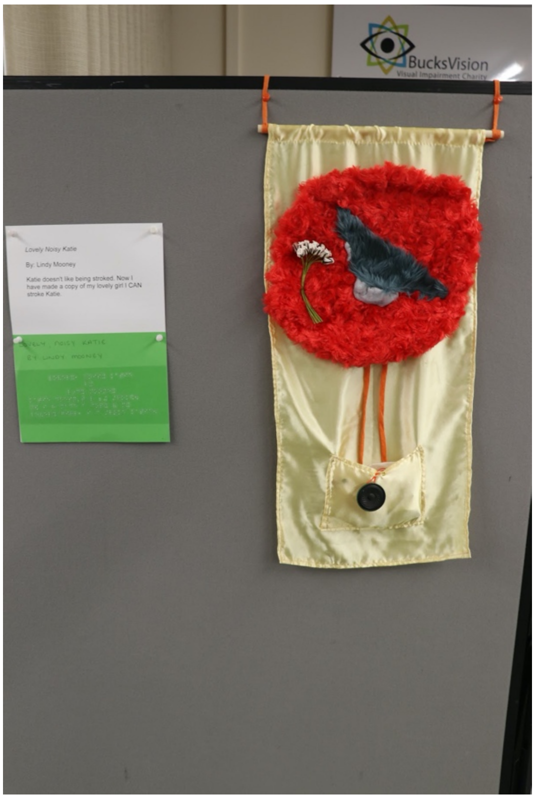
First workshop series (W1)

<table>
<tr><td>Participant</td><td>Hailey</td><td rowspan="7"></td></tr>
<tr><td>Object made</td><td>Wall hanging</td></tr>
<tr><td>Title of work</td><td>Cow Children</td></tr>
<tr><td>Theme of piece</td><td>Her children</td></tr>
<tr><td>Number of e-textile switches</td><td>Three</td></tr>
<tr><td>Crafting methods used</td><td>Appliqué</td></tr>
<tr><td>Type of sound used</td><td>Sound recordings of her children’s voices</td></tr>
<tr><td colspan="3">Hailey’s piece, Cow Children, represented her three children. She selected fabrics to reflect their personalities and interests, used these to make coverings for three e-textile buttons, and recorded her children's voices on the sound boards so that they would be heard when the switches were touched. As her daughter loves the colour pink, Hailey requested fluffy pink fabric to represent her, crafting it into a heart shape. She also made a switch for each of her sons: one a sheeny, blue triangle - as he likes sci-fi and futuristic things; the other, a</td></tr>
</table>

black cotton square as he is very ‘cool’. Hailey chose the background from fluffy cow print fabric as a) she loves cows and b) the fabric resembled her daughter’s fluffy onesie.

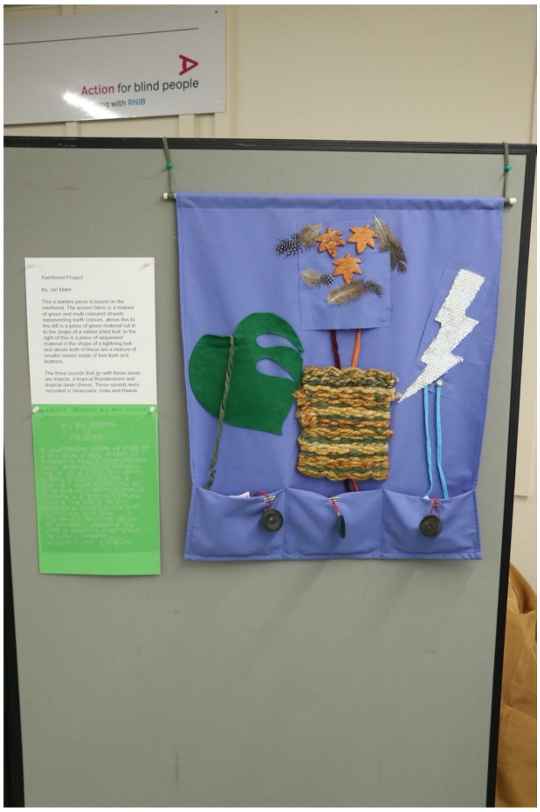
Participant	Karen
Object made	Wall hanging
Title of work	Green Grass Animals
Theme of piece	Her favourite animals
Number of e-textile switches	Three
Crafting methods used	Appliqué
Type of sound used	Animal sounds found online

Green Grass Animals represented Karen’s favourite three animals: her own cat, owls, and horses. The focus of her piece is texture, and for each button she chose to cut simple squares. The ‘cat’ switch covering was made from black velour fabric which represented the feel of her own cat (who in fact is a brown tabby). Her second switch covering was made from the ultra-soft grey fabric, representing owls. Karen had felt the soft fabrics to establish which one was the softest, as she perceives owls as being soft. The last switch covering represented a horse and was made from a brown suede fabric. Karen swayed between choosing this and brown felt, deciding the suede better represented the feel of a horse. The grass background was plain, green cotton. She also considered fluffy green fabric, but settled on the smooth cotton texture.

Participant	Louise	
Object made	Wall hanging	
Title of work	Lovely Noisy Katie	
Theme of piece	Her cockatiel: Katie	
Number of e-textile switches	One	
Crafting methods used	Appliqué	
Type of sound used	Sound recordings of Katie	

Lovely Noisy Katie represented Louise's cockatiel Katie. Louise joined the group late, and was therefore limited in time and decided to focus on one switch. This worked well, as Louise wanted to make a switch covering that looked and felt like Katie. In particular, Louise wanted to be able to stroke Katie (she will not let herself be stroked in real life). Louise wanted a fluffy fabric to represent Katie as a soft feathered creature, as well as additional fluffy fabric specifically for stroking. Both a light fluffy grey and a dark fluffy grey fabric were used for a cockatiel, mounted on a red fluffy ringlet fabric. The silky gold background fabric contrasted this. Using the textures of the fabric, and their appearance, Louise aimed to create an e-textile version of her bird, with the audio being an actual recording of Katie squawking.

Participant	Ewan
Object made	Wall hanging
Title of work	Rainforest Project
Theme of piece	Trip to the rainforest
Number of e-textile switches	Three
Crafting methods used	Appliqué, weaving
Type of sound used	Rainforest sounds found online



Rainforest Project reflected a trip to the rainforest when visiting Australia. For Ewan the first things he thought about were the sounds to use for his piece, with textiles being chosen along the way. He wanted his background to be the sky, requesting plain light blue fabric. For sounds he wanted to use insects, a tropical thunderstorm, and a tropical bird dawn chorus. For the bird switch he used plain blue cotton, adorning it with feathers and wooden leaves for birds and trees. Under this he placed his woven fabric to represent the earth. The ‘insect’ switch was covered with a green felt leaf. For the stem of the leaf, he twisted his e-textile wires together. The last switch played the sound of a tropical thunderstorm, represented by a white sequined fabric lightning bolt (mounted blue cotton to blend into the sky). His decisions on the fabric were based on the sounds chosen, a different approach from the other participants.

Participant	Jim	
Object made	Wall hanging	
Title of work	Thanks for the Memory Grandma	
Theme of piece	Crafting with his grandma and his friends	
Number of e-textile switches	Three	
Crafting methods used	Weaving, finger knitting, felting	
Type of sound used	Sound recording of his voice telling narrative	

Jim's piece, *Thanks for the Memory Grandma*, related to his grandparents and friends. The textiles he chose to use for his switches were linked to crafting experiences with his grandmother and were crafted by himself. The first, a finger-knitted red fabric, represented the London underground, his friends in Manchester, a friend in Glasgow who had passed away in an unfortunate manner, and his sister. The second was a woven fabric containing an array of different coloured, textured, and weighted yarns, with accompanying audio reflecting how he wished he had focused more when crafting with his grandmother. The third was a multicoloured felted fabric, triggering an audio of him explaining that when his grandma would try and teach him, he'd sneak off to the toilet instead. The background was a dark blue woven fabric, and he had spent a long time feeling it with his hands.

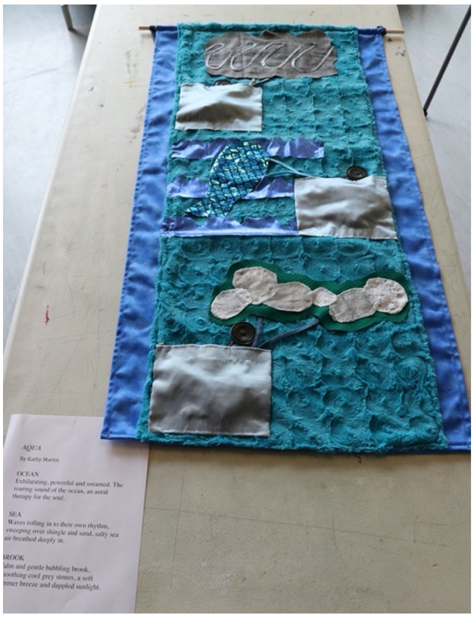
<table>
<tr><td>Participant</td><td>Uma</td><td rowspan="7"></td></tr>
<tr><td>Object made</td><td>Cushion</td></tr>
<tr><td>Title of work</td><td>Relaxez Vous</td></tr>
<tr><td>Theme of piece</td><td>A comfort piece for her</td></tr>
<tr><td>Number of e-textile switches</td><td>One</td></tr>
<tr><td>Crafting methods used</td><td>Appliqué, finger knitting</td></tr>
<tr><td>Type of sound used</td><td>Sound recording of her singing ‘You’ll never walk alone’</td></tr>
<tr><td colspan="3">For Relaxez Vous, Uma chose to make a comfort cushion for herself - something which she could hug when frustrated or upset, or in her words “uptight”. She chose the ultrasoft grey fabric as the covering for the pillow due to its softness, decorating it with the blue finger knitting she had made in one of the workshop sessions (to represent a cloud), and making a star as her switch cover. For this she wanted a shiny fabric, choosing sheeny blue. This comfort theme extended to her audio, with a recording of her singing “You’ll Never Walk Alone” - one of her favorite songs. Uma created a piece of work that was essentially a therapy object for herself, wanting to make something different from a wall hanging.</td></tr>
</table>

Participant	Sonja
Object made	Wall hanging
Title of work	Touch, Listen, and Use Your Imagination
Theme of piece	A comfort piece for her
Number of e-textile switches	Three
Crafting methods used	Appliqué, finger knitting, weaving
Type of sound used	Seagull/foghorn sounds found online, and sound recording of her voice sending an SOS.

Touch, Listen, and Use Your Imagination, was linked to the sea and Sonja's family's history of living by the river Rhine. For the background, silky grey/blue fabric was used as a sky at sea: blue but cloudy. Her first switch used white chunky finger knitting as a fishing net trailing from a ship, triggering a recording of an SOS message in her own voice. Switch two was a woven piece - with different blues - representing waves, triggering seagull sounds. Switch three was covered by a woven red, white, and black lighthouse, playing a foghorn sound. The composition was important, as were the detailed tactile elements. The ship was made of navy blue corduroy for the hull, brown felt for the cabin, beige canvas for the sail, and coarse twine for the mast, and Sonja added a small fabric German flag. She added additional tactile decorative elements: the ultra-soft grey fabric was used for seagulls, and brown felt and beige canvas were used for small boats.

Second Workshop Series (W2)

<table>
<tr><td>Participant</td><td>Jane</td><td rowspan="7"></td></tr>
<tr><td>Object made</td><td>Wall hanging</td></tr>
<tr><td>Title of work</td><td>My Achilles Healed</td></tr>
<tr><td>Theme of piece</td><td>Her journey to sight-loss diagnosis</td></tr>
<tr><td>Number of e-textile switches</td><td>One</td></tr>
<tr><td>Crafting methods used</td><td>Appliqué, printing,finger knitting,sewing</td></tr>
<tr><td>Type of sound used</td><td>Sound recording of lead researcher singing skipping song</td></tr>
<tr><td colspan="3">My Achilles Healed represents events leading to Jane’s sight loss diagnosis - ripping her achilles tendon whilst skipping, leading to not being able to drive, then finding out about her eyesight. Fluffy green fabric representing a grassy area was used as the background - decorated with a brown felt tree bearing multi-coloured and wooden leaves, and with feathers. A cord skipping rope connects two important elements and acts as a timeline: pink and clear mesh finger knitting depicts the cast Jane had to wear after the accident, and a photo of her car printed onto fabric covers the e-textile switch. The audio was the lead researcher singing a skipping song requested by Jane to remember the workshops: “Salt, vinegar, mustard, pepper, wee!”. A handmade God’s Eye, created by Jane and symbolising protection, was placed under the skipping rope.</td></tr>
</table>

<table>
<tr><td>Participant</td><td>Kelly</td><td rowspan="7">
</td></tr>
<tr><td>Object made</td><td>Wall hanging</td></tr>
<tr><td>Title of work</td><td>Aqua</td></tr>
<tr><td>Theme of piece</td><td>Her love of water</td></tr>
<tr><td>Number of e-textile switches</td><td>Three</td></tr>
<tr><td>Crafting methods used</td><td>Appliqué</td></tr>
<tr><td>Type of sound used</td><td>Water-related sounds from a personal CD of Kelly’s</td></tr>
<tr><td colspan="3">Aqua reflects Kelly’s love of water - something she finds relaxing. Her e-textile switches triggered different water noises to reflect a brook, the sea, and the ocean, all recorded at home from a CD she has. After much planning of the composition, she settled on the ocean scene at the top - in the form of a grey tweed with a shiny tape yarn on top to represent a wave. Further down the fabric was a shiny blue and green plastic fabric in the shape of a fish, with a sheeny blue fabric in strips underneath, triggering the sea. At the bottom of the work was a ‘brook’, with grey velour fabric ‘stones’ placed on top of ‘moss’ green felt. Her background was in two layers: the bottom one a smooth blue fabric and the top a fluffy teal. Kelly chose to distribute the pockets for the re-recordable devices around the composition, using a contrasting grey satin fabric.</td></tr>
</table>

Participant	Pam	
Object made	Cushion	
Title of work	The Electric Light Orchestra	
Theme of piece	Her favourite band	
Number of e-textile switches	Three	
Crafting methods used	Appliqué	
Type of sound used	Sound recording of ELO songs played by Pam on her tape machine	

Pam's work, *The Electric Light Orchestra,* linked to her favourite band (ELO) and a concert she attended at Wembley Stadium. All her e-textile switches were weather symbols, triggering recordings of ELO songs about weather. The first, made from yellow and orange felt and in a sun shape, played *'Mr Blue Sky'*; the second, a lightning bolt made from white foam played *'Summer and Lightning'*; the third, a cloud made from fluffy light grey fabric with ultra-soft grey fabric raindrops underneath, played *'Standin' In The Rain'*. These attached to a cushion cover background - made from blue denim and denim pockets provided by Pam, reflecting something one might wear to a concert. The work was bright and bold, making both a tactile and visual impact. Colour was important to Pam, holding the fabrics up close to her face as she decided what to use.

Participant	Verity	
Object made	Cushion	
Title of work	Nature Calls	
Theme of piece	Her love of nature	
Number of e-textile switches	Three	
Crafting methods used	Weaving, 3D weaving	
Type of sound used	Sound recordings of birds in her garden and online water and sheep sounds	

Nature Calls reflected Verity's love of nature, with a reference to collecting wool from a fence, which she then leaves for the birds in her garden to use in their nests. The cushion cover background was made from dark blue corduroy. Her three switches are covered by different woven covers. The first - mixed in texture and appearance - used soft thick purple yarn, bamboo fibre, and army green tube yarn, and triggered audio of a sheep. The second is a 3D woven 'bird's nest' made of yellow seagrass cord, a soft fibre, and orange, beige, and black raffia. The next is mounted on a flat woven layer made of burgundy tube yarn, beige raffia, and a coarse fibre. The switch triggered birds chirping, recorded from her garden. Switch three, covered with a weave resembling water, was made from strips of multicoloured fabric with a flash of turquoise; it triggered a stream sound.

Participant	Jacob	
Object made	Tabletop piece	
Title of work	Tambourine Taster and Bongo Brilliance: A Drummer's Delight	
Theme of piece	His love for drums	
Number of e-textile switches	Three	
Crafting methods used	Appliqué	
Type of sound used	Sound recordings of Jacob playing a drum, maracas, and reciting a poem	

Tambourine Taster and Bongo Brilliance: A Drummer's Delight, reflected Jacob's love for drums and poetry. A round, plain black cotton background representing a drum was adorned with his poem 'The Beat of My Art' printed on pieces of paper, and multiple circles representing a drum kit. These were made from a lightly patterned blue cotton, brown felt, a silky gold fabric, dark blue corduroy, thick and fine netting, white sequined fabric, and sheeny blue fabric. A dark blue corduroy switch played audio of Jacob reciting his poem. Switch two was covered by thick grey netting and triggered a recording of him playing the maracas. Switch three, covered by sheeny blue fabric - with two small teal seagrass drumsticks - triggered a recording of him playing a drum.

Participant	Patricia	
Object made	Fabric shopping bag	
Title of work	Handy Bag	
Theme of piece	A comedy piece to ask people for help	
Number of e-textile switches	One	
Crafting methods used	Appliqué, sewing	
Type of sound used	Sound recording of Patricia saying "'Ere, give us a hand, this bag's heavy!"	
Patricia made a comedy shopping bag she named *Handy Bag*. When the switch was pressed, a recording of Patricia saying: *"Ere, give us a hand, this bag's heavy!"* was played. She likes to make 'useful' things (and also turned multiple finger-knitted pieces made in the workshops into headbands, which she showcased too). Using a sewing machine, she sewed together pieces of canvas to make a tote bag. On top she sewed two brown suede hand shapes overlapping - cut out by her . One of these contained an e-textile switch playing her audio.		

Table 5.1: Art works produced in the e-textile workshops, including the piece names, images, their meaning, crafting techniques, and technical details.

All of the work produced was personal to its maker, in terms of the subject matter, the crafting techniques chosen, and the types of audio recorded by the participants. For example, the audio ranged from the makers' own voices or self-made sounds, to sounds they recorded (such as birdsong), to sounds they chose carefully from an online database. The following sections unpick the evidence associated with the criteria for success that align with the research questions.

5.2.2 Criteria for success

5.2.2.1 Completed a project

Of the 18 participants who began either the first or second workshop series, 13 completed a project. For a free workshop series for participants who could be classed as being ‘at risk’ or ‘vulnerable’, a completion rate of 73% was good. The reasons for participants not returning came down to health issues, booked holidays, or just general busyness - not a lack of interest.

5.2.2.2 Evidence of creative expression

Across both sets of workshops, all of the 13 completing participants created interactive e-textile art pieces which a) were of their own design; b) contained their own design choices regarding materials and techniques; c) expressed an idea personal to them. How far each participant wanted to take the work varied. Some were extremely satisfied with designing and making three e-textile switches and left the background plain. Others chose to extend the design onto the background, incorporating additional design elements that helped them to express not only their creativity but also the themes and narrative of the work.

5.2.2.3 Ownership and agency

Throughout the workshops, participants showed evidence of ownership and agency - not just over their final pieces but also with regard to the making process: they made strong decisions about the design elements, following their own opinions and beliefs, and positively discarding our advice when appropriate. They asserted what needed to happen next when working on technical aspects of the work, following a step-by-step structure in their minds. They connected the pieces to strong personal associations or narratives, representing them through the creative process. Several of them also exceeded the brief, choosing to work with a 3D structure (a bag or a cushion), rather than a wall hanging.

The participants also owned the work ‘physically’ after the workshops, taking their pieces home with them and being free to decide what should be done with them. Some of the participants proudly displayed them in their homes; others gave them away to friends or family who had shown great interest in what had been produced. That these artefacts did not belong to the researchers, but rather to those who had made them, was an important part of the process.

5.2.2.4 Expression of a personal story

Not only did participants express a personal story through their individual pieces, they also engaged with both e-textiles and textiles as a medium for storytelling. They embraced working with the e-textile circuits. They experimented with the re-recordable device, assessing what control they could have using a recording switch and soft circuit switch. When prototyping with the devices, they experimented with saying different things into the microphone, and played with the soft circuit switch trigger, training themselves in how to use it effectively. When recording the final audio for the work, they listened to each recording carefully, and decided critically whether it assisted effectively in the portrayal of their narrative.

Along with this critical engagement with the circuit boards and technology, every participant spent time feeling fabrics, and trying out different ‘swatches’. If they felt that a circuit fabric was not expressing what they wanted it to, they changed it. This way of thinking carefully about the textiles in order to express an association or narrative element was explored from the beginning of the workshops, starting with swatches of fabric provided by the lead researcher. From talking about what initial associations popped into their minds when handling fabrics, the participants soon engaged in story-telling activities with the fabric, drafting a narrative to share based on some fabrics given to them. This development in tactile narratives assisted with the development of their own work.

The first group struggled slightly more than the second one in articulating their associations with fabric swatches provided by the research team, but they still engaged fully in the process.

5.2.2.5 Ability to build soft circuits

The participants engaged with the e-textiles and circuit building in a way which was both patient and courageous. They threw themselves into the challenge of playing with electronics - most of them, if not all having only experienced this years before whilst at school. This began with making a simple circuit using an LED, two crocodile clips and a coin cell battery, with some assistance from the volunteers only as needed. The participants were able to gain practical experience of how a circuit can be built. Having already played a bit with some simple electronics helped to make using the re-recordable devices less intimidating. Each participant spent some time experimenting with the circuit boards, recording sounds and playing them back to themselves - laughing or looking extremely focused as they did so. As the research team spent time ensuring that everyone understood how the boards worked, they saw examples of participants repeating the recording and playback action, holding the appropriate switches for doing this in each hand.

The next step was to begin the process of making circuits themselves: constructing e-textile soft wires using conductive thread and tubular yarn; adding connections to these; making a soft circuit switch to which to attach the wires; and attaching all of this to the hacked re-recordable device provided by the research team. After creating all the elements for one soft circuit switch and putting them together, each participant was invited to test out what they had made, practising recording a sound, and then triggering it. When they moved onto creating their next circuit, participants were able to repeat the construction without direct instruction, pre-empting what had to be done. Some participants needed a little help with this, but others firmly took the lead.

5.2.2.6 Understanding soft circuits and ability to troubleshoot

Using the off-the-shelf re-recordable device seemed to make it a bit easier for the participants to grasp what they were working with, than it might have been with a more complicated board, such as a microcontroller. Karen instantly described the re-recordable devices as being like the ones found in greetings cards, saying *"I could tell it was a singing one 'cause you could feel it!"*.
As well as building their electronics, the participants were able to help each other debug them. If a soft circuit switch was not functioning, some of the participants guessed that it was stuck together; this problem had been flagged to the groups at some point during the making process. There were instances of participants helping each other, and even reminding one of the research team how to debug a circuit, quoting back to her a 'helpful' saying that she had used previously in encouraging them not to worry if circuits didn't work: *"Error is opportunity!"*. This brought some humour to the process, which otherwise could be quite frustrating at times.

There were examples of participants seeming to shy away from the technology. Participants demonstrated that they could test circuits, and could discuss them with other participants, but they were more reserved when asked by the researchers to explain how they worked. The research team did not think this was a matter of a lack of understanding, but of social unease. Alternatively, they genuinely might have forgotten; there is a lot to learn in an e-textile workshop, for anyone who is a beginner, so it would be feasible that for these participants some information might have slipped along the way.

5.2.2.7 Engaged in the group

Many examples were observed of how the participants engaged in the group environment - from taking part in conversations with other participants over a cup of tea, to advising each other on how they might take their design forward, to proudly presenting to each other what they had made at the end of the workshops.

Some people chose to chat as they created their pieces, whilst others worked in silence. Whatever each person chose was accepted by the rest of the group. Many participants in each workshop series had met other attendees previously, but there were new faces as well.

When asked if they would like to share a personal textile artefact with the group, each person considered carefully what to show, telling its personal story when invited to do so. In return, everyone in the room listened with care, asking questions, expressing empathy, or making jokes as appropriate. The same situation was almost repeated when participants unveiled their final pieces, showing group support and praise for each person.

During the sessions, participants were asked to collaborate in groups on some activities, for example, discussing the associations they had with fabric swatches. As this happened early in the sessions, it seemed to assist with participants getting to know each other, also helping to share creative thinking between participants.

Some of the participants, particularly those in the first workshop series, would also see each other between the workshops for events organised by Bucks Vision. This included walks, playing ‘blind’ tennis or taking part in evening activities such as a quiz or a dinner out. It was always interesting to hear their conversations at the workshops about these outings, and it encouraged other participants to perhaps get more involved in the regular social activities too.

Interestingly, one participant from the first group did comment after the workshops that she would have preferred to have undertaken her making individually, not in a group setting. She found the other people distracting sometimes. However, from observations during the workshops she did not seem unhappy in the environment, and she engaged in conversation, so the environment did not hold her back despite her preference. Some discomfort due to a recent hip break had affected her enjoyment of the sessions, so this might have contributed to her preference. She also was by far the most determined participant across all the groups, stating clearly that she wanted to win first prize for the charity’s annual art competition with the piece she created. In contrast, two of the participants in the same group stated that the social aspect of the workshops was something that they had very much enjoyed, and was one of the main reasons to attend: it was something to look forward to.

5.3 Returning to the research questions

The analysis of the data was iterative; the lead researcher watched the video data to explore relevant examples and identify themes to help answer the questions. The observations were discussed within the team of researchers. Handwritten notes, audio and photographs were re-explored to assist with finding relevant evidence. The following sections present the findings from the workshops that relate to the research questions.

5.3.1 What emotional associations do users have with textures and appearance of materials which can be used in e-textile interaction?

In exploring this question, the following elements will be discussed:

- What were the participants' initial reactions to fabrics?
- How did the participants tell stories with fabric swatches?
- Are there common associations with textures and textiles that were observed within the workshops?
- How did participants use specific fabrics for interaction design? (i.e., how did they want users to interact with objects based on fabrics and touch.)

Whilst 'interaction design' was not explicitly discussed with participants in those precise terms, they were encouraged to reflect on what material choices could be used to cover their e-textile switches so as to evoke a certain gesture in a user when triggering it. In this way, interaction design was communicated to them as something to consider.

The fabrics presented to participants were diverse in texture, visual appearance, and weight (see Figure 5.1). These were initially presented to participants in the form of 13 small swatches for exploring through handling; the participants were asked to discuss what thoughts or associations were prompted by the swatches. When working on their own pieces, the participants were invited to walk over to a table filled with materials, to give them the chance to explore the materials on their own terms and choose from them for their own pieces of work.

Figure 5.1: Left: Participants exploring fabric swatches on the table in front of them; Right: Participants exploring different yarns and fibres on the 'materials table' in the

workshop space.

The fabrics, yarns, and craft materials brought to the workshop sessions by the research team, or which were added by participants during the sessions, can be viewed in Table C.4 in Appendix C.

5.3.1.1 What were the participants' initial reactions to fabrics?

As discussed in Chapter 4, some time was spent in the first workshop session for both groups handling a variety of fabrics. Participants were invited to discuss these fabrics within groups of two or three. They were asked *"What do these make you think of?"* or *"What associations do you have with these fabrics when you feel them?"*. Table 5.2 below shows the associations made with the fabrics.

Type of Fabric	Association	Said by whom
Black and red fluffy ladybird print	Fake fur Ladybird Dressing gown Teddy bear	Hailey W1
	Fluffy ladybird	Kat W1
	Wool	Ewan W1
	The garden: greenery and ladybirds	Uma W1
White and black fluffy cow print	Milton Keynes concrete cows	Lorna (volunteer) W2
Brown felt	Fox kit owned by participant's own kids (linked with orange floppy)	Kelly W2
Yellow felt	Fabric participant uses to dry her mobility walker	Sonja W1
Orange floppy	Fox kit owned by participant's own kids (linked with brown felt)	Kelly W2
Grey, white and pink tweed	'Like' tweed	Ewan W1

	Participant's own tweed jacket	Jim W1
Dark blue woven	Base for cutlery tray Trees	Jim W1
	Suit worn by her own mother in 1960s	Patricia W2
Black velour	Cat	Karen W1
Blue woven plastic	Shopping bag	Hailey W1 Patricia W2
	Snakeskin	Ewan W1
	Plastic	Karen W1
Blue chiffon	Dress for day wear	Sonja W1
	Surgical dressings	Jim W1
White sequin	Participant's daughter's sewing factory	Patricia W2
	Christmas	Uma W1
Red ultra-soft	Pajamas	Hailey W1
	Teddy bear	Kat W1
Grey ultra-soft	Blanket	Hailey W1
Grey, green and dupplin white check	School uniform	Kelly W2 and Patricia W2
Blue and white gingham check	Napkin	Ewan W1
	Too thin	Jim W1
Thick green fabric with containing embroidery	Jute	Hailey W1
	Bridesmaid dresses	Kat W1

Grey denim	Participant’s own legs	Hailey W1
Black lycra	Silky pajamas	Ewan W1
Transparent thin packing foam	Polystyrene	Hailey W1
Purple tulle netting	Bridal veil	Kat W1
	Net curtain	Hailey W1 Sonja W1
	Leaves in rainforest	Ewan (W1)

Table 5.2: Participant’s associations with fabric in the initial fabric handling activity.

The initial associations with the fabrics emerged in conversations - both through the activity during which they were discussing associations and through the narrative activity. During the latter, they had more time to think about what they felt each fabric could represent, being asked to tell a story with them.

One observation was that if someone happened to mention what the fabric was called (tweed, cotton, felt etc.), then the participants would tend to fixate on that term, and make associations with how that fabric is often used, instead of with the texture (e.g., tweed - a man’s jacket; satin - a formal gown). Once the researchers noticed this, they asked participants to avoid naming fabrics, and to refer to them by description instead.

The participants were interested in the fabric samples, and discussing these facilitated their progression in telling stories using fabrics. It encouraged them to talk about associations, and reflect on how touch can evoke memories and emotions. Many more fabrics were made available for participants to use than just those listed in Table 5.2. Typically, when designing their pieces, they *requested* fabrics (based on descriptions of texture and colour or pattern) they wanted for their work, starting with an idea or theme and then seeking appropriate materials. The only participant who used a fabric from one of the introductory activities was Karen, who used the black velour fabric she had associated with her cat for the cat switch in her final piece.

5.3.1.2 How did the participants tell stories with fabric swatches?

Across the two groups, participants expressed a wide range of narratives, both in the introductory activities, and in their personal art pieces. The introductory fabric handling and discussion activity prompted participants to talk about initial associations with the feel of the fabrics, as well as as personal associations (as discussed above). At the end of the first session, both groups were invited to bring in a personal fabric item to the second workshop to share its story with the group. The second group took part in an additional introductory activity in which they were asked to construct a story using a small selection of fabric swatches. Working in groups again gave them an opportunity to have dialogues about texture, and to discuss any ideas or creative thoughts that popped into their minds.

Sharing personal items

Not everyone participated in the show and tell, either because they were absent or forgot to bring something, but across the two-workshop series nine participants took part. Table 5.3 below describes these personal items and the narratives about what they represented.

Participant	Item	What it represents
First Workshop Series (W1)		
Hailey	Fluffy black and white cow print fabric.	Her daughter (as it was fabric from one of her daugher's onesie) and her love for cows.
Karen	Red rosette	An award rosette that Karen had won in a Bucks Vision competition. She could not remember if it was for a cake, a painting, or a papier-mâché object!
Ewan	Hat with 'Czech' on it and Czech flag.	His late father's hat, which also resembled one which his parents had bought for him as a child. He had once worn his childhood hat to school on a day that they were sent home early due to snow. His father's hat had the word 'Czech' on it with a Czech flag, which Ewan had not realised.
Jim	Green and white Celtic scarf.	Bought for him by a friend during a trip to Scotland - apparently to help Jim 'fit in'. He had worn it to a football game there and had kept it ever since. Unfortunately, soon after his trip, his friend's brother was murdered. The scarf helps Jim remember him.
Sonja	Black velour dress with roses.	A beloved dress which she wears every year on Valentine's day - her birthday.
Second Workshop Series (W2)		

Jane	A pink cast	Jane shared the object that would become a focal point for her final project: the pink cast that she wore after ripping her Achilles tendon whilst playing a skipping game with her family. This event was significant to her as it led to the diagnosis of her sight issues.
Pam	2 x glasses cases	Two glasses cases: one made from a rag carpet material bought in Bury St. Edmunds, the other a Harris Tweed bought on a trip to Scotland (and which she also associates with Andy Murray winning the US open). She can carry both in her bag and tell which one is which by feeling them.
Jacob	Barnet football shirt	His favourite football team, Barnet F.C..
Patricia	Decorated cavalry man shirts	Worn by her late husband. She had decorated them with various illustrations, including super heros, as something to show to local children and for them to have a bit of fun wearing.

Table 5.3: Personal fabric items shared by participants.

The items shared by participants were diverse both physically and in terms of their meaning. Some were items they had bought themselves, some were passed to them by another person; some of the objects were linked to another person, but others were just about the participant.

The personal items and stories shared by the participants set them up well for thinking about how to use fabrics to support a narrative. It was a useful activity for encouraging them to speak about themselves, and something important to them. Passing the items around also encouraged tactile exploration in the groups.

Swatch storytelling activity

The participants in the second workshop series were given a selection of fabric swatches with which they were invited to create a story. These selections of swatches were all different, to ensure that groups did not influence each other. Each selection contained a variety of different textures, weights, and colours. The participants worked in pairs for the activity and were asked to use the fabric swatches to create a story, based on the fabric texture (and appearance, if they liked), and use them for whatever aspect they pleased, whether as objects, characters, events, emotions, etc. The swatch selections and stories are summarised in Table 5.4.

Group members	Fabrics given	Narrative constructed

Pam and Jacob	Faux lambskin Blue suede Silky grey/blue fabric Pink tulle netting Yellow felt Silky blue fabric Brown suede Black felt	Using some of their fabrics, Pam and Jacob constructed a narrative about a sheep called Esmeralda (represented by the faux lambskin) who does not want to be a sheep but a ballerina. She wants a posh outfit for dancing but can only afford some pink netting (uses the pink tulle) to make her tutu out of. She goes to an audition and meets a young man called Igor in a flashy 'nasty' suit (uses the silky grey/blue fabric) who charms her but then ends up not treating her well. Igor ends up being a wolf in sheep's clothing (uses the blue suede here) and Esmerelda does not get the part she wanted.
Jane and Kelly	A teal stretchy fabric Green stretchy fabric Pink tulle netting Purple tulle netting White lace A yellow sisal sheet Sheeny blue fabric Red velour Grey lightweight fabric	Jane and Kelly began by discussing their fabrics and relating them to films, then settling on some which to them related to Miss Havisham from *Great Expectations*. The first was the yellow sisal sheet, which reminded them of cobwebs and the characters' abandoned wedding decorations; the white lace made them think of a wedding dress; and the pink and purple tulle netting resembled a veil. Rather than telling their version of *Great Expectations*, the participants described their associations with the fabrics and their reasons for the associations.
Patricia (and her daughter)	Grey and black striped silky fabric Blue and white dish cloth Transparent netting	Patricia wanted to tell a story about attending the Ascot races. The day would start with her cleaning some surfaces in the kitchen with a blue and white dish cloth, and having a bit of a polish with a nice duster (the grey and black striped silky fabric). Then, if she were to attend the races she would need a nice hat. She decided this would be constructed out of the green foam (the colour

	Green foam Yellow felt Fluffy pink fabric Grey felt Ultra-soft red fabric Course burgundy fabric	wasn't right she said, but the texture was *"lovely"*), and from talking to her daughter she realised that this could be molded into the correct shape through heat. She described how it would be decorated with a combination of the yellow felt transparent netting to make it into a rose - the hat which would be covered with these.

Table 5.4 Selection of materials given to participants, and stories they constructed using these.

Table 5.5 below sets out the fabrics selected and how they were used in the story construction. Each group was critical in their choices, not feeling that they *had* to use every fabric that they were given, and being thoughtful about their response to the brief.

Type of Fabric	Association	Said by whom
Faux lambskin	Sheep	Pam W2 and Jacob W2
Yellow felt	Rose (combined with pink tulle netting) to go on hat for Ascot	Patricia and daughter (volunteer) W2
Yellow sisal sheet	Miss Havisham from Great Expectations	Jane W2 and Kelly W2
White lace	Veil	Jane W2 and Kelly W2
Blue suede	Wolf in sheep's clothing	Pam W2 and Jacob W2
Blue and white dishcloth	Participant cleaning surfaces	Patricia and daughter (volunteer) W2
Grey and black striped silky	Participant doing her own dusting	Patricia and daughter (volunteer) W2
Silky grey/blue	Man in nasty suit	Pam W2 and Jacob W2
Pink tulle netting	Tutu for dancing	Pam W2 and Jacob W2
	Veil	Jane W2 and Kelly W2

Purple tulle netting	Veil	Jane W2 and Kelly W2
Transparent tulle netting	Bridal veil Rose (combined with yellow felt) to go on hat for Ascot	Patricia and daughter (volunteer) W2
Green foam	Base for hat for participant to wear for Ascot	Patricia and daughter (volunteer) W2

Table 5.5: Different fabric swatches and their use in the storytelling activity.

Final art pieces

Table C.5 in Appendix C lists the fabrics used by each participant within their final pieces. This includes:

1) What the fabric was;
2) How the fabric was used;
3) What it represented;
4) If used for an e-textile soft circuit switch, what audio accompanied the switch.

The fabrics are organised by feel rather than appearance.

Table C.5 in Appendix C lists the textiles or other materials used by participants for their art pieces, what element of the composition they were used for, what they were used to represent, and, for switches, what audio they triggered. The table shows that participants' material choices varied widely. They used pre-made fabrics, textiles they created themselves, and also some unconventional materials such as paper. Participants used a wide range of fabrics within their pieces; for example, Jacob's piece used eight different types of fabric to represent the drums and cymbals. Participants' care in their choices included the background fabric, and each chose a different fabric.

Some materials were used to represent different things. Five different people used the 'fluffy' fabrics in some way, with Hailey and Louise using multiple fluffy fabrics. All five participants used these fabrics for different purposes, to represent cows, a daughter, a cockatiel, a cloud, a watery background, and a grassy background. This is a diverse range of subject matter for fabrics which feel very similar. Louise in particular chose the fluffy fabric because it suited how she wanted to interact with her wall hanging - by stroking - and so she chose the fluffy fabrics over real feathers (which were an option on the materials table) to represent her cockatiel.

Most (9) participants used the 'soft' fabrics; again their associations varied: an owl, seagulls, a comfort cushion, rain drops, a plant, stones, a trawler cabin, a hull on a regatta boat, a tree trunk, part of a drum kit, the sun, a flag on a trawler, flags on a regatta boat, a bag (handmade), a cat, a horse, a hand, a love of water, and the ocean. There were some parallels among the themes, such as representing animals; nevertheless, these are diverse associations. Some of the associations did not match their subject matter with respect to texture, but the choice worked visually. For Kelly, how the piece looked was important, and she focused primarily on appearance rather than feel.

Another interesting observation from the table is how similar subject matter may be represented with different textured materials. An example is grass backgrounds: Jane used fluffy green fabric, whereas Karen used a plain green cotton. Nature in general was represented using different textured materials, with attention to the colours. Ewan used his woven fabric, a piece of green felt and wooden leaves to represent plants and trees; Jane used brown felt and a little wooden notch to represent a tree and a hole in it. This was adorned with multicoloured leaf skeletons and wooden leaves. The audio triggered by the soft circuit switches was also varied, with recordings including participants' own voices, voices of people who are important in their lives, recorded sounds such as a musical instrument, recordings from a CD/tape player, or from Freesound.org (a free file sharing sound website) carefully chosen by the participant. The use of sound gave the participants an opportunity to give their work not only another sensory output for people to engage with, but it also helped to communicate their stories. The switches combined evocative tactility with interactivity, giving purpose to the tactile interaction with a clear output.

5.3.1.3 Are there common associations with textures and textiles that were observed within the workshops?

The data was examined to see if there were any patterns in the associations people made with fabrics, or in what the fabrics were used to represent. Table 5.5 demonstrates that, although there are certainly some repeated patterns in how participants linked fabrics and associations, there are also many different associations. Associations with certain materials are very literal. For example, in 'everyday use', the tulle netting fabric would most likely be used to make a veil or tutu. The woven plastic fabric is used for making plastic shopping bags, another association highlighted. In contrast, other associations are more metaphorical; they did not necessarily correspond directly to the use of that fabric experienced elsewhere, but rather were used to suggest attributes of something in the design. These included plant associations, such as: the yellow felt as a rose, the dark blue woven fabric as trees, and the purple tulle as leaves in a rainforest. Sometimes the association was based on a particular characteristic, ignoring others; for example, the ladybird print fabric reminded participants of ladybirds - based on its appearance - but the fluffy feel would be nothing like a ladybird.

Looking at Table C.5 in Appendix C to consider how participants used the materials for their final work, there were more differences than similarities. There were two types of similar use: consistent use by a given maker within a design (4 instances), and similar narrative use by different participants, that is, using the fabric to represent something similar in their story/art piece (2 instances). Table 5.6 below summarises the similarities.

Form of 'similarity'	Fabric	Participant	Expressive role in the design	Location on the art piece
Consistent repeated use within a piece	Light blue cotton	Ewan W1	Sky	Background Switch cover – to blend with the background
Consistent repeated use within a piece	Brown felt	Sonja W1	The hull or a cabin on boats	Background
Consistent repeated use within a piece	Beige canvas	Sonja W1	Triangular sails on boats	Background
Consistent repeated use within a piece	Netting fabrics - one thick and one finer	Jacob W2	Drum kit	background and switch
Similar narrative use by different participants	Green felt	Ewan W1 Kelly W2	Greenery: Leaf Moss	Switch
Similar narrative use by different participants	Wooden leaves	Ewan W1 Jane W2	Leaves in rainforest Leaves on tree	Background

Table 5.6: 'Similar' uses of a given material in the art pieces.

The contrasts in use are summarised in Table 5.7 below.

Material	Used as
Fluffy light grey fabric	Part of a cockatiel shape (Louse W1) - switch covering; A cloud (Pam W2)

Black cotton	A square to represent one son (Hailey W1) - switch covering; Background fabric (Jacob W2) - switch covering
Ultra-soft grey fabric	A square to represent an 'owl' (Karen W1) - switch covering; A seagull shape (Sonja W1)
Brown felt	Boats (Sonja W1); Tree trunk (Jane W2); Part of a drum kit (Jacob W2)
Beige canvas	Flags on a boat (Sonja W1); A shopping bag (Patricia W2)
Brown suede	The hull of some boats (Sonja W1); A square to represent a 'horse' (Karen W1) - switch covering; Two hand shapes (Patricia W2) - one covering a switch;
Silky gold fabric	Background (Louise W1); Circle as part of a drum kit (Jacob W2)
Silky grey/blue fabric	Background representing the sky and sea (Sonja W1); Pockets for the electronics (Kelly W2)
White sequined fabric	A lightning bolt (Ewan W1) - switch covering; Circle as part of a drum kit (Jacob W2)
Sheeny blue fabric	A triangle to represent one son (Hailey W1) - switch covering; A star (Uma W1) - switch covering; Circle as part of a drum kit (Jacob W2); Long rectangles under a fish switch (Kelly W2)

Hand woven pieces	Rainforest (Ewan W1) - switch covering; Crafting with his grandmother (Jim W1) switch covering; Waves (Sonja W1) - switch covering; Lighthouse (Sonja W1) - switch covering; Water (Verity W2) - switch covering; Sheep (Verity W2) - switch covering; 3D Bird's nest (Verity (W2) - switch covering
Finger knitting	The London underground, his friends in Manchester, a friend in Glasgow, his sister (Jim W2) - Switch covering; Cloud (Uma W1); Fishing net (Sonja W1) - switch covering; Cast (Jane W1)

Table 5.7: Contrasting uses of a given material.

Table 5.7 shows that there were more differences in use of the fabric and the associations than there were similarities. This demonstrates an independence in the participants' creative thinking and shows that the same textiles can often represent different things for different people. The dialogues between some of the participants around their contrasting thoughts was insightful and demonstrated a sense of opinion and creativity. For example, when Kat said that the green fabric represented a bridesmaid dress, Uma commented that she would never use the green fabric for that.

That there were *some* parallels between the association and use of some fabrics is suggestive. The research team chose to make these activities open - not imposing which fabrics could represent what. However, it appears that key qualities of materials that are strongly salient and are associated with common experiences (such as the distinctive pattern of ladybirds) can be built on for expressing a narrative. Participants also consistently used a given fabric to establish continuity within a piece of work, such as Sonja using the same fabrics for her boats. This suggests that designers could establish a visual and tactile language within a piece. If that consistent use is carried into multiple pieces, that visual and tactile language could be shared, perhaps even establishing a convention (as is suggested by the common reaction to fabrics when they are named, such as 'corduroy' and 'men's trousers').

5.3.1.4 How did participants use specific fabrics for interaction design?

All of the participants used both the tactile and visual qualities of fabrics to tell their stories, each person choosing how much or how little material they wanted to incorporate into their work, but everyone including coverings for their e-textile switches which related to the theme of the work in some way.

Some fabrics were also used specifically for the design of interaction - of how others would engage with the piece - although not many participants did this. Throughout the workshops, the participants had been encouraged to reflect on how they might want to touch their work, and in particular the e-textile switches. Of the 13 participants, Louise and Uma were the only ones who seemed to think of how the e-textile switch or entire object could be touched in a way that was different from just pressing it, and their fabric choices reflected this. Louise wanted to be able to stroke her 'Katie' switch, and thus chose a fabric which was soft and would feel nice when stroked. She had referred to how Katie would not let her stroke her in real life, but now she could. Uma wanted to create an object that would encourage her to hug it, choosing the ultra-soft grey fabric as a cushion cover for her pillow. The switch cover itself (a sheeny blue fabric) was not necessarily 'huggable', but she chose the ultra-soft fabric to cover the pillow in order to create a very huggable larger object.

5.3.1.5 Reflections on emotional associations users have with materials

It is clear that the participants had many emotional associations with the textures and appearance of materials - some that were used purely for discussion purposes, and others used within the design of their interactive e-textile piece. Some of these associations were used to communicate the subject matter, whilst others were used directly in interaction design, where the fabric was selected to evoke a certain interaction.

5.3.2 What objects, materials and techniques are practical for use by blind and visually impaired people making e-textiles?

In exploring this question, the following elements will be discussed:

- Were the participants able to realise their designs?
- What are the challenges and opportunities of e-textile making?
- Did the participants understand the soft circuits they made?
- Was the process challenging, and were the participants surprised about what they could do?

- Was the modular approach effective?

Table 5.8 below outlines the wide range of tools and techniques used by participants during the workshops; not everyone used all of the tools and techniques listed, but most participants used a wide range for their work.

Tool	Technique	For what	By whom
Wooden lateral loom	Weaving	Weaving small pieces of fabric from yarn/other materials	Everyone
Weaving comb	Batting weave down	To bat yarn down the loom to make space	Most participants
Scissors	Cutting	Yarn	Everyone
		Fabric	
		Thread	
Weaving needle	Threading conductive yarn through tape yarn	To make insulated, soft e-textile wires	Everyone
Fingers	Batting weave down	To bat yarn down the loom to make space	Most participants
	Finger knitting	To make a finger knitted sausage	Everyone
	Rubbing wet felt	To felt a fabric from fibre	Uma W1 Jim W1
Spray bottle	Spraying fibre for felting with water		
Bamboo mat	Rolling felt		
Press-stud pliers	Attaching press-studs to fabric wires e-textile switches	To make connections for e-textile circuits	Most participants

Glue	Gluing	Gluing together e-textile layers for switch	Hailey W1 Karen W1 Louise W1 Ewan W1 Jim W1 Uma W1 Sonja W1
		Gluing decorative elements onto the final pieces	
Fabric tape	Sticking	Sticking together e-textile layers for switch	All participants
		Sticking decorative elements onto the final pieces	
Sewing needle	Sewing	Sewing hem together on final work	Hailey W1 Jane W2
		Sewing together circle shape under cockatiel.	Louise W1
Sewing machine	Sewing	Sewing together tote bag and decorative elements/pockets onto it	Patricia W2
Printer	Printing	Printing image of car onto fabric	Jane W2
		Paper with printed poem on it	Jacob W2
Recording switch on soundboard	Recording audio	Recording sounds either made by participants or recorded from laptop onto re-recordable devices	Most participants

Table 5.8: Tools and techniques used by participants during the workshop series.

5.3.2.1 Were the participants able to realise their designs?

Overall, all of the participants who completed the workshops also realised their designs and were satisfied with their art pieces.

Some people required some assistance with construction, such as cutting fabric, or connecting the conductive thread to the press-studs, but this was achieved on their terms. The participants made the decisions and directed any help; the researchers provided helping hands as directed.

Sometimes, participants met construction challenges by adapting their designs. For example, Karen wanted to do her own cutting, but this meant that she had to choose between accepting the simpler shapes that she was able to cut herself, or accepting assistance to create animal shapes. She chose to cut out her own squares and seemed happy with this.

Participants readily appropriated the re-recordable devices in order to capture their chosen sounds. Some people took their soundboards home to re-record their sounds, or to capture something local to them. Verity recorded the birds at the end of her garden, happily commenting: *"I loved the idea of recording my own sounds to incorporate in the finished piece and took some devices home to experiment with."* Hailey also took the soundboard home to record her children's voices. Other participants would sit with the lead researcher and record audio, spending time going back and forth through files over Freesound.org until they found something with which they were happy.

5.3.2.2 What are the challenges and opportunities of e-textile making?

One of the main challenges for many of the participants was having the self-confidence to try the techniques and tools used in the workshops. However, with some encouragement and a bit of personal assistance at their request, their confidence grew. The workshops gave them an opportunity to try out new things and to practice existing knowledge. Some tools and techniques that particularly stood out are discussed below: weaving, finger knitting, using scissors, sticking, gluing and felting, and sewing.

Weaving on wooden lateral looms

None of the participants had recent prior experience with weaving, some perhaps having learned to weave as children but having since forgotten. Once settled into the activity, the participants seemed focused on the task, perhaps even finding it relaxing.

Ewan found weaving particularly challenging at first, fluttering his fingers about when feeling his way down the warp (a gesture that had been observed with other things too) and finding himself becoming a bit confused at times. One of the researchers spent some time with him, encouraging him to slow down and really feel what he was doing, 'looking' with his hands. She showed him how to tie the yarn to the end of the loom, ensuring that it did not 'run away' as it was threaded through the warp. He needed some help with this at times, convinced that it was something he could not do, but managing to achieve it after all.

Sonja focused very intently on her weaving, choosing two different blues to reflect her love of the sea. She accidentally twisted her yarn at one point, but then embraced this technique when she realised it resembled a wave.

Verity questioned her own abilities throughout the weaving process but demonstrated much skill and creativity through the three pieces of fabric she wove and used as switch covers for her final work. She used the workshops as an opportunity to try out new techniques, in this case weaving back on herself through the warp; weaving a 3D structure; and experimenting with a wide range of textures, weights of yarn, and colours (see Figure 5.2). She was pleased with the end result.

Finger Knitting

Jim struggled at first with finger knitting - getting muddled as the yarn wrapped around his fingers. With some perseverance, counting as he proceeded with the technique, he was able to build up a rhythm, increasing his confidence.

Patricia did not see much value in the finger knitting technique - highlighting that there is not much that you can make with it. However, she soon realised that if the knits were long enough that they could be attached back on themselves and made into headbands, and she built up a collection of them. She proudly displayed these alongside her final project at the showcase.

Jane used finger knitting to make one of the focal elements of her final work: a representation of the cast that she had worn after her accident. The cast was pink, and so she chose a light pink yarn. However, this yarn being soft, she also chose a transparent mesh to incorporate into the knit. This cleverly replicated the rough texture of the cast.

Using scissors

For the first workshop series, the research team was advised by the volunteer coordinator not to plan any activity with scissors, as the participants would find using them a huge challenge without sight. However, it was important to include them as a tool in case participants felt confident to use them for cutting thread, yarn or fabric for their work.

Karen embraced the opportunity to use scissors, but felt much happier working with one of the researchers to use the scissors. The lead researcher held up fabric that Karen wanted to cut and then Karen would cut across it in order to make a square shape. In order to give encouragement, the lead researcher would say 'Cut, cut cut!', which became a joke between them.

Ewan was anxious about using scissors, but when a researcher assisted him, he surprised himself. The two worked out a system where the researcher would fold the fabric on the cut line and position it in Ewan's hand, so that he could slide the scissors along the fold while holding the fabric taught against the blade with the other hand, and thereby cut accurately along the fold line. Hence, both of the totally blind participants were able to use scissors, with some assistance.

Sonja had a vision for her piece being extremely decorative, and she added elements over the sessions. She did some cutting herself, but instructed one of the researchers to cut the more complicated shapes, such as seagulls.

Other participants such as Hailey, Louise and much of the second group went ahead with their own cutting, and could be left to it in order to ensure they felt in control.

Sticking

Sticking was chosen as an accessible alternative to sewing, with the idea that all fabric elements, and any switch making that required sticking, could be secured with glue or tape. Fabric glue was attempted for use but proved too messy - thereafter just the fabric tape was used. Fabric tape was not without challenges, and there were occasions when the participants got the tape tangled with their fingers, or stuck it to something else inadvertently, or found that it folded onto itself. Another challenge with tape was ensuring that a long enough length was cut for its intended use, but participants managed, sometimes with help and other times independently. An advantage of sticking elements down with tape was that it allowed switches or decorative elements to be moved if needed, giving flexibility of composition.

Gluing and felting

It was observed that some of the participants were 'tactile defensive', when participating in the messier hands-on making activities, especially gluing and felting. Only two participants (Jim and Uma, W1) had a chance to try felting, while the others were occupied making the e-textile switches. Felting was chosen because of its use of tactility in the act of rubbing the wet fibre and rolling it in a bamboo mat. However, Jim and Uma both looked quite uncomfortable with getting their hands wet and soapy, as they sprayed the fibre with soapy water and then rubbed it. The research team had heard of tactile defensiveness before with regard to visually impaired children, but had not reflected that some visually impaired adults might find messy activities unpleasant as well.

Sewing

It was assumed that participants would not want to sew during the workshops, because it is fiddly and often relies on sight. Provision was made for any sewing the preparation of the circuit board shields to be done in advance, and the background chosen by the participants were hemmed by the researchers. Of course, if any participants wanted to do their own sewing, it was made clear that they certainly should do it if they would like to.

Louise wanted to sew up the edges of the red fluffy ringlet fabric she was using as part of her 'Katie' button, so that it could be crafted into a circle. This was to frame the shape of Katie the cockatiel. She took this home between the workshops and did her sewing there. Similarly, Hailey and Jane also took their backgrounds home to sew them. We had explained that the background also needed something so that it could be hung up with a wooden rod. They were keen to do this themselves, having had years of experience of sewing.

For Patricia's work, some intricate sewing was needed to stitch her shopping bag together neatly and to applique the hands onto the bag. She therefore requested a sewing machine. The research team brought in a couple of machines, and she settled on a modern Pfaff. Patricia appeared to do this with ease, her sight not being a problem in the slightest (see Figure 5.2).

Figure 5.2: Left: Verity's 3D weaving; Right: Patricia's use of the sewing machine.

Recording sound on hacked re-recordable devices

The participants experimented with the process of recording sound within the first two sessions of the workshops. Initially they were given the re-recordable devices with the playback switch still in place. The participants were shown how they could hold the record switch in one hand and the playback switch on the other, so as not to get them mixed up when working with the soundboards (see Figure 5.3). Everyone became confident in this process, giving them some experience in how the device worked before connecting the hacked soundboard to their e-textile switches (see Figure 5.3).

Figure 5.3: Left: Participant practising recording and playing back audio; Right: Participant testing her e-textile switch, with soft tube yarn wires and re-recordable device connected.

When it was time to record their final sounds for the pieces, the participants were told that it was up to them how their sounds were made. They were welcome to use their voices; they could bring along objects to create sounds for recording; or they could browse a free sounds website (Freesound, 2020) to find a pre-recorded sound. In the first workshops, two participants chose to do a combination of making their own sounds and finding audio files on the website; four participants chose to make their own sounds; and one participant used all audio recordings. In the second series four participants made their own sounds, and two chose audio files from the website. These sounds were recorded in the storage cupboard of MK Gallery's project space because it was a quiet room (see Figure 5.4). This place became known jokingly as the 'sound studio'.

Figure 5.4: Participants using different methods to record sounds onto the re-recordable devices. Left: Playing the drums; Right: Choosing sound files from Freesound.

Some participants took the opportunity to showcase their musical talents. Jacob brought a drum and maracas to make music for two of his recordings, and recited a poem for the third. Uma chose to sing one of her favourite songs. Pam did not sing herself, but brought along a tape player with a tape of her favourite ELO songs for recording, choosing three for her piece.

Other participants wanted to find sounds that, to them, reflected 'real' life - whether it be a tropical thunderstorm or a foghorn. Ewan's work was all about a trip he had taken to the rainforest, and finding sounds that accurately resembled those he had heard on the trip was important to him. He sat with the lead researcher listening to various sound files for each of his switches before deciding which ones he wanted. Sonja was similar, having a clear idea in her mind of what the sounds should be, but taking some time to find the perfect ones.

Verity, Kelly, Hailey, and Louise all took the re-recordable devices home with them to record their sounds. Verity wanted to record birds in her garden; Kelly wanted to record water sounds from a CD she had; Hailey wanted to record each of her three children's voices; and Louise wanted to record her cockatiel squawking.

All the participants were in charge of the process of recording, whether they had the research team recording them performing, they recorded their sounds whilst navigating a sound website with the lead researcher, or they took the soundboards home. Most of them had never created a sound recording before, and so it was an exciting moment. It was also tangible, being able to connect up their circuit afterward and play their sounds back using their e-textile switch.

Although challenges were faced by all participants in some way, they took these on board and persevered with every aspect.

5.3.2.3 Did the participants understand the soft circuits they made?

It was essential that every technique that was introduced to the participants, and every moment of making, was accessible through touch. This included the technical crafting of the circuit making - building e-textile switches and creating soft wires using the conductive thread and tube yarn. Everyone engaged with the circuit building, and appeared to find it accessible on some level. Modularity had been designed into the process, to allow participants to gradually learn in a step-by-step way how to build their switches, and also to develop standalone components that could be moved around to develop the final design. A key part of this was using soft wires and press-studs for connections, meaning that a 'plug-and-play' approach was taken when assembling all the electronic components together.

The initial activity with the electronics of just 'playing' with the re-recordable devices helped the participants understand how they worked. It meant that, once their e-textile switches were made, the concept became easier to grasp. During the first workshops, playing with e-textile objects had also helped to demystify e-textiles.

Creating the soft e-textile tube yarn wires was a fun and accessible activity to begin the circuit making as a tangible way of working, providing insight into how circuits are made in general. The research team explained how, usually, connections on a circuit board would be made using soldering, but that using press-studs instead allowed us to work with textiles, as well as making something which could be changed if wished. After participants had created their first e-textile switch including press-studs, the next task was for them to connect it to the fabric wires using the press-studs. This instant connection, and triggering of audio, seemed to help with the participants' understanding of the circuitry.

Throughout the workshops, some participants anticipated what had to happen next in the circuit building process. Pam seemed a bit nervous about her switch after first making it, confessing that she had forgotten that this would trigger the board until it was demonstrated back to her. After triggering it a few times, she giggled and exclaimed "That's amazing!", seeming very pleased with the process. When making her next two e-textile switches, she now knew what to do, explaining the process step-by-step to the researcher with whom she was working. During the showcase - when presenting her work - she commented:

> *"I thought that the whole process...about making the buttons ourselves, with conductive fabric, threading the wires through… The whole project was really interesting and reminded you of all those circuits that you learned about in school and everything. So it was really interesting to re-learn that...I love the different textures; I've got felt for the sun and a kind of plasticky for the lightning and this furry cloud".*

Pam seemed to feel a sense of nostalgia regarding the circuit making, relating it back to school. She had understood the technical process of making the e-textile wires using the conductive thread and tube yarn, along with creating the e-textile switches from conductive fabric and discussing the different textured fabrics covering them. Her confidence in explaining this process to an audience during the showcase showed an understanding of the electronics - as well as her enjoyment of it.

Uma had spent much time playing with the re-recordable device in the third workshop. She held it up close to her eyes so as to see the small LED on it flashing. Uma had also embraced the e-textile soft wire making activity in the first workshop, spending a lot of time threading the conductive thread through the tubular yarn. When the time came for participants to demonstrate their work, Uma claimed that she did not know what to press in order for us to listen to her sound recording, but as she said this she pressed the e-textile switch. It might have been that she became self-conscious when asked to demonstrate her work; it would certainly be surprising if she had indeed forgotten how to trigger it, as she had demonstrated through the workshops that she knew how to play sound back.

This slight confusion around how to trigger the circuits was observed with some of the other participants too, Ewan trying to trigger his switch by tapping it multiple times. The switch would trigger the audio after just one press, so by doing this he ended up turning it on and then off again. This tapping could have been connected to another gesture that the research team had seen Ewan display - a sort of fluttering of his fingers when trying to orientate himself when first exploring an object. Karen was also observed making a similar gesture when first exploring an object.

Overall, although there was perhaps some confusion under pressure about triggering the circuits, the participants remembered the step-by-step process of how to build circuits as well as how to record their audio. It was the triggering which seemed to be the main issue. This might have been because the research team sometimes referred to the switches as e-textile or soft circuit 'buttons', perhaps suggesting that they should be pressed.

5.3.2.4 Was the process challenging, and were the participants surprised about what they could do?

Throughout the workshop series, the research team observed examples of the participants persevering with activities or elements of the making that they did not necessarily enjoy or that they found difficult. Nothing that they did was particularly easy, but they embraced the challenges throughout.

Sonja was initially very vocal about disliking the technical aspect of the project, stating *"I might not come back if it does not get more creative!"* But she persevered, creating all the parts for her circuit herself and using the pliers for the press-studs even though she found this physically challenging. Afterward she was clearly pleased with her own determination during the process: *"Yes, I mean, I like to finish what I've started!"*.

Participants also developed tactics for elements that they experienced as challenging. For example, Karen, while finger knitting, spoke to herself out loud: *"Over and under and over and under…"* as she wove the yarn around her fingers, to remember the order. She also found the fabric tape challenging, panicking often when it stuck to her hands. But she quickly began to take ownership of the situation, cutting strands with assistance from a volunteer, and sticking it to her background.

Pam visibly enjoyed learning how to build an e-textile circuit, and after successfully recording her first sound, a general recording of the room, she laughed with delight when she triggered it. She proceeded to grow in confidence, pre-empting each step for making the next switch before building it, demonstrating that she understood the process.

Jane and Verity both had questioned their own creative abilities throughout the workshops, but pushed themselves very far in terms of the creative elements of their work. They were both pleased with the end results. Jane's work was also very conceptual. In an email, she commented that she felt she had gotten her 'creative mojo' back after a particularly challenging time in her personal life.

Some participants used unexpected methods such as twisted weaving, 3D weaving, and printing on fabric, or requested tools that had been considered too challenging when planning the sessions (sewing needles and sewing machine).

The participants showed patience when things went amiss. This was mostly regarding the circuits, either with e-textile switches or the soft wires. In several cases, the two parts of conductive fabric within the switches had either been sewn or glued together, making a constant connection. Another error was when the holes cut in the packing foam (insulating the two pieces of conductive fabric) were too big, resulting in the switch self-triggering. Sometimes switches were too big and had to be cut down to fit under the fabric covering. As discussed before, there were also misunderstandings about how to interact with the switches.

As the weeks progressed, the participants' confidence grew in troubleshooting their own work. By the time of the showcases, there was still the occasional glitch, but the participants did not panic, often explaining it in a very patient and humorous way. Patricia, on demonstrating her work to the gathered crowd, explained: *"This circuit is a little bit like me. It's not very well connected, it's a bit lazy, and it's not working very well. But if I can get it to go…"* and touched her e-textile switch in different places to trigger it. She had established that touching it gently and slowly, trying different points was the way to approach it.

The interviews which were conducted with some of the participants after the workshop series also confirmed a sense of achievement that they felt in the making process, particularly the crafting. Both Karen and Ewan discussed how they liked the weaving. Ewan also mentioned that he felt he had achieved a certain level of technique needed for weaving, corroborating the observation by the research team that, week by week, his confidence had grown and his approach had become more focused.

5.3.2.5 Was the modular approach effective?

The use of the e-textile soft wires, in the form of the conductive thread insulated by tubular yarn and with press-stud connections, was certainly a success, allowing for circuits to be made in a way which could be undone easily, should elements of the work needed to be moved around.

Every stage could be approached separately, with step-by-step learning and scaffolding, so that the participants had the opportunity to try out techniques, and then demonstrate their knowledge by applying it. This worked well, as opposed to overwhelming them by showing *everything* at once, and then expecting them to execute it. The e-textile tube yarn wires and the e-textile switches were all made in separate sessions, giving the participants time to consolidate knowledge in each workshop session. An example was Pam's e-textile switch building. She anticipated each next step and clearly understood the construction process, repeating it back to the researchers as she created them.

Several of the participants made late changes to their work, including the addition of switches and re-recordable devices. Ewan initially wanted to use just two e-textile switches and sound boards for his wall hanging. But after making the initial two, he decided a third was needed; it represented the birdsong he had loved on his trip. Participants also engaged creatively with the modular approach - for example, Sonja adding an increasing number of decorative elements to her work, helping her make her creative vision a reality. On the day of the participant showcase, Sonja brought along a small German flag that she had handcrafted for her work, to be added to the mast of her trawler. Being increasingly able to add elements to the work over each session seemed to have emboldened her to make a last minute addition. Louise also brought along a last-minute addition: a plastic flower to be added to the cockatiel.

For participants who had a lot of decorative elements that they wished to add to their work, the modular approach also worked well, as it allowed them more time to decide on their compositions. Kelly and Jane particularly needed this freedom, as they had many embellishments on their final pieces. For Jane especially, it seemed important to get this right, in order to represent a series of events, in a linear order.

The modular approach perhaps also allowed the participants to tell their stories in more detail - with each interactive element of the work representing something more specific about the overall narrative. Each added element gave further richness to the work.

5.3.2.6 Reflections on what materials are practical for use by blind and visually impaired people making e-textiles

It is clear that a range of tools and techniques are practical for use by blind and visually impaired people. Some of these might need to be adapted slightly - or require a little bit of help from an assistant - but from the experience of the research team, the participants were able to work with most things. The hands-on e-textile circuit making was perhaps the most challenging in some ways, both because it was new to everyone, and because it seemed intimidating to work with electronics. The scaffolded approach to making, with modular components and a simplified step-by-step process, seemed to break this down and make it more digestible. Mixing this with craft activities each week was important in keeping everyone engaged.

Using techniques that are a bit messier, such as fabric glue or felting, were found to be more challenging than using fabric tape and constructing surfaces using weaving or finger knitting, because people did not enjoy getting their hands messy.

5.3.3 Can visually impaired makers express themselves through e-textiles?

In exploring this question, the following elements will be discussed:

- How did the participants execute their design decisions?
- What evidence is there of creative thinking throughout the workshops?
- How did the pieces ‘come alive’ with the use of e-textiles, interactivity and sound?
- Did the participants feel ownership over their work?

As the pieces have all been discussed from a textile perspective in section 5.3.2, This section will focus more on the ‘electronic’ element of the textiles, but of course the crafting decisions and outputs of the crafting and electronics are interlinked.

5.3.3.1 How did the participants execute their design decisions?

As discussed in the previous sections, all participants explored and executed a range of crafting methods in their final designs; they all made e-textile circuits; and they all recorded sounds to be triggered by the e-textile switch. All participants embraced making the e-textiles a part of their work, successfully incorporating their use into their designs and embracing the potential for interactivity. Their design decisions are discussed below.

Pockets

Across both series of workshops, most participants integrated the pockets containing the electronics into the background. However, Sonja (W1) and Kelly and Jane (W2) chose to treat the pockets as part of the composition, either choosing different fabric or extending the decorative motifs onto the pockets. This made them both tactile and visually pleasing. Sonja’s were made from the same fabric as her background, but chose to stick some of her small crafted ships onto them for decoration. Kelly chose a completely different texture from the background fabric that she had chosen for her wall hanging. The pockets were made using a silky grey/blue fabric, while the background was a fluffy teal fabric. The pockets reflected the water theme and were themselves interesting to see or touch. Jane’s pocket was created from the same fabric as her background but adorned with feathers, making it more of a feature. Embellishing the pockets in this way actually helped them blend in with the rest of the work, hiding the bulkiness of the electronics inside, and giving them a different texture.

Switch design

All participants made switches and accompanying covers that related to the theme of their work in some way, and that incorporated interesting textures and shapes. The usability of the switches - the reliability with which they could be triggered - was more variable.

The larger switches worked the best. Everyone had made switches of a larger size apart from Jacob and Patricia. Jacob’s was challenging, as he wanted to fit a lot of decorative elements around his switches - in the form of a drum kit - of which the switches were also part. In order to both look as he wished and to fit, the drum kit ended up all being comprised of very small elements. One issue with the switch being so small was that parts stuck together.. This meant that upon completion it did not always work properly. A similar incident occurred with Patricia's switch. The hand cover she had made for her switch was designed to look a very specific way, and to fit next to a second hand on the front of her shopping bag. Since she had designed the wrists of her hands to be quite narrow, her e-textile switch - designed to fit inside it - had to be cut down somewhat so as to fit inside. This did not seem to be a problem, but once inside it seemed to be folding in on itself, failing to trigger when pressed, most likely due to short circuiting.

These two examples of the electronics not working as desired when the visual elements of a piece are prioritised, demonstrate the challenges of working with creative technology. It is a common issue with e-textiles in particular, as short circuits occur due to the lack of insulation and elements being designed close together.

Exploring the use of crafting and materials with e-textiles

As outlined in Table 5.8 a wide range of tools and techniques were explored by all participants, and as outlined in Table C.5 in Appendix C this also involved a wide range of materials. As discussed in section 5.3.1.4 Uma and Louise were the only 2 of the 13 participants who finished the workshops who seemed to consider the gesture used for triggering the interaction. However, by exploring a range of materials, combined with the e-textile circuitry and sound, everyone created work that was both interactive and aesthetically pleasing in some way.

5.3.3.2 What evidence is there of creative thinking throughout the workshops?

The use of different crafting techniques, the choices of fabrics for tactile and visual representation; the individual nature of the compositions; the inventive use of sound - were all evidence of creative thinking by everyone who took part. Creative thinking was evident in the different choices made by participants:

- Use of textures;
- Sound design;
- Incorporation of crafting techniques into work;
- Individually designed compositions;
- Reflection on interaction design.

Use of textures

In choosing textures, Hailey thought about her children's different personalities, and chose textures that reflected them. She also chose different representational shapes and colours: fluffy pink heart for her daughter; lustrous blue fabric for one son; black cotton for the other.

Karen spent a lot of time feeling a range of textures when designing her work, to find what would be the best choice to represent the animals on her wall hanging: a cow, a horse, and her cat. The simplicity of the square switch covers emphasised the textures.

Sound design

Because Hailey let her children decide which audio recordings they made, the sounds felt very genuine, and evoked laughter from the rest of the group as she played them. Hailey's piece was personal to her and her family, but also heart-warming and enjoyable to engage with.

Louise wanted her switch cover to look like Katie the cockatiel and sound like her too, and so took the re-recordable device home to record her. Louise reportedly had to hide the board from Katie as she recorded her, as the bird kept getting distracted by the LED light flashing as the record switch was held down. The perseverance that Louise took to get the sound is evidence of her 'design commitment'.

From the beginning of the project, Ewan's vision was in his sound design. When it came to sourcing audio on the free sound website, he took time to find tracks that for him resembled closely the real sounds that he had heard.

Jim's project was an oral history project through his voice recordings, which describing the memories he associated with the crafting and switch coverings, including people such as his grandmother, friends, and sister.

Uma was the only participant to record herself singing; she recorded a song to which she would listen when feeling sad. This was brave and made the work personal and moving.

Pam's method for recording the audio was interesting; rather than sit with one of the researchers to source the ELO songs online, she brought her tape player to the workshop, to play each track and record them onto the re-recordable devices. She sat in a quiet cupboard herself to do this, choosing to work independently.

To showcase his personal creative interests, Jacob played his own instruments and recited his own poetry.

Patricia's sound was designed to be funny. Her *"give us a hand"* voice recording, combined with the use of the fabric 'hand' covering for her switch, made it 'tongue in cheek'.

Incorporation of crafting techniques into work

Ewan’s creativity was apparent when he persevered with weaving after finding it quite challenging - proudly using it as an element in his final work.

All of Jim’s switch covers were made from hand-crafted objects that he made in the workshops, using weaving, finger knitting, and felting as a tribute to crafting with his grandmother.

Jane’s use of the netting material and pink yarn to construct the cast helped make it resemble her real one accurately, and printing an image of her own car onto fabric was a unique contribution to the piece.

Verity tried different techniques for her weaving, all of which were used for her final piece. This included: a form of 'clasped weft' where two threads meet in the middle and are clasped together; manipulations where the weft thread is twisted and individually manipulated through the warp; creating a different float length, by going over and under the warp threads at varying distances; lastly, she also created a 3D 'nest' for one switch.

Sonja’s piece was very tactile, with her making many small elements to touch and look at, including her small ships and seagulls. These were all hand crafted by her, and along with her finger knitting and weaving displayed a diverse range of techniques used for the final piece.

Patricia’s use of different techniques was seen throughout the workshops: making finger-knitted headbands, bringing in interesting fabrics and embellishments to share with the research team and her fellow participants, and requesting the sewing machine when creating her final piece.

The shapes used in Pam’s e-textile switch designs were bold, bright, and fun - each representing a different ELO song related to the weather, and all made to look like symbols. Her use of jeans pockets for the electronics made them an integral part of the design.

Reflection on interaction design

Throughout the process there were examples of participants deliberately setting out how they thought the interaction with their piece might work, particularly how they envisaged their e-textile switches being touched by a user, based on the material covering on it.

Louise was one of the few participants who thought about interaction design regarding her material choices for her final piece. She knew that she wanted to stroke her ‘Katie’ switch to trigger the sound of her cockatiel squawking, and so wanted a soft fabric to encourage this.

Uma wanted to hug her interactive cushion, and for the hug to trigger the e-textile switch to play her audio, and so chose the huggable ultra-soft fabric to be used for the cover, and she made a large, centrally positioned e-textile switch.

The outputs of the interaction were also very carefully considered by each person, through recording their own voices or other peoples, playing instruments, recording tapes and CDs and choosing audio from a selection of files.

5.3.3.3 How did the pieces come alive with the use of e-textiles, interactivity and sound?

As stand-alone textile art pieces, all of the work produced was aesthetically stunning in the way that tactile design had been incorporated into them; how they looked with the shapes, colours and unexpected techniques used; and how sound was used to convey their meaning. The use of e-textiles and interactivity certainly made the work multi-sensory and was essential in bringing the participant's stories alive. The use of texture and sound added levels of accessibility to the work, allowing people with a range of abilities to interact with it. Especially for anyone with no sight at all, the sounds were essential in communicating the stories and associations:

- **Transporting the audience to another place:** Ewan's evocation of the Australian rainforest; Sonja's evocation of fishing on the sea; Kelly's evocation of water;
- **Sharing something about the participant's personal life:** Hailey's depiction of her children; Karen's love of animals, including her cat; Louise's portrait of her beloved cockatiel;
- **Sharing life history:** Jim's personal oral history; Jane's depiction of how she lost her sight
- **Embodying personal interests:** Pam's love of ELO; Verity's love of nature; Jacob's music and poetry;
- **Expressing emotion:** Uma's evocation of comfort; Patricia's expression of humour.

The e-textiles brought the work alive, the participants pushing the boundaries of what they could do with them as they portrayed their different themes. Without electronics, they would be interesting textile pieces - but the 'e' component enabled interactivity and sound to assist in portraying the narratives that were so important in the work.

5.3.3.4 Did the participants feel ownership over their work?

All the participants ultimately made work that was personal to them and over which they had full creative authority. All of the concepts, ideas, and choices that went into the work were theirs.

Physically, the work was also theirs, everyone, from the beginning of the workshops, were told they would be able to take their work home afterwards and that it would along with this be fully working.

This sense of ownership and pride in the work was demonstrated in how the participants shared it with their friends and family afterward. They discussed this with the lead researcher when she visited them after the workshops.

When the lead researcher visited Hailey in her home to interview her about her work and the process of participating in the workshops, Hailey showed her how the work was displayed in the hallway of her family home. She explained how it had become a way to call everyone for dinner, by triggering the e-textile switches to play the children's voices. Her children had also started pressing it regularly when walking into the living room, or demonstrating it when their friends visited. Hailey explained that she felt smug that none of the young people had heard of e-textiles, feeling that she could teach them something. This conveyed a sense of ownership over the work – in the piece itself and also in the process of making it.

Upon visiting Karen, the lead researcher observed how she had hung up her work at home, above her bed so that she could feel it and listen to her animal noises before going to sleep.

Sonja's house is filled with her artwork - pieces created over the years in classes organised by Bucks Vision, some of which she has won prizes for in their yearly competition. She hung her interactive e-textile wall hanging among all these with pride. She chose a prime location, behind her kitchen door, where visitors would see it as they walked through her door. Sonja had shown 'ownership' throughout the process of the workshops, having a strong vision of how her wall-hanging should look, sound and feel. She not only made intricate elements for it but also directed the research team and volunteers in assisting her with this. During the post-workshop discussion with the lead researcher, she commented - in reference to the challenges of the e-textile making - on how she does not give up, but likes to see projects through. As discussed previously, she also mentioned her desire to enter the work into the Bucks Vision annual art competition; she discussed this both during the workshops and in the post-workshop interview.

Uma's placed her cushion on a chair in her kitchen, apparently often triggering conversations between herself and visitors. A friend had popped over who knows a lot about electronics but had never seen or interacted with anything like the cushion. Uma was very pleased to have the opportunity to share her newfound knowledge with him and explain about the re-recordable devices and the e-textiles.

A year after the research workshops, in a one-off e-textile felting workshop run by the lead researcher, Verity told her about how she would interact with her work every day. She said this without prompting, keen to share that the piece was still relevant to her.

Both Patricia and Jane had given away their pieces to people who were so impressed by them, that they wanted one themselves. Jane gave hers to one of her grandchildren, who could not stop playing with it every time she came to visit. Patricia gave hers to a friend, who designs and makes handbags, and who was impressed by Patricia's interactive bag.

To observe first-hand and hear about the journeys of the individual pieces of work after the workshops - how they still had relevance, and their importance to the participants and others around them - was heartening. The continued display of the pieces was evidence that making these unique e-textile pieces had indeed made an impact. Visiting the participants in their homes, observing where the wall-hangings were on display, and discussing their relevance to them, certainly confirmed the sense of ownership portrayed by the participants in the workshops.

5.3.3.5 Reflections on whether VI makers can express themselves through e-textiles

The participants provided compelling evidence that visually impaired people can express themselves and their stories through e-textiles. The hands-on making allowed for personalisation and self-expression, with participants incorporating both familiar techniques and crafting skills learned in the workshops.

Each participant displayed creative thinking, evident in their use of textures, their sound design, how they incorporated crafting techniques into their work, and how some of them reflected on the materials and sound to evoke a specific interaction with their work.

Most importantly, the use of e-textiles truly brought the work to life through the combination of textiles, interactivity, and sound. The objects became something which portrayed people's personal experiences and histories. Not only did making the work give participants the chance to showcase their creative skills, it also gave them a sense of pride and agency over their abilities, by embracing tools and techniques which can be very challenging.

The participants' enthusiasm when exhibiting their work during the showcase, and then displaying their work in prime locations in their homes, demonstrated pride in what they had created, and in the narratives they had told.

5.3.4 What are the challenges and opportunities for blind and visually impaired people in an e-textile participatory making environment?

In exploring this question, the following elements will be discussed:

- What did the research team learn about participatory making?
- Did the participants work independently?
- How did they share personal experiences?

- Did the participatory environment evolve?

5.3.4.1 What did the research team learn about participatory making?

During both workshop series, the research team learned a great deal about what it means to plan and deliver sessions within which participants are physically making something, while being in a group environment, and having the opportunity for discussions, input, and assistance if needed. The observations recorded and lessons learned can be broken down into:

- Empowerment and agency;
- Appropriate, non-intrusive support and the roles of volunteers;
- Avoiding assumptions.

Empowerment and agency

As discussed previously, throughout the workshops the research team saw evidence of the participants taking control of their work in terms of the ideas they wanted to express, the crafting techniques they used, the materials they chose, and the composition of the pieces. They also took control over the process, anticipating next steps and directing volunteers as they saw fit. The participants' readiness to alter the brief, make decisions, and direct the researchers were evidence of their agency.

One example is the location of the pockets for the circuit board and batteries. For the wall hangings, the brief put the pockets at the base, as part of the background, so that they would blend in. However, some participants chose to integrate them into their designs. Kelly, after discussing her pockets with one of the researchers, chose to follow her own creative vision, using a decorative fabric rather than background fabric. She also contemplated how to manage the balance between drawing the focus of a user toward the interactive elements (the switches) and away from the batteries and soundboard that were inside the pockets, joking *"You could put a big 'Do not touch!' thing on each pocket!"*. She also considered making the interactive parts more decorative to draw the users attention: *"If I make something, you know the actual thing you touch, I thought perhaps to make something that looks like pebbles for the bottom one, maybe a fish shape for the sea, and waves for the ocean."* Ultimately, she chose to distribute the pockets across the piece and highlight them with contrasting fabric. Similarly, Pam chose to make a feature of the pockets, using iconic jeans pockets on the front of her cushion. Several participants chose not to make wall hangings. Patricia preferred a more functional item: her shopping bag. She wanted to hide the pocket for her device and batteries inside her bag. Pam and Uma made cushions. Jacob changed the shape of his wall hanging to resemble a drum skin.

Participants also took ownership of the sound recordings; although the researchers might assist in sourcing and suggesting sounds based on the participants' themes, the participant made the decisions. Ewan wanted rainforest sounds. He remarked about one recording of birds and insects: *"It's too rushy! It would come up rubbish on the recording!"* As he had been testing the soundboard, he knew that the quality was not perfect, enabling him to make an informed decision about which sound would play well.

Even when participants requested help with the making, they retained control of their designs and the construction. This applied to almost all forms of crafting, but was particularly evident with cutting and sticking.

Ewan (who is registered as fully blind), wanted help with cutting. He was very particular about the design of his piece, and he described to the researcher just what he wanted, such as a Monstera leaf of a certain size, or a lightning bolt that would shimmer in the light. She would cut out paper prototypes of the shapes - often more than one - and he would assess them with his fingers, asking for alterations or alternatives until he was entirely satisfied. He went through a similar process with fabric selection, asking for fabrics with particular characteristics, and then quizzing the researcher about the colour or pattern, until he was satisfied. He laid out the composition himself, before asking the researcher to stick it in place, checking each step as it occurred.

Pam asked for help cutting and assembling shapes. She went through a similar process with the researcher, starting with paper prototypes of the weather-themed switches. When she was not happy with the paper cut-outs that a researcher made for her, she asserted that they were not quite right, requesting the shapes to be re-made several times before she was satisfied with the result. Similarly, once the sun shape was cut, she was not satisfied with the colour configuration and asked for it to be re-done.

Sonja was fiercely independent and wanted to make everything herself, but when her hands became tired, she accepted help. She cut her own pieces and then worked closely with the researcher, directing every action, to cut the fabric tape and place the pieces on the background.

Uma struggled with the fabric tape and asked for help sticking things in place. While the researcher was busy cutting tape for the star, Uma took one of the discarded tangles of fabric tape and used it to attach her finger knitting.

Karen (who is registered as fully blind), chose a simpler design so that she could cut the fabric herself, with help from the researcher (as described above).

The showcases at the end of each workshop series were an opportunity for the participants to appreciate their achievement and to share it with their peers, friends, family, and staff from Bucks Vision and MK Gallery. Making the showcase a special event and treating it like a real art exhibition was important to the participants; it was a time for celebration and to recognise the participants as artists in their own right. In a follow-up reflection email, Jane wrote to the lead researcher that:

> *"Re the Showcase, I was pleasantly surprised at the turnout, which I felt was very good and those who came seemed really interested in the exhibits. They tried them out and asked questions. I was particularly pleased when I arrived to see a young girl having fun with my exhibit, repeatedly pressing the button and feeling the different textures. I felt I'd achieved what I'd set out to do, create a memory that would encourage others to touch.*
>
> *I didn't mind talking about my work, I just hoped I explained enough for those attending to understand where the work came from."*

Appropriate, non-intrusive support and the roles of volunteers

The research team and volunteers learned a great deal about how to help participants without imposing on them - about what to do and what not to do.

During the first session of the first workshop, the research team observed that it could be frustrating for the participants if someone helping them was *too* hands-on with their assistance. One of the volunteers was very helpful with Ewan's weaving, but to the point where he began to do it for him. Ewan became visibly frustrated with the volunteer. The research team made a decision to have a subtle word with the volunteers at the start of the next session, about not providing hands-on help unless asked explicitly. This observation also helped the research team shape its approach to facilitating the workshops.

Thereafter, they voiced their role as being purely 'assistants'. They used the analogy of a sculptor and a forge worker: the sculptor is clearly the artist, and the forge worker is simply an anonymous assistant who executes the work in metal to the artist's precise specification. Should participants want an extra pair of hands to assist with cutting or something fiddly, then they could most definitely ask for assistance; they were encouraged equally to tell the volunteers and research team *not* to help if preferred. There is a danger within any learning environment that hierarchies might form, resulting in participants feeling unable to question or instruct facilitators in a workshop, so it was important for the participants to feel that it was entirely acceptable to decline help. Verity had noticed the effort that the research team and volunteers were making during the second workshop series to not take over with anything, lest they disempower participants. She commented over email: *"I loved that people were there to help us if we needed it but we were allowed to do our own work, that often doesn't happen as helpers take over and do things "for us". Being able to be independent is very important."*

Some examples of where the working together of volunteers/research team and the participants was visibly a success was with the making of Karen's, Ewan's, Sonja's, Uma's, and Pam's work, as discussed above. For participants who had an ambitious vision for the design of their work, this was important, and they seemed very happy to have someone who could help shape the switch covers. Karen wanted some assistance with cutting out the fabric for her switch covers but instead of these being shaped into a horse, owl or cat she *just* wanted help in cutting out the shape of a square. The technique which she and the lead researcher developed was for the researcher to hold the fabric and say, *"Cut cut cut!"* whilst Karen cut along it, then the lead researcher would turn it to enable Karen to cut the next side of the square.

All participants asked for some help at some point during the process, which is normal in a making environment. Some wanted to check their circuitry, some wanted the researcher's opinions about where to place objects on their background. This was all approached with openness and conversation.

All participants mutually respected each other's making, listening intently as the work was shown to the public.

Avoiding assumptions

When meeting with Bucks Vision, the research team had been told quite clearly that the participants would find it too challenging to use tools such as scissors or needles. Therefore, when planning the sessions, the research team did not assume that the participants would be able to use these, instead planning that they would assist if these tools were required. However, as discussed, many participants did in fact do their own cutting, whether snipping yarns or shaping fabric for the switch covers. Everyone across the two groups used the scissors for yarn, and Hailey, Louise, Jane, Kelly, Jacob, and Patricia all cut the fabric themselves. As discussed previously, other participants had some assistance with this.

Regarding needles, all participants used weaving needles to thread their conductive thread through the tubular fabric yarn, seemingly doing this with ease. As discussed previously, both Hailey and Jane hemmed their own work, and Patricia requested a sewing machine to construct her piece. These participants showed that, although they have a visual impairment, through the experience they had gained through crafting over the years, they could still perform an intricate crafting method.

Practically, the research team assumed that the participants would not mind where the tables were placed in the room, as the making was meant to be more touched-based than visual in any case. However, for the second group, many of the participants had some vision which was affected by light conditions. Verity requested after the first workshop for the tables to be moved closer to the windows. It was useful for the research team to get this feedback and of course they obliged.

5.3.4.2 Did the participants work independently?

As the workshops progressed, some participants wanted to take their project home to continue to work on it. Contrary to our expectations, Hailey and Jane chose to do their own hemming by themselves at home.

Some would re-record their sounds between sessions, at home or in their garden (Verity, Hailey and Louise). Participants also brought additions for their work, decorative and personally meaningful to them. Louise adorned her representation of her beloved cockatiel with a craft flower, asking us to pin it on carefully. Sonja added a finishing touch to her interactive seascape, by proudly attaching a German flag onto a fabric trawler. Participants were clearly thinking about their pieces in between sessions, making them their own and feeling responsible for the design and the finishing touches.

Participants were also keen to plan their work and discuss it with the lead researcher over the phone or over email between workshops. Verity used it as an opportunity to share her reflections on her work with the lead researcher, after beginning her weaving:

> *"My default position is to usually work with blue but this time I deliberately tried not to and moved out of my comfort zone."*

Between the sessions Ewan frequently discussed his work with the lead researcher over email, after the second session emailing:

> *"I'm still going ahead with the rainforest idea. I thought of general birds and insect noises for the first button and then rain and thunderstorm sounds for the second...I would like the sky background to be blue although, I'm not sure what fabrics I would like to use for this…"*

He was still very keen to follow his rainforest idea and was enjoying planning his work in his own time. Jane used email to discuss her plans for her piece, as well as materials that she wanted to contribute to the group:

> *"I am going with Jacob's idea of using the skipping rope as a timeline along which I'll place the cast, a facsimile of my car in felt and I thought of a mini 'Eye of God'. I also had some ideas with regard the finger knitting and sourced the findings on eBay. Tomorrow I'm going hunting through my craft boxes for leaves for the tree. I've also got some material I can donate to your workshops, providing I can find it."*

These reflections and conversations between the workshops show a commitment to the work and independence and creativity in planning.

Interestingly, although she appeared to enjoy working in the group environment, Sonja mentioned to the lead researcher after the workshops how she would have preferred to have worked individually, having sometimes found the group to be a distraction. However, the research team had observed her laughing during the sessions, participating in discussions, and showing pride when sharing her work.

5.3.4.3 How did they share personal experiences?

Participants frequently worked with each other and the volunteers, providing creative and helpful suggestions and offering support. “Mutual Learning” certainly occurred (Bratteteig, 1997: 1), where the participants learned from the researchers, and the researchers from them. For example, Verity demonstrated how it is easy to ‘feel’ which way up the press-studs go when placing them in the pliers. Jane showed how yarns can be combined to create complex textures. Both are examples of the participants having a more nuanced understanding of using the tactile aspects of tools and materials. Participants also shared materials, collecting samples from home that they believed could be useful for another person’s project, as well as adding to the researcher’s material collection. One week, Patricia had been visiting a local farm shop cafe which is connected to a field of sheep - at this point recently sheared. She asked if she could have some fleece for the workshops and the owners obliged. She emailed the lead researcher afterwards: “So you now have the opportunity to have a fleece of your very own! Complete with various bits of adhering vegetation and small brown objects. If you don't want it, that's fine, I'll chuck it in the bin. Let me know your thoughts!”. Patricia was very enthusiastic throughout the session, both making contributions and emailing: “do you need an iron for tomorrow? I have a tabletop board and electric iron I can bring, if needed”. The participants also shared components when they had made too many (such as e-textile switches or soft wires), and helped each other with hand tools. This demonstration of generosity helped create a true community feel.

Ideas were shared too: Jane was struggling as to how she could incorporate a skipping rope into her work, linked to a story about an injury that had affected her life. Jacob suggested she use a piece of yarn to represent the rope, and to make it into “the narrative strand” of her work, connecting other symbolic objects together. Jane was very pleased by his suggestion, and she made it part of her design.

Personal stories or associations were also shared over the sessions, through the participants sharing their personal textile objects (see Table 5.3), talking about personal associations in relation to fabric swatches (see Table 5.2), and discussing their pieces as they constructed them. The showcases at the end of each workshop series also gave an opportunity for each maker to present their work and its concept, and to discuss their experiences in creating it.

5.3.4.4 Did the participatory environment evolve?

As the weeks went by, the workshop environments changed. The first workshop group did not know each other as well as the second, although some of the participants had socialised occasionally through other Bucks Vision activities. During the first and second sessions, participants were quite reserved, reluctant to begin conversations. During the group activities, however, and as work on their interactive pieces began, conversations flowed more easily, and participants appeared to be bonding more. As the workshops progressed, more laughter happened as well, participants easing into the practice, and becoming more relaxed around each other and the research team. They responded to each other's work with delight and appreciation. Sonja's sounds were very realistic and matched her button covers well, with Hailey commenting on one sound *"It's a foghorn!"*, and Ewan repeating one of her recordings back: *"Mayday! Mayday!"*. The research team observed participants helping each other when stuck on a specific task, or commenting positively about each other's work. Louise explained that the learning element of the workshops along with being with others was very important to her: *"For me, it's being able to learn how to do something, be with other people and not being stuck on your own…"*

For the second group, it seemed perhaps easier for them to discuss ideas and to have general conversation with each other from the beginning of the workshops, as most of them knew each other already, through the Eye for Art crafts group and through general networking around Milton Keynes for visually impaired people. As with the first group, as the weeks passed, the laughter increased, and the environment relaxed. This group largely saw the workshops as an extension to their existing art and craft activities, but embraced it as an opportunity to learn something new and to harness a technology with which they were not previously familiar. They were also inspired by each other, and enjoyed listening to their fellow makers' ideas. Verity commented to the lead researcher: *"The others had such wonderful stories and ideas and seemed very inspired. I was so impressed!"*. They were also excited about having the opportunity to see each other's final pieces at the showcase, Patricia writing to the lead researcher that:

> *"It is good to see how each participant is producing something entirely different to everyone else! I feel that my own project is rather unambitious compared to the rest, although sewing takes a bit more effort than gluing! I'm looking forward to seeing all the finished items displayed together."*

Facilitating the experience for each participant in a person-centered way, ensuring that they were happy in their making, was important throughout the process. Verity commented:

> *"I love the way you are so tuned into us all individually and somehow make us all feel special. I don't know how you manage to keep all the balls in the air, especially as you were largely working without any help...Really enjoying myself and being with the others."*

Other participants had positive feedback on the sessions too, with Karen commenting:

> *"I really enjoyed them and would do it all again if I could." and Ewan seemed keen to work on another project: "I have enjoyed working with conductive textiles and would do further projects in the future if you were doing any more projects."*

There was some sadness at the end of the workshops, the participants and the research team all having gotten used to and enjoyed the weekly sessions. Hailey commented in an email after the first workshops: *"Yes, I'M sad too, whatever will I do on Friday's"*. This highlights a dialogue around ethics, and the issues that researchers face when walking away from a group of participants after a period of time on a study. At this point, the research team had only been working with the participants for approximately 5 months from their first meeting with them. But bonds had formed, and the workshops had become a happy social occasion as well as research. However, the research team was always open from the beginning that it would only be for a set time. The possibility of future workshops had been brought up, especially because the lead researcher is also a practicing artist, with a history of running similar projects under an arts umbrella. This will be discussed further in the future work section.

5.3.4.5 Reflections on the challenges and opportunities for Participatory Making for blind and visually impaired people in an e-textile making environment

The challenges lay in providing an appropriate environment, which scaffolded the development of needed skills, introduced e-textile making in a comprehensible and accessible way, encouraged participants to make design decisions, and allowed participants to feel comfortable and engage freely. A key challenge was providing assistance for the making in a way that respected participants' creativity and agency. This was achieved by articulating - and observing - some ground rules about not providing assistance unless asked.

Within the participatory workshop environment, where discussions were encouraged, collaborative working was facilitated, and the sense of creating a 'group project' was present, participants demonstrated empowerment and agency, working increasingly independently, and happily giving and receiving feedback from others. They shared their personal experiences, and week by week the community dynamic developed.

Being together gave the participants not only an opportunity to give feedback on each other's work, but also an opportunity to be part of something, which for most of them seemed to be important and satisfying. There was some clear disappointment about the sessions finishing, but in a way that encouraged potential collaboration in the future.

5.3.5 How do blind and visually impaired people interact with textiles (and e-textiles) using touch?

In exploring this question, the following elements will be discussed:

- How did the participants handle fabric?
- How did participants interact with soft circuit switches?
- How did technical knowledge and touch relate to one another?
- Did participants show a sense of identity through fabrics and touch?

Figure 5.5 depicts the analysis of 'touch', from observations, hand-written notes, video footage and photographs. This was all recorded in a first iteration 'touch table' (Table C.6 in Appendix C) before being cleaned up and entered into Table C.7 in Appendix C and Table C.8 in Appendix C.

The research team began by discussing what aspects of the use of touch during the workshops should be analysed.

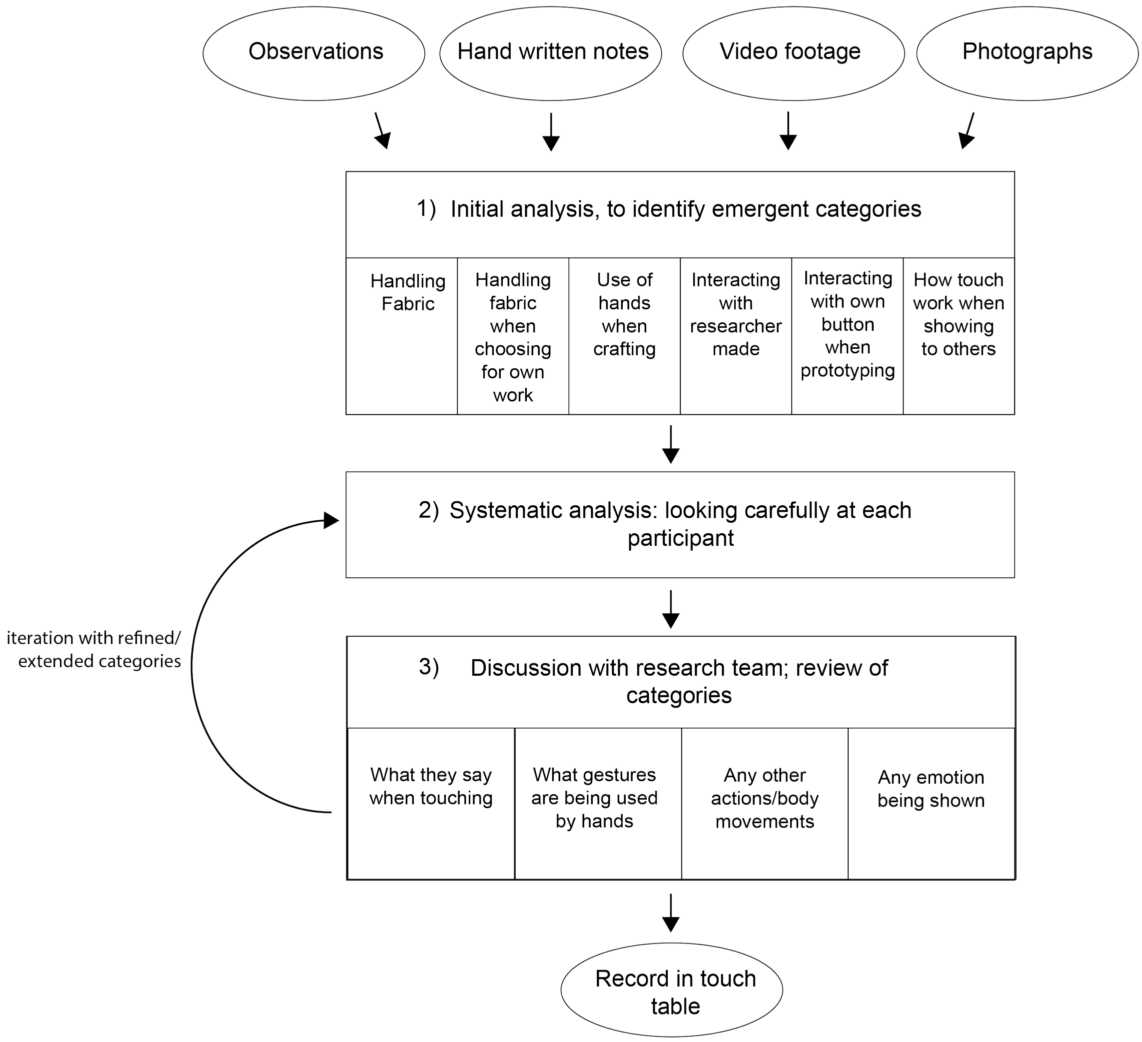


Figure 5.5: Diagram outlining how data for Table C.6 in Appendix C was coded.

The following aspects were identified:

- Handling fabric;

- Handling fabric when choosing material for the art piece;
- Interacting with prototypes (brought in by the lead researcher);
- Interacting with an e-textile switch when prototyping;
- Touching work when demonstrating to others.

Notes were made for each participant regarding each aspect of the use of touch. For some participants, there was no evidence of certain uses, or, they were absent from a specific session. The notes for each example were annotated with contextual information:

- What they said when touching;
- What hand gestures were made;
- Any other actions/body movements;
- Any emotion being shown.

These were recorded in the table and rechecked against video and handwritten notes to ensure all instances were captured.

Workshop one was much easier to document and therefore analyse due to the room being much smaller and participants all working around the same table. For workshop two, when looking at the video footage which was taken of the whole room in the second workshop series, because participants chose to spread out to different tables, it was difficult to see how every participant handled fabric. The research team had made handwritten notes and taken some additional video footage with a DSLR camera which had been shot closer up. Useful data around the handling of the fabric by some of the participants was collected. This can be found in Table C.6 in Appendix C.

5.3.5.1 How did the participants handle fabric?

The participants handled materials in a number of different ways, listed in Table C.7 in Appendix C.

Feeling the fabric with their hands was important to the participants, who performed gestures such as rubbing or stroking it, or flopping the fabric around to gauge how it performed. As mentioned in the literature review, the way in which a fabric performs in the hand is of great importance when deciding what to use it for (Philippe et al., 2003).

When handling fabric which might possibly be used for their work, the participants seemed to take more time. They either showed more expression when discussing it, for example hugging it or clearly showing an emotion like excitement, or used more hand movement when feeling it.

Multiple participants (Karen, Kat, and Jim) appeared to use an anchoring technique when feeling fabrics or triggering soft circuit switches. Karen was observed touching the material with one hand and then following shortly with the other. Kat and Jim showed similar behaviour but with a more dynamic movement, often using two hands to rub fabrics, sometimes going in the same direction but also with one going horizontally and the other vertically. This could have been to obtain an idea of scale and what it was, before exploring more focused details, doing it as an initial scanning of the object.

Some fabrics appeared to invite a wider range of gestures - the sequined fabric in particular perhaps causing a greater sense of curiosity. Overall, gestures showed that the participants were experimenting with the materials - trying to discover what they might do, and how they might react through flopping, dropping, and wiggling. Other gestures, such as anchoring, seemed more related to their visual impairment.

5.3.5.2 How did participants interact with soft circuit switches?

Table C.8 in Appendix C outlines the gestures that were observed during participant's interaction with e-textile switches during the workshops: their own and those on the lead researcher's prototype.

The research team assumed that, as the participants were making a piece of work that was personal to them, and which contained fabrics (reflecting a story or memory) that they wanted to touch in a specific way, their soft circuit switch would be triggered using a specific gesture. However, most participants triggered their piece by either tapping or pressing their switch. There was a reflection by the research team that they might have biased the interactions by referring to the switch as a 'button' a number of times. 'Soft-circuit button' is a common term within e-textiles.

Table C.7 in Appendix C shows that participants used more gestures when handling fabrics without the electronics. Perhaps this was because the fabrics were easier to handle when not attached to a background, or perhaps it was because the participants did not perceive the need for tactile exploration when they knew they were interacting with a switch.

Upon demonstrating her work to the group, Louise stroked her switch cover as she described the piece (a gesture she had referenced wanting to do throughout the workshops), but then in fact triggered it using a tap. Uma explained that she wanted to make an object that she can hug (a cushion), but when she was asked to demonstrate the interaction, she claimed she did not know how to interact with it.

5.3.5.3 How did technical knowledge and touch relate to one another?

Touch not only played an important role in the participants exploring the tactile qualities of the materials provided for the workshop, but it also played a role in participants testing out their technical knowledge during the project. In the first workshop, Karen figured out early on that we were using circuit boards very similar to the ones found in greetings cards, saying *"I could tell it was a singing one cos you could feel it"*. Uma spent a lot of time handling a re-recordable device during the first workshop, pressing both the record and play switches, discarding the fabrics in front of her. Uma also demonstrated her knowledge of making insulated soft wires by speeding through the construction of multiple soft wires during one of the workshop sessions. All participants, in fact, demonstrated tactile knowledge when making the e-textile yarn wires, ensuring that the conductive thread was fully through the tube yarn before wrapping the conductive thread around the ends of the tube and adding press-studs.

During the second series of workshops, participants anticipated the next stages of circuit making regarding the e-textile switch. Pam told her volunteer what needed to happen at each point as she made three switches. She had been very focussed while making her first switch, memorising the process completely through touch.

5.3.5.4 Did participants show a sense of identity through fabrics and touch?

For most of the participants in the first group, the *feel* of the fabrics which they chose for their work reflected a sense of personal identity. Hailey certainly did this by choosing her beloved cow print fabric; Louise's 'Katie' piece and the 'strokable fabric' reflected her relationship with her pet bird; Karen conveyed the importance of animals to her as she considered a specific 'feel' for each button representing a different animal.

For the second workshop participants, the textures of the fabrics were important to them, but the visual elements of the work seemed perhaps more important. For Pam's switch covers, for them to be big, bold and bright was important. For Patricia, the hands she created for her bag *had* to look like hands, and a lot of care was put into making them. The visual detail that went into both Jane's and Kelly's pieces also seemed incredibly important to them as well.

5.3.5.5 Reflections on how blind and visually impaired people interact with textiles (and e-textiles) using touch?

To observe such detail concerning touch in a 'messy' in-the-wild workshop environment was ambitious. The research team did not manage to gain as much data from the second workshop series as they would have liked, because the participants dispersed to different tables. What was observed and recorded while the participants were gathered at one table in the early sessions was the diversity of how fabric was handled and experimented with, as well as how the participants chose to interact with the e-textiles.

Throughout the workshops some participants displayed a tacit knowledge of textile making and crafting, with them leading the way as they created their work - from years of experience before and after losing their sight. They used their sense of touch to make the e-textile circuit, particularly the soft wires, often speeding through the process.

The feel of the materials was important for the work, with many of the participants spending time going between fabrics to find the 'right' one to reflect their subject matter. Interestingly, this touch was not always transferred into how they handled their e-textile switches afterward, with most participants performing a push, tap or press to trigger the switch, rather than performing a gesture which might reflect the feel of the material.

The participants often spent more time when exploring fabric than when handling e-textile prototypes. Gestures such as pressing, rubbing, stroking, and patting were observed as a way to explore the materials, with participants often asking, *"What does it feel like?"*, to themselves as a reminder to reflect on touch, but also to find out information from the researchers. Not only did they feel the fabrics, but they also looked at the fabrics, bringing them close to their eyes when needed, particularly Uma and Hailey.

The research team decided to build on what they had observed from this study, regarding touch, associations and gestures - and to run a study focusing on the use of touch with different forms of e-textile sensor. This is discussed in Chapter 6.

5.4 Limitations

The workshops were broadly exploratory and relied on the interpretation of rich qualitative data. Inevitably, there was potential for bias, for example in the structure of the workshops and the associated constraints on the activities, the particular participants, the facilitation, and the analysis.

The **workshops** inevitably embodied some design decisions, for example the use of the modular approach to constructing soft circuits, the constraint to three sensors to trigger sounds, and the exclusion of programming. Hence any observations must be understood within that context. Nevertheless, many of the design decisions were effective and can be re-used, including in new contexts. The observations provide a well-grounded starting point that can inform further work that extends the making context, ideally adding new elements step-by-step to assess their efficacy for participatory making by visually impaired people.

The **participants** across both workshops self-selected to take part in the sessions. They had an interest in learning new crafting skills, and how to combine these with electronics. It could be considered therefore that they are not broadly representative of the wider visually impaired public, due to an active interest in the study content - and for some of them existing crafting knowledge as well. Nevertheless, they did represent a range of visual impairments and crafting skill, and all were able to construct soft circuits effectively and to complete a personal art piece. Engaging with them provided considerable insight into how to such ‘making’ can be accessible to visually impaired people, and some of the approaches and insights are likely to generalise to other settings and other user groups - a matter for further research.

The **facilitation** of the workshops evolved, as the researchers learned from the participants. There were a number of slips along the way. As discussed, it was found that using certain terms such as ‘buttons’ potentially biased the interaction with the e-textile sensors. Some expectations, such as the engagement with colour, and the use of scissors, proved erroneous. The role of the volunteers and how they offered their help was problematic initially within the first workshop series. The researchers were alert to issues as they arose and adapted their expectations and facilitation. The lessons learned allowed the second series of workshops to run smoothly and can inform future studies.

Qualitative **analysis** always carries a danger of bias. The analysis was systematic and cross-referenced notes and recordings as well as input from the participants. It was not feasible to conduct independent coding, but the coding was iterative, and the analysis was discussed repeatedly by the research team, providing scrutiny and challenge as appropriate, and the coding was adjusted accordingly. In general, the researchers were vigilance against bias, returning to the data whenever questions arose, and seeking counter-evidence as well as supporting evidence. The reporting is grounded in the data to allow further scrutiny.

Despite the limitations and potential bias, the study provides well-grounded observations, many of which are consistent across the two-workshop series (and hence the different settings and participant groups). Both workshop series demonstrated the feasibility of the making approach, the creative empowerment of the participants, and their sense of agency, making it plausible that these basic observations are likely to generalise in similar settings. The observations suggest further work, including the study reported in Chapter 6, which attempts to address limitations in the tactile interaction with the e-textile sensors. Hence, this study is informative, and is intended to focus and inform further research, but is not treated as conclusive.

5.5 Summary

Through careful planning and execution, the series of workshops resulted in each participant learning how to work with e-textiles and create an interactive art object linked to a personal story that in some way used electronic textiles. They made their own piece of technology, to fulfil their own goal.

Some of the tools and techniques were more successful than had been anticipated, such as the creation of the e-textile fabric tube yarn wires, while some were not, such as the felting which was not particularly popular. The methods chosen to work with were robust enough to deal with failure; the participants solved problems when making their work - such as Karen giving instructions to herself out loud when trying to remember how to finger knit - and surprised the research team by offering innovative uses for techniques when creating objects for use in their final piece - such as the 3D weaving by Verity. They embraced the participatory environment and worked not only with the researchers and volunteers, but also with each other. They all created an e-textile object, interactive and personal to them, for which they showed a sense of pride - not only when demonstrating it in the showcase events, but also afterwards in their home, and sharing it with friends and family.

The key findings from the workshops are summarised in the following sub-sections.

5.5.1 Creative making with materials

- Participants were critical in how they chose their materials, letting their ideas guide their choices, and wanting to find the ‘right’ ones to reflect their ideas;
- The use of a given fabric varied, although there were some consistent uses of a fabric within a given piece, and there were some similar narrative uses of fabric by different participants;
- The compositions designed and made by participants demonstrated individuality;
- Participants were experimental and varied with their crafting techniques.

5.5.2 Grasp of the technology

- Through the step-by-step scaffolded learning approach, and the modular approach to e-textiles, the participants learned successfully how to build and test e-textile soft circuits;

  Participants seemed to understand the technology and how it worked; they grasped the idea of troubleshooting and had an idea about what was wrong when their e-textile switches were not working.

5.5.3 Accessibility of making

- The circuit making, using soft wires and press-studs, seemed accessible for all participants;
- The participants needed some assistance with making techniques - including recording the audio for their sound boards - but nevertheless showed independence in their making;

  Certain techniques were more accessible than others, e.g., fabric tape instead of glue, and using weaving instead of felting.

5.5.4 Expressing a personal narrative

- All participants were able to choose a personal fabric artefact from home and share its story;
- The second group engaged creatively in making stories about fabric samples, whether fitting swatches to an existing narrative or inventing a story from them;
- Every final piece was unique to its maker and expressed a personal story;
- Themes seemed to be about either: transporting the audience to another place, or sharing something about the participants' personal life, life history, personal Interests, or emotion.

5.5.5 Participatory making environment

- The participants worked well in the groups; everyone seemed comfortable sharing ideas and working together on certain tasks. Conversations happened naturally, and participants praised each other as well as making helpful suggestions about the work;
- Participants demonstrated a sense of ownership and agency, taking control of their designs, following their own opinions and beliefs to make design decisions, and positively discarding others' advice when appropriate;

  The research team learned in the first workshop to avoid providing hands-on help unless asked explicitly. Hence participants could have assistance if they needed it, or they could decline it freely.

5.5.6 Interaction design and gestures

- Participants exhibited more gestures when handling fabrics than when touching the e-textile switches. Only two participants (Uma and Louise) seemed to think about what gestures they would like to use with their switches/objects when designing their work;
- All the e-textile switches made by participants were linked to the themes of their work and the audio which they triggered.

The entire process of the workshops involved careful design decisions and planning, considering what was accessible, affordable, and modular, in order to promote ownership and creativity. It was about demystifying the processes, providing assistance only on demand, and providing a comfortable environment in which design and techniques could be discussed, in order to enable participants to engage successfully with e-textile making and to create something personal to them. This mix of a very practical yet reflective approach made the technology, tools, materials, and ideas accessible to the participants.

Chapter 6 describes a laboratory study that follows up the questions about whether there are patterns of gesture and association, comparing different participants' interactions and storytelling with pre-made e-textile sensors.

6 Storytelling with e-textile objects

6.1 Introduction

Popular gestures for handling e-textiles include stroking, squeezing, stretching and folding - but how might users who are less familiar with this technology interact with it, and what meanings might they link to the gestures? This chapter reports a study which explored how visually impaired (VI) participants interacted with five different e-textile switches and sensors in order to enhance storytelling activities. To save any confusion, and to simplify the description of the five e-textile objects created by the research team, in this chapter these shall be described just as 'sensors'. Sensors or switches referenced that have been created by other designers or researchers shall retain their names when referred to.

The study explores a potential gap that was uncovered in the workshop study, in which it appeared that participants demonstrated a wider variety of gesturing with ordinary fabrics, than they did with the interactive e-textile elements. Based on observations, the research team suspected that this was because the participants had become more familiar with the e-textiles and their interactions by the time they were being handled, whereas the textiles were examined as 'fresh' artefacts. Another consideration was that the researchers sometimes referred to the e-textile switches as 'buttons', which might have biased the participants to use them as push buttons. The e-textile switches also worked more predictably and reliably when pushed or tapped. As a result, the way participants interacted with these buttons seemed not particularly linked to gestural or tactile associations. The study, described in this chapter, was designed to discover whether different e-textile devices could offer a richer palette for expressing story elements through touch. This was explored through gestures and with personal association and storytelling. Figure 6.1 shows the three elements explored in this study: gestures participants used when handling the e-textile sensors; participants' associations with the e-textile sensors; and use of the e-textile sensors in storytelling.

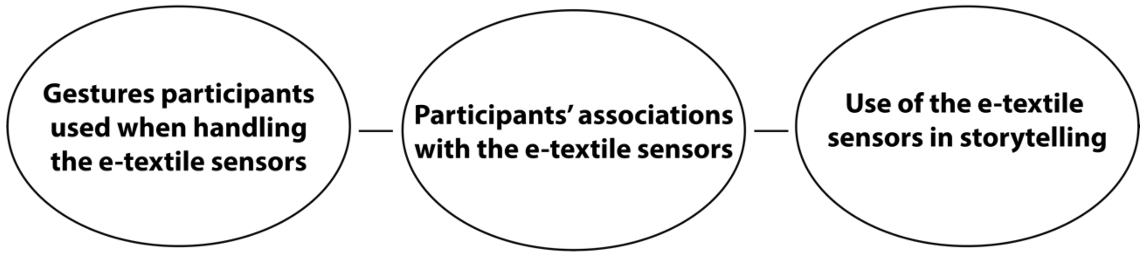


Figure 6.1: The three elements explored in the lab study.

The findings discuss consistencies found between the sensors and gestures and associations - both for individual participants, and across the group. Hence, the use of these objects within e-textile interaction design is discussed.

6.1.1 Association through touch

As discussed in the literature review, associating touch with meaning is often used for objects of reference. Although these objects can be useful in communicating events such as going outside, or an activity such as 'story time', there are some issues with the practicalities of using objects of reference. As discussed in chapter 3, it was found that facilitators often use them in different ways, so the same objects might have different meanings, potentially creating confusion should a participant change facilitators. However, the study did find that the general use of sensory objects, with a sound element present, was enjoyed by both groups that were observed. This leads to the possibility that when used consistently, objects of reference could be practically used in a more successful way. How can the concept of using objects for associations be combined with e-textiles to make a more enhanced interactive experience that users can engage with? The study described in this chapter builds on literature in this area, specifically the work by both Davis (2015) and Petrelli et al. (2016) who, as discussed in the literature review, each explore the user's preference with objects, partly through touch.

As discussed in the literature review, this concept of association and touch can also be seen in narrative-driven objects that use e-textiles. Examples such as interactive soft books for children (Posch, 2019, Holloway, 2019) and Kenning and Treadaway's (2018) research working with people with dementia and their family or carers, demonstrate that the enhancement of objects with e-textiles to make them interactive can contribute to creative engagement.

6.1.2 Gesture and e-textiles

Over the years, engineers and e-textile designers have created a variety of e-textile sensors, each which are handled in a specific way to activate (Perner-Wilson and Buechley, 2013). I will refer to this way of handling as 'assumed interaction', or 'assumed gestures' - to indicate that the makers or engineers of these technologies assume it will be clear to users how these objects should be used. For example, a 'stroke' sensor (see Figure 6.2), constructed with alternating parallel rows of conductive and non-conductive tufts of yarn or thread on a non-conductive base, is intended to be stroked, causing the conductive elements to touch and close the circuit.

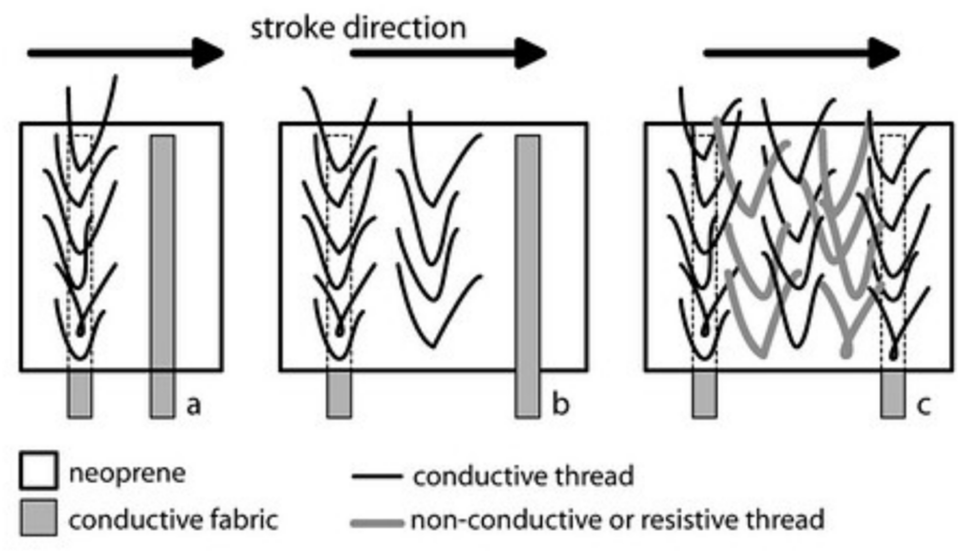


Figure 6.2**:** Diagram of a stroke sensor by Kobakant (2009). Image used with permission.

Another example, a 'squeeze' sensor (see Figure 6.3), is typically a ball-shaped sensor crocheted from conductive material and containing a soft fibre, non-conductive centre. The intention is for the sensor to be picked up and squeezed in the user's hand, contracting the conductive fibres in the crochet together and therefore allowing for either a change in the threshold to trigger an output or to allow a current to pass through it by closing the circuit.

Figure 6.3: Squeeze sensor by Kobakant (2011). Image used with permission.

Lederman and Klatzky (1987), in their seminal work on touch and objects - Hand Movements: A Window into Haptic Object Recognition - also discuss what gestural interactions people might do with specific objects, although they refer to it as "exploratory procedures" (1987:342) or "EPs" (1987:344), describing what a user might do in order to find out about the quality of an object. Their work very much explores what people do when handling objects, thus these EPs being examined in a study to see if they are in fact used to find out a certain knowledge about an object (weight, shape, etc). From their predictions of what EP might go with the finding out of an object's specific feature, temperature was the one which was went against their initial prediction. They thought that users would put their hand on an object, using 'static contact' whereas actually it was more common for them to 'enclose' an object to feel the temperature. It seems appropriate for this work to be built on, but by e-textile switches being explored in a similar way to see if users do actually perform the 'assumed gestures' they are named by in order to trigger them.

The idea of assumed interaction does, to a certain extent, reduce the user's agency. That is, the engineer or designer 'dictates' the nature of the interaction with the object. For the study discussed in this chapter, it was felt important that participants could feel ownership in how they interacted with the different e-textile objects. Therefore, although there may be an intended way of interacting which is shared knowledge in the e-textile community, it was important to not demonstrate any of this to the participants. This was part of the approach for this study, so as not to introduce bias and also to ensure that the participants did not think there is a 'right' or 'wrong' way to interact with the objects. The objects used in this study were designed for interaction within storytelling, but also to observe how the participants would handle them in an open play activity - would some of the gestures outlined by Lederman and Klatzsky (1987) be observed?

6.2 Study focus

This study questions the assumption that e-textile sensors are intuitive in their functionality. Within the field of e-textiles, the way to interact with objects is often described through maker videos online, participatory workshops, and research papers; there is widespread knowledge across the field of how to interact with certain sensors, with little deviation by experienced users. But what about users who are unfamiliar with e-textiles? Will interacting with the e-textile objects be intuitive to them?

6.2.1 Aim

The aim of this user study was:

> To explore whether e-textile devices can offer a rich palette for expression through tactile interaction and gesture.

6.2.2 Returning to the research questions

The study aimed to address two of the main research questions:

- What emotional associations do users have with texture and appearance of materials which can be used in e-textile interaction?

As participants handled e-textile objects, what would their association or emotional reaction be? Are there patterns or commonalities in their associations? Could this be used in designing e-textile objects for other activities where the sensors could be personalised, for example, for interactive storytelling as character objects or as sensory objects for stimulation or relaxation?

- Can visually impaired makers express themselves through e-textiles?

How might pre-made e-textile sensors be used for storytelling - both existing stories and those created by the visually impaired participants? Would they use the sensors to express themselves in other ways too?

- How do blind and visually impaired people interact with textiles (and e-textiles) using touch?

Would the participants have a consistent approach for handling or interacting with the objects in the study? Is there a 'gestural language' implied in their interaction? Exploring this might help to establish how e-textile objects can be used in designing interactions for other situations.

6.3 Study design

This second study investigated how e-textile sensors were handled, and how they were used in two interactive storytelling experiences. The participants were presented with five interactive e-textile objects, with different shapes and requiring different gestures for the interaction (see section 6.3.1 for details). The activities involved an open exploratory session, followed by two interactive storytelling activities. In all these activities, the focus was on investigating the choice of gesture when interacting with the various e-textile sensors, asking questions such as: What associations are made with these objects? For which part of the narrative (what action, event or actor) are they used?

The technology setup consisted of five different sensors laid out on a table, each connected to an Arduino board hidden in a plain white box. It was important to provide feedback to participants when they 'triggered' the objects with their gestures, in order to observe how they would carry on their interaction and also to give them a sense of agency over the interaction. Given the participants' different levels of sight, the decision was made to use sound output from the circuit boards as the most accessible feedback, as opposed to an LED which not everyone might see, or vibration, which tactile defensive participants might dislike. The sound was implemented by attaching a speaker to each Arduino board, positioned on top of the box so that participants could clearly hear when they triggered the objects (see Figure 6.4). Each of the design decisions is discussed in the sections below.

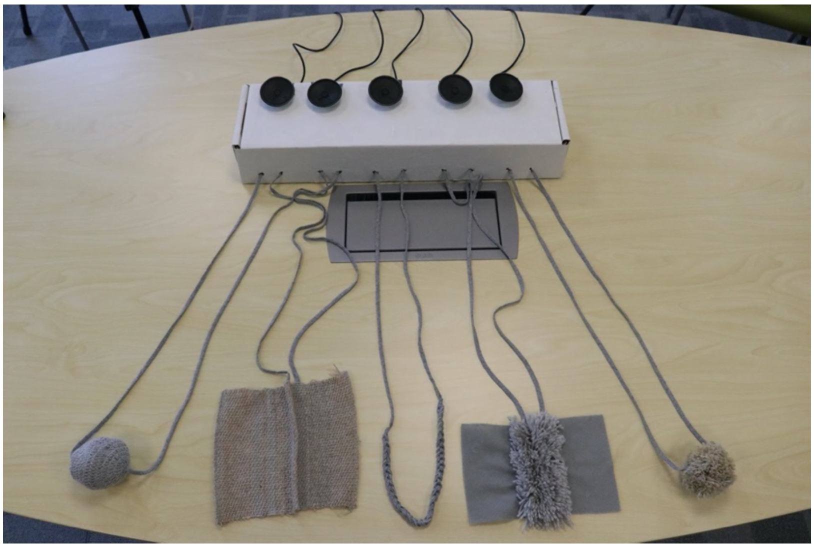


Figure 6.4: The study's technology setup on a table, including five sensors in front of a box of Arduino microcontrollers with speakers on top.

6.3.1 The e-textile sensors

The five sensors created for use in the study were:

1) **Pom pom sensor:** Designed to be triggered by ruffling/stroking/squeezing (see Figure 6.5):

Figure 6.5: Fluffy grey and beige pom pom sensor, created from conductive and non-conductive yarns, and conductive thread, standing alone and being handled.

2) Stroke sensor: Designed to be stroked and consisting of two parallel areas of conductive and non-conductive tufts which trigger when stroked over one another (see Figure 6.6):

Figure 6.6: Grey stroke sensor, created from felt, conductive and non-conductive yarns, and conductive thread, standing alone and being handled.

3) **Stretch sensor:** A crochet chain containing both conductive and non-conductive yarns which triggers when pulled (see Figure 6.7):

Figure 6.7: Grey stretch sensor, created from conductive and non-conductive yarns and conductive thread, standing alone and being handled.

4) Fold sensor: A less common sensor, this was a woven piece of fabric containing two conductive tracks, one on a flat part and the other on the fold so that, as the fold is pressed, or folded down, it touches the other conductive part and triggers (see Figure 6.8):

Figure 6.8: Grey and beige fold sensor, created from conductive and non-conductive yarns and conductive thread, standing alone and being interacted with by a hand.

5) Squeeze sensor: Crochet conductive yarn ball containing stuffing. Squeeze to trigger (see Figure 6.9):

Figure 6.9: Grey fold squeeze sensor, created from conductive and non-conductive yarns, fibre padding and conductive thread, standing alone and being handled.

The sensors were selected to allow a variety of gestures. The objects also varied in shape and texture, to give participants a range of tactile properties which could be matched to their associations and storytelling choices. All of the sensors created were based on examples which already exist within e-textile research and practice. Much of this practice-based knowledge was inspired by Kobakant, who post a blog documenting experiments and making with e-textiles (*How To Get What You Want*, 2020). The fold sensor was influenced by a similar one created by Aniela Hoitink at the E-textile Summer Camp Summer School in 2017 (*Summer of E-textile*, 2017). Other sensors were considered, but not included in this study for various reasons:

1) Tilt switch: Often designed with a metal bead which touches a conductive patch of fabric or another bead. This sensor can be difficult to use and is not as ‘soft' as the sensors that were made for the study (see Figure 6.10):

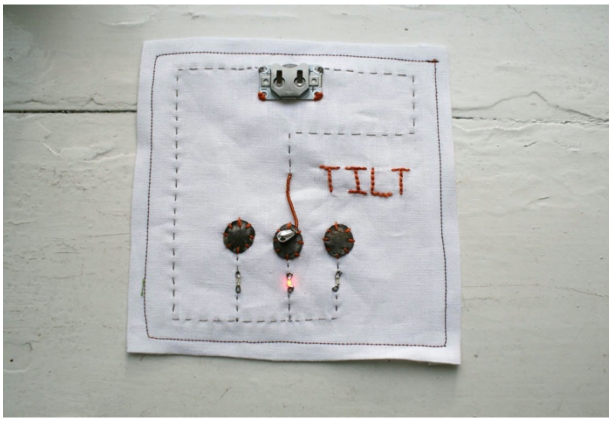


Figure 6.10: Tilt switch with a bead and three conductive fabric pads, each connected to an LED.

2) Velcro switch: Based on connecting two conductive Velcro pieces containing conductive material. This sensor does not allow for a range of gestural exploration (see Figure 6.11):

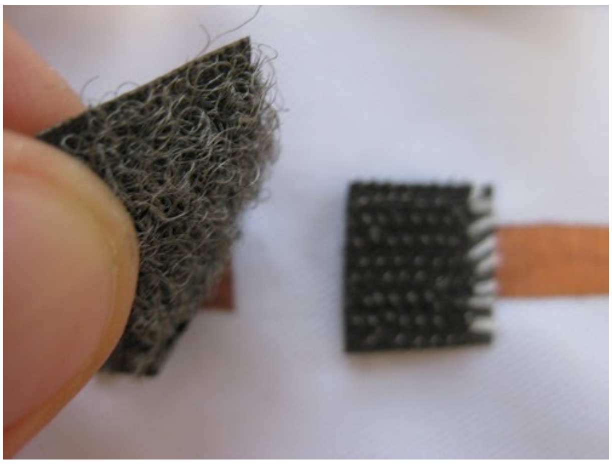


Figure 6.11: A velcro switch by Kobakant (2009). Image used with permission.

3) Press-stud switch: Based on connecting the two parts of the metal press-stud. Like the velcro sensor, this sensor does not offer much potential for gestures. These had also been used in study one to make circuit connections, so were familiar to the participants (see Figure 6.12):

Figure 6.12: Press-stud switch by Kitronik (2015). Image used with permission.

4) Push button: These had been used already in study one, in which participants had restricted their gestures to pushing on them with their fingers or palm. This limited interaction was one of the drivers for the third study (see Figure 6.13):

Figure 6.13: Push button being used to turn on an LED.

In summary, the selected sensors would be unfamiliar, would allow a range of gestures to be used, could be made entirely out of textiles, without any hard components such as the tilt and press-stud sensor. It was decided that five was a good number to work with, in order to keep the sessions to a reasonable time.

Within the e-textile community, there is a known collection of sensors often used by designers, artists, creative technologists and engineers within interactive e-textile pieces, each with assumed interactions (i.e., an existing gestural repertoire) implied in the name, e.g.,: a squeeze sensor will be squeezed, a stretch sensor will be stretched etc. There is not much research into the wider possibilities of *other* ways which users might interact with them should they be new to the technology. In the e-textile community, the discussion largely concerns the making aspects: which tools to use, which materials work well, with lots of sharing of patterns. How people might handle the sensors is less discussed.

This study builds on the existing sensors within the e-textile field. The visual aspects of the sensors were kept to a minimum so as to not bias the participants' associations with them. This was also to encourage them to focus on the feel of the e-textile objects and to handle them, so that their gestures could be explored. It was decided that making the e-textile objects plain in appearance, and grey or grey and beige in colour, would encourage the participants to use their imaginations as to what the sensors could 'be'.

6.3.2 Hardware

Lilypad Arduinos were used to control the interaction for the e-textile objects. These were easy to program, within budget constraints, and flexible in how they can be set up. The programming for each board was simple; each sensor triggered either when the circuit of which it was part was closed, or when the capacitive sensing reached a certain threshold level (see Arduino code D.1 and D.2 in Appendix D). The inbuilt Arduino speaker sound was used as output to signify that the sensor was working and that the interaction had 'triggered'. A 'beep' sound was selected as a neutral sound, so as not to bias or disrupt the participants' thought process or associations.

6.3.3 Activities

The box containing the Arduino boards and speakers was placed in front of the participants, so that it was just over arm's length away. The sensors were wired to the box and placed in front of the person in easy reach. A script was used to introduce the study, and each exercise, to each participant, so as to provide a uniform briefing.

1) Open play: The purpose of the first activity was to give the participant an opportunity to become familiar with the sensors and to ensure that the participant was comfortable with handling them. This was presented as an 'open' activity, with no set task apart from 'playing' with the objects to try whatever was natural for them. The sensors were described in neutral terms to avoid influencing the associations people might have.

2) Construction of participant's own story: In this activity, participants were asked to 'tell a story' of their own choosing, using the interactive objects in front of them. The first purpose of this activity was to observe whether the participants would use the associations given to the objects in the open play activity, to shape their narrative. The second was to find out whether the gestures exhibited in the first activity would be repeated or not.

3) Narrating Hansel and Gretel: For the last activity, again the purpose was to observe if any of the associations and gestures observed in the first activity were repeated. How would the participants use the sensors in a situation in which they had to match them with an existing story? The story of Hansel and Gretel was chosen as it would be familiar to participants (in this case adult westerners). Further, the Hansel and Gretel narrative has a rich set of action points, emotions and atmosphere that could be associated with the sensors and expressed gesturally. Hansel and Gretel also clearly follows Todorov's five stages of a narrative (Todorov, 1971):

1. A state of equilibrium at the outset;
2. A disruption of the equilibrium;
3. A recognition that there has been disruption;
4. An attempt to repair the disruption;
5. A reinstatement of the initial equilibrium.

Choosing a clear, familiar narrative with a common structure, meant that there would be many opportunities for interaction, and it would be more likely that the participants could remember key points when re-telling the story. The choice of Hansel and Gretel also addressed practical considerations:

- It was presented as the final activity, to avoid biasing participants' own storytelling in activity two, in case they had a 'rich' narrative that they wanted to share;
- It provides a strong, structured story in case their own story (from the previous activity) proved a bit limited for analysis;
- It provided a common structure across participants, in order to observe whether themes might emerge.

6.3.4 Execution and data collection

The study was run in a controlled environment within the university. There were a number of reasons for this:

- To be able to setup the sensors on a table in advance of the study, to test everything in good time, and ensure the layout was the same for each person - this might have been tricky outside the controlled environment;

- To be able to conduct the study in a room without other noises or distractions, so that the focus could be on the e-textile objects and activities;
- To ensure the study would take place in a relaxed environment, where tea and coffee could be provided, and where participants could carry out the activities with some privacy, so that they did not feel that they had ‘an audience’ when telling their tales.

After introducing each activity using a script, the research team took a non-interventionist, observational approach once each activity had begun, only introducing it and intervening if the participants became stuck or confused with the activity. If any issues did occur, then the lead researcher would step in and show them how to use the sensor or elaborate a little more on the task. This was rarely needed, and any intervention which occurred happened toward the end of each activity.

The study was run with five people, with each participant individually carrying out the tasks described above, during a morning or afternoon depending on what suited them. Participants were allowed to take their time with each activity, in order to feel that they had fully explored the sensors and also achieved what they wanted to with the narrative-based activities.

Although there were no time limits, the study took approximately two hours for each participant, divided roughly as follows:

- 10 minutes - arrival and settling into the environment;
- 10 minutes - introduction to the study and any questions;
- 15 minutes - activity 1: open play with objects;
- 20 minutes - activity 2: participant’s own story narratives;
- 10 minutes - comfort break;
- 20 minutes - activity 3: participant narrating Hansel and Gretel;
- 20 minutes - open discussion;
- 15 minutes - roundup and goodbyes.

Two stationary cameras were placed facing the participant and the table with the sensors (see Figure 6.14). The cameras thus captured hand gestures as well as facial expressions, body language, and audio. In addition, in order to obtain good quality audio, two audio recorders were positioned on the table at angles facing the participant. Still images were also taken during the study at points when the participants were interacting with the sensors in particularly interesting ways, and small video clips were recorded.

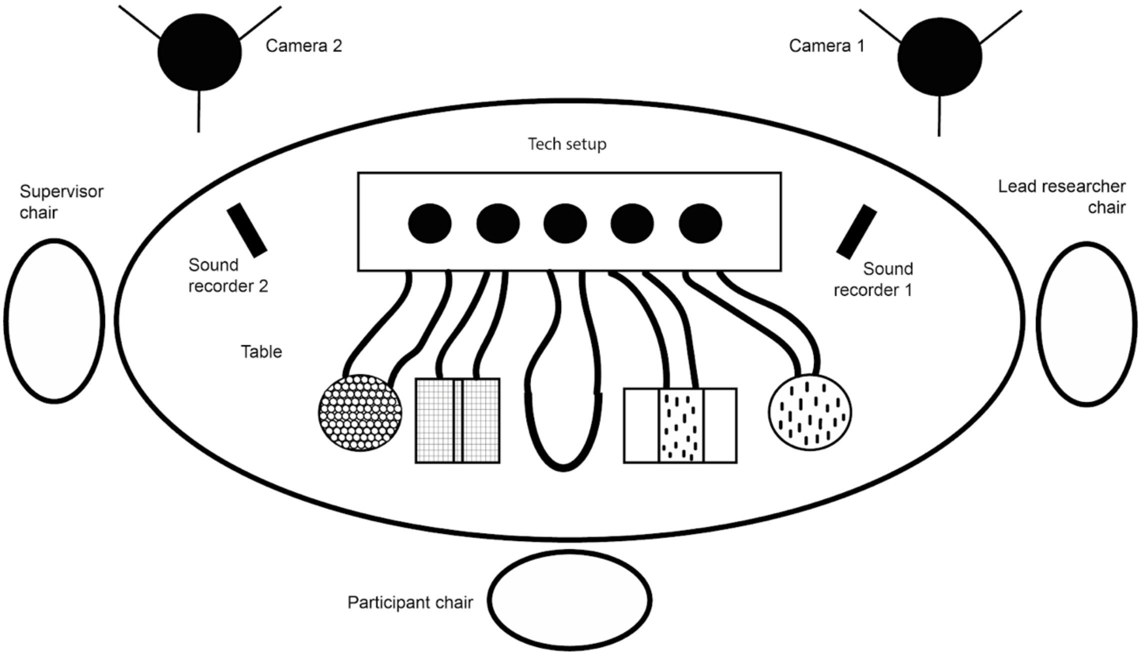


Figure 6.14: The technology setup, including seating arrangements for the research team and study participant, with data recording devices.

The lead researcher guided each session, with at least one of her supervisors, sometimes both, sitting quietly to the side to observe. Throughout the sessions, both the lead researcher and the observers made notes.

6.3.5 Participants

Five participants took part in the study. They had all interacted with e-textiles previously and also had other hands-on making experience, varying in their crafting ability. They were recruited personally for the study: four had taken part in the workshop study at MK Gallery and one had acted as an 'expert' providing feedback on prototype technologies prior to running the workshop studies. All five had a visual impairment of varying degrees of severity. Table 6.1 summarises the participants.

Name	Age & Gender	Interests
P1	60 - 65 F	Arts and crafts and her grandchildren
P2	55 - 60 F	Arts and crafts and music
P3	55 - 60 F	Arts and crafts and being in the countryside

P4	45 - 50 M	Poetry and playing the drums
P5	60 - 65 F	Arts and theatre and psychology

Table 6.1: Participants who took part in the e-textile storytelling study.

6.4 Data coding and analysis

The videos were first studied with an open mind for any interesting things that might have occurred. What did participants talk about? How did they handle the objects? How did they fit ideas together? After gaining an initial understanding of what happened during the study, the video materials were studied again, but now with more focussed questions.

- How comprehensible is each e-textile sensor?

Are the objects intuitive in their functionality? Do participants know how to trigger them? Do they trigger them accidentally? The useability and intuitiveness of the e-textile objects is relevant to their potential use in touch-based interfaces.

- What associations, meanings or actions do participants link with each sensor across tasks?

This question aligns with the first main research question, but more specifically explores parallels in how the participants perceive the e-textile objects over the three activities. Are there similarities in what they imagine the objects to be, or how they make the participants feel? Are the participants consistent in their associations across activities?

- Does the comprehensibility of the sensors affect the storytelling?

Does using the sensors hinder or enrich a narrative?

- Are participants consistent with their interactions and associations?

Do the participants use their hands constantly when interacting with the e-textile objects, or do they change how they handle the objects? Is there an association that accompanies the gesture? Do the objects change their role within activities or across all three?

Coding the video was an iterative process, the lead researcher re-watching the footage repeatedly and becoming more familiar with it each time, and sharing insights with the rest of the research team. The analysis was informed by the Interaction Analysis approach. This is a method discussed by Jordan and

Henderson (1995) which allows researchers to focus on specific aspects of an interaction, in collaboration with other researchers. The analysis works particularly well with video, helping to bring out the finer details of the data. Interaction Analysis is described by Jordan and Henderson as the *"empirical investigation of interaction of human beings with each other and with objects in their environment"* (1995: 39). Jordan and Henderson highlight the following 6 key procedures:

1) Ethnographic context;
2) Content logs;
3) Group work;
4) The Individual researcher's work;
5) Transcription;
6) Video review sessions.

Apart from the video review sessions, the procedures by Jordan and Henderson were followed and adapted as follows:

Ethnographic context

Interaction Analysis suggests that ethnographic fieldwork is undertaken alongside videotaping, to give framing to the work carried out. For study 3, there was already a connection with the participants from the previous study, and from spending time together at the community centres when taking part in arts activities. This had all helped the lead researcher to become familiar with the participants, their interests, and their creative abilities.

Content logs

Content logs are useful for giving a general overview of what participants do, hence giving a basis for transcription. Spreadsheets were created that included a video number and timestamp for footage, as well as a summary of what transpired during the video recording. These were compiled from the video footage before transcribing the audio data.

Group work

Interaction Analysis has researchers working in a group to investigate the video, letting coding emerge as the data is examined, as opposed to deciding on a coding scheme beforehand. Here the group consisted of the lead researcher and two supervisors. Together, they analysed selected sections of video selected by the lead researcher, and the categories for coding emerged as the research team went through the data. Notes of these conversations, and of the emergent themes, were made to inform the detailed analysis. The videos were selected based on 'actions happening' during the content; a lot of video content during the study is irrelevant e.g., it might be the participant being offered a drink, or general conversation - so this footage was of course not selected

The individual researcher's work

Following the model of Jordan and Henderson, the lead researcher spent time reviewing the audio data of the discussions had between herself and colleagues, and partially transcribed these. Having this written up gave the research team the opportunity to pick out key elements of the discussions - this being described by Jordan and Henderson as *"cannibalizing the audiotape"* (1995: 46).

Transcription

Significant sections were transcribed, with the level of detail determined by the researcher's analytic interests. The lead researcher transcribed what the participants said when handling the sensors, but only for specific sections of the study which they thought were relevant. This might be where a participant was discussing what associations they had with a sensor, what it felt like, or discussing how they could imagine it being used.

Video review sessions

Jordan and Henderson describe this as the step in which the participants in the research are invited to view the study material with the researchers. They either use it as an opportunity to ask participants to explain an action which is perhaps unclear to the researchers, or they ask the participants themselves to stop the tape at places which they think are significant. Because the participants' visual impairments would have made the review of such visual material difficult and potentially stressful, this procedure was omitted.

As the analysis was conducted, the videos were re-watched several times. As discussed by Jordan and Henderson, it's easy to misinterpret a clip or think something is occurring, when on second inspection it is not. To begin the process, the lead researcher watched the video footage all the way through, in order to familiarise herself with it. Next, she used Premier Pro to split it into chunks which aligned with the three activities. This removed footage containing discussions irrelevant to the research questions. Then, markers were inserted at points where gestures could be seen, with participants handling the sensors in some way. All these gestures were noted in a spreadsheet, with a time code against each gesture. After doing this, all of the research team watched the footage to discuss what was happening during the activities (i.e., procedure 3 described above).

The next step involved noting down dialogue from the participants as they handled the e-textile objects: - whilst holding the sensors just before interacting with them, during interaction, and just after sensors were placed back on the table.

The analysis identified gestures repeated by individuals, and those exhibited across participants. Alongside this, associations were also identified, noting those repeated by individuals and across participants. A thematic analysis was used for this, drawing out key themes that were identified, as described below.

6.5 Findings

This section will discuss the findings from the study, describing how each of the different sensors was used in the three parts of the study: Activity 1: Open play; Activity 2: Participants' own narratives; lastly, Activity 3: Participants' Hansel and Gretel narratives. This discussion covers how intuitive each sensor was, associations made by the participants, and what gestures were observed.

6.5.1 Activity 1: Open play

The participants were asked to explore the various objects in front of them, to *"play with them"*, and to *"tell us what you think of them"*. This was introduced as follows:

> *"We would like you to familiarise yourself with the objects in front of you. You will find that there are five of these and that they have fabric wires attached to them - the same as the ones which you made in the workshops which we did. At the ends of these are circuit boards - again, not that dissimilar to the ones which we worked with before.*
>
> *So now, we'll spend some time with you freely interacting with the objects. Please feel free to voice anything which comes into your head - what you think about them, whether they trigger any associations for you and even what you think about their functionality."*

This allowed the researchers to see whether they were able to trigger the sensors, and whether the interaction was obvious.

6.5.1.1 Analysis 1: How understandable was each sensor?

The first analysis checked, for each object, whether participants could work out by themselves how to trigger it, or not (Table 6.2).

	P1	P2	P3	P4	P5
Pom Pom	Yes	Yes	Yes	Yes	Yes
Stroke	Yes	Yes	Yes	Yes	Yes
Stretch	No	Yes	No	No	Yes
Fold	Yes	Yes	Yes	Yes	Yes
Squeeze	Yes	Yes	No	Yes	Yes

Table 6.2: Were participants able to trigger the sensors in Activity 1: Open play?

The initial interactions with and reactions to the different sensors are described in turn:

Pom Pom sensor

All participants were able to trigger this sensor with ease, and it seemed intuitive to use. Participants were observed picking it up, rotating it in their hands, and stroking it. Their experience in interacting with it was positive, and it appeared to operate reliably. It was observed that the sound could be triggered through a number of different gestures which possibly helped people's engagement with it. Most participants triggered the sound immediately - in fact, the sensor is hard to pick up without triggering.

Stroke sensor

Although the participants all managed to get it to work eventually, the stroke sensor was not as straightforward as the researchers had thought. In most cases it was triggered after trying several times. Everyone seemed to assume that the whole area of the sensor is interactive, instead of just the conductive fluffy area. Within the fluffy area itself, one must stroke it in a particular way (because the conductive thread is stitched in parallel rows), and none of the participants seemed to grasp that. They often stroked it vertically, which does not trigger it, as opposed to horizontally - the correct direction. This might have been connected to the orientation of the piece, that is, how it was presented on the table in front of the users. When participants did trigger it, they often would not understand how to stop it, often with some panic. P4 seemed quite fearful of it, whereas P5 said it made her feel safe.

Stretch sensor

P1 referred to the stretch sensor as a “puzzle” which sums up the reaction to the sensor very well: none of the participants knew how to trigger it, experimenting with a range of gestures but not succeeding. P2 and P5 both triggered it accidentally. P2 could not repeat this, as she thought she had triggered it by squeezing, rather than stretching it, which she had done without realising. The squeezing *did* in fact work in triggering the sensor, *but* only if done very hard. Stretching required a lot less effort. The other participants tried a range of actions: shaking it, running it through their hands, flattening it, holding it and walking the fingers as pressing on it - a kind of ‘grippy walk’. P1, P2, P3 and P4 all did eventually make small stretching gestures, but not enough to trigger the sensor. It is worth considering that had the threshold of the sensor had been configured to be more sensitive on the microcontroller board, that perhaps the participants would have triggered it successfully with stretching.

Fold sensor

Although all participants were able to trigger it, the reaction to the fold sensor was similar to that to the stroke sensor - a sense of confusion because it had to be triggered horizontally. Even when participants did fold it down, triggering the sound output, they did not always realise how they’d achieved this, particularly P4. When P3 realised the interaction, she exclaimed “Ah, it’s folding it!”. It was observed that the participants explored its textural properties, often stroking it. P1, P2 and P5 were observed exhibiting an ‘anchoring’ gesture, with both sets of hands resting on the fabric, either side of the fold.

Squeeze sensor

4/5 participants managed to trigger this sensor relatively easily. P1 squeezed and triggered it immediately, commenting that the sound did not go with the action. After a short exploration, P2 triggered it by squeezing with her fingers, as opposed to using the palm of her hand. The only participant not to trigger this sensor was P3, who seemed to struggle with the amount of pressure needed to do this. In attempting to trigger it, P3 rotated it, dropped it, shook it about. When questioned, she seemed to know that it had to be squeezed, but needed to be shown how to actually trigger it. It is possible that the threshold for this object was set too high in the Arduino code - that is, in an attempt to avoid it triggering when picked up lightly, it had been accidentally programmed into requiring a ‘big squeeze’, which appeared to be a difficult gesture for one participant.

Overall, only P2 and P5 worked out how to use all the sensors, whereas the other three participants did not. All participants struggled with the stretch sensor, even P2, who triggered it by chance. P5 triggered it initially by accident by tying the sensor into a knot, then trying to stretch it - triggering it as she did so. It is possible that the orientation of the sensors influenced how intuitive the interaction was - particularly with the two flat objects, (the stroke and fold sensor). P1 said that she would have preferred the objects to be vertical, which is the way Davis displayed her e-textiles for user studies in the previously discussed paper (2015).

6.5.1.2 Analysis 2: Gestures during open play

The second part of the analysis focused more specifically on three aspects:

- The gestures shown during interaction;
- Which participants carried out these gestures;
- The associations made with the gestures.

These are summarised in Table 6.3 and reported comprehensively in Table D.3 in Appendix D.

Sensor	Gesture	Association
Pom pom	Squeezing (all); Stroking (all); Ruffling (P1, P2, P4, P5).	Something *"Comforting"* (P1); Something "Sensual" (P5); Stress ball (P5); Pom pom/making pom pom (P2, P3, P5); Toys for a cat or child (P2, P3, P4, P5); e.g., childhood toy - Womble (P4).
Stroke	Stroking (all); Tapping (all); Anchoring gesture - placing one or both hands on the felt part of the sensor (P1, P2, P4, P5).	Rug or carpet-like (P1, P2, P4); "Shaggy-scarf" (P2); Nan and coat with fur-collar (P2); Sheep (P3); Cat (P5); *"Felty"*/Fuzzy Felts (P5); "Robust" (P5); Made participant feel safe (P5).

Stretch	Running through their hands/fingers (all); Gripping (all); Stretching (all); Neatening (P1, P2, P3, P4).	Gum-ball machine (P1); Puzzle (P1); "The comic of the piece" (P1); Corn dolly; Craft or related to: Nan and crochet, thread or chain, ball of wool, mum who knitted, knitting machine, cardigan (P2, P3, P4); A made object: corn dolly, fabric necklace and catapult (P2, P3, P4); Plaited hair (P4); Something to manage stress/OCD: elastic band to ping, greek worry beads (P5);
Fold	Tapping (all); Folding (all); Pushing (all); Rubbing (P1, P2, P4, P5).	"Scratchiness"/"Rough" (P1, P2, P5); "Sackcloth and ashes" (P1); *"Something to walk on"*/carpet/rug (P2, P4, P5); Clothing: jacket/jumper(P3); Flannel (P4); "Puzzle" (P5).
Squeeze	Squeezing (all); Cupping (P1, P2, P3, P5).	Ball-like object: a stress ball, a *"knitted sort of ball"*, a ball of wool (P1, P2, P4, P5); "Comforting" (P1, P5); "Something cats would like" (P3); Toy for a cat or a child (P3);

		Dishcloth made from *"cottony string stuff"* (P2); "Puzzling" (P5); "Soft" (P5); "Squidgy" (P5) Contemporary knit-wear (P5); "Love it" (P5).

Table 6.3: Overview of most common gestures and all associations exhibited in Activity 1: Open play. For more gestures see Table D.3 in Appendix D.

Gestures

Overall, a diverse range of gestures was observed during the open play activity. The stretch sensor was the most diverse, with 37 different gestures used by participants. For the pom pom sensor 25 different gestures were noted; for the stroke, 22; for the fold sensor there were 31 gestures and the squeeze, 32 (see Table D.3 in Appendix D).

There were some strong commonalities, with some gestures used by all the participants for a given sensor - such as everyone naturally squeezing the pom pom and squeeze sensors. But there were also interesting differences, for example P3 and P5 both coiling the stretch sensor, or P5 opening the fold sensor like a book - something not seen by other participants during Activity 1.

Associations

The participants did not all make the same associations, and expressed a range of possible associations for each sensor. Some parallels did occur, with the pom pom sensor mostly likened to a toy; the squeeze sensor likened to a ball-type object (two of these being craft-related); both the fold and stroke sensors related to a rug or carpet by four different participants; the stretch sensor associated with a craft or a craft-based object (knitting, crochet, thread and a fabric necklace) by three different participants.

The participants referred to different aspects of the e-textile objects when describing their associations: tactile qualities, construction and conceptual similarities with other objects. They also made associations related to their own gestures in handling the e-textile objects. For example, P2 focused on the construction methods of the stretch sensor (*"crochet"*) and the pom pom sensor ("pom pom making") - as did P3 with the pom pom. P4 focussed more on the materials, discussing *"balls of wool"* with both the stretch and squeeze sensors. P1 was more conceptual in the associations, referring to the squeeze sensor being like a stress ball, the stretch sensor being like a ‘gumball machine’, and the fold sensor like *“sackcloth and ashes”*. This last association was interesting as in fact the fold sensor had a scratchy feel to it. She also described the squeeze sensor as being *“the comic”* (as in comedian) among the sensors and like a *“puzzle”*. P1 also commented on the texture of the fold sensor, referring repeatedly to the *“scratchiness”* of the fabric. P4 referred to the stretch sensor as being like a catapult. Although a small sample, these results show us that there is some commonality in how participants perceived these objects, but that one given association cannot be assumed.

This initial activity offered an opportunity for the participants to approach the objects in their own time and in their own way. That is, they were given the chance to explore the objects’ tactility and functionality in their own terms, rather than being told how they should interact with the objects or what the research team thought the objects resembled. Introducing the user study with this activity gave clear findings for the two research questions, whilst also prepping the participants for the next two narrative-based exercises, which required creative thinking.

6.5.2 Activity 2: Participants’ own narratives

The second activity required the participants to craft their own narrative with the e-textile objects. That is, they were asked to tell a story using the objects as interactive props to represent any story element they wished (e.g., people, events, or an environment) and to trigger them when appropriate. The activity was introduced as follows:

> *“We would like you to construct a story of your own, but within it also using the e-textile objects as props, or sensory enhancements to your tale. This could be to emphasise moments within the narrative whether they be action based, emotional or where some sort of tactile element is happening. Like we did within the e-textile workshops at MK Gallery, we would like you to really focus on the feel of the objects and how you might interact with them using your hands, as something to be very much connected to your story. The story itself can be fictional or factual and it can be as simple or detailed as you like!”*

6.5.2.1 The stories

P1 created a story about a little girl - a lonely only child - whose father brought her a kitten which he had found in a sack in a river. The kitten became a companion for the girl, and together they loved to play on a rug with the kitten’s favourite ball. The girl was wearing a headband, resembling Elizabeth Taylor.

P2, after some initial re-exploration of the e-textile objects, explained that *We're Going on a Bear Hunt* was one of her and her children's favourite stories. She wanted to re-tell that story using the sensors as characters and physical locations within the story.

P3 found this activity quite challenging, and, instead of telling a story, discussed imagined uses for the e-textile objects. These ranged from creative uses to more practical ones.

P4 built on one of his associations in the previous activity - his childhood toy Womble. He crafted a story about a little girl - who is comforted by her toy Womble after she trips over a carpet in her house, and who then has her hair plaited by her mother before she goes to school.

P5 believed that she had already started her story through the associations given to the e-textile objects in the first activity. She explained that she would base her narrative on a typical day in her life - how it would unfold, and her emotions at different points. It would be a day when she woke up and felt awful.

Different approaches were observed in the types of narrative given, with P1, P4 and P5 creating their own stories, P2 adapting one of her favourite story books, and P3 creating scenarios and uses for the objects.

6.5.2.2 The gestures and associations

Table 6.4 below reports the main gestures observed. It is reported comprehensively in Table D.4 in Appendix D.

Sensor	Gesture	Use in own narrative
Pom pom	Stroking (P1, P2, P3); Squeezing (P2, P3, P4); Tapping (P2, P3, P4); [Not handled by P5].	Cat/kitten/cat's favourite ball (P1); Bear in We're Going on a Bear Hunt (P2); Discussed sound design and how it could be a cat purring, a child giggling or a cow mooing (P3); Other associations by P3: toy, pleasing to play with, but not durable, discussing textures, orange (colour), visual impairment, noisey thing to throw around, colour coordination, necklace, bobbles; Toy Womble for his story, a *"mother's head"* (P4);

		[P5: no associations].
Stroke	Tapping (all); Anchoring - placing one or both hands on the felt part of the sensor (P2,P3, P4, P5); Pushing (P1, P2, P3, P4).	A carpet on which the girl and cat would be playing - girl giggling (P1); Cat's meow (P1); River (P2); Nan's coat (P2); Associations by P3: pet animal, animal noise - woof or meow, toys, objects to be used for Dementia or Parkinson's patients, items for kids, sheep, *'Build a Bear'*, to represent *"real"* things like lemon. Nice feel, soft/fluffy (P4); A *"good carpet"*, carpet which girl sits on in narrative (P4); Sort of rug or carpet - something to put feet on and encourage her to get up for the day - makes a crackle (P5).
Stretch	Pushing (P1, P2, P3, P4); Tapping (P1, P2, P3,P4); Gripping (P1, P2, P4); Pulling (P2, P3, P4); [Not handled by P5].	A girl's hair: her favourite headband, girl having hair plaited on carpet (P1, P4); Elizabeth Taylor (P1); Obstacles in *We're Going on a Bear Hunt* rope bridge - running over it with *"Dsh, dsh, dsh"* noise (P2);

		Crochet (P2); Necklace (P2, P3); Discussed sound design - cat purring, a child giggling or a cow mooing (P3); Other associations by P3: Items for kids, snake, something for VI person or person in care home, something for clothes, colours, animals, linked to texture and pleasure in interacting (P3); [P5: no associations].
Fold	Folding (all); Tapping (all); Anchoring (P1, P2, P3, P4); Straddling - rested their hand on the sensor, positioning their thumb or index finger on one side of the fold, and the rest of the fingers on the other (P1, P2, P3, P4); Pushing (P1, P2, P3, P5).	*"Sackcloth"*, specifically a sack in which the cat in her story was found (meow sound) (P1); Army assault course (P2); Mat - specifically mat sat on by nan by fire (P2); Associations by P3: Twiddlemuff, could be used for alert, is like something smooth, liked the feel of it, jacket, likes how works one way and not the other; Carpet, including abrasive one, *"bad guy"*, *"bad carpet"* (P4, P5).
Squeeze	Squeezing (P2, P3, P4, P5); Tapping (P1, P2).	Spherical objects: Girl playing with favourite ball (boing boing noise), ball to leapfrog over (P1, P2); Discussed sound design - cat purring, a child giggling or a cow mooing (P3); Associations by P3: For learning of colours, light sensors and triggers included, to represent *"real"* things like lemon, toys for children/elderly people, alert;

		Like mum: soft on inside & hard on outside (P4); Sensory object: comfort, likes the feel, helps her feel calm (P5); *"Emergency"* one on the bathroom door. (P5).

Table 6.4: Overview of most common gestures and all associations exhibited in Activity 2: Participants' own narratives. For more gestures see Table D.4 in Appendix D.

Each participant was creative in how they used the sensors - both in terms of gestures and in how the objects could be used to represent characters, objects and environments in each of their stories.

Gestures

Similarly to Activity 1, during Activity 2 a diverse range of gestures were noted. The stretch sensor again was the most diverse, with 32 different gestures used by participants. For the pom pom sensor 29 different gestures were noted; for the stroke, 28; for the fold sensor there were 25 gestures and the squeeze, 25 (see Table D.4 in Appendix D).

Again, there were many gestures common to multiple participants, and more than one gesture was used for all of the sensors. Not all the participants handled all of the sensors in this activity; P5 did not handle the pom pom or the stretch sensor and had no associations with them. Some gestures were used more in Activity 2 that were only used by one participant in Activity 1, such as straddling the fold sensor (see Table D.4 in Appendix D); there were some new gestures introduced which were not seen in Activity 1, such as P3 crossing the ends of the stretch sensor; and some gestures that were observed in Activity 1 did not appear again in Activity 2 such as ruffling the pom pom. Perhaps these differences were due to a new context or an already existing knowledge around the sensors through activity 1 along with more confidence in exploring the objects.

Associations

Many associations were new (e.g., a bear for the pom pom, a river for the stroke, a rope bridge or a snake for the stretch). Some were repeated (e.g., sackcloth and a jacket for the fold sensor; rug or carpet for the stroke sensor; toy, cat, and Womble for the pom pom; spherical objects for the squeeze). Some of the sensors were used for more than one element in a given narrative (e.g., the pom pom used as a Womble and a mother's head by P4). As observed in Activity 1, the participants used them in a diverse and creative way.

6.5.3 Activity 3: Participants' Hansel and Gretel narratives

For the final activity, the participants were asked to use the objects to enhance the fairytale

of *Hansel and Gretel* in a way they saw fit - whether by representing characters in the narrative, objects or scenes, or to be used when a certain action or event was occurring. This was introduced as follows:

> *"We would like you to listen to a well known children's story and think about how you would use the e-textile objects to enhance the experience as a listener. Imagine that different e-textile objects could be used to amplify the sensory experience at certain parts, with the listener being offered tactile objects to interact with. You can also think about a replacement sound to the buzz, which you might match with the objects - this sound can be anything."*

This introduction was followed by reading a simple version of *Hansel and Gretel* (see B.4 in Appendix B), and they were asked to retell their own version of the story with the sensors.

6.5.3.1 The gestures and associations

Table 6.5 below reports the main gestures observed. It is reported comprehensively in Table D.5 in Appendix D.

Sensor	Gesture	Use in narrative
Pom pom	Squeezing (P2, P3, P4); Stroke (P1, P2); Tap (P1, P4); Push (P1, P5).	Breadcrumbs, or breadcrumbs taken away by the wind (P1); Textures (P1); People: The father, the witch (specifically, the witch being thrown into the pot by Gretel) Hansel and Gretel (P2, P3, P4); [P5: no associations].

Stroke	Anchoring (all); Stroking (P1, P2, P3, P5); Tapping (P1, P3, P4, P5).	A path in the forest/the forest/trail (P1, P2, P5); Textiles: Bling and shiny one/70s shagwell carpet (P1); Hansel and chicken bone (P2); Birds eating breadcrumbs (P3); Cage clanging (P3); Friendly sound on Hansel and Gretel's return (P3); Chocolate cottage (P4); Witch pushed into cauldron by Gretel (P4); Witch going to cook them (P4); Bird's chirping (P5).
Stretch	Stretching (P2, P3, P5); Picking up (P4); Pushing (P1, P3, P5); Tapping (P1, P2, P5).	Hair: Headband, plaited hair for Gretel (P1, P4); Wealth/lack of: Poor (the family), blingy, treasure and coins clinking (P1, P3); People: The children, witch (P1, P2); Navigation: Direction to take/follow path home, breadcrumbs, chord for trail to guide children back (P1, P2, P5); Umbilical cord (P5); Sweet house (P2).
Fold	Anchoring (P1, P2, P3, P4); Folding (P1, P3, P4, P5).	Oven (P1); Cage, clanging of it (P1, P2, P3); Cottage roof/chocolate cottage (P2, P4); Poverty/rags (P1);

		Sackcloth and ashes (P1); Witch, electric sound to go with her (P1, P5); Forest, stepmother taking Hansel and Gretel into woods, prickly floor with twigs (P1, P3, P5); Texture, *"rough"*, (P1, P5);
Squeeze	Squeezing (all).	A trail of pebble/something spherical (P1); Sweets stuck to cottage wall (P2); Cauldron, witch falling into the cauldron and boiling, water being poured into the cauldron (P2, P3); People: Father, Hansel and Gretel (P4); Soft building cottage/light building with windows/a nice place/bright light - comforting (P5).

Table 6.5: Overview of most common gestures and all associations exhibited in Activity 3: Participants' Hansel and Gretel narratives. For further information, see Table D.5 in Appendix D.

Gestures

During Activity 3, the range of gestures used with the sensors was less than in Activities 1 and 2 (see Table D.5 in Appendix D). Perhaps this was due to the participants feeling more focused and experienced in how they might use them by this exercise. The fold sensor was this time the most diverse, with 29 different gestures used by participants. For the pom pom sensor 12 different gestures were noted; for the stroke, 20; for the stretch sensor there were 22 gestures and the squeeze, 20.

Similarly to Activity 2, P5 did not have any associations linked to the pom pom for this activity, however she did push it before going into her narrative, almost using it as a starting object.

New gestures introduced during this activity were sometimes strongly linked to the narrative (see Table D.5 in Appendix D) - for example P2 making an eating gesture with the squeeze sensor or holding the fold sensor up like a roof shape. These gestures were different to the other gestures, whereby the objects had been handled *like* props or handled for interactivity. In this instance the objects were actually being *used* as props for the narrative, their shapes being exploited to this end. P1 also gestured a 'de-fluffing' motion when describing the breadcrumbs as being left in the woods but then being blown away.

There were also the same gestures exhibited as seen before across Activities 1 and 2: the squeeze sensor was squeezed by either 4 out of the 5, or all participants; anchoring and folding were both seen by 4 out of the 5 participants with the fold sensor; pushing, tapping and stretching were observed by 3 out of the 5 participants with the stretch sensor; anchoring, stroking or tapping were used with the stroke sensor by either all, or 4 out of the 5 participants and 3 out of the 5 squeezed the pom pom.

The new gestures performed that saw the objects being used more as props was interesting as it demonstrated a real switch from their purpose of interactive objects as playful things which triggered an output to tangible narrative devices; this goes beyond the usual scope of how e-textile sensors are used. The gestures performed again that were already observed in Activities 1 and 2 show that again, there is some consistency in how objects are handled. It might not map as exactly the same across every Activity, but there is enough consistency to suggest that perhaps some of the gestures performed fit quite intuitively with the objects.

Associations

Table D.5 in Appendix D demonstrates how, for Activity 3, there were fewer gestures exhibited than in Activities 1 and 2. Perhaps due to participants developing more confidence in how they wanted to use the interactive objects for their own creative purpose, and beginning to get a sense of what they worked well for.

The spherical sensors - the pom pom and squeeze ones - were used for elements in the narrative which are spherical, from people to objects such as pebbles or the cauldron. The forest in the narrative was represented by either the fold or the stroke sensor (the ‘flat’ sensors), with some participants using both. P1, P2, P5 used the stroke one as the forest or forest path, and P1, P3, P5 the fold sensor as the forest, the act of the stepmother leaving Hansel and Gretel in the forest and the prickly floor in it, with twigs. The stretch sensor was used for different narrative elements, as can be seen in Table 6.5. It was again used to represent hair related associations, as it was in Activities 1 and 2; an interesting association made by P5, and discussed after the storytelling was how the stretch sensor made her think of an umbilical cord, regarding Hansel and Gretel *“it being the attachment to the other place they live”*.

6.5.4 Grouping the findings

Observations across all the activities were grouped together thematically. Themes include:

- Shapes and associations;
- Design of the e-textile objects;
- Reliability and thresholds;
- People and interaction;

- Texture and concept;
- Gestures used across sensors.

The themes lead to a wider discussion around opening up the possibility for e-textiles (6.5.4.7).

6.5.4.1 Shapes and associations

Excluding the stretch sensor, the sensors either fell into two categories of shape: a) spherical and b) flat and square. Of course, they had their own personal qualities which went beyond this but this is what the pom pom and squeeze and then stoke and fold sensors can be classed as in their simplest forms. Throughout the three activities these seemed to be linked repeatedly with similar associations by the same, or different participants:

- Spherical sensors: toys, living beings (people or animals), a spherical object (craft-related ball, stress-ball, pebbles or cauldron);
- Flat and square sensors: rug/carpet or forest.

It is worth noting that in Hansel and Gretel the flat and square sensors *were* related with more than just the forest, but this seemed like the most common consistency across participants. More details on this, along with how they were handled during these discussions can be read in Table D.5 in Appendix D.

The stretch sensor had multiple associations attached to it, and in some ways due to its shape was the ‘odd’ one out of the group of sensors. However, one association which popped up consistently was its association to hair - either a headband or plaited hair. Within Activity 1 and Activity 2 ‘craft’ was also very much associated with it e.g., crochet or knitting.

6.5.4.2 Design of the e-textile objects

The sensors were all a similar colour - grey and beige - so as to not distract from the feel of the objects, given that some of the participants have limited vision. The concern was that, if different colours were used for the objects, it might bias the participants’ associations with them. However, P2 was surprised that brighter colours were not used, as she felt that that would have enabled her to see the objects more clearly (which she wanted to).

The participants were encouraged to focus more on what associations they might place with the objects, as opposed to commenting on their *literal* design i.e., construction method, colours, material used, size etc. however this was something which for some participants they wanted to discuss - almost engaging in a dialogue around redesigning them. Along with P2 commenting on the lack of colour, P1 mentioned how she would have liked them to be vertical. Throughout Activity 2, as opposed to using the objects for an imagined, narrative based association, P3 wanted to re-imagine them in a very practical way, as objects that could help visually impaired people, elderly people or children. She was almost taking the activity to the next level of how the participants could play a part in re-designing these objects - something which would be very interesting to explore.

6.5.4.3 Reliability and thresholds

There were challenges of some form with each of the e-textile objects, associated with how reliably the participants could trigger them, and the thresholds for triggering:

- **Pom pom:** The pom pom triggered consistently with no issues, albeit perhaps a bit too well as it triggered often just from being picked up.
- **Stroke:** The stroke sensor needed the conductive fibres to be a bit longer to make a consistent connection; hence its usability was not as good as it could have been. Participants failed to trigger it most of the time, sometimes because the conductive parts did not connect when stroked, but often because it was stroked the wrong way. As P1 said, perhaps it would have been better had it been orientated differently.
- **Stretch:** Everyone but P2 found the stretch sensor confusing, and the interaction was not understood fully even when it was triggered.
- **Fold:** The fold sensor was perhaps the most robust and reliable as a sensor - always triggering when the fold action was performed to connect the two sides of the sensor.
- **Squeeze:** One of the participants was not able to trigger the squeeze sensor. It had been programmed to be less sensitive than the pom pom sensor, but this meant that participants had to put more pressure on it to trigger the output. Both P3 and P4 said that they would have liked it to have been a bit easier to trigger, with less pressure. It is challenging to get the right threshold for objects in a study such as this.

The sensors were only tested amongst the research team prior to being used for the study. In hindsight, it would have been advantageous to have a two part process to the prototyping, similarly to the workshops studies in which a VI expert could have inputted their opinions as well. However, due to time restraints this did not occur.

The purpose of Activity 1 was to demystify the sensors, along with giving participants a playful opportunity to explore them and for the research team to observe their initial reactions or reflections. It also created an opportunity for everyone to be brought up to the same 'level' with their experience of using them, the lead researcher demonstrating the sensors to everyone, and asking them to have another go if something did not trigger or not be clearly understood. This should have meant the objects were reliable enough to use for Activity 2 and Activity 3 with the narrative exercises. It might be assumed that the objects were often used just as 'props' due to some of them not triggering as easily as others, but it is also worth considering that, as the participants were asked to use them *to represent* characters, objects, the environment, etc. in a narrative, they did just that, and did not feel the need to trigger them each time.

6.5.4.4 People and interaction

Despite the variation in personality, all of the participants were able to engage with the e-textile objects and to use them creatively and expressively in their own individual way.

P1 very much ‘flowed’ in her engagement with the objects, coming back to consistent references (particularly the *“sackcloth and ashes”* association) and freely exploring the objects.

P2 was successful in triggering the sensors within the first activity as well as matching them to events, characters and objects in her own story (*We’re Going on a Bear Hunt*) as well as during her telling of *Hansel and Gretel*. She threw herself into the activities with ease, and was very considered in her choices as she made them. She was probably the participant who was also the most ‘dramatic’ in her telling of tales.

P3 was inspired by the objects in imagining amazing ideas for the use of e-textiles, but also jumped around a lot within discussions. This was reflected in her style of interaction with the objects , with her hands going between these in a very fluid motion.

P4 almost held back when interacting with the objects, spending much time thinking through each instance of touching them as if slightly fearful of them.

P5 enjoyed touching them and discussing their associations in a way which was very much linked to therapy (she is a trained psychotherapist). She herself uses ‘comfort’ objects in her everyday life, linked to anxiety, and so this study seemed very relevant to her in a lot of ways regarding sensory engagement. Interestingly, she finished her version of *Hansel and Gretel* at the children being at the witch’s house and not being able to see their trail anymore - with no ‘happy’ ending’; she did not want to give it a traditional ending.

Although the interactions were all individual, and in some ways the approaches reflected the different personalities, as discussed above and as can be seen in the tables recording the different gestures and associations, there was still consistency amongst individuals and across individuals - it was mainly the telling of the stories, their timings with their interactions and their ‘approaches’ which varied.

6.5.4.5 Texture and concept

The participants formed conceptual associations based on different characteristics of the sensors: texture, shape, construction (or some combination of those). Some of the associations were based on evident physical similarity (e.g., the squeeze sensor associated with a stress ball; the stroke sensor associated with a 1970's shagwell carpet), and some were less obvious (e.g., the stroke sensor associated with the cauldron). Sometimes the participants did not discuss the physical properties explicitly before discussing the conceptual association, so it was difficult to determine what prompted the association (e.g., the stretch sensor being linked to the children and witch by P1 and P2). Once an association was made, it often 'stuck', for example P1 referred repeatedly to the fold sensor as *"sackcloth and ashes"*, and commented on the scratchiness of it - the texture and the imagined form being very much connected.

Perhaps the participants who focused on the material and textural elements of the objects brought in their own knowledge of crafting - allowing them to 'deconstruct' the objects mentally and focus on the textures and materials. For example, the fold sensor (which was woven with a tight weave) was referred to as being like a 'jacket' or a generic 'carpet'. The narrative activities seemed to prompt the participants to use the objects in a more conceptual way, re-imagining the objects as environmental elements, objects, or people, but the participants still commented on the objects' textures, such as the stroke sensor being used as a 'forest' by P2. This indicates that the feel and the construction of objects are both important.

6.5.4.6 Gestures used across sensors

The participants were fluid with their hands, touching one object, but whilst doing so moving to another object to touch or interact with it. They were also observed using the items on the table as things to walk around with their fingers.

An interesting observation was that participants sometimes interacted with objects, without triggering them, using them as props when telling their narratives. There were more instances of them using the objects in this way than triggering the audio on the Arduino boards.

Some objects were intuitive in how they should be handled for interaction, others not so much. The pom pom and squeeze sensors were largely triggered with no issues - apart from P3 finding it difficult to squeeze the squeeze sensor enough to trigger the beep. The rest of the sensors were less obvious, either not being triggered or taking longer to be triggered.

There were gestures for each sensor which were more common and have been recorded in the above tables. But how do these map across the sensors? Which of the most common gestures were performed across all sensors? The table below demonstrates this:

Performed gestures	Pom pom	Stroke	Stretch	Fold	Squeeze
Squeeze	x				x

Performed gestures	Pom pom	Stroke	Stretch	Fold	Squeeze
Stroke	x	x			
Ruffle	x				
Tap	x	x	x	x	x
Cup					x
Anchor		x		x	
Run through hands			x		
Push	x	x	x	x	
Pull			x		
Straddle				x	
Neaten			x		
Fold				x	
Grip			x		
Stretch			x		
Rub				x	
Pick up			x		

Table 6.6: Most common gestures observed with sensors and how they map across each.

The 'tap' and 'push' gestures are ones which seem to be performed across most of the sensors - with other gestures only being performed with a particular sensor or across two of them. This suggests that certain shaped sensors, and their designed interaction afford certain gestures. For example, it would perhaps be difficult to 'run' the pom pom through one's hands as a user, but the stretch sensor through its form can do this.

6.5.4.7 Opening up the possibility for e-textiles

All of the participants demonstrated how the e-textile sensors could be used in diverse and creative ways, through their openness to play, their inventive use of objects with a fabricated narrative and by embracing them in the telling of *Hansel and Gretel*. The study demonstrates that there is a potential for these types of soft sensors to be used to accompany storytelling in a creative way, and that certain sensors do indeed encourage certain gestures to be performed *but* that they also encourage gestures which might not even have been thought about by designers previously. For example, the fold sensor invited a sort of 'straddling' gesture to be performed by P1, P2, P3, P4, something which is not an 'assumed interaction' or 'assumed gesture' of the sensor (hence being called a 'fold sensor'). This study has very much built on the work of Lederman and Klatzsky (1987), by taking the approach of exploring what could be classified as 'assumed exploratory procedures' regarding e-textile sensors through a user study - which as discussed has confirmed some gestures but also introduced other ones - similarly to Lederman and Klatzsky's study with their objects. This opens up a dialogue around how they can be used.

The discussion around future uses of e-textiles or wider associations with the sensors did not come out as much with the other participants as it did with P3 - who chose to focus on this in Activity 2. She found the brief of using the sensors to express a personal narrative challenging; however, she did respond with many ideas about the use of e-textile objects. These included: to enhance twiddle muffs (a sensory fabric object often used by people with dementia); to provide sensory objects for children and older people; something which could be used for people with dementia or Parkinsons; as wearables - particularly a jacket; as interactive objects to represent 'real' objects such as a lemon; and as an object that could help visually impaired people find something. P3 apologised for not being able to create her own narrative using objects, but it was useful to have this conversation with her about the use of e-textiles. Having already engaged in the series of hands-on making workshops in the last user study, it seemed that she had been very much inspired by this technology.

Sound also seemed important to her. In the workshops, the participants had recorded their own sounds, whereas with this user study a 'beep' sound was simply used to indicate chosen to signify to the participants that they had successfully triggered the sensors. She discussed the challenge of VI people being able to tell what colour an object might be, for example an item of clothing. She discussed the idea of a different sound used for different colours - orange and blue being examples. P3 talked about sound design a lot and how different sounds should go with different objects.

It was also interesting to see her make connections with more theoretical ideas, related to objects of reference. In particular, she reflected on the notion of real life 'things' and their e-textile representation, and where this would sit in the objects of reference framework. P3 did seem to think that it might not be possible to represent something like a 'fish', but she was reminded that the e-textile objects could have another textural property added to them in the making, meaning this could be done.

P3's ideas about therapy objects is very relevant to e-textile research; as discussed in the literature review, e-textiles have been used as therapy objects by a number of researchers (Vaucelle et al., 2009; Profita et al., 2015; Schelle et al., 2015; and Kenning and Treadaway et al., 2018) and so it is encouraging to see participants, who have never worked in a research context with these objects, have similar ideas and independently imagine them as having these uses. It was also good to see a participant push against the brief and take ownership of how she wanted to use the sensor; it is so important for participants and users to partake in the design thinking for the potential of interactive objects, particularly in a way which might be important or empowering for them.

6.6 Limitations

There were some potential limitations to the study. The five participants who took part had worked with e-textiles before – either through the workshop studies or during the prototyping in preparation for them. This provided certain advantages. They were already familiar with the researchers and at ease with the research setting. Their experience meant that they could focus on the functioning of the sensor, because they already understood how the technology worked. However, that experience might equally have biased their interaction, for example influencing their expectations. What would the outcome have been, had this study been conducted with visually impaired people who had not interacted with e-textiles before? It would be appropriate to repeat the study with participants without such experience, in order to test the generalisability of the findings. Nevertheless, they did represent a range of visual impairments from completely blind to having some vision. They also had a range of different crafting skills from experienced artists to absolute beginners. In order to make the workshops at all possible it was necessary that participants would be able to construct soft circuits effectively and to complete a personal art piece. Engaging with them provided considerable insight into how to such ‘making’ can be accessible to visually impaired people, and some of the approaches and insights are likely to generalise to other settings and other user groups – a matter for further research.

Another potential issue is how the sensors were displayed for interaction. The research team chose to position these flat on a table in front of users. However, these could have been positioned vertically – as suggested by P1. The chosen positioning may have affected the participants’ interaction with the sensors. Similarly, other details of the presentation might have influenced the interaction. Nevertheless, the range of gestures and associations observed suggests that the participants were able to engage with the sensors; future work might focus on how the presentation of sensors influences different aspects of the interaction, such as initial engagement, or the use of sensors for different purposes (e.g., control vs story-telling).

The selection of sensors for the study is a potential limitation. It would be appropriate to extend the study with more and different sensors, having different textures and different activations, in order to investigate the range of gestures and interaction more fully, and to understand better the initial engagement with unfamiliar sensors.

Despite the limitations, the study provided additional evidence that extended the understanding of tactile interaction with e-textile sensors.

6.7 Summary

This chapter has discussed the planning, execution and results of a lab study, exploring what gestures and associations users link with hand crafted e-textile sensors through three different activities. The study builds both on the work of Davis (2015) and Petrelli et al. (2016) through its exploration of the associations that users make with objects when touching them, but also Lederman and Klatzsky (1987) by exploring the gestures that users show when handling objects as well; the study essentially brings these two approaches together.

Some findings have emerged from the study regarding association and gesture including:

- There is consistency across both open play and narrative based activities, of sensors being used repeatedly to represent certain objects, living beings or environments: e.g., the spherical sensors for people and the flat ones for carpets;
- Although some objects were used to represent the same thing through the activities, they also sometimes had another association linked with them as well - across users as individuals along with across users as the group;
- Some gestures are repeatedly used for certain sensors: e.g., squeezing for the pom pom and squeeze sensors and tapping for the stroke sensor;
- However, throughout the activities the research team also observed new gestures being introduced such as the crossing over of the ends of the stretch sensor;
- The sensors were often used more as ‘props’ for storytelling than as interactive objects.

These findings show that users are not wedded to interacting with interactive e-textile sensors in just one way; they are open to exploring them and *changing* the gestures and associations depending on *how* they are being used - what the context is. However, the fact that there was some consistency in how the spherical vs. flat square sensors were used demonstrates that the shape of the sensor perhaps impacts on what it might be linked to.

As discussed earlier in this chapter, e-textile sensors are often designed with an intended gesture for interaction in mind, e.g., stroke sensor, squeeze sensor, etc. This study has demonstrated that there are many more gestures that a user might perform with sensors, should the activity be introduced in an open way and with participants not being given a sensor name for before the interaction. This comes back to ideas about empowerment and working with people who might not always get to *be* the designer - asking them for their input and how *they* might want an object to work. This process both in this study and in previous work is valuable in opening up the e-textile design space in a participatory way with visually impaired participants.

All participants threw themselves into the challenge of re-imagining what the objects might be and how to use them. E-textiles could certainly make a valuable contribution to interactive storytelling and sensory play, giving people the chance to use their hands in more creative ways than technologies such as touch screens, joysticks and push buttons currently offer.

7 Conclusions and future work

7.1 Introduction

This research has explored how blind and visually impaired people can engage with e-textiles in creative and tactile ways, by designing and making their own interactive textile art pieces and to accompany creative storytelling.

The literature review explored an array of different areas on which this research builds, including HCI and e-textiles; designing for and with people; and the use of touch with objects, and meanings associated with them. The literature review identified the following gaps:

- A lack of literature addressing the use and evaluation of objects of reference;
- A lack of literature focusing on hands-on participatory making methods using e-textiles with people who have impairments or disabilities - specifically with people who have visual impairment;
- How touch can be linked to an object and used to engage with narratives or encourage interaction;
- What gestures might be used when handling objects - and what associations might accompany them.

The research has addressed these through three studies (Figure 7.1) that have been described and discussed including:

(i) A preliminary observational study, which took place in two different schools for children and young people with a visual impairment and/or complex needs;
(ii) A two-part in-the-wild study in the form of hands-on e-textile making workshops;
(iii) A laboratory study in which participants explored, discussed, and used a selection of e-textile sensors in storytelling.

This chapter will discuss the overall findings of the research, how the research questions have been addressed, and potential future work.

7.2 Findings across the studies

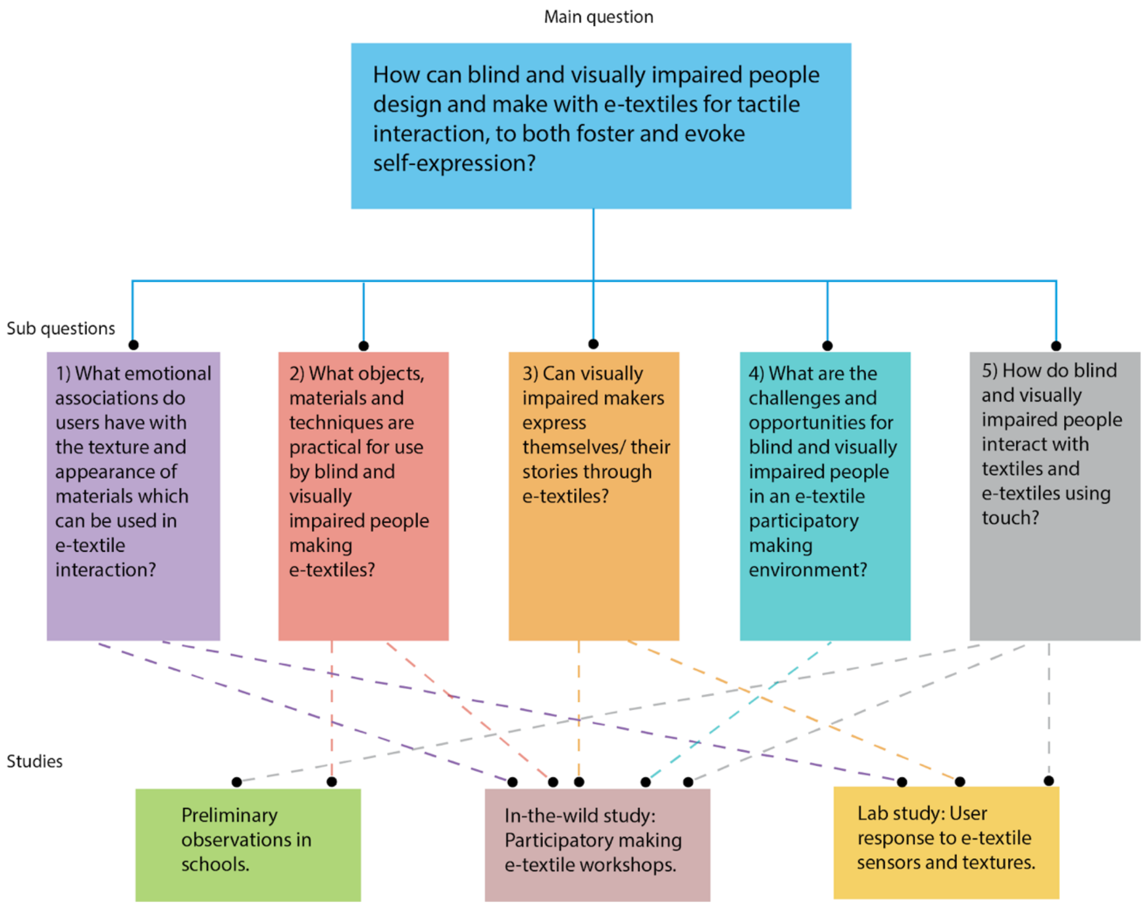


Figure 7.1: Research questions addressed through each study.

The three studies (Figure 7.1) addressed the five key research questions, and the findings are summarised in turn.

1) What emotional associations do users have with the texture and appearance of materials which can be used in e-textile interaction?

The key findings (from studies 2 and 3) are:

- For the hands-on e-textiles making workshops, participants were critical in how they chose their materials - requesting certain types of fabrics, and letting their ideas guide their choices - to ensure that the 'right' choices reflected their ideas.

- The use of a given fabric varied, although there were some consistent uses of a fabric within a given piece, and there were some similar narrative uses of fabric by different participants.

- The participants were creative with their associations with fabrics, but once the fabric was named, they tended to make a literal association: e.g., denim - a pair of jeans. Two participants chose a specific fabric to cover their e-textile switch based on how they would like to 'touch' it.
- Every participant based their material and sound choices on the themes of their work, making an association between the qualities of the materials and sound and some element of the narrative.
- Within the open play activity in the lab study, there was consistency in the associations that users made with the sensors; for example, three of the participants referred to the stroke sensor as being like a rug, and stroking it.
- However, during the storytelling in the lab study, although some objects were used to represent the same thing, participants also sometimes used them to represent something else - with multiple uses by individuals as well as by different participants.

2) What objects, materials and techniques are practical for use by blind and visually impaired people making e-textiles?

This research question was broadened for the preliminary observations in the schools to: What objects, materials and techniques are practical for use by blind and visually impaired people when making?

The key findings (from studies 1 and 2) are:

- Within the preliminary study, objects of reference were not used consistently.
- Soft objects were important in creative play and in musical activities, for sensory engagement and focus.
- Differently textured and shaped objects are used within the classroom environment to prepare the young people for learning braille.
- Some hands-on making with the young people was observed in schools; it was not textile based, but using glue and paper to make collage.
- In the workshops, through the scaffolded learning and modular circuit construction approaches, the participants successfully grasped how to build e-textile soft circuits.
- The circuit-making techniques (e.g., soft wires, press-studs, switch assembly using fabric tape) were accessible for all participants, albeit sometimes with moderate assistance.
- Participants demonstrated their understanding of the technology and how it worked. For example, they grasped the idea of troubleshooting and had an idea about what was wrong when their e-textile switches were not working.
- The participants needed some assistance with some of the making techniques - including the recording of the audio for their sound boards - but showed independence in their making.

- Certain techniques were more accessible than others, e.g., fabric tape instead of glue, or weaving instead of felting.
- Tools or techniques which were not expected to be accessible, such as machine or hand sewing, were feasible for some participants. Participants found that they could use some tools and techniques that they assumed were too challenging, such as weaving and cutting.

3) Can visually impaired makers express themselves through e-textiles?

The key findings (studies 2 and 3) are:

- All participants in the workshops were able to choose a personal fabric artefact from home and share its story.
- The second group engaged creatively in storytelling using fabric swatches, whether fitting swatches to an existing narrative or inventing a story from them.
- Every piece was unique to its maker and expressed a personal story in some way.
- Themes seemed to be about either: transporting the audience to another place, or sharing something about the participants' personal life, life history, personal interests, or emotion.
- In the lab study, there was some consistency in what the sensors were used to represent, such as certain objects, living beings, or environments, e.g., the spherical sensors for people, and the flat ones for carpets.
- However, similarly to the open play activity, participants also sometimes linked another association with the sensors as well - with multiple uses by an individual, and by different participants. The sensors were often used more as 'props' for storytelling than as interactive objects.

4) What are the challenges and opportunities for blind and visually impaired people in an e-textile participatory making environment?

The key findings (study 2) are:

- For the first workshop, establishing the roles of the participants as the makers and the volunteers/the researchers as facilitators/assistants in a non-intrusive way was challenging, but open discussion and observation of the 'assistance only when asked' principle ensured that the participants knew they were in charge.
- After the initial activities, which gave participants a chance to meet each other, the participants worked well in the groups; everyone seemed comfortable sharing ideas and working together on certain tasks. Conversations happened naturally, and participants praised each other as well as making helping suggestions about the work.

- Participants demonstrated a sense of ownership and agency, taking control of their designs, following their own opinions and beliefs to make design decisions, troubleshooting their own work, and positively discarding others' advice when appropriate.

5) How do blind and visually impaired people interact with textiles (and e-textiles) using touch?
For the preliminary observations in schools, this research question was broadened to: *How do blind and visually impaired people interact with objects using touch?*

The key findings (studies 1, 2, and 3) are:

- In the preliminary observational study, students used touch to feel textures, find shapes and identify objects.
- Within the workshops, participants displayed more gestures when exploring fabrics than when triggering their sensors (which they tended to tap or press).
- Only two participants (Uma and Louise) seemed to think, when designing their work, about gestures they would like to use for touching their switches/objects. Calling the switches 'buttons' potentially biased the interaction with them, by suggesting the use of gestures normally used with buttons: pressing and tapping. In the lab study, some gestures were used repeatedly for certain sensors, e.g., squeezing for the pom pom and squeeze sensors, and tapping for the stroke sensor.
- However, participants also introduced new gestures, demonstrating an ability and desire to adapt.

  Although there is no inherent common 'language of gesture' for touch-based interaction with e-textiles, conventions can be established through example or consistent use.

7.3 Reflection across the studies

Key themes that emerged across all three studies will be discussed in turn.

7.3.1 Self-expression through making

Throughout the hands-on e-textile workshops, participants demonstrated making for self-expression rather than just for functionality, as can often be the case with technology made for blind and visually impaired people. As discussed in Chapter 5, there was evidence of different forms of creativity, from the materials participants chose for their work; to the techniques used for fabrication; to how they chose to combine materials and audio for the interactive elements; to the overall composition. For all of these aspects, the participants took ownership and control over the process and displayed a sense of agency

7.3.2 An accessible making approach for blind and visually impaired people

Accessibility and flexibility were key for ensuring that everyone taking part in the hands-on e-textile making workshops could engage with the process on their own terms, and feel happy and confident in their work.

The research team had made some initial decisions when designing the workshops, regarding the planning and execution of the sessions: a schedule at hand for each session; well planned selection of tools that would be available for participants to use for their making; the techniques taught during the first few workshop sessions, both for creative purposes and the circuit making; and the types of materials bought for sessions. This was to ensure that the workshops would be accessible for everyone, no matter what their ability or experience was. However, a flexible approach was taken throughout, with more tools such as a sewing machine brought along when requested; with participants doing their own cutting and hand sewing should they choose; and with specific materials bought for the sessions, as conversations with participants about the work progressed.

Teaching scaffolded learning approach - giving participants key elements which can then be built on and repeated- was important for the participants, in order for their confidence to increase, and to ensure that they understood the processes involved in the e-textile making- particularly the circuit making. Linked to this was the modular approach, whereby the elements could be reconfigured, and the circuits could be disassembled and reassembled.

Throughout the workshops, participants were encouraged to attend to the tactile qualities of the materials. The appearance was of course important to the participants (even the participants who are completely blind made considered decisions about the colours of fabrics), but they designed explicitly with texture as well.

The participants demonstrated that they were able to do more than had been expected, which was both empowering and demonstrated that, although it is important to think about accessibility and plan well in advance, it is also important not to make assumptions. Providing flexibility (such as responding to participant requests, and improvising with methods) and offering assistance only on request, helped to ensure that participants had the latitude to push themselves and experiment with creative methods. This approach of making *with participants* with an impairment as opposed to *for them* builds on researchers such as Hurst and Tobias (2011), Buehler et al. (2015), Meissner et al. (2017) and Bennett et al. (2019).

7.3.3 Objects for communication and for creativity

The three studies demonstrated that e-textile objects have considerable potential for both communication and creativity.

As discussed in Chapter 3, objects of reference were not used in a consistent way within the school environment. However, certain objects used for storytelling and musical engagement seemed to be successful, with creativity playing a large part in this.

The e-textile art pieces created by participants in the workshop study were all individual and beautifully creative. The pieces were used to communicate the makers' own stories. All the e-textiles objects created or engaged with were evocative in some way - both expressing the makers' stories, and triggering associations in the audience. They were used for bonding with someone, for telling a narrative, to share a joke and to showcase a talent - all linked to creativity and communication.

During the lab study, all the participants used the e-textile sensors for communication, primarily for storytelling, but also re-imagining how e-textiles could be used in creative and/or beneficial ways for visually impaired people.

7.3.4 The use of gestures and touch, linked to association

Across both the workshop and lab study, there were some patterns in how participants used their hands to explore certain materials or e-textile sensors; however, there were also variations. There is not enough evidence to speak of an inherent 'gestural language' emerging from the studies. However there was some consistency *within* participants (where a person would consistently use the same type of gesture for the same type of association), and *across* participants (where several participants used the same gesture with the same association), which alludes to the possibility that a tactile language could be established based on people's actions, which could then be passed on to others.

The studies have shown that people have an ability to make multiple different associations and are not always anchored to one.   It also appeared that naming a fabric or switch could act as an anchor, restricting the exploration by participants. For example, if a fabric was named as denim, they would associate it with 'jeans'; and once the e-textile switches were referred to as buttons, they were primarily pressed or tapped for interaction. This has implications for how e-textile researchers and designers design and make sensors. It seems important for e-textile designers and researchers to work more with potential users of sensors to co-design these interactive objects, and perhaps co-naming them, in order to build meaningful conventions. This might open up the possibilities for novel e-textile sensors, along with novel gestures for interaction. The research team certainly observed participants using gestures with different sensors that they had not previously observed outside the study.

Through the exploration of *what associations* users make, along with *what gestures* they use when touching an object, the research in this thesis has built on the work of both Davis (2015) and Petrelli et al., (2016) but also Lederman and Klatzsky (1987) and Carbon and Jakesch (2013) - bringing user association and gestures through touch together using e-textiles.

7.3.5 The success of a participatory making environment

The participatory making environment was integral to ensuring that the making happened *with* participants and not *for* them in the workshop studies. It created a space within which participants could focus on their making, while also having open discussions with one another about their process. The following elements were found to make the environment successful:

The workshops had a mixture of scheduled activity *and* open making. Both of these allowed for participants to discuss and share ideas and reflections but in a way which became more relaxed through the atmosphere of a ‘craft circle’. The informal elements of the workshops, such as participants being invited to bring their lunch to eat at the beginning of the sessions, and ensuring there were regular tea breaks with cake throughout, helped the participants relax into the environment, to share their personal stories about how their week had been going, and also discuss their making progress and ideas. Combining making time with social time appeared to be important.

The brief given to both workshop groups was structured enough to give a clear focus, but had enough degrees of freedom for the participants to take ownership over their projects. This also gave participants the chance to make requests: about what materials they wanted, what tools they needed, and what techniques they wanted to use.

Assumptions should not be made based on ability. It was initially challenging to get the appropriate balance of hands-on help from the volunteers when needed, whilst ensuring that the participants did not feel disempowered. But it was vital to give the participants a genuine sense of control, in order to create an effective dynamic in the workshops. Openness in conversations, and observing the ‘assisting only when asked’ principle, seemed to achieve a productive balance.

The workshop spaces were carefully planned, ensuring that participants were comfortable and had access to everything they needed. The rooms were well lit (although the gallery project space was quite large, and so participants requested the making tables to be moved closer to the windows), with good access to toilet facilities and a kitchen for making refreshments. There was enough room for participants to walk round the making tables to a materials table, to have the freedom to pick their own fabrics, yarns, and embellishments. Initially, the tables were organised in a square, so that the participants could all speak to one another.

The exhibitions at the end of the workshops gave participants an opportunity to show their work with pride, with friends and family as well as the organisations involved in the project. They all spoke about their work clearly and with confidence, talking both about the ideas behind the pieces and how they worked.

This considered process of the participatory making environment, and using it not only as a making space for participants, but also using the making as a means of data collection for research, builds on the work of Gauntlett (2007), along with Twigger Holroyd and Shercliff (2014).

7.3.6 Recommendations for other researchers/designers

The research suggests recommendations, or points of consideration, for designers and researchers wanting to conduct similar participatory making research:

- A rigorous prototyping plan, testing and iterating with multiple circuit boards and experimenting with circuitry;
- Ensuring that as a researcher you test the making yourself, to gain an understanding of the process and to be a good facilitator with others;
- User testing with intended users before running any workshops with a larger group;
- Within workshops, structuring activities to give participants a chance to share and reflect on ideas with one another;
- Ensuring enough ‘tea breaks’ to allow for participants who did not know one another to socialise;
- Giving time for participants to share their work with one another;
- Giving a well-designed brief to participants for their making, but allowing customisation;
- Not making assumptions about what everyone could do, but being open;
- Expressing positivity and good humour throughout the workshops to help participants relax;
- Ensuring a diverse range of materials combined with making participants feel welcome to request more, or add to the collection;
- Briefing helpers about how to assist in a way which is non-intrusive and useful;

- A well-thought-out physical workshop space;
- Organising an exhibition when the work is complete to enable participants to showcase their work to a wider audience.

More specifically when using e-textiles with visually impaired people, the findings of the research recommends:

- Be aware that the naming of a fabric can bias an association with it, and so try to avoid doing this.
- Be critical of how objects or orientated or presented to participants – whatever the context – as they can alter how an object is interacted with.
- Ensure that the use of language when describing a switch might bias the gesture for interaction.
- Accessible making can be enabled by replacing certain techniques (such as the sewing of circuits) with more accessible techniques (such as threading conductive thread through tubular yarn, and using press-studs for connections).
- Experiment with different crafting techniques to establish what a group likes/dislikes, e.g., fabric tape vs. fabric glue, weaving vs. felting, etc.
- When creating e-textile objects for a study, be aware that participants may want them to be coloured, rather than neutral such as grey.
- Encourage participants to explore objects with their hands, whatever the type of study.

Much has been learned from working on this research, and perhaps some practical guidelines on how to run an e-textile workshop specifically for people with a visual impaired could be published for facilitators, similar to the learning materials for *An Internet of Soft Things* toolkit (2016) which takes facilitators through the team's approach. If something similar were produced based on the research in this dissertation, it would be important for the visually impaired participants to be consulted on its content and production.

7.4 Furthering the research

The research reported in the thesis has contributed to interaction design by exploring participatory making with visually impaired people, and the combination of personal association with gesture and touch, especially by e-textile users who are visually impaired. There are a number of ways in which this work could be built on - either by the research team themselves or by other designers, artists, or researchers who would like to do so.

7.4.1 Programming the hardware

Because of time restrictions, it was decided that the research would not focus on programming This also avoided giving the project too many different foci, and hence overwhelming participants by giving them too much to absorb and do in limited time.

As programming was not used in this project, the re-recordable devices were chosen as the electronics platform. However, in future projects Arduino boards could be used, with the new challenge of how to program them in an environment which would be user-friendly for blind and visually impaired people. A paired programming approach could be taken with a sighted participant, or perhaps a screen reader could be used, if that is possible. Some participants in the studies were keen to gain experience of this in the future.

7.4.2 Using the modular approach for further accessible electronics

The modular plug-and-play approach to making circuits, enabling a more accessible way of construction, could be expanded for other e-textile projects. From a research perspective, it would be useful to test it with other profiles of user - such as children - both those with and without impairments. This would build on the work of researchers such as Buechley et al. (2008) and Rode el al. (2015), and it would allow for more time designing and thinking about personal projects, given the relative ease of the modular circuit-making.

The modular approach could also be used with other makers. As discussed in the introduction, the lead researcher has years of previous experience in running hands-on making workshops in creative technology. This is particularly focused on e-textile workshops in museums such as the V&A, with keen textilers who want to learn about electronics as well. To introduce a partly pre-made circuit ‘kit’ into the process would be advantageous, as the electronics element can often cause stress and displeasure; this would allow the participants to focus more on the creative side of the e-textile making, and on interaction design - similarly to the participants in this research.

The modular approach to e-textile making could be furthered to introduce other hardware and components as well. Although all of the participants who took part in the workshop and lab study were visually impaired, most of them still had some form of vision. When they interacted with the lead researcher’s e-textile samples in the first session, many of the participants were excited by the idea of integrating LEDs into soft objects, wanting to do this themselves. This would not have worked with the specific sound boards used for the study, but opened up a conversation about how this type of output could be used in future workshops with the participants.

7.4.3 Designing interactive sensors for storytelling, moving toward a tactile language

Future projects could build on the laboratory study, by encouraging participants to design and make different e-textile interactive sensors for specific stories, and to be used with specific gestures. As discussed, other researchers could build on this, working with participants to find interesting ways of interacting, rather than making sensors with a set name, and an intended interaction in mind. These objects could then be used not only for the makers for their own stories, but also to feed into a wider discourse around language, gesture, and interaction.

7.4.4 Expanding the project

Being from an arts outreach background, using creative technology, throughout the PhD research process the lead researcher has been considering how the type of workshop designed as part of the studies could be adapted and facilitated with more participants as an arts project. Increasingly, museums and galleries are expanding their education and outreach programmes, with accessibility and inclusion as important goals. The gallery which hosted the second series of workshops for the hands-on making studies themselves hired a Curator of Inclusion during the course of this PhD research, to expand the gallery's offerings to people who might not always have the opportunity to partake in contemporary arts practice, and to increase their impact in this area. From a practice-based perspective this research contributes to such inclusiveness aims, and could work with other arts-based organisations toward such aims.

This research could also be applied to working with other participants, such as those with neurodiversity or complex needs, or people with mental health issues, by working with charities and educational establishments.

7.5 Summary

The research questions in this thesis have been addressed through a range of approaches - an observational study, participatory making workshops and a lab study - resulting in the collection and analysis of a rich set of data.

There is much potential for touch to be further exploited through the medium of e-textiles, not just through the gestures that people use to interact with sensors but also in how materials such as fabrics, yarns, and embellishments can be combined with sensors to encourage a more sensory and varied interaction. The work in this thesis has focussed on working with blind and visually impaired people, but could be expanded to other user groups a well.

The research has also demonstrated how e-textile making can and should be expanded to people who have an impairment or disability, in the case of this research, VI people. This should be built on to accommodate other profiles of users too. It should also be expanded beyond a research project, with similar making workshops happening through arts organisations and charities for people with disabilities to expand impact.

A more accessible way of working with electronics has been explored using e-textiles, focusing on a modular plug-and-play approach, something which is less common within the e-textile world. This perhaps opens up the possibility for more ‘kit’-like options to be created, again expanding the profile of makers engaging in the medium and making it more accessible for all.

Much has been discussed and there is much to build on around accessibility and e-textiles. Not only do the research team wish to further this but also hope to see other designers, researchers and artists doing so as well, to ensure that more gaps within maker culture around outreach and inclusivity are addressed.

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9 APPENDICES

Appendix A:
Ethics approval, consent forms and info sheets

A.1 Ethics approval

The studies in this thesis had ethical approval from The Open University (ref. HREC 2016 2286 Giles) and I was DBS checked. All participants were asked to sign a consent form after they had the study explained to them and had read the information sheet or had it read to them. The schools involved with the observations gave permission on behalf of the children and young people observed.

The Open University

From [redacted]
Chair, The Open University Human Research Ethics Committee

Email [redacted]

Extension 52462

To Emilie Giles MCT

Subject Observing the use of physical objects by blind and visually impaired children in their school

Memorandum

Ref HREC 2016 2286 Giles

AMS (Red)

Submitted 27/04/2016

Date 28/07/2016

This memorandum is to confirm that the research protocol for the above-named research project, as submitted for ethics review, **has been given a favourable opinion** by the Open University Human Research Ethics Committee. Please note that the OU research ethics review procedures are fully compliant with the majority of grant awarding bodies and their Frameworks for Research Ethics.

Please make sure that any question(s) relating to your application and approval are sent to Research-REC-Review@open.ac.uk quoting the HREC reference number above. We will endeavour to respond as quickly as possible so that your research is not delayed in any way.

At the conclusion of your project, by the date that you stated in your application, the Committee would like to receive a summary report on the progress of this project, any ethical issues that have arisen and how they have been dealt with.

Kind regards,

[redacted]

Chair OU HREC

HREC 2016 2239 Funer.doc

Appendix A:
Ethics approval, consent forms and info sheets

A.2 Participant consent form for the school teachers

The Open University

Department of Computing and Communications

Observing the use of physical objects by blind and visually impaired children in their school

Consent form for persons participating in a research project

Name of participant:

Name of principal investigator(s): Emilie Giles

1. I consent to participate in this project, the details of which have been explained to me, and I have been provided with a written statement in plain language to keep.

2. I understand that my participation will involve being observed and taking part in a hands on making activity and I agree that the researcher may use the results as described in the plain language statement.

3. I acknowledge that:

   a. the possible effects of participating in this research have been explained to my satisfaction;

   b. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point on 30th November 2016, After this point data will have been processed and it will not be possible to withdraw any unprocessed data I have provided;

   c. the project is for the purpose of research;

   d. I have been informed that the confidentiality of the information I provide will be safeguarded subject to any legal requirements;

   e. I have been informed that with my consent the data generated will be stored in an anonymised form in a private folder on a secure sever at The Open University as well as on an encrypted hard drive.

   f. If necessary any data from me will be referred to by a pseudonym in any publications arising from the research;

   g. I have been informed that a summary copy of the research findings will be forwarded to me, should I request this.

   h. I under

I consent to observations and hands on making being audio-taped/video-recorded □ **yes** □ **no**
(please tick)

I wish to receive a copy of the summary project report on research findings □ **yes** □ **no**
(please tick)

Participant signature: Date:

Emilie Giles emilie.giles@open.ac.uk
Dr. Janet van der Linden (supervisor) janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor) m.petre@open.ac.uk

Appendix A:
Ethics approval, consent forms and info sheets

A.3 Participant consent Form for the young people

The Open University

Department of Computing and Communications

Observing the use of physical objects by blind and visually impaired children in their school

CONSENT FORM FOR CHILDREN
(to be completed by the child and their parent/guardian)

Please circle the answers you agree with below:
(Parent/guardian to complete if the child is unable)

Have you read (or had read to you) information about this project?	Yes/No
Has somebody else explained this project to you?	Yes/No
Do you understand what this project is about?	Yes/No
Have you asked all the questions you want?	Yes/No
Have you had your questions answered in a way you understand?	Yes/No
Do you understand it's OK to stop taking part at any time?	Yes/No
Are you happy to take part?	Yes/No
Are you happy for any photos or videos of you created during the study to be used in academic presentations or publications	Yes/No

If any answers are 'no' you can ask more questions.
But if you **don't** want to take part, **don't** sign your name!

If you do want to take part, please ask your parents or guardian to write your name and today's date

Your name ____________________________

Date ____________________________

Your parent or guardian must write their name here too if they are happy for you to do the project

Print Name ____________________________

Sign ____________________________

Date ____________________________

The researcher who explained this project to you needs to sign too:

Print Name ____________________________

Sign ____________________________

Date ____________________________

If you have any questions or concerns you can contact:

Emilie Giiles emilie.giles@open.ac.uk
Dr. Janet van der Linden (supervisor) janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor) m.petre@open.ac.uk

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Appendix A:
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A.4 Info sheet for the school teachers

The Open University

Department of Computing and Communications

Observing the use of physical objects by blind and visually impaired children in their school

STUDY INFORMATION
(to be read by teachers and teaching assistants)

The aim of this study is to observe how young people who are blind or visually impaired use physical objects within their day-to-day lives in their school and explore what the function of these objects are within their lives and also how they interact with them. This might be as prompts for learning or for play/arts activities.

As part of the study we would also like to run a hands on making workshop with the young people during which they can make their own interactive, soft objects using conductive threads, yarns and fibres, otherwise known as electronic textiles (e-textiles). This will take the form of weaving or another accessible craft process.

The study will involve the researcher spending the first two days in the classroom observing the use of objects by the young people with the making activity taking place on the third day. The sessions will take place during normal school hours and in the classroom with teachers and teaching assistants present at all times.

During the study notes will be taken by the researcher as well as photos and videos of what the children are doing. All photographs and videos will avoid having the faces of teaching staff or the children in them, with the objects being used as the focus of this content. Data will be anonymised within five days of being captured and will be stored in a private folder on a secure sever at The Open University as well as on an encrypted hard drive. You have the right to have the data destroyed upon request up to the point of anonymisation. All data are treated as confidential, and in compliance with the Data Protection and Freedom of Information Acts.

The findings of the study will be used toward my PhD thesis and in future publications. Any reference to participants will be made with a pseudonym. If you wish, I will be happy to inform you of any such publication when it occurs.

If you have any questions or concerns you can contact:

Emilie Giiles emilie.giles@open.ac.uk
Dr. Janet van der Linden (supervisor) janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor) m.petre@open.ac.uk

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A.5 Info sheet for the young people at the school

The Open University

Department of Computing and Communications

Observing the use of physical objects by blind and visually impaired children in their school

STUDY INFORMATION
(to be read by parent/guardian themselves and to their child)

The aim of this study is to observe how young people who are blind or visually impaired use physical objects within their day-to-day lives in their school and explore what the function of these objects are within their lives and also how they interact with them. This might be as prompts for learning or for play/arts activities.

As part of the study we would also like to run a hands on making workshop with the young people during which they can make their own interactive, soft objects using conductive threads, yarns and fibres, otherwise known as electronic textiles (e-textiles). This will take the form of weaving or another accessible craft process.

The study will involve the researcher spending the first two days in the classroom observing the use of objects by the young people with the making activity taking place on the third day. The sessions will take place during normal school hours and in the classroom with teachers and teaching assistants present at all times.

During the study notes will be taken by the researcher as well as photos and videos of what the children are doing. All photographs and videos will avoid having the child's faces in them with the objects being used as the focus of this content. Data will be anonymised within five days of being captured and will be stored in a private folder on a secure sever at The Open University as well as on an encrypted hard drive. You have the right to have the data destroyed upon request up to the point of anonymisation. All data are treated as confidential, and in compliance with the Data Protection and Freedom of Information Acts.

The findings of the study will be used toward my PhD thesis and in future publications. Any reference to participants will be made with a pseudonym. If you wish, I will be happy to inform you of any such publication when it occurs.

If you have any questions or concerns you can contact:

Emilie Giles	emilie.giles@open.ac.uk
Dr. Janet van der Linden (supervisor)	janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor)	m.petre@open.ac.uk

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Appendix A:
Ethics approval, consent forms and info sheets

A.6 Participant consent form for the staff and volunteers at Bucks Vision

The Open University

Department of Computing and Communications

Touch, E-textiles and Participation:
Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Consent form for BucksVision staff and volunteers participating in the research project.

Name of participant:
Name of principal investigator(s): Emilie Giles

1. I confirm that I have read the information sheet and consent to participate in the project.

2. I understand that if I no longer want to participate that I can stop at any time.

3. I confirm that I am happy for photographs or videos to be taken for academic purposes and that I might feature in these.

4. I understand that the researchers will contact me should they want to use any photographs or videos of me in a publication or presentation.

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5. I understand that if I am referred to in a publication arising from the research it will be with a pseudonym.

6. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point on 1st May 2017. After this point data will have been processed and it will not be possible to withdraw any unprocessed data I have provided.

Participant signature: Date:

For any additional information or questions, please contact the researchers:

Emilie Gilles
emilie.giles@open.ac.uk
Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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Appendix A:

Ethics approval, consent forms and info sheets

A.7 Participant consent form for the participants taking part in the Bucks Vision hands-on making workshops

The Open University

Department of Computing and Communications

Touch, E-textiles and Participation: Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Consent form for participants taking part in the research project.

Name of participant:

Name of principal investigator(s): Emilie Giles

1. I confirm that I have read the information sheet, or had it read to me, and consent to participate in the project.

2. I understand that if I no longer want to participate that I can stop at any time.

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The Open University

3. I confirm that I am happy for photographs or videos to be taken for academic purposes and that I might feature in these.

4. I understand that the researchers will contact me should they want to use any photographs or videos which show my face in a publication or presentation.

5. I understand that if I am referred to in a publication arising from the research it will be with a pseudonym.

6. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point by 1st May 2017. After this point data will have been processed and it will not be possible to withdraw any unprocessed data I have provided;

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The Open University

Participant signature: Date:

For any additional information or questions, please contact the researchers:

Emilie Giles
emilie.giles@open.ac.uk
Prof. Janet van der Linden (supervisor)
j.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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Appendix A:
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A.8 Info sheet for the staff and volunteers at both Bucks Vision and MK Gallery

The Open University

Touch, E-textiles and Participation: Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Study Information
Would you like to participate in an Open University research project and make interactive objects using textiles and soft electronics?

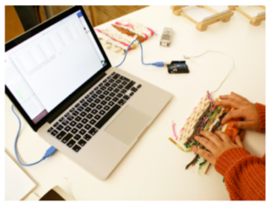
Creating E-textile Objects
As part of my PhD research I will be running a series of six workshops at BucksVision in Aylesbury, during which you would create your own interactive object using textiles and soft electronics. E-textiles, otherwise known as electronic textiles, is a field which combines together conductive threads, made of silver or steel, with electronics such as small circuit boards. From these you can create interactive objects. These can light up, make sound, vibrate or move. The aim of these workshops is to work with people who are blind or visually impaired to create their own objects that are personal to them. To create these objects we will be exploring how different textures of materials can be linked to stories or memories, working with sounds, that will be embedded into the objects using small electronic boards.

The Aims of the Study
By carrying out the research I hope to not only answer a number of research questions but also to achieve some aims, which are both academic and more practical. These include:

- Identify a range of accessible hands-on crafting techniques which are not reliant on sight.
- Establish whether there is a link between the texture of materials and emotional association upon touch.
- Design an accessible toolkit that can be used by facilitators for working with people who are blind and visually-impaired.

What Will We Do?
Over the six workshops, you would learn to work with e-textiles from a beginners level. Materials we will be working with includes silver plated fabric, thread spun with steel and yarn which contains silver. All of these materials can be embroidered, woven, knitted or crocheted to make an interactive surface. You will learn how to work with a small soundboard that contains a sound file of your choice. We will make a button or switch to trigger the sound and this can be done in creative and exciting ways using the conductive materials. It could be something which you stroke, press or even shake.

We will explore how textures of textiles and objects can be associated with memories or stories. After years of running crafting workshops I have found that the act of making and working with materials often prompts us to discuss these and I am interested in participants creating objects which reflects this.



Documenting the Workshops
During the workshops I will be writing notes and taking photos or videos of the process which might show your face. I might wish to use this data in publications or presentations but will only do so with your consent. You will be contacted should I want to use this in a publication or presentation to get your consent. A separate consent form will be distributed to confirm your permission to participate in the study.

Your name will not appear in any publications or presentations. I am happy to inform you of any publications released.

Data Storage
Raw data will be anonymised and will be stored securely so that only the researchers can access it.

Right to Withdrawal
You have the right to withdrawal from the project at any point. Should you wish to withdraw we will ensure that no information is noted about you during the observation process and that no data is collected about you.

If you have any questions please contact one of the researchers:

Emilie Giles
emilie.giles@open.ac.uk

Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk

Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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A.9 Info sheet for the participants taking part in the Bucks Vision hands-on making workshops

The Open University

Touch, E-textiles and Participation: Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Study Information
Would you like to participate in an Open University research project and make interactive objects using textiles and soft electronics?

Creating E-textile Objects
As part of my PhD research I will be running a series of six workshops at BucksVision during which you would create your own interactive object using textiles and soft electronics. These workshops will take place on Fridays from 17th February 2017 and ending on 31st March 2017.

E-textiles, otherwise known as electronic textiles, is a field which combines together conductive threads, made of silver or steel, with electronics such as small circuit boards. From these you can create interactive

objects. These can light up, make sound, vibrate or move. The aim of these workshops is to work with people who are blind or visually impaired to create their own objects that are personal to them. To create these objects we will be exploring how different textures of materials can be linked to stories or memories, working with sounds that will be embedded into the objects using small electronic boards.

The Aims of the Study
By carrying out the research I hope to not only answer a number of research questions but also to achieve some aims, which are both academic and more practical. These include:

- Identify a range of accessible hands-on crafting techniques which are not reliant on sight.
- Establish whether there is a link between the texture of materials and emotional association upon touch.
- Design an accessible toolkit that can be used by facilitators for working with people who are blind and visually-impaired.

What Will We Do?
Over the six workshops, you would learn to work with e-textiles from a

Appendix A:
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A.9 Info sheet for the participants taking part in the Bucks Vision hands-on making workshops (continued from previous page)

will be writing notes and taking photos or videos of the process which might show your face. I might wish to use this data in publications or presentations but will only do so with your consent. You will be contacted should I want to use this in a publication or presentation to get your consent. A separate consent form will be distributed to confirm your permission to participate in the study.

Your name will not appear in any publications or presentations. I am happy to inform you of any publications released.

Data Storage
Raw data will be anonymised and will be stored securely so that only the researchers can access it.

Right to Withdrawal
You have the right to withdrawal from the project at any point. Should you wish to withdraw we will ensure that no information is noted about you during the observation process and that no data is collected about you.

If you have any questions please contact one of the researchers:

Emilie Giles
emilie.giles@open.ac.uk

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Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk

Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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beginners level. Materials we will be working with includes silver plated fabric, thread spun with steel and yarn which contains silver. All of these materials can be embroidered, woven, knitted or crocheted to make an interactive surface. You will learn how to work with a small soundboard that contains a sound file of your choice. We will make a button or switch to trigger the sound and this can be done in creative and exciting ways using the conductive materials. It could be something which you stroke, press or even shake.

We will explore how textures of textiles and objects can be associated with memories or stories. After years of running crafting workshops I have found that the act of making and working with materials often prompts us to discuss these and I am interested in participants creating objects which reflects this.

Documenting the Workshops

During the workshops I

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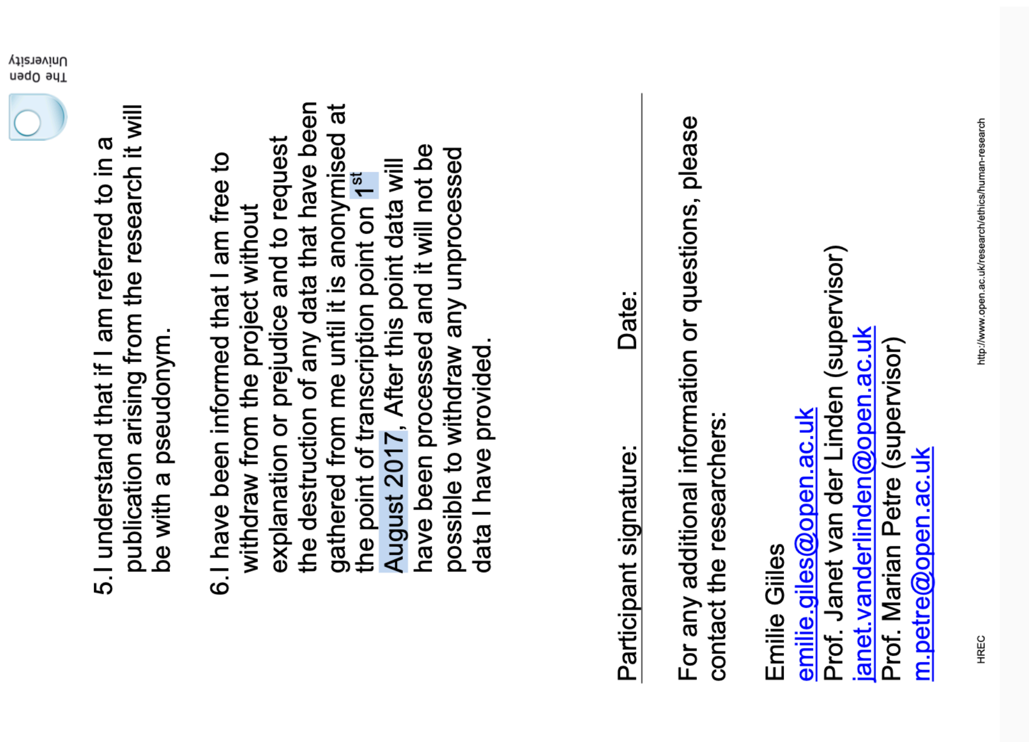
A.10 Participant consent form for the staff and volunteers at MK Gallery



5. I understand that if I am referred to in a publication arising from the research it will be with a pseudonym.

6. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point on 1st August 2017. After this point data will have been processed and it will not be possible to withdraw any unprocessed data I have provided.

Participant signature: Date:

For any additional information or questions, please contact the researchers:

Emilie Giles
emilie.giles@open.ac.uk
Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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The Open University

Department of Computing and Communications

Touch, E-textiles and Participation:
Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Consent form for MK Gallery staff and volunteers participating in the research project.

Name of participant:

Name of principal investigator(s): Emilie Giles

1. I confirm that I have read the information sheet and consent to participate in the project.

2. I understand that if I no longer want to participate that I can stop at any time.

3. I confirm that I am happy for photographs or videos to be taken for academic purposes and that I might feature in these.

4. I understand that the researchers will contact me should they want to use any photographs or videos of me in a publication or presentation.

Appendix A:
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A.11 Participant consent form for the participants taking part in the MK Gallery hands-on making workshops.

The Open University

Department of Computing and Communications

Touch, E-textiles and Participation: Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Consent form for participants taking part in the research project.

Name of participant:
Name of principal investigator(s): Emilie Giles

1. I confirm that I have read the information sheet, or had it read to me, and consent to participate in the project.

2. I understand that if I no longer want to participate that I can stop at any time.

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3. I confirm that I am happy for photographs or videos to be taken for academic purposes and that I might feature in these.

4. I understand that the researchers will contact me should they want to use any photographs or videos which show my face in a publication or presentation.

5. I understand that if I am referred to in a publication arising from the research it will be with a pseudonym.

6. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point by 1st August 2017. After this point data will have been processed and it will not be possible to

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withdraw any unprocessed data I have provided;

Participant signature: Date:

For any additional information or questions, please contact the researchers:

Emilie Giles
emilie.giles@open.ac.uk
Prof. Janet van der Linden (supervisor)
j.vanderlinden@open.ac.uk
Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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A.12 Info sheet for the participants taking part in the MK Gallery hands-on making workshops.

The Open University

Touch, E-textiles and Participation: Using e-textiles to facilitate hands-on making workshops with visually-impaired users.

Study Information
Would you like to participate in an Open University research project and make interactive objects using textiles and soft electronics?

Creating E-textile Objects
As part of my PhD research I will be running a series of six workshops at MK Gallery in Milton Keynes, during which you would create your own interactive object using textiles and soft electronics. These workshops will take place on Mondays from 5th June 2017 and ending on 10th July 2017.

E-textiles, otherwise known as electronic textiles, is a field which combines together conductive threads, made of silver or steel, with electronics such as small circuit boards. From these you can

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create interactive objects. These can light up, make sound, vibrate or move. The aim of these workshops is to work with people who are blind or visually impaired to create their own objects that are personal to them. To create these objects we will be exploring how different textures of materials can be linked to stories or memories, working with sounds that will be embedded into the objects using small electronic boards.

The Aims of the Study
By carrying out the research I hope to not only answer a number of research questions but also to achieve some aims, which are both academic and more practical. These include:

- Identify a range of accessible hands-on crafting techniques which are not reliant on sight.
- Establish whether there is a link between the texture of materials and emotional association upon touch.
- Design an accessible toolkit that can be used by facilitators for working with people who are blind and visually-impaired.

What Will We Do?
Over the six workshops, you would learn to work with e-

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A.12 Info sheet for the participants taking part in the MK Gallery hands-on making workshops. (Continued from previous page)

textiles from a beginners level. Materials we will be working with includes silver plated fabric, thread spun with steel and yarn which contains silver. All of these materials can be embroidered, woven, knitted or crocheted to make an interactive surface. You will learn how to work with a small soundboard that contains a sound file of your choice. We will make a button or switch to trigger the sound and this can be done in creative and exciting ways using the conductive materials. It could be something which you stroke, press or even shake.

We will explore how textures of textiles and objects can be associated with memories or stories. After years of running crafting workshops I have found that the act of making and working with materials often prompts us to discuss these and I am interested in participants creating objects which reflects this.

Documenting the Workshops

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During the workshops I will be writing notes and taking photos or videos of the process which might show your face. I might wish to use this data in publications or presentations but will only do so with your consent. You will be contacted should I want to use this in a publication or presentation to get your consent. A separate consent form will be distributed to confirm your permission to participate in the study.

Your name will not appear in any publications or presentations. I am happy to inform you of any publications released.

Data Storage

Raw data will be anonymised and will be stored securely so that only the researchers can access it.

Right to Withdrawal

You have the right to withdrawal from the project at any point. Should you wish to withdraw we will ensure that no information is noted about you during the observation process and that no data is collected about you.

If you have any questions please contact one of the researchers:

Emilie Giles
emilie.giles@open.ac.u

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http://www.open.ac.uk/research/ethics/human-research

k

Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk

Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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Appendix A:
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A.13 Participant consent form for the participants taking part in the E-textile storytelling lab study

The Open University

Department of Computing and Communications

Storytelling with E-textile Objects

Consent form for participants taking part in the research project.

Name of participant:

Name of principal investigator(s): Emilie Giles

1. I confirm that I have read the information sheet, or had it read to me, and consent to participate in the project.

2. I understand that if I no longer want to participate that I can stop at any time.

3. I confirm that I am happy for photographs or videos to be taken for academic purposes and that I might feature in these.

4. I understand that the researchers will contact me should they want to use any photographs or videos which show my face in a publication or presentation.

5. I understand that if I am referred to in a publication arising from the research it will be with a pseudonym.

6. I have been informed that I am free to withdraw from the project without explanation or prejudice and to request the destruction of any data that have been gathered from me until it is anonymised at the point of transcription point by 1 August 2018. After this point data will have been processed and it will not be possible to withdraw any unprocessed data I have provided;

Participant signature: Date:

For any additional information or questions, please contact the researchers:

Emilie Giles
emilie.giles@open.ac.uk

Prof. Janet van der Linden (supervisor)
j.vanderlinden@open.ac.uk

Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

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A.14 Info sheet for the participants taking part in the E-textile storytelling lab study

Storytelling with E-textile Objects

Study information
Would you like to participate in an Open University research project and explore storytelling through interactive objects?

As part of my PhD research I will be running a study exploring how people engage with interactive e-textile objects in a storytelling scenario. The sessions for the study will take place during the week beginning 19th March 2018 and will last approximately 2 hours. These sessions will help us understand how e-textile mechanisms can support tactile storytelling.

Image 1: A person's hand touching a textured woven e-textile object attached to a circuit board.

What are e-textiles?
E-textiles, otherwise known as electronic textiles, is a field which combines together conductive threads, made of silver or steel, with electronics such as small circuit boards. From these you can create interactive objects that can light up, make sound, vibrate or move but may also have interesting tactile qualities.

What will we do?
No previous experience or technical knowledge is needed. You will interact with pre-made e-textile objects that all feel different to touch and have been made using varied crafting methods. Each will have the potential to trigger an output on a circuit board and be unique in how they can be handled to do this.

Documentation
During the study I will be writing notes and taking photos or videos that might show your face. I may wish to use this data in publications or presentations but will only do so with your consent, and as such you would be contacted accordingly. A consent form will be distributed to confirm your permission to participate in the study. Your name will not appear in any publications or presentations, instead a pseudonym would be used. I am happy to inform you of any publications released.

Data storage
Raw data will be anonymised and will be stored securely so that only the researchers can access it.

Right to withdrawal
You have the right to withdrawal from the project at any point. Should you wish to withdraw we will ensure that no information is noted about you during the observation process and that no data is collected about you.

If you have any questions please contact one of the researchers:

Emilie Giles
emilie.giles@open.ac.uk

Prof. Janet van der Linden (supervisor)
janet.vanderlinden@open.ac.uk

Prof. Marian Petre (supervisor)
m.petre@open.ac.uk

OU CONTACT DETAILS FOR PI AND RESEARCH ORGANISATION/DEPARTMENT
http://www.open.ac.uk/research/ethics/human-research

Appendix B: Study content

B.1 Schedule and list of tools/materials for hands-on making workshops at Bucks Vision

Aylesbury workshops - 8 participants, 2 researchers and 2 volunteers

Workshop 1 - *17th February*

Aims:

- To introduce the participants to the project.
- Getting hands-on with the electronics
- To start the process of thinking about textures and associations.
- Exploring hands-on making

Things to bring:

- Laptop with Pure Data patch

- Arduino Board

- Crocodile clips

- My finished project

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Looms

- Materials for weaving (conductive and non-conductive yarns)

- Scissors

- Big paper

- Marker pens

12:00 - 12:30: Cup of tea/ lunch and explaining project

Becoming familiar with each other in an informal setting - a good chance to find out what other activities the participants are involved in through Bucks Vision and anything they've been up to recently which they want to discuss. The participants who came before won't have seen each other since Xmas. Also, there is a new participant to settle in.

Re-introduce the project at this point, demo the example wall hanging and discuss the idea of a showcase in session 6 on March 31st.

12:30 – 12:45: Getting to know each other - memory game - having a chat about themselves in pairs and feeding back to the group.

Participants spend 6 minutes talking to each other, 3 minutes about each person. They will discuss:

- What their name is
- Where they live
- A hobby which they love
- What their favourite sound is - can be song, nature, animal etc.

Spend approx. 2 minutes per pair reporting back to the group about what they found out about each other.

12:35 - 12:45: Demo my example of project

Show the participants the latest iteration of the story cloth - containing a personal story of mine. This will be a table mat or wall hanging type object. There will be the chance to ask any questions about it and for everyone to interact with it via the soft circuit buttons which have different textured textiles on them.

12:45 - 13:15: Have a go at making cables for the sound board

13:15 - 13:35: Exploring textures and association and describing it and why

In pairs the participants will handle different textured textiles and discuss what they think of them. They will discuss:

- How they feel to the touch
- Do the textiles trigger any thoughts or associations?

13:35 – 13: 45: Tea break

13:45 – 13:55: Discuss choosing of textiles vs making own textiles

I will discuss with the participants that whilst they can choose what textiles they use to make their soft circuit buttons, they can also make their own textile through a hands-on crafting technique. We'll go through a variety of these during the workshops including weaving, feeling and knitting. If they feel that the textiles they make fits with their memory or story then they can use that as the texture on their buttons.

13:55 - 15:45: Weaving

The participants will spend two hours weaving their own fabrics. Four of them will have done this before but one participant will not have.

15:45 - 16:00: Brief about what to bring for next week/ homework and roundup

I'll brief the participants about bringing a piece of textile from home which is important to them in some way. We'll discuss this next week.

Also give them recorders and instruct them to make one recording about their thoughts after the workshop about what they've been doing and how they are finding the process.

16:00 - Time to go home

Homework

- Bring a piece of textile from home which is important to them or they like very much

- Reflect on workshop - mini diary recording

Workshop 2 - *24th February*

Aims:

- To start the process of thinking about sounds with textiles
- To explore how to construct a story with the textile
- Decide on theme for objects
- Exploring hands-on making

Things to bring:

- Laptop with Pure Data patch

- Arduino Board

- Crocodile clips

- My finished project

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Chunky yarn

- Scissors

- Big paper

- Marker pens

12:00 - 12:30: Cup of tea/ lunch and catch-up

Chance for everyone to catch-up and have their lunch and tea.

12:30 - 13:00 Sharing textiles which they have brought in for homework

The participants will all tell us what their textile is and why it is important to them. How would they describe the texture? What do they look like or how do they imagine them to look? Passing them around for other participants to feel as they describe.

13:00 - 13:30: Construct a story with the textile or one I've brought in

In groups of 2 or 3 I want the participants to discuss how they would incorporate their textiles into a story which is personal to them. They can just discuss in their groups - they don't need to report back.

13:30 - 14:15: ***Decide on theme for touch/ memory patches*****

To focus the participants a bit when working on their memory objects, we'll brainstorm together to pick a theme for them. This could be anything from a day out which they remember to a room in their home.

14:00 - 14:10: Tea break

14:10 - 14:40: Construct a story with the textiles that I've brought in, within pairs/ threes

In their small groups of 2 or 3 people, the participants will now have a go at constructing a story using the textiles which I've brought in. They should spend 20 minutes working on this and spend 5 minutes each presenting back to each other. (This gives the chance to have participants reflect on appropriate textiles for the theme and what they might need. From me – choosing things which are appropriate for their memory/ story.)

14:40 - 15:45: Finger knitting

We will spend just over an hour finger knitting. This is a very quick and accessible way to create a textile in a tactile way. It's not too fiddly but some of the participants might need a bit of help to get started.

15:45 - 16:00: Brief about constructing a personal story and choosing 3 textiles to go with them

The participants will be briefed to decide on what they want their personal story to be which their interactive object will reflect. For this they will be asked to either choose 3 textiles from home which they would like to represent three key moments or memories in their story or to think about 3 textiles they feel would represent it well from my collection, or 3 textiles that they want me to buy. They can email me this or let me know at this point.

Also instruct them to make one recording about their thoughts after the workshop about what they've been doing and how they are finding the process.

16:00 - Time to go home

Homework

- Write/ talk personal story for session 3 and choose textiles

- Reflect on workshop - mini diary recording

Workshop 3 - *3rd March*

Aims:

- To introduce the participants to the hardware
- To start to work with sound
- Confirm story/ memories for object
- Start building the interface

- Exploring hands-on making

Things to bring:

- Sound boards

- Laptop

- Crocodile clips

- My finished project

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Felting wool

- T-shirt yarn

- Popper snaps

- Popper snap tool

- Conductive thread

- Scissors

- Sound boards

- Big paper

- Marker pens

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 - 13:00: Intro to board and paying with it

Everyone will have the chance to play with one of the little sound boards to gain an understanding of how they work. They can have a go at recording a sound on them and recording over it, and triggering it with the button attached to the board.

13:00 - 13:20: Share what everyone's story and textile set for homework

Everyone will share what story they want their objects to reflect and pass round any materials they have brought in or ones which they have chosen from me/ I have bought.

13:20 - 14:50: Building buttons

The participants will start to build their soft circuit buttons. There will be 3 of these which will be used to reflect 3 key moments or memories in their story.

14:50 – 15:00: Tea break

15:00- 15:45: Wet felting

The participants will try out the last crafting technique we'll be trying during the workshops - wet felting.

15:45 - 16:00: Brief about thinking about sounds to go with stories and textures

The participants should think about what sound should go with their textile textured buttons for their story objects. This is to prepare for recording them next week.

Also instruct them to make one recording about their thoughts after the workshop about what they've been doing and how they are finding the process.

16:00 - Time to go home

Homework

- Think about sounds and pre-prep work.

- Reflect on workshop - mini diary recording

Workshop 4 - *10th March*

Aims:

- Build buttons for objects
- Record sounds for objects

Things to bring:

- Sound boards

- Laptop

- Crocodile clips

- My finished project

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Felting wool

- T-shirt yarn

- Popper snaps

- Popper snap tool

- Conductive thread

- Sound boards

- Velostat

- Foam

- Different fabrics (big!)

- Needles

- Glue

- Embroidery thread

- Scissors

- Big paper

- Marker pens

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 - 14:00: Building buttons and Record sounds

The participants will start to build their soft circuit buttons. There will be 3 of these which will be used to reflect 3 key moments or memories in their story.

The participants will record 3 sounds which will be triggered by the buttons when pressed. These again should be linked to the key moment or memory in the story.

14:00 - 14:10: Tea break

14:10 - 15:00: Making more yarn wires

Participants have chance to make more wires

15:00 - 15:45: Open Time (participants can work on what they want).

15:45 - 16:00: Brief participants about wall hanging vs. table mat

Participants should think about whether they want their piece to be a wall hanging or a table mat type piece.

Also instruct them to make one recording about their thoughts after the workshop about what they've been doing and how they are finding the process.

16:00 - Time to go home

Homework

- Reflect on workshop - mini diary recording
- Think about wall hanging or table top piece.
- Reflect on what might want to decorate with and bring in for next session

Workshop 5 - *24th March*

Aims:

- Decorate objects
- Decide on position for buttons and stick down with sticky velcro
- Share with each other

Things to bring:

- Sound boards

- Laptop

- Crocodile clips

- My finished project

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Felting wool

- T-shirt yarn

- Popper snaps

- Popper snap tool

- Conductive thread

- Sound boards

- Velostat

- Foam

- Different fabrics (big!)

- Needles

- Glue

- Embroidery thread

- Scissors

- Beads

- Scrap fabric

- Pom poms

- String

- Tissue paper

- glitter glue

- Fabric paint

- Foam

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 - 13:30: Put objects together on backing fabric

The buttons will all be placed on the participant's backing fabric - they will choose where this will be - and we'll use fabric sticky tape to stick them down. All the buttons will be connected to the boards using the fabric connectors and we will test them!

13:30 - 14:00: Decorate objects

The participants can now decorate their objects using a variety of crafting materials.

14:00 - 14:10: Tea break

14:10 - 15:00: Carry on decorating objects

15:00 - 15:50: Share final objects

The participants will all share their objects with each other, taking it in turn to tell their stories, trigger their songs and pass the objects round for everyone to feel.

15:50 - 16:00: Brief about next week

Remind participants that the next week will be a showcase week where they can invite friends/ family to come and see their work.

16:00 - Time to go home

Homework

- Reflect on workshop - mini diary recording

Workshop 6 - *31st March*

Aims:

- Finish decorating
- Evaluate/ group discussion
- Showcase with friends and family and staff at Aylesbury

Things to bring:

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 – 13:45: Finish decorating/ adding hanging element

Participants will have time to finish decorating their objects and also add a wooden bar to the top should they want their object to be a wall hanging.

13:45 – 14:00: Tea break

14:00 - 15:00 Evaluation and discussion

Myself and the participants will have a discussion about their objects and the process of having made them. This will take the form of an informal group discuss with some pre-written questions by me.

I will also discuss the idea of interviewing them separate in their homes/ place of choice one month later about their experience of the workshop, the making process, their objects and their use of them.

15:00 - 16:00: Showcase

Staff of Bucks Vision and friends and family of the participants can come and interact with the objects and discuss with the participants.

Appendix B:
Study content

B.2 Schedule and list of tools/materials for hands-on making workshops at MK Gallery

MK workshops - 10 participants, 3 researchers and 3 volunteers

Workshop 1 - *5th June*

Room Setup:

- Three trestle tables setup in a rectangle to accommodate 11 people. They will sit so looking in at each other.
- Materials table with different fibres and yarns on it ready for weaving.
- Cakes, napkins and cups to be setup ready on the bar area for serving.

Aims:

- To introduce the participants to the project.
- Getting hands-on with the electronics
- To start the process of thinking about textures and associations.
- Exploring hands-on making: Weaving

Things to bring:

- Laptop
- Video cameras x 2
- Tripods x 2
- Digital SLR
- Sound recorders x 2
- Arduino Board with Capsense sketch

- Crocodile clips

- E-textile examples

- My finished project

- Sample fabric wires GONE

- Sample un-hacked soundboards GOT

- Sample hacked soundboards GOT

- Sample hacked buttons

- Batteries GOT

- Tube yarn GOT

- Pliers GOT

- Press-studs GOT

- Conductive thread

- Other little crafty bits

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt) to do

- Looms GOT

- Materials for weaving (non-conductive yarns and fibres) GOT

- Scissors GOT

- Big paper

- Marker pens

- Post-its GOT

12:00 - 12:30: Cup of tea/ lunch and explaining project

Becoming familiar with each other in an informal setting - a good chance to find out what other activities the participants are involved in through Bucks Vision and anything they've been up to recently which they want to discuss. The participants who are attending have either been regular participants of the Eye for Art sessions or used to attend them. This is also a good moment to gain a better understanding of their interests and perception of their making skills.

Introduce the project at this point, demo the example wall hanging and mention how we might be able to have an informal exhibition of everyone's work after the workshops during end of July/ beginning of August.

Our aim is to help you only as much as you want help. So – we can leave you to it, or we can act as your 'agents', executing actions that you specify (like a foundryman casting a sculpture).

12:30 - 12:45: Getting to know each other - memory game - having a chat about themselves in pairs and feeding back to the group.

Participants spend 6 minutes talking to each other, 3 minutes about each person. They will discuss:

- What their name is
- Where they live
- A hobby which they love
- What their favourite sound is - can be song, nature, animal etc.

Spend approximately 1 minute per pair reporting back to the group about what they found out about each other.

12:45 - 12:55: Demo my example project and e-textile samples

Show the participants my story cloth with the fishing memory. There will be the chance to ask any questions about it and for everyone to interact with it via the soft circuit buttons which have different textured textiles on them and are in the shape of a fish, a jacket and an abstract water one. Also an opportunity to pass around different e-textile objects

12:55 - 13:15: Have a go at making fabric wires for the soundboard

13:15 - 13:25: Test fabric wires with sample boards

13:25 - 13:45: Exploring textures and association and describing it and why

In pairs or threes the participants will handle different textured textiles and discuss what they think of them. They will discuss:

- How they feel to the touch

- Do the textiles trigger any thoughts or associations?

They will then feed this back to the group.

13:45 - 14:00: Tea break

14:00 - 16:15: Weaving

Introduce the weaving activity. Explain to participants that they will be able to use their crafted objects on their projects but that they also can just use textiles. The idea of the crafting is to explore different ways of making.

The participants will spend just over two hours weaving their own fabrics. It would be great to finish this so we do not bring it over to the next session.

16:15 - 16:25: Brief about what to bring for next week/ homework and roundup

I'll brief the participants about bringing a piece of textile from home that is important to them in some way. We'll share everyone's objects next week.

Also brief them about keeping a diary about the sessions - if they can to email me a few lines with their thoughts on the session.

16:30: Time to go home

16:30 - 17:00: Pack up!

Homework

- Bring a piece of textile from home which is important to them or they like very much.

- Reflect on workshop - mini diary entry over email or reflect on phone call with me.

Workshop 2 - 19th June

Aims:

- To introduce the participants to the hardware
- To start exploring sounds with textiles
- To explore how to construct a story with the textile

- Decide on theme for objects
- Exploring hands-on making: Finger knitting

Things to bring:

- Laptop
- Video cameras x 2
- Tripods x 2
- Digital SLR
- Sound recorders x 2
- Arduino Board with Capsense sketch
- Crocodile clips
- E-textile examples
- My finished project
- Sample fabric wires
- Sample soft shields
- Sample un-hacked soundboards
- Sample hacked soundboards
- Batteries
- Tube yarn
- Pliers
- Press-studs
- Conductive thread
- Other little crafty bits

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Looms

- Materials for weaving (non-conductive yarns and fibres)

- Conductive fabric

- Needles

- Foam

- Fabric glue

- Scissors

- Big paper

- Marker pens

- Post-its

12:00 - 12:30: Cup of tea/ lunch and catch-up

Chance for everyone to catch-up and have their lunch and tea.

12:30 - 13:00: Sharing participant's textiles and telling their story

The participants will all tell us what their textile is and why it is important to them – what is its story? How would they describe the texture? What do they look like or how do they imagine them to look? What sound would they make? Pass them around for other participants to feel as they describe.

13:00 - 13:20: Intro to board and paying with it

Everyone will have the chance to play with one of the little soundboards to gain an understanding of how they work. They can have a go at recording a sound on them and recording over it, and triggering it with a button attached to the board.

13:20 - 13:40: Construct a story with textile patches

In groups of two or three I want the participants to discuss how they would incorporate one or two of the sample textiles into a story. Also, what sounds would go with them? They can just discuss in their groups - they don't need to report back.

13:40 - 13:55: Any ideas or themes to follow

Do any of the participants have ideas of themes they would like to base their piece around that they want to share with us at this point? Also, is there an objects they would like to make? E.g. Wall hanging, cushion, toy, bag etc.

13:55 - 14:10: Tea break

14:10 - 15:10: Start to build one soft circuit, e-textile button

The participants will start to build their soft circuit buttons. They will each begin with one but can choose to make up to three depending on what the object is that they want to make and how many interactions and sound they want it to have.

15:10 - 16:15 Finger knitting

We will spend an hour finger knitting. This is a very quick way to create a textile in a tactile way. It can be a bit fiddly so some of the participants might need a bit of help to get started.

16:15 - 16:25: Brief about constructing a personal story and choosing textiles to go with them

The participants will be briefed to decide on what they want their personal story to be which their interactive object will reflect. For this they will be asked to either choose textiles from home which they would like to represent three key moments or memories in their story or to think about textiles that they feel would represent it well from my collection. They can also think about textiles that they want me to buy and I can get for them. I can follow up with them to find out what the request is.

Also brief them about emailing me a diary entry about the session, or to think about what they want to say when I call them.

16:30: Time to go home

Homework

- Think about personal story/ memory that participants want their piece to be about.

- Think about what fabric they want to use for it and make a request over email or phone (or bring something from home).

- Reflect on workshop - mini diary entry over email or reflect on phone call with me.

Workshop 3 - *26th June*

Aims:

- Confirm story/ memories for object
- Start building the interface
- Carry on making buttons
- Exploring hands-on making: Wet felting

Things to bring:

- Laptop

- Video cameras x 2

- Tripods x 2

- Digital SLR

- Sound recorders x 2

- Arduino Board with Capsense sketch

- Crocodile clips

- E-textile examples

- My finished project

- Sample fabric wires

- Sample soft shields

- Sample un-hacked soundboards

- Sample hacked soundboards

- Batteries

- Tube yarn

- Pliers

- Press-studs

- Conductive thread

- Other little crafty bits

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Looms

- Materials for weaving (non-conductive yarns and fibres)

- Conductive fabric

- Needles

- Foam

- Fabric glue

- Tools and materials for felt making

- Scissors

- Big paper

- Marker pens

- Post-its

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 - 13:00: Share what everyone's story or memory is and textiles they plan to use

Everyone will share what story they want their objects to reflect and pass round any materials they have brought in or ones which they have chosen from me/ I have bought. Spend approx. 3 minutes each on this.

13:00 - 14:00: Start to build structure for first iteration of interface

Together with the participants, make a quick mock-up of what they want the structure for their interface to be shape wise e.g. wall hanging, table cloth piece, cushion etc.

14:00 - 14:15: Tea break

14:15 - 15:00: Build more soft circuit buttons

If participants would like more than one button they can make another now.

15:00 - 16:15: Wet felting

The participants will try out the last crafting technique we'll be formally introducing them to during the workshops - wet felting.

16:15 - 16:25: Brief about thinking about sounds to go with stories and textures

The participants should think about what sound(s) should go with their textile textured buttons for their story/memory objects. This is to prepare for recording them next week.

Also brief them about emailing me a diary entry about the session, or to think about what they want to say when I call them.

16:30 - Time to go home

Homework

- Think about sounds and pre-prep work.

- Reflect on workshop - mini diary entry over email or reflect on phone call with me.

Workshop 4 - *3rd July*

Aims:

- Carry on building buttons for objects
- Create coverings for buttons
- Participants to give feedback on structure for interface so that I can

iterate if needs be for following week.

- Record sounds for objects

Things to bring:

- Laptop

- Video cameras x 2

- Tripods x 2

- Digital SLR

- Sound recorders x 2

- Arduino Board with Capsense sketch

- Crocodile clips

- E-textile examples

- My finished project

- Sample fabric wires

- Sample soft shields

- Sample un-hacked soundboards

- Sample hacked soundboards

- Batteries

- Tube yarn

- Pliers

- Press-studs

- Conductive thread

- Other little crafty bits

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Looms

- Materials for weaving (non-conductive yarns and fibres)

- Conductive fabric

- Needles

- Foam

- Fabric glue

- Tools and materials for felt making

- Scissors

- Big paper

- Marker pens

- Post-its

12:00 - 12:30: Cup of tea/ lunch and catchup

Chance for everyone to catchup and have their lunch and tea.

12:30 - 16:00: Record sounds

Throughout the workshop the participants will work with me to record the sounds for their work.

12:30 - 16:15: Everything happening as it needs to:

- Participants making more fabric wires for their work
- Soft circuit buttons
- Coverings for soft circuit buttons
- Show participants their fabric structures and get feedback or they are happy with them
- If happy with structures then decide on position for buttons and stick down with sticky tape

14:30 - 14:45: Tea break

16:15 - 16:25: Brief participants about last session

We will explain to the participants that the last session will be quite similar to this one in that it will be quite freeform. They should bring anything with them which they wish to decorate their piece with should there be anything special at home that they want to use.

16:30: Time to go home

Homework

- Reflect on workshop - mini diary entry over email or reflect on phone

- Reflect on what might want to decorate with and bring in for next session

Workshop 5 - *10th July*

Aims:

- Decorate objects
- Finish positioning buttons, sticking them down and putting coverings on top.
- Share with each other

Things to bring:

- Laptop
- Video cameras x 2
- Tripods x 2
- Digital SLR
- Sound recorders x 2
- Arduino Board with Capsense sketch
- Crocodile clips
- E-textile examples
- My finished project
- Sample fabric wires
- Sample soft shields

- Sample un-hacked soundboards

- Sample hacked soundboards

- Batteries

- Tube yarn

- Pliers

- Press-studs

- Other little crafty bits

- Textile textured fabrics x 12 (furry, netting, Plastic bag woven, Cotton, Plastic fabric, crocheted, woven, knitted, felted, sheet of felt, dishcloth, super soft felt)

- Looms

- Materials for weaving (non-conductive yarns and fibres)

- Tools and materials for felt making

- Conductive fabric

- Needles

- Foam

- Fabric glue

- Scissors

- Big paper

- Marker pens

- Post-its

- Pom poms

- String

- Tissue paper

- glitter glue

- Fabric paint

- Foam

12:30 - 15:00: Finish recording sounds

Throughout the workshop the participants who have not yet recorded their sounds will do so.

12:30 - 15:40: Everything happening as it needs to:

• Participants making more fabric wires for their work

• Soft circuit buttons

• Finish sticking any buttons to main fabric structure

• Coverings for soft circuit buttons

• Decorate with extra bit if wish

14:30 - 14:45: Tea break

15:40 - 16:25: Showcase work to each other

A chance for the participants to show each other what they have created and also to have a chance to discuss the workshops and their experience of them.

We can also briefly discuss the showcase for July/ August.

Appendix B:
Study content

B.3 Schedule for e-textile storytelling lab study

Schedule

10 minutes arriving and settling

10 minutes - intro to study and any questions

15 minutes *Activity 1:* playing with objects and question around them

20 minutes *Activity 2:* participant story activity and any discussion

10 minutes comfort break

20 minutes *Activity 2:* fairy tale activity and discussion

20 minutes open discussion around

15 roundup and goodbyes

Appendix B:
Study content

B.4 Script for e-textile storytelling lab study

User Study Script

Intro:

Begin by signing consent form and then read out information sheet.

Thank you for coming to take part in the user study with us today. As outlined on our information sheet, today is about combining pre-made e-textile objects - which are in the form of different switches and sensors - with storytelling. The idea behind this is to explore how storytelling can be made more interactive for people with a sensory need or impairment and how soft conductive objects can play a part in this, with a particular focus on touch and association.

You will interact with these objects and trigger sound on a circuit board, but we would encourage you to focus on how the objects feel and what sort of associations you might make with them - we will discuss this. You will find that all the objects work in a slightly different way to trigger sound, as well as feeling different due to being constructed using different methods. Please feel free to explore them with your hands freely and see what they do!

Activity 1:

For the first activity we would like you to familiarise yourself with the objects in front of you. You will find that there are five of these and that they have fabric wires attached to them - the same as the ones which you made in the workshops which we did. At the ends of these are circuit boards - again, not that dissimilar to the ones which we worked with before.

So now, we'll spend some time with you freely interacting with the objects. Please feel free to voice anything which comes into your head - what you think about them, whether they trigger any associations for you and even what you think about their functionality.

*************** **Free play time** ***************

Activity 2

Now, we will move onto our second activity! We would like you to construct a story of your own, but within it also using the e-textie objects as props, or sensory enhancements to your tale. This could to be emphasise moments within the narrative whether they be action based, emotional or where some sort of tactile element is happening. Like we did within the e-textile workshops at MK Gallery, we would like you to really focus on the feel of the objects and how you might interact with them using your hands, as something to be very much connected to your story. The story itself can be fictional or factual and it can be as simple or detailed as you like!

We don't need to rush the activity - you can first have a think about what story you would like to tell and rehearse it a bit to yourself.

*************** **Participants have some time to think about their story** ***************

Now let's hear your story!

Activity 3

For the last activity we would like you to listen to a well known children's story and think about how you would use the e-textile objects to enhance the experience as a listener. Imagine that different e-textile objects could be used to amplify the sensory experience at certain parts, with the listener being offered tactile objects to interact with. You can also think about a replacement sound to the buzz, which you might match with the objects - this sound can be anything.

****** **Read story to participants** *******

Hansel and Gretel:

A poor woodcutter and his wife had two children named Hansel and Gretel. Their mother died when they were young. Hansel and Gretel were very sad. Soon their father remarried but their stepmother was very cruel. One day, she took the children deep into the forest and left them there. Clever Hansel had some breadcrumbs in his pocket and had dropped them on the way so that they could find their way back home. Alas! The birds ate all the crumbs and they couldn't find the path that led back home.

Hansel and Gretel went deeper and deeper into the forest. They were hungry and tired. Finally, after walking for a long time, they saw a cottage made of chocolate, candies, and cake. "Look, Hansel! A chocolate brick!" shouted Gretel in delight and both ate it hungrily.

Now, a wicked witch lived there. When she saw Hansel and Gretel, she wanted to eat them. She grabbed the children and locked them in a cage. The witch decided to make a soup out of Hansel and eat him first. She began boiling a huge pot of water for the soup. Just then, Gretel crept out of her cage. She gave the wicked witch a mighty push from behind and the witch fell into the boiling water. She howled in pain and died instantly. Hansel and Gretel found treasure lying around the cottage. They carried it home with them. Their stepmother had died and their father welcomed them back with tears of joy. They never went hungry again!

Time to read: 1.48 minutes.

So now we would like you to re-tell the story in your own words, but as you do so, choose e-textile objects to interact with for the following sections:

Key moments:

- Stepmother taking them into the wood and leaving them there;
- Hansel dropping breadcrumbs to make path home;
- Birds eating the breadcrumbs;
- Hansel and Gretel finding the sugary cottage;
- Eating the cottage;
- Witch grabbing Hansel and Gretel and locking them in a cage;
- Gretel pushing the witch into the boiling water;
- The children being reunited with their father.

Appendix C: Extended tables for e-textile workshop study

Table C.1 Prototyping with different hardware boards.

Considerati-ons	Board								
	1) Rapid Electronics Re-recordable device	2) Ebay Re-recordable device	3) Amazon Re-recordable device	4) Touchboard Pi Cap shield with Raspberry Pi Zero	5) Bare Conductive Touchboard	6) Adafruit Audio FX Mini Sound Board - WAV/OGG Trigger (no amp or headphones | 7) Adafruit Audio FX Sound Board - WAV/OGG Trigger - with headphone jack	8) Adafruit Audio FX Sound Board - WAV/OGG Trigger - with stereo amp	9) Adafruit VS1053 Codec + MicroSD Breakout - MP3/WAV/MIDI/OGG Play and Record	10) Square Wear
Capacitive Touch sensing	No	No	No	Yes	Yes	No	No	No	No	Yes
Button(s) to trigger audio	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No
More than one trigger	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Programmable	No	No	No	Yes	Yes	No	No	No	No	Yes
Inbuilt Sound capability	Yes	Yes	Yes	Yes	With with Pi	Yes	Yes	Yes	Yes	No
Uses MP3s	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Uses board's internal sound	No	No	No	No	No	No	No	No	No	Yes
Uses External	No	No	No	Yes	Yes	No	Yes	Yes	No	No

Speaker/headphones with jack										
Need to upload sound via computer?	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Can use DIY speaker as opposed to larger one	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Power	AA batteries	Tiny coin cell batteries	Tiny coin cell batteries	Lipo	9v battery, rechargeable battery or wall power	Rechargeable battery or wall power	Rechargeable battery or wall power	Rechargeable battery or wall power	Rechargeable battery or wall power	3v battery, rechargeable battery or wall power
Total price of kit at time of purchase	£8.87	£4.99	£4.32	£45	£72	£28 with battery holder and amp and speaker	£27.50 with battery holder	£28 with battery holder	£34 with amp and speaker	£19 with speaker and battery holder
Easy to buy?	Yes	Yes	Yes	Yes	Yes	No (limited stock)	No (limited stock)	No (limited stock)	No (limited stock)	No

Table C.1: Comparison of the different circuit boards which were considered for prototyping for use in the participant's e-textile pieces.

Appendix C:
Extended tables for e-textile workshop study

Table C.2 Prototyping Iterations

Prototype number and name	Prototyping focus	Circuit Board	Peripheral devices: sound recording (microphone) and output (amplifier, speaker)	Method of sound recording	Soft circuit connection	Surface materials	Construction methods
1: Fabric textures	Incorporating textures into the 'interactive surface' Prototyping non-functional fabric surface elements	N/A	N/A	N/A	N/A	Non-functioning fabric textures.	Double sided fabric tape
2: Yellow felt tubes	Making soft circuits modular	Adafruit Audio FX Mini Sound Board (board 6)	No amplifier on board (so quiet sound). Used with external 8 ohm ultraslim Speaker.	Recorded sound and uploaded as library via computer	Sewn non-conductive tubes for insulation of conductive thread; Circuit board sewn onto a fabric	Felt	Press-studs; Sewing; Fabric glue

					shield, with press-stud connections to tubes		
3: Three-switch sea sounds	Executing the full brief: design and implementation (touch, sound, and 'narrative')	Adafruit Audio FX Sound Board (board 7)	Inbuilt amplifier. Used with external mini portable travel speaker.	Recorded sound and uploaded as library via computer	Sewn connections.	Different fabrics/textures used expressively for same-shape actuators.	Sewing; Fabric glue
4: Ladybird re-recordable device	Evaluating alternative technology for circuit board and connections	Two different re-recordable devices (boards 2 and 3)	Inbuilt amplifier. Used with external 8 ohm ultraslim Speaker. Inbuilt amplifier. Used with external speaker (taken from soundboard to test with tube yarn wires and press-studs.	Recorded sound directly onto board using record button and microphone	Tube yarn wires and press studs to form connections.	Different surface textures for actuators.	Double sided fabric tape; Sewing; Press-studs; Fabric glue

5: Single fish circuit	Combining and evaluating emergent design decisions for soft circuit implementation	Third, more advanced re-recordable device (board 1)	Inbuilt amplifier with external speaker (part of soundboard)	Recorded sound directly onto board using record button and microphone	Tube yarn wires and press-studs for connection.	Texture and shape of surface fabric chosen to match sound and 'narrative;'.	Double sided fabric tape; Sewing; Press-stu; Fabric glue
6: Three-switch fishing expedition (final prototype)	Final prototype: a complete, fully-functioning 3-actuator project with a narrative, designed sound and expressive actuator design, on a background with pockets for electronics.	Same advanced re-recordable device as Prototype 5	Inbuilt amplifier with external speaker (part of soundboard)	Recorded sound directly onto board using record button and microphone	Tube yarn wires and press-studs for connection.	Background template with pockets for electronics.	Double-sided fabric tape Sewing Press-studs Fabric glue

Table C.2: prototype iterations, categorised in terms of key features: the purpose of the prototype; circuit board; peripherals (e.g., sound output); method of sound recording; soft circuit connection, surface materials, construction methods.

Appendix C:

Extended tables for e-textile workshop study

Table C.3 Prototyping final design designs taken forward

	Input to Design Decisions				
Prototype number, name and description	Textiles, general crafting context and textures	Circuit board and sound	Connection, conductive materials	Trigger/actuations: Materials Construction	Workshop structure: Tasks, Technology introduction Narrative design
1 Fabric textures	The contrast of using different textures and shapes.	(N/A)	(N/A)	Exploring different textured materials for covering the e-textile switches; Using fabric tape to stick material down; The potential of using different textures to represent different emotions or associations.	Need to make sure that any making tasks requiring cutting are given appropriate support - helpful but not overbearing; Ensure that a large range of different textured materials offered.

2 Yellow felt tubes	(N/A)	Sound input was fiddly, requiring a computer; Without an amplifier, the sound quality was poor; The Adafruit needed an external battery holder sewn to it or to be powered from USB hub/mains - adding extra 'baggage' to the project.	Circuit board was stitched to a fabric shield to facilitate handling and connection; Press-studs worked well with connecting felt covered wires; Insulation of conductive thread worked well; But sewn felt tubes for insulation were too much work - need an alternative; In general, handling the conductive thread was awkward.	The insulation layer in the e-textile switches was too thick and made it difficult to trigger sound; The use of fabric glue to stick the insides of the e-textile switch together; Sewing e-textile switch together a bit fiddly.	Need to protect participants from fiddly electronics management that distracts from the design and making (the latter being what should be the focus); Facilitators might have to make fabric shield part due to being fiddly and requiring sewing.
3 Three-switch sea sounds	The contrast of using different textures but with the same shape.	Sound output was improved by using a board with an internal amplifier, and an external	Sewing circuit using conductive thread is too challenging - needs	Using a specific texture to represent a specific association.	Tested 3 button brief - both basic execution of technology and execution of design idea with a

		speaker; Recording sounds using voice, and then uploading onto the board worked well - but might be fiddly for participants.	precision; Need something to insulate conductive thread.		narrative; Selection of sounds - and the creation/recording of sounds; A richer surface design (e.g., using different shapes); Although the focus was on the tactile quality of the e-textile switches, the visual composition should be considered too.
4 Ladybird re-recordable device		Re-recordable device made sound capture simpler and was affordable; Re-recordable device sound quality good; ‘Hacking’ the sound board to replace playback button worked well; Speaking into	Introduction of tube yarn to insulate conductive thread wires worked well (tube yarn wires); Press-studs worked well with connecting tube yarn wires to circuit board shield.	Confirmed that a thinner insulating layer in e-textile switch was more effective; Using fabric tape to stick material down on e-textile switch.	The ‘hacking of the circuit board to incorporate an e-textile button might need to be done by a facilitator.

		the microphone to record sound was simple; Use of coin cell batteries more compact but fiddly and internal holder on board easily broken.			
5 Single fish circuit		Use of AAA batteries made board easier to power;			Nicely modular for building step-by-step; The use of an interesting shape, related to the theme of the piece.
6 Three-switch fishing expedition (final prototype)	The fabric background with pockets for the electronics gave a place for them to live, but made them accessible if needed; Background might be too fiddly for most				The facilitators might need to help participants with hemming their background fabric.

	participants to hem.				

Table C.3: What design decisions each prototype contributed to the final project design, and with considerations for the running of the workshops. Black text represents decisions taken forward for final design and blue text in progress prototyping considerations.

Appendix C:
Extended tables for e-textile workshop study

Table C.4 Materials and tools from the workshops

Type of Textile:		Yarns:		Tools	
Brought along by the lead researcher					
Fluffy/Soft	Fluffy ladybird	Fluffy	Fluffy thick royal blue yarn	Construction	Weaving looms
Cottons	Black cotton		Fluffy thick fuchsia yarn		Bamboo mats
	Blue and white gingham check cotton		Fluffy thick white yarn		Washing up liquid
	Green and white plaid check		Fluffy thick red yarn		Flannels
	Grey, green and dupplin white check cotton		Fluffy thick orange yarn		
Soft texture	Green felt		Fluffy multi-coloured browny-beige thick yarn	Deconstruction	Scissors
	Brown felt		Fluffy hot pink yarn	For Connecting	Press-stud pliers
	Yellow felt	Tube yarn	Skyblue tube yarn		Fabric glue (PVA)
	Red felt		Burgundy tube yarn		Fabric glue (strong adhesive)
	Grey felt		Army green tube yarn		

	Black velour		Sky blue tube yarn		Sewing needles and thread
	Packing foam sheet		Orange tube yarn		
	Blue denim		Novelty shiny tube yarn		
	Grey, white and pink tweed	Novelty yarn	Multcoloured pink/ purple/yellow hairy yarn		
	Ultra-soft red fabric		Multicoloured blue, green and yellow yarn		
	Blue and white dishcloth		Dark blue hairy yarn		
Lighter Weight Fabrics	Tulle		Black hairy yarn		
	Silky grey blue		Purple fluffy yarn		
	Black lycra	Soft yarn	Sunny yellow yarn		
	Green stretchy fabric		Luminous yellow yarn		
	Purple tulle netting		Luminous orange		
	Blue tulle netting		Baby yellow yarn		
	Transparent thin packing foam		Peppermint green yarn		
	Teal stretchy fabric		White yarn		

	Green foam		Cream yarn		
Rough Texture	Beige Canvas		Dark green yarn		
	Postal Bag		Grass green yarn		
	Thick fabric containing embroidery		Baby dusty pink yarn		
Bought Craft Objects	Wooden leaves		Brown yarn		
	Feathers	Unspun fibre	Milk protein tops		
	Pipe cleaners		Bamboo tops		
	Beads		Eri Silk - natural yellow fibre		
	Pom pom		Finnish brown fibre		
	Sequins		Blue faced Leicester - humbug fibre		
	Buttons				
	Ribbon				
	Bark Squares				
	Gold bark leaves				
	Glitter sisal sheets				
	Tissue paper				
	Seagrass bundles				
	Mini shells				
Added by participants or researchers during the workshops					

Fluffy/ Soft	Fluffy green	Tube yarn	Indigo tube yarn	For Connecting	Sewing machine
	White and black fluffy cow print fabric		Pink tube yarn		
	Fluffy pink		Grey tube yarn		
	Fluffy, ringletty red		Red tube yarn		
	Fluffy grey dark		Black tube yarn		
	Fluffy grey light		Brown tube yarn		
	Faux lambskin				
Cotton	Green cotton		Dusty yellow tube yarn		
	Light blue cotton		Navy tube yarn		
Soft texture	Brown Suede	Unspun fibre	Unwashed sheeps wool		
	Blue suede				
	Black felt				
	Ultra-soft grey				
	Green suede				
	Red and white tweed				
	Red velour				
	Grey denim				
	White lace				
Lighter Weight Fabrics	Silky gold				
	Grey and black striped silky fabric				
	White chiffon				

	Blue chiffon				
	Pink tulle netting				
	Silky blue fabric				
	Transparent netting				
	Grey lightweight fabric				
Rough Texture	Dark blue corduroy				
	Blue/grey corduroy				
	Dark blue woven fabric				
	White lace				
	White sequin				
	Course burgundy fabric				
Shiny Fabric	Sheeny blue				
Embellishments	Beaded black flowers				
Bought craft objects	A yellow sisal sheet				

Table C.4: Materials and tools initially brought to the workshops, along with those added or requested by participants and the researchers during the process.

Appendix C:
Extended tables for e-textile workshop study

Table C.5 Materials and audio for final e-textile pieces

Type of Textile:	Formed into:	By whom	Representing/reason for using:	Associated sounds:
Fluffy				
Fluffy cow fabric	Background (square)	Hailey W1	Loves cow fabric	N/A
Fluffy pink fabric	Heart shape		Daughter switch	Daughter exclaiming: *“I’m a unicorn!”*
Fluffy red ringlet fabric	Red circle	Louise W1	Decoration/part of ‘Katie’ switch	N/A
Fluffy dark grey fabric	Part of cockatiel shape		‘Katie’ switch	Katie the cockatiel chirping
Fluffy light grey fabric	Part of cockatiel shape			
	Cloud shape	Pam W2	Cloud switch	Recording of ‘Standin’ In The Rain’ by ELO
Fluffy teal fabric	Background (rectangle)	Kelly W2	Love of water	N/A
Fluffy green fabric	Background (square)	Jane W2	Grass	
Cottons				
Black cotton	Square	Hailey W1	Son switch	Son saying flatly: *“Close the door”*
	Background (circle)	Jacob W2	Plain background for drums - stretched on a round frame like a drum skin	N/A
Green cotton	Background (square)	Karen W1	Grass	

Light blue cotton	Background (square)	Ewan W1	Sky	
	Square	Ewan W1	Switch made from blue cotton (to blend into the 'sky' background), leaves and feathers to represent birds in the rainforest	Birds chirping in the rainforest
Lightly patterned blue cotton	Circle	Jacob W2	Part of drum kit	N/A
Blue denim fabric	Rectangle cushion cover (background)	Pam W2	Wanted something 'rock 'n'roll' as background for the piece	
Blue denim pockets cut from jeans provided by Pam from charity shop)				
Soft texture				
Ultra-soft grey fabric	Square	Karen W1	Owl switch	Owl hooting
	Abstract seagull shapes	Sonja W1	Seagulls	N/A
	Square cushion cover	Uma W1	Soft and wanted to make a comforting 'worry not' object	
	Rain-drops	Pam W2	Decoration under cloud switch	
Green felt fabric	Green leaf	Ewan W1	Plant from the rainforest he visited	Rainforest noises - insects
	Wavey shape underneath grey circles	Kelly W2	Part of stones in a brook switch	Water running down a brook
Brown felt fabric	Rectangle		Cabin on trawler switch	Sonja saying: "Mayday! Mayday! Annabel is sinking! Please come to the rescue…"

	Little irregular rectangles	Sonja W1	Hull of some regatta boats decorating the background	N/A
	Large vertical rectangle	Jane W2	Trunk of tree	N/A
	Circle	Jacob W2	Part of drum kit	
Yellow felt	Circle on top of circle with spikes	Pam W2	Sun switch - centre	Recording of *'Mr Blue Sky Sky'* by ELO
Orange felt	Orange circle with spikes underneath yellow circle		Sun switch - rays	
Beige canvas	Triangle	Sonja W1	Sail on trawler	N/A
	Little triangles		Flags on regatta boat	
	Bag shape	Patricia W2	Background	
Black velour	Square	Karen W1	Cat switch	Karen saying: *"I love my cat"*
Grey velour	Grey circles on top of green wavy shape	Kelly W2	'Stones in a brook' switch	Water running in a brook
Brown suede	Little irregular rectangles	Sonja W1	Hull of some regatta boats	N/A
	Square	Karen W1	Horse switch	Horse neighing
	Hand shapes x 2	Patricia W2	Hand switch	Recording of Patricia saying: "Ere, give us a hand mate, this bag's heavy!"
Thick blue smooth fabric	Background (rectangle)		Love of water	N/A

Grey tweed	Wavy rectangle	Kelly W2	Part of ocean switch	Roaring waves crashing
Silky Fabric				
Silky gold fabric	Background (rectangle)	Louise W1	Thought the fabric contrasted with fluffy fabrics	N/A
	Little circles	Jacob W2	Part of drum kit	
Silky grey/blue fabric	Background (square)	Sonja W1	Sky	
	Squares	Kelly W2	Pockets for holding electronics - related to water	
Rough/more prominent texture				
Dark blue bumpy fabric	Background (square)	Jim W1	Wanted to use something textured	N/A
Dark navy blue corduroy	Boat shape	Sonja W1	Hull on trawler switch	Sonja saying: "Mayday! Mayday! Annbel is sinking! Please come to the rescue…"
Dark navy blue corduroy	Circle	Jacob W2	Part of drum kit/switch	Artist reciting poem written for the work
Dark blue corduroy	Background (rectangular cushion cover)	Verity W2	Liked the fabric	N/A
Thick grey netting	Circle	Jacob W2	Part of drum kit/ switch	Sound of maracas playing
Fine netting	Circle		Part of drum kit	N/A
	Circle with white sequined circle underneath			
Shiny Fabric				
	Lightning bolt shape	Ewan W1	Thunder he heard in the rainforest	Thunder sound

White sequined fabric	Circle with netted circle on top	Jacob W2	Part of drum kit	N/A
Sheeny blue fabric	Triangle	Hailey W1	Son switch	Son saying: *"Oi oi savaloy!"*
	Star	Uma W1	Star switch on 'worry not' cushion - she wanted something glittery	Uma singing 'You'll Never Walk Alone'
	Circle x 2 overlapping	Jacob W2	Part of drum kit/ switch	Jacob playing a drum
	Long rectangles under fish shape	Kelly W2	Part of fish switch to represent the sea	Waves splashing and bubbling
Shiny blue and green plasticy fabric with scale pattern on it	Fish shape over long rectangles			
Embellishments				
Wooden notch shape	Used 'as is'	Jane W2	Hole in felt tree	N/A
Brown wooden leaves		Ewan W1	Switch representing birds in a rainforest	Birds chirping
		Jane W2	Leaves on a tree	N/A
Multicoloured leaf skeletons				
Brown feathers		Ewan W1	Switch representing birds in a rainforest	Birds chirping
		Jane W2	Decoration on pocket holding electronics	N/A
Plastic white and green flower		Louise W1	Decoration to go on 'Katie' switch	Katie the cockatiel chirping
Teal seagrass	Used 'as is' but cut small	Jacob W2	Drumstick embellishment on sheeny blue fabric drum switch	Jacob playing a drum
Spongey				

Green foam	Leaf shapes	Jane W2	Leaves on a tree	N/A
White foam	Lightning bolt shape	Pam W2	Lightning switch	Recording of 'Summer and Lightning' by ELO
Yarn				
White tube yarn	Used 'as is'	Jane W2	Line to connect her finger-knitted cast to the image of her car - conceptually connecting two events	N/A
Stretchy, shiny tape yarn	Placed down in wavy shape	Kelly W2	Portraying waves on ocean switch	Roaring waves crashing
Hand Crafted Pieces				
Woven piece	Woven into square shape using multi-coloured browny-beige thick yarn and green tube yarn.	Ewan W1	Woven square decoration on wall hanging - rainforest	N/A
	Woven into square shape using thick red, blue, orange, multi-coloured brown/beige yarns, and green and burgundy tube yarn.	Jim W1	Woven square for 'crafting with grandma' switch	Jim saying: "This is something I was trying to achieve with my grandmother…"
	Woven into square shape using thick blue yarn and blue tube yarn which	Sonja	Woven square background for 'wave' switch	The sound of seagulls

	has been twisted.			
	Woven into rectangle shape, with lighthouse colours. Using thick brown, white and red yarns. With a fine yellow one at the top and a fluffy black yarn roof.	Sonja W1	Woven rectangle for 'lighthouse' switch	The sound of a foghorn
	Very mixed in texture, using a soft thick purple yarn, bamboo fibre and army green tube yarn. Irregular weaving technique.	Verity W2	Woven square for switch	The sound of sheep 'baa-ing'
	Strips of multicoloured fabric, with a strong flash of turquoise woven		Woven square for stream switch	The sound of a stream
3D woven piece	Two woven pieces attached together: underneath a small rectangular weave		Woven bird nest switch	Bird in a nest chirping at the end of Verity's garden - recorded by the artist.

	incorporating burgundy tube yarn, beige raffia and a coarse fibre. On top, a 3D structure of yellow seagrass cord, orange, beige and black raffia and a softer fibre			
Finger knitting	Red knitted sausage shape	Jim W1	Small finger knitting for switch representing friends in Manchester, unfortunate incident in Glasgow and sister in London	Jim saying: "This reminds me of the underground, in Manchester and my friends…"
	Long white knitted sausage shape	Sonja W1	Fishing net for trawler	N/A
	Shaped into knitted circle	Uma W1	Decoration on cushion	
	Pink yarn and clear netting knitted into sausage shape	Jane W2	The artist's cast that she had to wear on her leg after tearing achilles tendon	
Felting	Layered felting in circle type shape with bitty parts on top. Using yellow, red, purple and turquoise fibre	Jim W1	Crafting with grandma switch	Jim saying: "This is something my grandmother used to try to teach me…"

Little Flag made from card and thread	Little black card rectangle with yellow and red thread on it	Sonja W1	Made little German flag for trawler out of black card, red thread and yellow thread	N/A
God's eye made from cocktail sticks and thread	Cocktail sticks with a white thread woven around them	Jane W2	Represents an 'Eye of God' - a traditional form of Mexican weaving that the Eye for Art group had made in their own workshops and for Jane represented her eyesight in the piece.	
Other				
Printed image of car on fabric	Printed onto transfer paper and then ironed onto white cotton fabric	Jane W2	Switch for piece, represents car that would have driven if sight issue not diagnosed	Lead researcher singing: *"Salt, vinegar, mustard, pepper, wee!"* - a song which Jane sang as a child when playing with a skipping rope - also sung when she tore her Achilles tendon when skipping with family.
Paper with printed out poem on it	Printed white paper cut into sections with printed poem on it	Jacob W2	The lyrics for a poem he wrote about his piece, also features as one of the sound recordings	N/A

Table C.5: The textiles or other materials used by participants for their pieces, what they were used to represent and, for switches, what audio accompanied them.

Appendix C:
Extended tables for e-textile workshop study

Table C.6 First iteration of touch table: use of hands and touch by participants

Particip -ant	Handling fabric	Handling fabric when choosing for own work	Use of hands when crafting	Interacting with prototypes (brought in by me)	Interacting with own switch when prototyping	How touch work when demonstrating to others
First Workshop Series (W1)						
Kat	S1 – 1:32:54 – picks up samples and feels with fingers. Also gently presses on them with palms when they're on the table	N/A Didn't make final piece	N/A don't have any videos of her weaving. She had to leave early so didn't get far.	S1 – 56:38 – runs hands up my demo project when first feeling it. Walks fingers up toward switches – when lands on switch triggers it. S1 – 56:53:14 - Kat touching with both hands - placed on fabric background - rubbing them along	N/A didn't make any	N/A Did not attend after first workshop

				it to feel - same with the soft circuit switches.		
Jim	S1: 1:34:19 – picks up fabric and rubs with thumbs and fingers but also flops it around in hands. S3: MVI_0540.MP4: Black velour – gently stroking but tapping lightly with fingers as well. S3: MVI_0539.MP4 Exploring sequin fabric. Marian has presented to him – put hand on it and asks 'What does it feel like?'Rubbing sequins with finger tips and palm with	S3: MVI_0542.MP4 – textured blue fabric used for background. Pushing right hand on fabric still, on right side, and with left hand running palm but more pressing on fingers up and down and across. Talking about 'pattern' and association with 'trees' and 'cutlery trays.	S2 MVI_0443.MP4 – getting a bit muddled with finger knitting. S3: MVI_1404.MP4 Felting – 'dabbing' with finger tips – pushing. And banging with fist.	S1 – 58:10 – Strokes switch very lightly but firmly to trigger it.	S6: MVI_1427.MP4 When demonstrating piece – felted piece not finished so demonstrating switch without covering. Presses gently with palm outstretched, with fingers making contact – does twice until triggers. Rests hand on it as listens. At the end lifts up but then presses again, re-triggering.	S6.1 – Presses gently but firmly with tips of fingers or with all area of fingers.

	fingers. Also walking fingers up and down fabric.					
Uma	S1 – 1:34:50 – picks up fabric swatches, turns them over to look at them and then drops them again. Not much touching, more interested in re-recordable device. S3: MVI_0540.MP4 Handling sequin top brought in by Marian. Almost scrunching with both hands and then patting gently with right hand.	S4: IMG_3588.MOV Talking about what final project will be. As explains that will make a cushion which she can cuddle. She picks up the soft, felty fabric and hugs it.	S6: MVI_1404.MP4 Felting – rubbing felt with palms using some pressure.	S1 – 58:10 – taps switch lightly with tips of fingers but seems more interested in feeling pockets and finding re-recordable device in them. S3: MVI_0591. MP4 Rubbing/ stroking outwards with tips of fingers – when I say can rub starts rubbing in this same way quicker – going outwards.	S3: MVI_0558.MP4 Testing her switch – taps it with three fingers with stiff hand. When I ask her to record something to play back she records 'Aren't we clever girls making this together!?' Uses one pointy finger to trigger this.	S.6.1 – 9:32 - She says she 'I don't quite know what to say' and that she would like to cuddle it. As she says all this she gently taps where the switch is on the cushion with her palm as if she does know how it works. I explain circuit and how it works and I trigger it for her. When it's being demonstrated she fiddles with felted piece of fabric.

Karen	S1 - 1:34:03 - touches the fabric gently as exploring it. Here she is rubbing it with thumbs or uses fingers to stroke softly. Also taps it gently with fingers. S3: MVI_0536.MP4 Feeling sequin fabric – running hand stretched out over fabric gently, feeling with tips of fingers.	S4 - 1:27:02 – With the 'horse fabric' holding it with both hands – gripping it and stroking. Much bigger movements S4 MVI_0591.MP4 – 0:26 – Runs hand over 'ultra-soft' fabric but also grabs with hands. Rubs lightly with thumb and fingers. S3: MVI_0541.MP4 Runs palms across velour 'cat' fabric very gently.	S2 - 38:23 - uses her hands in a very gentle way when making - keeps them close to the loom and uses both together to guide yarn through (when weaving)	S1 – 00:50:10:13 - Karen tapping VI expert's switch lightly with hand - excited 'Oh, is it that???' - Marian then explains it. S1 – 00:54:39:08 Karen about greeting card 'I could tell it was a singing one cos you could feel it' S1 - 1:03:18 - fingers along as touches my demo for the project	S3: MVI_0551.MP4 – testing switch. Before I ask her to do it, she's trying herself and repeatedly tapping just below on the poppers. Then I ask her to demo it. She finds the right area and pats/ taps once with fingers/ palm, slight delay in holding it there - and hovers above as if listening. S6: IMG_6087.MOV Karen testing switches with coverings on.	S6.1 - 2.08Touches with both hands at once with palms and fingers – triggers with tap. Sometimes touches object with left hand first as if to find it and then triggers with right hand (with the tapping technique again).

				1:03:43 - Touches gently with left palm and fingers - then brings in right palm and fingers to trigger again at same time . S1: 1:03:32:17 Karen and Sonja touching switches - Karen presses fish one and says 'bubbling		
Sonja	S1 - 1:35:03 – Handling fabric - picks up with both hands and presses it with fingers – also turns it over as looking at it.	S3: MVI_0541.MP4 – handling corduroy fabric for hull of boats. Rubbing between ends of fingers and	S2 - 34:40 - When Sonja is making she peers at her work in front of her and uses both hands in a focused way when building her piece (in	S1 - 42:43 – Handing e-textile hand puppet. Looking at it and also picking it up with both hands. Turning it around in hands. Not	N/A cannot find example of Sonja playing interacting with switch – her own or one I've made – with no cover on it.	S6.1 – 4:49 – Whacks first switch with right palm and fingers to trigger. Touches next two switches more gently with

		thumbs quite quickly,	this instance, weaving). Uses left hand to help weaving along and uses right hand to lead	looking for interaction. S1 - 44:22 – Picks e-textile flashing badge and turns it over to look at it in both hands. Not looking for interaction. S1 - 48:20 – Picks up Gamebot and like other prototypes, looks at back and front whilst holding in two hands. Not looking for interaction. 1:03 - triggers e-textile switch - she taps with fingers and		fingers on right hand.

				brings them back very quickly S1 – 01:03:02:23 - Sigrid picking up switch in my prototype to look at rather than pressing to trigger		
Hailey	S1 – 1:25 – picks up fabric when handling it and rubs it between fingers and thumbs. Sometimes gives it a little tug outwards. S3: MVI_0536.MP4 Exploring sequin fabric. Marian has presented to her – put hand on it and asks 'What does it feel like?' She uses tips of fingers to explore –	S4 - MAH00003. MP4 - 23:05 – Is presented with 'cow' fabric. Excitedly strokes it with left hand and then strokes it quickly from centre outwards with left and right hand. Straight after this is handed shiny fabrics. Strokes them like	S2: MVI_0423.MP4 Very happily getting on with finger knitting, pushing it down on her fingers and wrapping yarn knitting with round her fingers	S1 – 1:05:18 Strokes jacket switch – then triggers – seemingly to tap it more. Triggers fish switch by pressing on it with fingers from both hands. Pressing water switch gently with tips of right fingers.	S3: MVI_0551.MP4 –Hailey testing her switch. Gesture is a stoking but almost touch and slide. As doing so says 'meow' as if it's a creature. Testing with my jacket switch – she repeated 'She loves to wear her fleecy jacket'.	S6.1 – 3:39 – Presses all switches with knuckle when demonstrating. This was after some problems with them triggering. Before realising no batteries in one of them was triggering by pressing firmly with palm.

	wiggling them on fabric as touches it. Thumb going under fabric and almost rubbing. Then holding with left hand and running right along with thumb under and fingers over fabric. Describes as ‘cold and smooth and bits in it as touches – then Sequins!’. Holdi ng with tips of fingers and pulling away from grip saying ‘stretchy’.	the cow but also picks up in both hands. S3: MVI_0542.M P4 Handling possible switch fabric – sequins. Rubs between fingers and thumb.				

Ewan	S1 1:34:19 – shapes fabric as handling it with both hands.	S5: MAH00004.MP4 Ewan feeling his backing – walks fingers over bottom part of front – finds pockets and says 'There's the pockets' – Slides palms up the fabric to the top – touching with fingers. Reaches to the top and picks at it to the underneath side. Run palms back to near base and holds them there – tapping them on the fabric once. Sits there twiddling/ tapping fingers on the cloth.	S2 - 39:35 - Ewan using both hands to thread through yarn carefully through warp S2 - 45:31 - fluttering hands as doing movements for weaving - hands quite 'busy' S2 MVI_0442.MP4 Getting more into rhythm with weaving one tied on. Say's 'I love this'.	S1 – 1:06:05 – gently touching with ends of fingers of placing hand on switches.	S4: IMG_3593.MOV taps 3 times with a final push to trigger switch.	S6.1 – 5.57 – presses continuingly with palms and fingers softly to trigger and then taps switches repeatedly with palms and fingers to make them trigger. Also presses repeatedly with tips of fingers. Could describe as 'busy hands' again
Louise	Cannot find clip	Cannot find clip	S4 – MAH00003.MP4	S4 – 03:30 - MAH00003.MP4	Do not think Louise tested her	S6.1- 10:50 – As discussing

			- 1:31:59 – When weaving, brings yarn through with one hand and then guides with the other. Lays yarn on top across loom and then pulls through. Spends some time patting yarn down with fingers	Exploring my demo piece – feels pockets first with both hands. As running hands across piece accidently triggers water switch. Taps it with both sets of fingers after doing this.	soft circuit switch before it got integrated into her piece. She clips it together in s6: MVI_1396.MP4 and in MAH00019.MP4 at approx. 00:58:45	what her piece is she gently strokes the piece around the switch – it's soft and fluffy. She carries on stroking when triggering it, but also gives a very gentle tap with her hand (palm and fingers).
Second Workshop Series (W2)						
Jane	MAH00014.MP4.MP4: 20:49 - stroking fluffy		MAH00027.MP4: 1:43:08 - Finger knitting very quickly!		MAH00027.MP4: 1:09:38 - repeatedly pushing it with her finger tips quickly and then banging it with first! Not sure if this is because the soundboard is glitchy and she has to do this to	MVI_4251.MP4: 03:42 -

					make it trigger each time or because she thinks that's how to do it. Marian goes on to explain to her that it is an on and off switch.	
Kelly		MAH00011. MP4: 0:16:52 - running yarn wires through fingers and stretching it. MAH00025. MP4 - 00:40:13 - holding weave as if judging weight and rubbing it	MAH00027. MP4: 1:43:08 - Finger knitting very quickly!		MAH00027. MP4: 1:11:02 - Pressing with left fingers, close to palm - stretched out and leaning on the table - pressing and holding for a second then lifting away - whilst listening and bringing head closer - repeating this at least 13 times (I'm in the way of camera so	MVI_4251. MP4: 12:15 -

					can't fully see). Does it at different speeds. Picks up LED with right fingers and peers at it.	
Pam					MAH00027. MP4: 1:15:03 - Pressing switch lightly with fingers held together and stretched out.	MVI_4251. MP4: 07:10 - talks about how she decided to make her own merchandis e based on ELO concert went to (as the stuff there wasn't very good) - chose to represent 3 songs to do with weather on a big cushion - blue denim as it's rock n' roll. Mr Blue sky - shiny sun, Summer Lightnight with a big

						lightning bolt. Last one about rain (couldn't remember song name) - has a fluffy cloud with some raindrops. Pushes sun switch very lightly with finger tips. 'Feel free to press the switches'. Says that she 'loves the different textures' and as says this her fingers are resting lightly on the work - and then goes on to say what they are: 'Felt for the sun - and rests fingers on the sun; Pasticy for the

						lightning, and rubs with 3 middle fingers on the lightning bolt; and this furry cloud - with left hand brushing it with fingers very lightly. Note, after the sun switch is triggered she's just talking through the others, NOT triggering them (like Verity) - must understand pressure needed to trigger compared to just touching. Describes as 'The Electric Light

						Orchestra in a cushion'.
Jacob					NA - cannot find example.	MVI_4251. MP4: 00:23 - pressing switches gently but firmly with finger tips - 2 switches not working as got recorded over and Jacob is not sure which one is working so is tapping around on all the switches (and decoration as there is more of that then switches) - does this approx 9 times before I step tin to trigger it.
Verity						MVI_4251. MP4: 04:58 - Verity has turned her

						piece around for the showcase so speakers are pointing toward the windows. As she is talking about her work and the meaning and ideas behind it. She is particularly doing this with the ‘sheep’ switch’. As she explains when each switch is and how they are all woven from different materials, again she is touching them - as discusses the sheep in the field she touches the soft

						and slightly fluffy sheep switch lightly with her right hand - almost stroking it too; the bird nest switch (which is woven from raffia) she touches the 3D bird nest bit of the switch with both hands - her fingers more so - and fiddles with it. As she touches the last switch - which represents water (the pond in their garden) - she taps it lightly with the palm of her left hand. 'Press all of these

						together or one at a time' - Verity is touching her switches lightly with the tips of her fingers during this - not triggering them but referencing them - must know what pressure is needed to trigger them and what pressure can be applied when just referencing. Does then trigger them - taps sheep switch (two quick little taps) to trigger, with finger tips, middle finger makes

						contact - holds piece up so people can see/ hear it more clearly. Presses water switch gently with only a couple of fingers - pointy finger makes contact. Tries to trigger bird nest switch with the nest itself. Appears that she is squeezing the nest part and pushing the switch at the same time.
Patricia			MAH00027. MP4: 1:43:08 - Finger knitting very quickly!		MVI_2068.MP4: 00:02 - Places right fingers on switch - to the right side and at an angle	MVI_4251. MP4: 10:02 - pressing switch very lightly with tips of fingers -

					- then quickly presses left fingers underneath these to trigger, more flat and in middle of switch. Holds fingers on switch in place as listens to recording.	repeatedly to
Mark		N/A didn't finish			N/A didn't finish	N/A didn't finish
Susie		N/A didn't finish			N/A didn't finish	N/A didn't finish
Evie		N/A didn't finish			N/A didn't finish	N/A didn't finish
Carrie		N/A didn't finish			N/A didn't finish	N/A didn't finish

Table C.6: First iteration of touch table: use of hands and touch by participants. Observations from notes and notes from videos used.

Appendix C:
Extended tables for e-textile workshop study

Table C.7 Gestures that participants used to handle fabric throughout the workshops

Gesture	Type of fabric	Participant
Pressing	Green corduroy	Kat
	Yellow felt	Sonja
	Dark blue bumpy (background)	Jim
Turns fabric over	Yellow felt	Sonja
	Yellow felt	Jim
Rubbing	Fluffy ladybird print	Ewan
	Louise’s green knitted cardigan	
	Sequined	Karen
	Ultra-soft grey	
	Green coarse	Karen
	Louise’s green knitted cardigan	
	Grey tweed	
	Woven plastic	
	Black velour	
	Green coarse	Hailey
	Sequinned	
	Black velour	
	Ultra-soft brown	

	Woven plastic	
	Red felt	
	Yellow felt	Jim
	Sequinned	
	Louise's green knitted cardigan	
	Woven plastic	
	Plaid check	
	Grey tweed	
	Ewan's small woven sample	
	Woven piece	Kelly
	Corduroy	
	Yellow felt	Sonja
	Green corduroy	Kat
	Plaid check	
	Blue tulle	Sonja
	Louise's green knitted cardigan	
	Louise's green knitted cardigan	Uma
	Fluffy ladybird print	
	Ultra-soft grey	
Tugging	Green coarse	Hailey
	Woven plastic	
	Blue tulle	
	Red felt	

	Black velour	Sonja
Holding	Woven piece	Kelly
Grabbing	Ultra-soft grey	Karen
Stroking	Black velour	Jim
	Yellow felt	
	Fluffy ladybird print	Karen
	Ultra-soft brown	
	Brown suede	
	Red felt	
	Fluffy cow	
	Green cotton	
	Fluffy	Jane
	Fluffy cow	Hailey
	Shiny blue and green plastic fabric with scale pattern on it	
	Ultra-soft brown	
	Fluffy ladybird print	
	Plaid check	
	Red felt	
Tapping	Black velour	Jim
	Yellow felt	Karen
	Sequinned	Uma
	Ultra-soft brown	

	Ultra-soft grey	
	Blue cotton	Ewan
Gripping	Brown suede	Karen
Grip walking	Louise's green knitted cardigan	Karen
		Sonja
		Ewan
	Woven piece	Jim
	Woven piece	Uma
	Louise's green knitted cardigan	Uma
Picks at	Blue cotton	Ewan
	Fluffy ladybird print	Uma
Walking fingers/hands	Sequinned	Jim
	Green corduroy	Kat
	Blue cotton (background)	Ewan
	Brown suede	Karen
	Woven piece	
Running fingers/hands along	Sequinned	Hailey (holding with left hand at same time)
	Blue cotton (background)	Ewan
	Dark blue bumpy (background)	Jim
	Sequinned	Karen
	Ultra-soft grey	

	Black velour	
	Green corduroy	
	Green corduroy	Louise
	Blue tulle	Kat
Running through fingers/hands	Tube yarn	Kelly
	Ultra-soft grey	Uma
Picking up and dropping	Fluffy ladybird print	Uma
Scrunching	Sequinned	Uma
Stretching	Tube yarn	Kelly
Wiggling fingers on fabric	Sequinned	Hailey
Pushing on with hand	Dark blue bumpy (background)	Jim
Hugs	Ultra-soft grey	Uma
Patting	Sequinned	Uma
	Fluffy ladybird print	Hailey
	Plaid check	Jim
Touching gently	Sequinned	Karen
	Brown suede	

Table C.7 Gestures that participants used to handle fabric throughout the workshops.

Appendix C:
Extended tables for e-textile workshop study

Table C.8 Gestures that participants used to touch e-textile switches throughout the workshops

Gesture	Fabric covering on e-textile switch	Participant
Pressing with palm(s) and finger(s)	E-textile switch without cover (conductive fabric)	Jim
	Woven thick red, blue, orange, multi-coloured brown/beige yarns, and green and burgundy tube yarn square	
	Red knitted sausage shape	
	Black cotton square	Hailey
	Green felt leaf	Ewan
	White sequined fabric lightning bolt	
	Woven square of royal blue chunk and sky blue tube yarn	Sonja
Pressing with finger(s)	E-textile switch without cover (conductive fabric)	Uma
	Woven red, black and white chunky yarn rectangle	Sonja
	Dark navy blue corduroy boat shape	
	Square plastic green fabric	Hailey
	Sheeny blue triangle	
	E-textile switch without cover (conductive fabric)	Ewan
	Blue cotton square decorated with leaves and feathers	
	Woven square of strips of multicoloured fabric, with a strong flash of turquoise woven	Verity
	Fleecy jacket shape switch with fluffy ladybird print	Kat
	Square plastic green fabric	

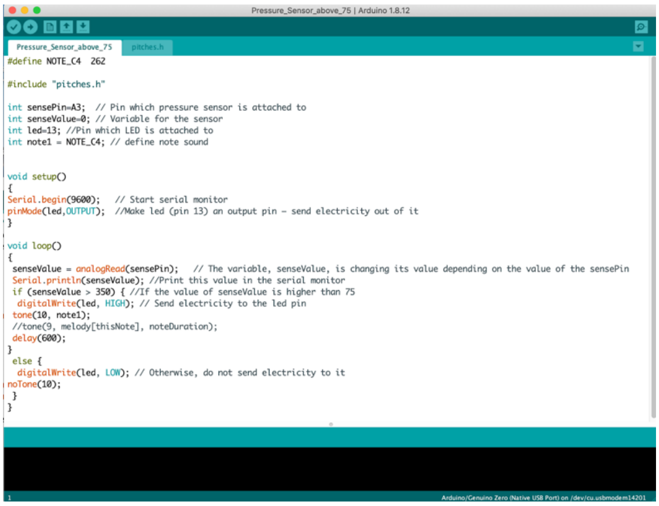
	Woven plastic fish	
	Square plastic green fabric	Louise
	Woven plastic fish	
	Fleecy jacket shape switch with fluffy ladybird print	
	Scaly fish switch made from woven plastic fabric	Hailey
Pressing with knuckle	Black Cotton square	Hailey
	Fluffy pink square	
	Sheeny blue triangle	
Tapping with finger tips	Sheeny fabric	Uma
	Fleecy jacket shape switch with fluffy ladybird print	Hailey
	Square plastic green fabric	Louise
	Fleecy jacket shape switch with fluffy ladybird print	Karen
	Black velour square	
	Ultra-soft grey square	
	Brown suede square	
	E-textile switch without cover (conductive fabric)	Ewan
	Green felt leaf	
	Blue cotton square decorated with leaves and feathers	
	Square woven of soft thick purple yarn, bamboo fibre and army green tube yarn.	Verity
	Fluffy dark grey	Louise
Tapping with palm/heel of hand	Woven square of strips of multicoloured fabric, with a strong flash of turquoise woven	Verity

	White sequined fabric lightning bolt	Ewan
Walking with fingers	Sheeny blue triangle	Hailey
Stroking	Fleecy jacket shape switch with fluffy ladybird print	Hailey
	E-textile switch without cover (conductive fabric)	Hailey
	Fluffy dark grey	Louise
	Fluffy light grey	
	Woven square of soft thick purple yarn, bamboo fibre and army green tube yarn.	Verity
	Green corduroy	Jim
Pushing	Woven square of burgundy tube yarn, beige raffia, and a coarse fibre	Verity
	Sun shape - orange circle with spikes underneath yellow circle	Pam
Banging	E-textile switch without cover (conductive fabric)	Jane
Squeeze	3D woven structure of yellow seagrass cord, orange, beige and black raffia and a softer fibre	Verity
Rub	Lightning bolt - white foam	Pam
Touches gently with both palms	3D woven structure of yellow seagrass cord, orange, beige and black raffia and a softer fibre	Verity
Touching	Woven plastic fish switch	Karen
	Woven square of soft thick purple yarn, bamboo fibre and army green tube yarn	Verity
Brush	Fluffy grey cloud light grey fabric	Pam
Patting	E-textile switch without cover (conductive fabric)	Karen
Whacking with palm	Woven square of royal blue chunk and sky blue tube yarn	Sonja

Table C.8: Gestures that participants used to touch e-textile switches throughout the workshops.

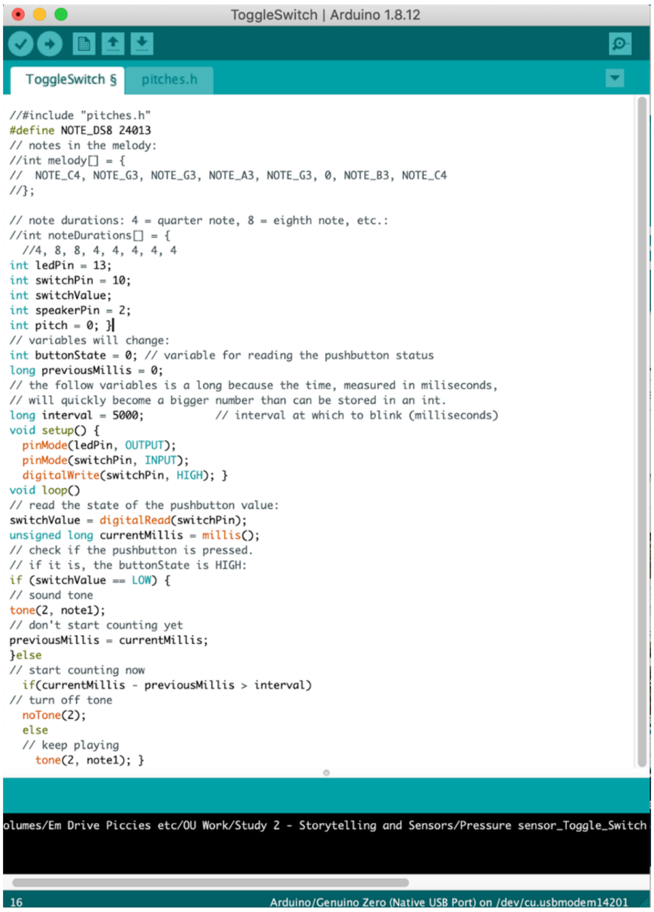
Appendix D:
Extended tables and coding for storytelling study

D.1 Arduino programming code used for the pom pom, stretch and squeeze sensors




```
#define NOTE_C4  262

#include "pitches.h"

int sensePin=A3;  // Pin which pressure sensor is attached to
int senseValue=0; // Variable for the sensor
int led=13; //Pin which LED is attached to
int note1 = NOTE_C4; // define note sound


void setup()
{
Serial.begin(9600);   // Start serial monitor
pinMode(led,OUTPUT);  //Make led (pin 13) an output pin - send electricity out of it
}

void loop()
{
 senseValue = analogRead(sensePin);   // The variable, senseValue, is changing its value depending on the value of the sensePin
 Serial.println(senseValue); //Print this value in the serial monitor
 if (senseValue > 350) { //If the value of senseValue is higher than 75
  digitalWrite(led, HIGH); // Send electricity to the led pin
 tone(10, note1);
 //tone(9, melody[thisNote], noteDuration);
 delay(600);
}
 else {
  digitalWrite(led, LOW); // Otherwise, do not send electricity to it
noTone(10);
 }
}
```

D.2 Arduino programming code used for the stroke and fold sensors




```
//#include "pitches.h"
#define NOTE_DS8 24013
// notes in the melody:
//int melody[] = {
//  NOTE_C4, NOTE_G3, NOTE_G3, NOTE_A3, NOTE_G3, 0, NOTE_B3, NOTE_C4
//};

// note durations: 4 = quarter note, 8 = eighth note, etc.:
//int noteDurations[] = {
  //4, 8, 8, 4, 4, 4, 4, 4
int ledPin = 13;
int switchPin = 10;
int switchValue;
int speakerPin = 2;
int pitch = 0; }
// variables will change:
int buttonState = 0; // variable for reading the pushbutton status
long previousMillis = 0;
// the follow variables is a long because the time, measured in miliseconds,
// will quickly become a bigger number than can be stored in an int.
long interval = 5000;           // interval at which to blink (milliseconds)
void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(switchPin, INPUT);
  digitalWrite(switchPin, HIGH); }
void loop()
// read the state of the pushbutton value:
switchValue = digitalRead(switchPin);
unsigned long currentMillis = millis();
// check if the pushbutton is pressed.
// if it is, the buttonState is HIGH:
if (switchValue == LOW) {
// sound tone
tone(2, note1);
// don't start counting yet
previousMillis = currentMillis;
}else
// start counting now
  if(currentMillis - previousMillis > interval)
// turn off tone
  noTone(2);
  else
  // keep playing
    tone(2, note1); }
```

Appendix D:
Extended tables and coding for storytelling study

Table D.3 Gestures and associations observed in Activity 1: Open play

Activity 1: Gestures and associations with sensors during open play					
	p1	p2	p3	p4	p5
Pom Pom	Squeeze x3 Stroke x2 Air fists x2 Cup Air cup Ruffle Run fingers through Scratch Flick	Ruffle x2 Stroke Squeeze Cup Tap Drop Picks at	Rotate x6 Picking x2 Dangle x2 Pass x2 Squeeze x2 Tap x2 Stroke Roll Grip Bounce Tap	Squeeze x3 Ruffle x2 Stroke Rotate Rock Pointed finger on it Air cup	Squeeze x7 Rotate x6 Stroke x3 Grip x2 Roll x2 Tap x2 Ruffle x2 Pull Drop Rub Fondle Bounce
Associations	Comforting	Pom pom would make in school Baby Soft baby toy baby would	Something for cats Making pom poms Like a pom pom on a	Child's Toy His toy womble	Thought would be like Squeeze Sensua Can hold in palm Stress ball

		like to put fingers in	children's jumper or toy Fluffy animal Soft toy		A pom-pom thing Child-like Toy Teddy Feels too young for her Might wear out
Stroke	Stroke x10 Tap x4 Ruffle x6 Push x3 Frame x2 Pull x2 Anchor x2 Hover Walk	Stroke x15 Tap x6 Ruffle x5 Anchor x4 Rub x3 Walk x2 Push x2 Pull x2 Walk fingers Squeeze	Stroke x4 Tap x4 Grip x4 Walk x4 Press x4 Touch x2 Scrunch x2 Fiddles x2 Rub Rest Neaten	Tap x6 Touch x4 Anchor x3 Stroke x2 Hover x2 Pull	Stroke x11 Scratch x8 Tap x6 Anchor x6 Push x2 Rotate x2 Ruffle Rub Run fingers Hover Rest Pick up corners
Associations	70s shag-pile carpet	Shaggy scarf Rug Nan and coat with fur collar	Sheep	Carpet	Cat/ her cat Felty Makes her feel safe

					Fuzzy felts Robust
Stretch	Tap x8 Stretch x7 Grip x7 Run through hand x6 Push x6 Stroke x3 Press x2 Bunch x2 Pinch Run palm Twist Rub Neaten	Run through fingers x4 Squeeze x4 Grip x3 Walk x2 Flop x2 Tap x2 Stretch x2 Touch Rest Dangle Shake Pull Press Scrunch Neaten Touch plait together	Stretch x20 Hold x13 Run through hand x6 Push x5 Grip x5 Squeeze x5 Tap x5 Shake x4 Neaten x3 Grab x2 Coil Drop Pass	Run through hand x3 Grip x2 Walk grip x2 Rub Shake Squeeze Press Pointy finger Stretch Neaten	Wrap around fingers x4 Run fingers x2 Run through fingers x2 Grip x2 Scrunch Drop Tie in knot Stretch Pull Stretch Place down in coil Poke between coil
Associations	Gum-ball machine Puzzle	Corn dolly Nan & crochet	Necklace Thread or chain	Ball of wool Mum (who used to knit a lot)	To manage OCD Elastic band to ping

	The comic of the piece		PI's fabric Necklace	Knitting machine Cardigan Plaited hair Catapult	Has a second purpose - not just touchy/ feely Greek worry beads
Fold	Stroke x9 Tap x4 Fold x3 Frame x3 Hover Scratch Put hand under it walk Push Rub Tent hand Anchor	Anchor x6 Tap x5 Rub x5 Fold x5 Grip walk x3 Ruffle x2 Walk Grippy walk Run fingers Grab Fiddle Slide Push Press	Fold x31 Stroke x7 Pull x3 Grip x3 Tap x1 Flick Push	Fold x6 Grip walk x4 Runs fingers x3 Walk x4 Close like book x2 Grip x 2 Push x2 Unfold x2 Rub Holds like book Open like book Run fingers Slip Straddling - Placing pointy and middle left finger either side of fold Tap	Run fingers x8 Fold x8 Stroke x4 Rub x3 Push x3 Tap x2 Squeeze Roll Fold in Press Pull Turn over Grip Anchor Fold Scrunch Rest

Associations	Sackcloth and ashes Scratchiness	Rough Something to walk on floor Dolls house rug - rush matting	Jacket Jumper	Flannel Carpet	Puzzle one Carpet Rough
Squeeze	Squeeze x11 Hover x2 Tap Cup Bounce Rest Touch Fist Stroke Air tap	Squeeze x2 Touch x2 Shake Drop Hold Push Wiggle Rub Cup Stroke Pull Rotate	Pass x17 Squeeze x15 Shake x13 Drop x7 Pull x3 Push x3 Rotate x2 Flick motion x2 Hover Scoop Tug ropes Neaten Roll Cup Tap Rest	Squeeze x4 Neaten x2 Rotate	Squeeze x10 Rotate x7 Hold x2 Pick at x2 Tap Drop Run fingers Air gesture cup Roll Poke Pull Push Neaten Cup

Associations	Stress ball Comforting	Knitted sort of a ball Dishcloth made from cottony string stuff	Something cats would like Cat's toy Child's toy	Ball of wool	Puzzling Comforting Soft Squidgy Sophisticated fabric Crocheted Contemporary knit-wear Stress ball Love it

Table D.3: Gestures and associations observed in Activity 1: Open play.

Appendix D:
Extended tables and coding for storytelling study

Table D.4 Gestures and associations observed in Activity 2: Participants telling their own stories

Activity 2: Gestures and associations with sensors when telling own narrative					
	p1	p2	p3	p4	P5
Pom Pom	Hover x 5 Cups Air points Stroke	Touch x 6 Squeeze x 4 Tap x 4 Re-organise Grips Moves Retreat Stroke Grab Finger walk Claw touch Wave fingers above Move right	Squeeze x 6 Stroke x 3 Rotate x 2 Gestures to Touch Holds Passes throws throwing Pass Shakes Throwing gesture Push away Pushes away Push down Neaten -	Squeeze x 3 Tap x 3 Passes x 3 Pulls toward Air tap Rotate Rests Push	

			Hovers fingers Taps Dangles		
Associations	Cat Purr Kitten's toy Chasing ball Cat's favourite fluffy ball	Bear 'We're going on a bear hunt'	Sound design: cat purring, child giggling, cow mooing Pleasing to play with, but not durable Discussing textures Orange (colour) Visual impairment Noisy thing to throw around Colour coordination Audio trigger to find it Sound triggered by user Toys for children/ older people Necklace Bobbles	Toy Womble Mother's head	

Stroke	Push x2 Finger wiggle in air Ruffle Air wiggle Tap Point at Draw air circles with clawed fingers Air frames	Stroke x 6 Touch x 6 Tap x 4 Push x2 Walk x2 Anchor Frames Run fingers Pulls	Push x 13 Stroke x 9 Tap x 6 Touch x 4 Rotate x2 Pick at x2 Ruffle Anchor Rub Squeeze Ruffles Press Neaten	Tap x 7 Anchor x 2 Rest x2 Pulls Squeeze Stretch Touch Air signal Air tap Push	Scratch x5 Tap x3 Anchor x3 Stroke x3 Rotate x2 Rub x2 Scrunch Pull
Association	Girl & cat chasing on carpet in living room Girl's giggle as playing with cat Cat's meow	River Nan & coat	If items coloured to noise Toys Pet animal Sound design Objects good for dementia/ Parkinson's patients Animal noise: woof or meow	Soft/ fluffy Nice feel Carpet on which girl sits 'Good carpet' Carpet as flat	Something to put feet on and rub (hinting at rug) Comforting Makes a crackle Encouraging object

			‘Real’ things & shaped, e.g., lemon Items for kids Colours Sheep Build a Bear		
Stretch	Hovers x 5 Taps x 5 Rest x 3 Push Passes Holds Shake Grips Runs left fingers down Neatens Flattens with palms Air tap Push Stroke	Push x 10 Tap x 8 Neaten x 5 Grip x 4 Stretch x 4 Runs through fingers x 5 Touch x 3 Pass x 3 Push x 3 Pull x 2 Drop x 2 Pull x 3 Stack Hold Fiddle	Stretch x 7 Neaten x 4 Push x 3 Touch x 2 Pull x 2 Runs through hand x 2 Walky grip Shake Cross ends Tap Touches own necklace Runs through fingers Spins round Unwinds Air taps	Push x 3 Squeeze x 2 Grip x 2 Air signal x2 Pull Rotate Touch Shake Rest Taps x 3 Pass	

	Air draw circles Air draw above Sweep air motion Squeeze Clasp	Dangle Air gesture Air wave above Stroke Runs fingers along Hold			
Association	Little girl's favorite headband Headband Elizabeth Taylor as young girl Lonely little girl, only child	Rope bridge 'We're Going on a Bearhunt' Climb rope Necklace Crochet Obstacles Running over ropebridge, 'dsh dsh dhs' noise Moving of time	Sound design: cat purring, child giggling, cow mooing Discussing textures Discussing output & colour & pleasure in interacting Items for kids Necklace, like hers Snake when wrapped For person in care home, or VI person Something for clothes Colours	Girl sits down & has hair plaited on carpet Daughter's hair	

			Animals		
Fold	Between thumb & finger x3 Frame x2 Air hover x 2 Fold Anchoring Rest Push Hover Tap Air scrunch	Crawl x 6 Anchor x4 Walk x 3 Tap x 2 Touch x 2 Push Runs fingers Press Straddling - Between pointy and middle finger, squeeze Pull Fold Neaten Rub	Push x 14 Tap x 5 Touch x 4 Fold x 5 Rub x 3 Stroke x 5 Pull x 3 Anchor x 2 Fold x 2 Rest x2 Touch Neaten Pulls Grips Press Scratch Pick at Straddling - between fingers & thumb Forward Runs fingers down fold	Fold x 4 Rest x 4 Anchor x 3 Grip x 2 Tap x 2 Straddling - between fingers & thumb x2 Straddling - between pointy and middle finger x 2 Un-grip Rest hand Air tap Straddling - between pointy and middle finger in air	Tap x2 Stroke x2 Fold x3 Run fingers x2 Grip x2 Push x2

Associations	Cat in sack in river Sack Sackcloth Meow	Army assault course Mat Nan sat on mat by fire	Twiddlemuffs An alert Something smooth Likes this one, likes the feel Like jacket Gesture to put jacket on Like how works one way and not other	Girl trips over carpet Abrasive, might graze knee 'Bad guy' 'Bad carpet' Carpet as flat	Carpet
Squeeze	Hover x 2 Cups Framing Pointing Taps	Squeeze x 6 Push x 4 Leap x 3 Tap x 2 Touch x 2 Walking Stack Stack Rolls Leapfrog over ball Grip Grab	Squeeze x 18 Rotate x 9 Pass x 5 Push x 3 Roll x 3 Hold x 4 Neaten x 4 Stroke x 3 Pull x 3 Touch x2 Fiddle x2 Run fingers	Touch Rotate Squeeze	Push x2 Squeeze x2 Stroke Pick at Roll

			Move Fiddles Runs rope through fingers Cup Shake		
Associations	Girl playing with favourite ball in front yard Boing boing for ball	Ball to leapfrog over	Sound design Items coloured Blue (learning of colours) Could have light sensors and triggers 'Real' things & shaped, e.g., lemon Cat purring, child giggling, cow mooing Toys for children/ elderly people Alert	Mother Like mum: soft on inside & hard on outside	Favourite one Emergency one on bathroom door Comfort Likes feel Helps feel calm

Table D.4: Gestures and associations observed in Activity 2: Participants telling their own stories.

Appendix D:
Extended tables and coding for storytelling study

Table D.5 Gestures and associations observed in Activity 3: Participants telling their own versions of Hansel and Gretel

Activity 3: Gestures and associations with sensors when telling the story of *Hansel and Gretel*					
	p1	p2	p3	p4	P5
Pom Pom	Touch x2 Hover x2 Stroke Cup Push Air motion de-fluff Tap	Cup x4 Squeeze Stroke Pull	Squeeze x2	Squeeze x 3 Tap x 2 Re-organise Tap Ruffle Shake	Push
Associations	Breadcrumbs Breadcrumbs taken by wind Textures	Father	Gretel throw witch into cauldron	Hansel Hansel & Gretel playing in garden Witch	

Stroke	Stroke x2 Anchor x2 Air flick Air walking Hover Tap	Anchor Stroke	Scrunch x2 Tap x2 Stroke x2 Hold x2 Anchor Ruffle Rest Squeeze Run fingers	Tap x3 Anchor x2 Re-organise Swivel Touch Pull Ruffle	Stroke x6 Scratch x5 Anchor x3 Push x2 Tap x2 Pull x2 Rub Move
Associations	Path in forest 70s shagwell carpet - riches Blingy shiney textile	Hansel & chicken bone Forest	Birds eating breadcrumbs Cage clanging Friendly sound on return	Chocolate cottage Witch pushed into cauldron by Gretel Witch going to cook them	Hansel and Gretel walking on it - floor Birds chirping Trail
Stretch	Anchor x6 Tap x4 Running hand x2 Grab Pinch Air gesture Touch	Neaten x3 Stack x2 Tap x2 Rope x2 Push Pull Stroke Stretch	Stretch	Picks up	Stretch x7 Push x6 Pull x4 Neaten x4 Run through fingers x3 Shake x2 Tap x2

	Pointy finger Air gesture path Push				Rest Run fingers Air loop Grippy walk Run fingers down it
Associations	Kids Poor Headband Direction to take Follow path home Discussing blingy object	Breadcrumbs Witch Sweet house	Treasure & coin clinking	Plaited hair for Gretel	Chord for trail to guide them back Umbilical cord
Fold	Tap x5 Anchor x 4 Fold between thumb & fingers x2 Frame x 2 Tent hands x2 Rub x 2 Fold Scratch	Cage shape x3 Fly x2 Roof shape x2 Stroke x2 Anchor x2 Touch	Fold x3 Fold Between fingers and thumb Close inwards Grip	Anchor x6 Tap x3 Grip run down fold x2 Fold between fingers x2 Hover Grip walk Pull	Tap x7 Push x5 Rotate x5 Run fingers x4 Pull x3 Rub x3 Scrunch x3 Stroke Fold x2

	Push				Holds up like person Bounce up and down Grip Drop/ Throw Shake Drop Hold up Bonce Lift up Open like book Scratch Standing it up Bounce Grip walk Rest
Associations	Poverty Rags Sackcloth & ashes Witch Cage	Bird eating breadcrumbs Cottage roof Cage in cottage	Stepmother taking them into woods & then leaving Breadcrumbs Noise of birds Clanging of cage	Chocolate cottage	Rough Prickly floor with twigs Witch (goes with electricity sound)

	Forest Oven Discussing texture				
Squeeze	Roll x2 Tap Squeeze Left finger on it Anchor	Squeeze x3 Hold x2 Cup x2 Re-organise Air signals Rotate Cauldron Eating sweets Tap Push	Push x2 Squeeze Neaten Scrunch	Squeeze x3 Rotate x2 Re-organise Touch Points to	Rotate x4 Squeeze x3 Push x2 Pull x2 Fondle Shake Flick
Associations	Grey spherical object Leaving trail Trail of pebbles	Sweets stuck to wall on cottage Witch falling in cauldron & boiling Cauldron	Water poured into cauldron	Father Hansel/ Gretel	Soft building (cottage) Not chocolate Light building with windows A nice place Comforting Bright/ light

Table D.5: Gestures and associations observed in activity one - participants telling their own versions of Hansel and Gretel.