

Weaving Lighthouses and Stitching Stories: Blind and Visually Impaired People Designing E-textiles

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ABSTRACT

We describe our experience of working with blind and visually impaired people to create interactive art objects that are personal to them, through a participatory making process using electronic textiles (e-textiles) and hands-on crafting techniques. The research addresses both the practical considerations about how to structure hands-on making workshops in a way which is accessible to participants of varying experience and abilities, and how effective the approach was in enabling participants to tell their own stories and feel in control of the design and making process. The results of our analysis is the offering of insights in how to run e-textile making sessions in such a way for them to be more accessible and inclusive to a wider community of participants.

Author Keywords

E-textiles; Participatory making; Visual impairment; Crafting; Creativity; Touch-based interaction; Story-telling.

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation - User Interfaces: Prototyping, User-Centered Design.

K.4.2. Computers and Society - Social Issues: Assistive technologies for persons with disabilities.

INTRODUCTION

The tangible nature of e-textiles provides new expressive potential for interaction. The varying textures and other tactile qualities of different materials, and the amenability to different gestures or manipulations (such as squeezing and stroking), suggests a range of interactions. Because tactile/tangible interaction offers an expressive range that does not rely on visual qualities, it provides an opportunity to enrich interaction for people with visual impairments.

E-textile materials are becoming easier to find; many hobbyist electronic retailers will stock conductive threads,

fabrics or fibres that contain metal such as silver or steel. One might use conductive thread to sew a simple, soft LED circuit [16], or knit conductive yarn into sensors [20].

To date, much research that explores the use of e-textiles focuses either on the engineering aspects of the technology, such as yarns containing embedded electronics [22], or on the visual aspects of fashion, such as runway fashion pieces [8]. These works are visually stunning and push how the technology can be used on the human body. However, there remains a gap in the research focussing on the tactile potential of e-textiles to create new interactive experiences, especially from the perspective of maker culture.

This paper explores how visually impaired (VI) people can work with e-textile materials to create objects that are meaningful to them, and how these objects can reflect their own stories and associations. Our approach aligns with the focus of third-wave HCI as discussed by Bødker, which is centred largely around emotions and experiences as opposed to “purposefulness” [2]. Our work builds on existing literature around accessibility, inclusion and making, particularly where participants have the opportunity to share ideas with one another and work in a group environment [6, 7, 17, 32]. Through a series of participatory making workshops that involved hands-on making activities with VI participants we asked what needs to happen to enable e-textile making, particularly so that participants feel they are in control of the making process, can express themselves creatively, and have a sense of autonomy. Taking a longitudinal approach we reflect on the design process involved in enabling the workshops, sharing our experience of working with tangible uses of e-textiles and how this can be explored in maker sessions, with and by users for whom a visual approach is not always accessible. This research aims to make hands-on crafting and making with creative technology more accessible, ensuring that it is a positive and empowering experience for participants. The paper outlines:

- A modular approach for making interactive e-textile art pieces with blind and VI people to allow for a more flexible construction that is inclusive and accessible;
- Guidance on structuring a creative workshop series which allows for openness and degrees of freedom whilst providing a scaffold to assist with the technical learning experience;

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- Insights into crafting with e-textiles using methods which do not rely on sight but are more tangible and which allows for autonomy and ownership.

This work on the exploration of tactile and personal stories, may also be relevant to working with participants with different profiles and in different settings and contributes to the field of HCI, but also community arts and smart textiles.

BACKGROUND

Making for all

Maker culture is everywhere – in local hackspaces, makerspaces, libraries, museums and galleries. Increasingly, members of the public are embracing this culture and using tools such as 3D printers or digital embroidery machines to create their own work and learn new skills, in environments where they can meet like-minded people and share their work. However, participation in these activities is often dominated by privileged demographics [23], and public activities tend to focus more on children [10].

As maker culture has the potential to empower those who are differently-abled, Meissner et al. argue that it is important to consider how to design methods that facilitate participation in maker culture for individuals with disabilities [17], particularly since this offers an opportunity for empowering such users. The authors worked with a variety of participants with disabilities to create their own objects in a makerspace environment. Participants were introduced to 3D printers, laser cutters and other tools and worked on a range of DIY-AT (Do It Yourself Assistive Technology) projects. The participants not only took on the identity of ‘makers’ but also shaped a form of empowerment personal to them through their projects. Similarly, Hurst and Tobias [14] discuss the strengths of custom built and DIY-AT in how it can empower users. By having control over the design elements of the technology, users are able to control the aesthetics of it, can fix it themselves and also own something which is less costly. The ability to be able to custom build something for oneself is not only satisfying from a sense of creativity but it is also enables independence. In the research project *An Internet of Soft Things*, Briggs-Goode et al. worked with mental health service users, combining participatory design and e-textiles with a person-centred approach to psychotherapy [6]. Participants created small e-textile objects, reflecting both on the making process and how they felt emotionally.

Making is thus beginning to give people with a range of impairments control over their lives, whether through physically functioning products that they made, or through providing emotional support. In our research we seek to widen this physical making to include people with visual impairments, and thus contribute to insights about the democratisation of maker culture.

Collaborative making

Close collaborations between researchers and participants with differing abilities bring a range of benefits. Treadaway

and Kenning [27], while working with participants with dementia, explain that designers do not always fully understand the condition of the participant they might be working with and that through working in a group, which offer different levels of expertise, the needs of the end user are better met. This not only benefits the final designs, but also gives participants a sense of enjoyment of working in a group. Toombs et al. [28] also touch on the sense of enjoyment and importance of collaboration and cooperation, while exploring values of care in a hackerspace. They argue that ideas around inclusivity and accessibility go beyond just what is needed physically, but also what is required in terms of the social and community setting of these collaborative making activities. Buehler [7], when working with people with intellectual disabilities (ID), towards increasing their technical 3D printing skills, closely collaborated with someone with ID in order to better understand their learning process. This close collaboration led to the creation of personalised learning materials which were used in follow-on collaborative making sessions with a wider group. Being an active partner in the production of these learning materials gave a strong sense of empowerment and ownership to the person involved.

Our focus is on making with participants who are blind or visually impaired. Whilst technologies that address pragmatic concerns have been explored for a while, there is now also a growing move towards more creative uses of technologies for this user group. For example, haptic devices to guide VI audience members through immersive theatre experiences [29, 30] or a haptic device aimed at VI audio and music producers [18, 26] were developed in multidisciplinary teams. In each case, the blind and VI users were actively involved in the haptic designs for these creative uses, as experts on the experience for VI users and as co-designers during the process. What about examples of VI users as makers, creating their own technologies through hands-on making with digital technologies?

E-textiles as tactile objects

As e-textile technology is increasingly used for touch-based interaction, the tactile qualities of the materials in which interaction is embedded becomes increasingly important for the quality of the tactile interaction. Philippe et al. describe this as “the hand”, that is: “the reaction of the sense of touch, when fabrics are held in the hand” [21]. Tactile qualities are equally important for a user’s personal engagement with the object and what associations they then make with it. Davis investigated people’s preferences and emotional associations for fabrics which were both still and dynamic, based on sight and touch [9]. These textiles were mounted on the wall and resembled animal skin, fur or feathers. Davis found that touch can override visual feedback, and that a moving texture, whether seen or touched, was preferred to a still one. Vaucelle et al. produced wearables for therapy, aimed at people with mental health issues who might be at risk of self-harm [31]. The actuation of all these were touch-based: haptic, heat and

inflatables. Using objects in therapy or for communication with individuals that might find verbal reasoning or expression challenging is being increasingly explored [24].

The sensory side of e-textiles, including personal association and touch, is becoming increasingly explored, particularly within wellbeing scenarios. Alongside this, maker culture linked to empowerment and accessibility is also a growing area of interest, not just regarding the running of hands-on workshops with participants who are often excluded from mainstream activities but also through dialogues of what makes an environment inclusive and accessible. Our research brings together these areas: e-textiles, touch and personal association with methods of tactile making in an environment in which participants can feel ownership over their work. In particular, our research builds on our previous studies [13], through which we designed a series of one-off e-textile weaving workshops, which embraced an open toolkit approach for participants to make their own tactile woven interfaces. This research highlighted the feasibility of working with e-textiles with this user group and identified a range of creative choices made by participants. This paper takes this work further both in terms of technology, but also through building a collaborative peer support setting, and a focus on ownership of work that is personal to them.

AIMS

Our goal was to explore both pragmatics and self-expression: (i) identifying crafting and circuit making techniques using materials that are accessible and creatively engaging for blind or VI people; (ii) how they can use touch, sound, and association to express themselves by creating evocative interactive art objects; (iii) run a series of hands-on making workshops, in a group environment in which the participants can explore creativity on their own terms.

METHODOLOGY

We take influence from Lee's concept of 'Method Stories', with designers "presenting the story as it is – how it actually gets done by designers...within particular circumstances" [15]. The rationale behind this is that designers and researchers will think more reflectively about methods they use, and discuss what they have learned from the process, not just the outcome. This should help other designers to build on the work. In the spirit of this approach, we discuss our process in planning and prototyping for the participant workshops, as well as our approach and design decisions in running them. The research took a longitudinal approach with the following four main phases:

1. Exploring the design space, visiting groups and prototyping;
2. Consulting and evaluating with VI people;
3. Running hands-on e-textiles making workshops using a participatory making approach;
4. Reflection and follow-up interviews.

Phase 1: Prototyping the process

The research team has a background in running hands-on e-textile making and physical computing workshops often with participants new to working with these materials, including blind and VI people [13]. For this project we visited a number of VI groups in our local area who meet regularly to do things together. These visits, in which we also demonstrated some e-textile projects, helped us familiarise ourselves with potential participants for future workshops, understanding their interests, their general 'making' skill levels and their differing levels of sight. From this we identified some project requirements for the workshops:

- We could not rely on the participants' sight as each had a different level of vision. To be inclusive, the making process had to be as touch-based as possible;
- To focus on the circuit building and creative making of the object – as opposed to for example programming the board's functionality – in order to keep the focus on the touch-based interactions-
- We wanted participants to feel they had *ownership* of the making process and to physically build their project themselves. It was also important for the participants to be able to take the object home afterward. This meant that the object had to be usable without the researchers present and relatively low-cost to fit within budget;
- We could not assume any knowledge of computing or electronics. Therefore, the technology should not be complicated and should be suitable for beginners;
- Many VI people struggle with fine stitching. Therefore, construction should limit the need for stitching and use other fabric construction techniques such as gluing, felting and weaving;
- Many e-textiles projects do not work because the conductive threads short circuit. Therefore, we required constructing methods that would prevent short circuits.

We spent time working with different making techniques with various materials and electronics to establish what would be suitable to use in the workshops. Design decisions had to be made on both the materials and the making techniques we could support. The goal of the workshops was for the VI participants to create their own interactive e-textile art piece that was personally meaningful to them.

Circuit Boards: E-textile circuits often have light, using LEDs (light-emitting diodes) as an output, which we thought might not be appropriate for our VI participants. We quickly settled on using sound as the output modality; easily integrated into a circuit (unlike, say, smell) and customisable to the art piece.

We wanted to find a circuit board which could easily accept sound files recorded or chosen by the participants, and that would accept multiple buttons or sensors to trigger the sound files. We tested a variety of different microcontrollers

and sound boards and made several prototypes with products designed for work with e-textiles, including those by Adafruit, the LilyPad Arduino, and other small re-recordable sound devices. One aspect we explored was the logistics of uploading sound files in the busy setting of a workshop to minimise the number of steps necessary in uploading a sound. For the Adafruit products, a computer was needed for the transfer of MP3 files, whereas the re-recordable devices could simply capture sounds from a microphone independently of a laptop.

Another consideration was how the sound device could be activated. In previous research we had used a capacitive sensing board, attached to a laptop, allowing different outputs to be activated based on different gestural inputs. But this technology would be too expensive for each participant to take home so we selected a board which simply worked with an on/off trigger.

The board we chose was a simple re-recordable device that could be ‘hacked’ so as to integrate a soft circuit with a personalised e-textile button. It was much lower in price than using the Adafruit projects, costing approximately \$10, meaning participants could keep their creations. The recordable device consisted of a PCB, a microphone, a speaker, a record button and a playback button. We planned for the playback button to be disconnected and to be replaced by an e-textile button (see figure 1).

Soft circuits: Soft circuits are electrical circuits constructed out of e-textile materials. Most commonly stitched, we needed to find an alternative method of construction for our VI participants. We experimented with a variety of stitching, wiring, and gluing techniques, and considered different materials, including conductive materials, insulators, and input/output devices. One emergent need was flexibility: we wanted participants to be able to dismantle and re-arrange circuits. Another need was robustness: circuits would need to be handled and folded. We considered different ways of making connections, including press-studs.

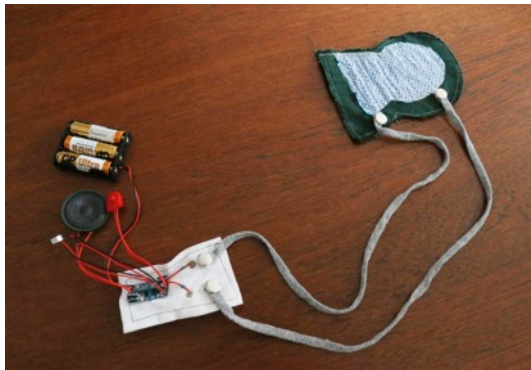


Figure 1. ‘Hacked’ re-recordable device with e-textile button and soft wires.

This set of needs led to our idea of a ‘modular’ approach, which we defined as a combination of both technical components and an approach to making so that it is divided

into distinct steps. On the components side we identified that e-textile soft buttons should be created separately from the wires/threads that link them to the wider circuit and:

- Use press-studs as robust but detachable connectors between buttons and wires;
- Create ‘soft wires’ using conductive thread inside long fabric tube yarn. The tube yarn provided insulation, so that if the soft wires overlapped they would not short circuit. The soft wires terminated in press-studs;
- Use a system of pockets to hold the electronics such as the board and battery, so that they were held somewhere securely and be out of the way from the main design.

(Note that the use of press-studs or insulated wires is not in itself novel, as this and other approaches have been explored by e-textile practitioners [11]. Our contribution is to use it to support the work with this specific set of participants.)

Through this system of soft wires and pockets we aimed for a making process where participants could do the maker activities (building soft buttons, recording sounds, making soft wires) one step at a time, and use these components to lay them out in a ‘plug and play’ fashion. They would be able to change the design until they’d found a lay-out that pleased them and had the best fit with their story.

The button was built from several material layers and we prototyped a special feature through the use of a very thin layer of foam with small holes. This layer would sit between the conductive layers allowing them to meet when the button was touched: either by gently stroking or pressing down. Buttons could be constructed in different shapes and sizes, and could use any available material as the surface layer (e.g. felt, corduroy, foam, fleece, sequined fabric etc.), as desired by the participant.

Construction/crafting methods: To avoid fine needlework we considered a range of other application/fastening methods, from heat-activated bonding tape (often used for hems) to textile glue. We decided to use double-sided fabric tape and glue to attach the e-textile buttons and any decorative parts of the work, to avoid participants having to sew.

In general, we decided to be careful about how to offer the participants help on their projects; they would be encouraged to do as much as they could without assistance, but help would be offered under their direction for tasks they found problematic. For example, if fine stitches were required to make the connections work, or pieces cut with scissors, we could execute such tasks.

We considered a range of other textile crafting approaches that participants might like to use. Simple weaving on small looms can be effective [13], as VI participants can ‘feel’ the threading (warp) through which they are working (weft). There is also evidence that finger knitting is popular with VI people, as all the ‘work is on the hand’ [25]. Felting was also considered as an option because it is both hands-on and tactile. These various approaches were offered in the

workshops to allow people to experience different methods, and use them in their creative process.

Structuring the project: The structure of the project was constrained by time and budget, but also because we did not want to overwhelm the participants during their first introduction to making with creative technology and e-textiles. As each of the two sets of workshops was planned as a series of five or six sessions, we were concerned that it should be feasible for all participants to complete their pieces in the given time – including having circuits that worked *and* have an art object which they were happy with. We therefore took a scaffold approach [33] – a common approach to learning – setting some pre-defined techniques for circuit making and giving the participants a brief of making an ‘interactive wall hanging’, incorporating e-textile buttons. We encouraged participants to focus on the feel of the work and the shape and sounds of their interactive elements. The re-recordable devices and battery packs would be placed in open pockets, allowing access without attracting undue attention. The scaffolding was particularly important, as none of our participants had worked with e-textiles before. As discussed by Wood et al. this approach enables a participant to carry out a task which otherwise they might not be able to do. To balance this, and to encourage ownership and creativity, the participants led on other parts of the process, choosing the fabrics to use for their work as well as any crafting techniques used to make elements of the piece. They also chose their own sounds, using pre-recorded ones or creating their own.

We offered to hem the backgrounds to the wall hangings so that the participants did not have to sew – comparable to providing a frame for a painting. The intention was to maintain a focus on story-telling and making, with e-textile construction presented as a means, rather than an end in of itself. Our own prototyping (see figure 2) suggested that three buttons offered artistic flexibility without making the project too complex. The project framing was meant to be facilitative and so was not to be interpreted strictly if participants wanted to try something different. Participants would make all other design decisions.

Overall, this prototyping phase was about understanding which compromises had to be made. The main driver was accessibility and inclusivity: keeping the participants in control and facilitating them in completing something during the available time. In particular 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.

Phase 2: Evaluating the process with users

We piloted our selected materials and processes with two VI users: (i) a blind artist who makes sculptures designed to be touched and who had participated in previous workshops, (ii) a woman who is slowly losing her sight and is starting to

establish routines such as putting her phone or remote control in a basket so she can find it.

We wanted to see how they might interact with our prototype which was made using the modular approach. We also wanted them to make their own interactive e-textile piece, to evaluate the suitability of the making process. Finally, we wanted to test the concept of expressing a personal story with e-textiles. Hence, the pilot considered all three aspects of the proposed workshops: the materials, process, and product.

The pilot sessions provided some evidence that the users engaged with the prototype and responded to the associations. The blind artist engaged actively with the prototype, triggering and experimenting with the circuits: pressing the buttons in different combinations, triggering them on and off to try to get what he called an “orchestration” (see figure 2).



Figure 2. Artist who is blind interacting with our prototype.

The second VI participant created a very personal e-textile piece: a heart that triggers a recording of a Bob Dylan song, *Shelter From The Storm*. She made a heart-shaped button out of ladybird-print fur as she loves that pattern, and has an object on her fridge with those colours to touch when she wants reassurance. The song reminded her of an ex-partner from whom she had recently separated. It had just been Valentine’s Day, and she and her ex-partner were meeting at the *Fear and Love* exhibition at the Design Museum. She spoke about her fear of meeting him, but also her fear of taking part in the making, due to her worsening vision. She felt she has overcome this fear by creating her piece.

The pilot sessions provided feedback about the materials and approach. They demonstrated that our design decisions and approaches could work. Importantly it showed that the VI user was able to make an interactive piece which was personal to her and that seemed to empower her – making her feel ready to face a difficult situation. Besides these observations we also noted a number of practicalities that we realised would be important to make things work, such as ensuring that materials and tools are within easy reach, perhaps in a basket; to use contrasting colours so that objects and tools stand out, which is helpful for people with residual sight; ensure that fabric pieces are big enough to

give the participant room to design with. We also learned to refine explanations and step-by-step instructions for the circuit building process.

Phase 3: E-textile making workshops

The workshops took place over six weekly sessions of four hours. The intention of the workshops was that participants would acquire skills and techniques, and gradually develop their ideas and confidence, to create their own interactive e-textile art pieces. These would be exhibited in a public showcase for friends and family after completion. Both the learning of technical circuit making skills and the learning of crafting techniques contributed to what the participants chose to do in the construction of their final work. In the first workshop we demonstrated our example wall hanging (see figure 2) to explain the possibilities for what could be made within the workshop series time. As discussed we framed the project as an ‘interactive wall hanging’ which would incorporate up to three e-textile button, and represent a personal memory or association for the maker. We explained how the work would be designed to be touched and so the feel of the fabrics and materials chosen for the art piece should reflect what they wanted to convey in the work. Similarly the sound they would select for recording onto their recordable device was meant to be related to the e-textile button. However, rather than just focusing on building the final piece in one burst, the workshops were structured with the following elements:

Different crafting techniques: Each week participants were given the opportunity to try out a range of techniques that they may not have used before, including finger knitting, weaving, felting, appliqué and collage

Exploring associations with materials: In order to give participants a palette of tactile materials from which to draw for their own projects, they were engaged in explorations and discussions about the tactile qualities of fabrics and about the ideas, thoughts, and associations they can evoke.

Introduction to e-textiles/ soft circuits: Examples and step-by-step hands-on activities to introduce the properties of conductive fabrics and thread, the electronics components, and the basics of soft circuits – both how they work, and how to construct them. Each week, we explored technical aspects of building a circuit with e-textiles in a tactile focused way: creating soft wires using tubular yarn, press-studs and conductive thread; making soft circuit buttons using layers of conductive fabric, a textured fabric of the participant’s choosing and press-studs for connecting; lastly, working with re-recordable devices to record sounds and also connecting it all together to complete the circuit.

Project planning and execution: Participants were prompted to think about their own projects, including what story they wanted to tell, how to express it, choosing materials (including sounds), constructing the elements (including soft wires and buttons), and designing the composition overall. Participants worked independently or with individual

support to execute their pieces. Helpers were careful to maintain the principle of providing assistance only when requested by the participants.

Sharing ideas: Participants were regularly invited to share their ideas and work with one another. They were also encouraged to bring things from home to share, particularly objects that were meaningful to them.

Each week included a mix of the above elements, including hands-on making and discussion, with individual projects taking increasing prominence as the series progressed. The workshops were also designed to be a safe space for enjoyment and fun. People with impairments or disabilities can often feel isolated, especially when elderly, and so the social dimension of the sessions was important [32]. Each week we had lunch together, to catch up on news, and plenty of tea breaks to keep the atmosphere relaxed and friendly.

The workshops were followed by a public showcase event, where the participants were invited to introduce their own work and discuss it with an audience.

Phase 4: Reflection

During the workshop period we encouraged participants to share their thoughts and reflections on the making process, either by email or by phone. After the workshops we visited the participants at home, to understand how they looked back on the workshops, where they had placed their e-textile creation and whether they were still interacting with it. The visit was thus an opportunity for reflection and discussion.

Participants

The participants were recruited through a local charity for blind and VI people that offers social activities and guidance with everyday needs such as support at home or information on equipment. The participants varied in age and ability, having different levels of sight and experience with hands-on making. We had a total of 13 people participate, aged between 30 and 85, with 10 women and three men in the workshops. Two of the participants had no vision whilst the rest had different levels of sight (see table 1).

Participant	Approx. age & gender	Level of sight and experience of crafting
Hailey	50 - 55 F	Partially sighted - does some crafting at home.
Karen	31 F	Registered blind - attends art and craft sessions.
Louise	50 - 55 F	Partially sighted - experienced in knitting.
Ewan	30 - 35 M	Registered blind - No crafting experience.
Jim	50 - 60 M	Partially sighted - used to do crafting with grandma.

Uma	70 - 80 F	Partially sighted - used to work in textiles.
Sonja	80 - 85 F	Partially sighted - Has a passion for arts/crafts.
Jane	55 - 65 F	Partially sighted - Part of art and craft group.
Kelly	55 - 65 F	Partially sighted - Part of art and craft group.
Pam	55 - 65 F	Partially sighted - Co-leads art and craft group.
Jacob	45 - 55 M	Partially sighted - No crafting experience but is a talented poet.
Verity	55 - 65 F	Partially sighted - Co-leads art and craft group.
Patricia	75 - 85 F	Partially sighted - Part of art and craft group.

Table 1. Participants listed with their pseudonyms.

DATA COLLECTION AND ANALYSIS

Data was collected during the workshop series through field notes, photographs, videos, audio recordings, emails and phone calls. The authors each spent time after the workshops to reflect on what they had observed or discussed with participants, highlighting aspects that were deemed important. This ranged from how participants used their hands, to stories that were re-told. We shared these thoughts with one another, discussing points of interest, in order to identify themes within the data [5]. We also transcribed sections of videos. Our process was iterative; from field notes and observations, to looking back through media, and adapting themes through continued discussions.

The creative art pieces functioned as artefacts in this analysis process, as they were an embodiment of each participant's journey through the weeks, their struggles with textile techniques, their way of overcoming technical issues, their creative choices, and how they had held other participants in conversation around their piece. The art pieces thus helped us bring into focus each individual's making process and helped us identify common themes.

FINDINGS

Overall, the workshops were a success and the participants found them to be pleasurable. All participants created a project, to their own design, and engaged in the textile crafting, the technology and the telling of a story. Through our analysis we identified the following themes:

- (i) The evolving participatory making environment;
- (ii) Accessible making with e-textiles;
- (iii) Creativity and learning;

(iv) Glitches and tolerance of error.

(i) The evolving participatory environment

We observed different aspects of participation during the workshops, in terms of how participants took control of their own making experience and how they worked with each other and the research team.

Taking control of design and making: We observed numerous examples of participants taking control of their own making, taking ownership over fabric choices and how to integrate the technology into their design. Exactly where to put the circuit board and batteries was an issue. For the wall hangings we had initially thought that participants would put the pockets at the base of the front of the object, and that they would be made from materials that would not stand out from the background, but rather blend in. However, some participants insisted instead on making them into decorative highlights. 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 towards the interactive parts (the buttons) 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.*”

Patricia didn't want to make a wall hanging and instead wanted a more functional item: a bag. She wanted to hide the pocket for her device and batteries, fitting them inside her bag. Other participants requested help in refining their design and asked for paper cut-outs to be made so that they could feel the shapes they needed. For example, Pam wanted to make weather themed buttons but 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.

Participants also took ownership of the sound recordings, with the researchers sourcing and suggesting sounds based on the participants' themes, but the participant being the curator. Ewan wanted rainforest sounds, his work reflecting a trip to a forest in Australia. 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 accurate decision about what sound would play well.

Working independently: As the workshops progressed, some participants wanted to take their project home to continue to work on it. Contrary to our expectations, multiple participants chose to do their own hemming by themselves at home. Others would re-record their sounds between

sessions, at home or in their garden. Participants also brought additions for their work, decorative but also personally meaningful to them. Louise adorned her work, a representation of her beloved cockatiel, with a craft flower, asking us to pin it on carefully. Sonja added one last touch to her piece, an interactive seascape, by proudly attaching a German flag onto a fabric trawler she had cut out of corduroy fabric. Participants were clearly thinking about their pieces in between sessions, making it their own and feeling responsible for the design and the finishing touches.

Persistence in the face of challenges: Participants faced multiple challenges during the making process, both technical issues but also creative decisions. Sonja was initially 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. Afterwards 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 coping strategies for things 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 was challenged by using the fabric tape, 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.

Sharing experiences: Participants frequently worked with each other and the volunteers, providing creative and helpful suggestions and offering support. We found that ‘mutual learning’ [1, 3, 4, 12, 19, 34] and ‘mutual respect’ [4] occurred, where the participants learned from us but we also from them – sharing knowledge across skillsets and disciplines. For example, we demonstrated and taught the participants how to make e-textile buttons, but we also learnt crafting methods from them – in particular, Sonja and Verity used interesting weaving methods which we were not familiar with such as 3D weaving or twisting the yarn to create ‘waves’. Jane showed us how yarns can be combined to create complex textures, something she had not tried in her making before. Not only did this contribute to her own learning experience [34] but it also added to ours.

Participants also collected samples from home that could be useful for another person’s project, as well as adding to our material collection. And ideas were shared too: Jane was struggling on how to incorporate a skipping rope into her work, linked to a story that had impacted on her life. Jacob suggested she use a piece of yarn to represent the rope, making it into *“the narrative strand”* of her work to bring symbolic objects together. Jane was pleased by his suggestion, making it central to her design. Participants also shared components when they had made too many, and helped each other with hand tools. Participants who

struggled with using scissors ended up working in pairs with a sighted assistant – some developing specific methods of folding fabrics prior to cutting, so that the VI person could follow the ‘feel of the fold’ whilst cutting. There were thus a range of examples of people retaining their independence, taking control of their designs and the process of making, and supporting each other.

(ii) Accessible making with e-textiles:

The technical crafting aspects of the circuit making – building e-textile buttons and creating soft wires using the conductive thread and tube yarn – were successful, with each participant making and incorporating them into their interactive e-textile project (see figure 3).



Figure 3. Participant testing their e-textile button.

The modular approach worked well in different ways:

- It allowed for the composition of the pieces to be played around with, participants moving their electronics around on their background before choosing a final place to attach them, adding their pockets and decorations;
- It allowed participants to approach every stage separately, with step-by-step learning as opposed to being shown everything at once, and then asked to create their project;
- Several participants were able to make late changes to their work, adding buttons and re-recordable devices, well into the process of constructing their piece. This flexibility is not usually possible in e-textile pieces which often require careful planning up-front to ensure threads don’t cross each other resulting in shorting.

Jane spent time considering where her pocket with electronics should be in relation to the rest of her work. She went between making her pocket part of the ‘tree’ in her work, or the grassy background. Due to the modular approach, she was able to move the electronics around her piece, eventually settled on it blending into the grass.

As participants gained experience in building their soft circuits, they began to anticipate the next stages in building the technology. Pam became very confident, instructing the researcher working with her what she needed next after each button layer was made. The flexibility of this approach allowed for openness with making, changes being able to occur during the process, whether technical or creative. This gave participants more control over their work.



Figure 4. Work by (a) Sonja: about her family history (b) Pam: about a trip to a concert and (c) Patricia: her shopping bag.

(iii) Creativity and learning

Each participant's work was unique, with specific design elements being used to tell their story, from what sounds to record to what textured materials to use. Every piece created was personal to its creator, being either about a (i) loved one, such as a long lost friend, teenage children, or a distant family history; (ii) a memorable event, from seeing a favourite musical band perform, a favourite pastime, sounds of wildlife in the garden; or (iii) were associated with something the person longed for, such as a huggable cushion or a talking shopping bag. Figure 4 depicts examples of these, with (a) Sonja's work depicted a seascape, with a fishing trawler, waves and a woven lighthouse, with seagulls circling. This piece was inspired by her great-grandfather who was the captain of a fishing trawler and lived in Düsseldorf; (b) Pam had recently attended a concert of her favourite band, and selected songs about the weather to go with various weather buttons; (c) Patricia made a bag which would demand help when carrying a heavy shopping load.

Everyone showed a sense of creativity whilst also embracing the opportunity to learn. One participant said when presenting her work: *"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 plasticity for the lightning and this furry cloud"*.

Hailey's wall hanging represents her three children, with audio recordings of them saying things typical to them, using fabric that matched with their personalities. Upon visiting her afterwards we noticed the work displayed in the hallway of her family home. It is used daily to call everyone for dinner. The children regularly press it when walking into the living room or demonstrate it when their friends visit. Hailey felt smug that none of the young people had heard of e-textiles, feeling that she could teach them something.

The participants enjoyed sharing their work with friends and family, not only demonstrating their creativity but also the knowledge learned in the process. Louise explained that the learning element of the workshops was very important to her *"For me, it's been able to learn how to do something, be with other people and not being stuck on your own..."*

New applications to old techniques: Having mastered hands-on crafting techniques, some participants were seen to experiment and utilise them for their own purposes. Ewan connected all the circuitry together and twisted his soft wires to create a stem for his leaf button. Sonja twisted her yarn in the weaving loom to make waves in her fabric. Verity made knots and gaps in her weaving to accentuate texture. She also experimented with 3D weaving to create a small bird's nest, which when pressed, triggered a bird tweeting.

Problem Solving: Using the re-recordable devices could be a challenge. Verity was determined to record wildlife sounds in her garden and so had to know how to use the devices herself. She used creative problem solving, attaching masking tape to buttons on her devices so that she could easily distinguish between them and not muddle them up.

(iv) Glitches and tolerance of error

The participants showed patience when things went amiss. This was mostly regarding the circuits, either with e-textile buttons or the soft wires. In several cases the two parts of conductive fabric within the buttons had either been sewed 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 button self-triggering. Sometimes buttons were too big and had to be cut down to fit under the fabric covering.

There were misunderstandings about how to interact with the buttons. Some participants tried to activate these with multiple taps, resulting in them being turned on and off as just one tap was actually required. Some of the re-recordable devices were wiped off their sound files when the recording button was accidentally pressed or pushed.

As the weeks progressed we observed how 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 button in different places to trigger it. She had established that touching it gently and slowly, trying different points was the way to approach it.

DISCUSSION AND GUIDANCE

Through careful planning and execution, we delivered a series of workshops where every participant learned how to work with e-textiles and create an interactive art object. Our methods were robust enough to deal with failure; the participants solved problems when making their work, and surprised us by offering innovative uses for techniques when creating objects for use in their final piece. They embraced the participatory making environment, created an e-textile object, personal to them, and showed a sense of pride – not only when demonstrating it in the showcase events, but also afterwards, sharing it with friends and family.

Our work presents an approach to scaffolding and initial engagement with e-textiles that empowers blind and VI participants: both providing a sound understanding of e-circuits but also giving them the space and confidence for creativity and self-expression. The approach includes:

- A modular approach to e-textiles based on creating discrete components that can be connected and disconnected, and developed in a step-by-step process;
- Selection of accessible and affordable tools and materials (such as soft wires and press studs);
- A design brief that provides a focus without constraining creativity;
- Choices about the workshop focus (i.e. focusing on electronics rather than programming);
- Attention to agency of and ownership by the participants (e.g. providing assistance only when requested and needed; ensuring individual gains in each workshop, such as tangible outputs and new craft skills; ensuring that participants could take their art pieces away at the end and thus ‘owning’ their art piece);
- Attention to the social context of making (e.g. developing a tolerance of error).

Our research focused on working with blind and VI people, but we believe that our process can be applied to other participant groups as well. Toomb’s et al [28] focus on the social side of making environments, opening the dialogue on how to help more people feel that they can take up making: the community can help people feel welcome in a space and can offer forms of care such as lending each other tools. Our approach combined attention to the social side of making in a group environment, with practical scaffolding, exploring creative hands-on making and open project making using accessible and affordable tools and materials.

Dealing with assumptions

One major insight we gained from the workshops was avoiding inappropriate assumptions about what the participants could or could not do – and as a result surprising both participants and researchers about what they could achieve. Prior to running the workshops we were advised that our participants have difficulty with scissors and fine needlework. Whilst this was indeed a hurdle for a number of the participants, it was one they could overcome with encouragement and limited assistance, so that several

participants who balked at first ended up using these tools and doing tasks themselves. Some even requested that we bring along sewing machines, something we had not anticipated. We also encountered participants who were interested in the precise colours they were using, and took pleasure in getting the right ones, although they could not see them. We possibly had a simplistic notion of what it means to be visually impaired, despite all our preparations.

Our response to requests of materials or tools we had not considered, was “*Yes, we can provide that!*”. Our ability to improvise with what we saw as more technical assistance or provide tools when asked was important to both the participants’ feeling of control and their creativity.

The importance of participation and dialogue

Our research builds on existing literature on maker culture which explores accessibility and inclusivity in a wider sense. Prior work [7, 32] notes the benefits that participants gain from being in the group environment; we also found this to be the case. Frauenberger et al. [12] discuss how researchers and participants become closer over time, understanding each other’s perspective more. This certainly happened in our workshops, communication and the building of trust being key to this. As discussed by Bratteteig [4], sharing knowledge between researcher and participant also helps to shape similar future design and making experiences for participants. What we learned from our participants in the first series of workshops helped us prepare for the second series; we could smooth out anything that did not work well, but also try methods that we found successful. We would encourage all researchers conducting similar research in a hands-on making environment to take a conversational approach, not just between themselves and the participants but encourage this among participants as well.

Conclusion

Our process has involved careful design decisions and planning, considering what is accessible, affordable and modular – to allow for ownership and creativity. We delivered a series of workshops where every participant embraced participatory making. All participants completed highly personal e-textile art pieces that expressed stories of their own choosing using texture, shape, and sound. The rich qualitative data collected throughout the workshops provides evidence of learning (each participant was able to create and test soft circuits), of creativity and self-expression (the art pieces are highly individual, and some of the participants altered or expanded the design brief), that participants exceeded their own expectations (e.g. using tools or techniques they initially said they could not handle), and that they took pride in their art pieces – not only when demonstrating them in the showcase events, but also when sharing them with friends and family in their homes.

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