Textile Game Controllers: Exploring Affordances of E-Textile Techniques as Applied to Alternative Game Controllers

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ABSTRACT

Invested in increasing access to computational literacy, this paper explores the development of a series of free public workshops in partnership with an equity-seeking group. These workshops cover e-textile techniques that lend themselves to making alternative game controllers leading up to a concept-led game jam. We use research creation approaches to prioritize creative exploration within a community group for marginalized makers. The goal of the research is to explore and elucidate the overlap between e-textiles and experimental game making. We discuss our playful use of workshops as research method to iterate on the embodied experience of making on behalf of our participants. Our contribution maps the connections between workshop design and development, learning materials generated, through to application within an online game jam setting.

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[A] Game controllers constructed with capacitive sensors made with conductive thread and fibre.

Author Keywords

DIY games, alternative game controllers, e-textiles, wearables, cross-sector partnerships.

CSS Concepts

- Human-centered computing ~Interaction design~Interaction design process and methods~Interface design prototyping

INTRODUCTION

Do-it-yourself (DIY) game making is an area of growing significance in the push towards a more diverse and equitable technology sector [6, 31]. Groups such as Dames Making Games (DMG) provide community hubs that offer "production space, education, advocacy, archiving, resource sharing and more collaborative practices" for queer and gender-marginalized people interested in games [37]. This research explores the intersection of two making practices: alternative game controllers and electronic textile (e-textile) sensors. Just as alternative game controllers focus on the creation of DIY and bespoke game controllers, e-textile sensors take an analogous approach to sensor-making, resulting in interfaces that are pliable, flexible and customizable. We bring together academic researchers, community organizers, and attendees in a workshop format to learn from each other on site. Project partners have complementary areas of expertise and a shared interest in DIY, game, and art-making practices, and bringing these groups together to explore, experiment with, and elucidate methods, approaches, and themes is a core research goal. We adopt a research creation approach [3] to these workshops to target this emerging hybrid area to explore physical affordances, identify (through making) current challenges, survey community interest, and develop materials and resource kits for a culminatory game jam.

RELATED WORK

Alternative Game Controllers

For digital games, controllers have evolved significantly since the early days of buttons and joysticks [4]. Microsoft's Kinect and Nintendo's WiiMote are just two commercial examples of the capacity for novel controllers to encourage new kinds of embodied interaction [8]. Specific to the DIY, art and maker communities discussed here, there is ongoing interest in building alternative game controllers. This is evidenced by the ongoing success of the alt.ctrl.GDC showcase [35] at the Game Developers Conference. According to Granzotto Llagostera "(a)lternative controllers provide opportunities to explore interactions which move away from prescribed and hegemonic design values or expectations. " [9] Community groups have been at the forefront of offering game jams to explore the development of unconventional input devices [37]. Early response to our proposed workshops from the community members suggested significant interest in the possibilities (noted by Foottit et al [7]) for alternative game controllers to enhance tactility, person-to-person interaction and physical engagement with the game environment.

Maker Movement and E-Textiles

The maker movement has been instrumental in the rise of DIY hardware and software practices since the 1990s [5] and offers an important source of democratized social and technological innovation via a focus on making as opposed to consuming [15, 16, 29]. While not immune to accusations of a lack of diversity, discussions around digital craft practices in maker groups have enabled a feminist corrective to critical design work [27]. This is particularly evident with e-textile and wearable technology [2, 23].

Intersections

Academic work to date has explored the potential of e-textile and wearable game controllers from the perspectives of HCI [14, 30] and education [13, 16] often in a workshop or informal learning environment. This has proven to be generative as a space to enhance both embodied interface design practices and to informal learning contexts. However e-textile techniques have yet to be popularized in creation of alternative game controllers. It is this intersection at which the contributions of this research sit.

METHODOLOGY

Our Textile Game Controller (TGC) workshops focus on skill building, ideation and, iteratively, the design of future workshops. This provides a forum for exploration and experimentation of the affordances of e-textiles for textile game controllers, including their embodied, social, and political aspects. Subsequent to the workshops, a game jam focuses on the creation of more developed concept sketches [32]. The focus of this paper is the design, delivery, and development of the research workshops as well as the culminatory game jam. We take a 'sketching in hardware' approach [21] where hands-on 'critical making' results from combining critical thinking with making [12, 25], with an emphasis on expression and experimentation, rather than technical sophistication. Workshops and game jams offer generative sites for research praxis [17, 26, 28, 33] and have been staged here as distinct phases of research, with the workshops enabling the authors to refine and develop learning materials and communication strategies.

The research objectives of the workshops were multiple: to identify affordances that an e-textile (including wearable electronics) approach can bring to making alternative game controllers; to develop materials and resource kits for knowledge mobilisation to be used in a follow up game jam, and to provide domain expertise to a wide range of participants within an equity-seeking community. Specific to the use of workshops as research sites, Ørngreen and Levinson's literature review indicates perspectives of "...workshops as a means, workshops as practice, and workshops as a research methodology" [34] in their discussion of the ways in which these settings can collaboratively enable the investigation of research design across time and place. As sites of research, workshops already have a rich collaborative dynamic; researchers act as facilitators who prioritize participant experience whilst participants and their practice are central to the research process [34]. The emphasis of the research is on embodied ways of knowing across a range of communities invested in equity work. Multiple partners imply the need to speak to multiple publics; from individual community members to arts organizations to the academy itself. Hjorth et al's set of heuristics for the intersections of ethnography and creative practice consist of "techniques, translation, and transmission" [20] and offer one approach to modelling these processes. In Hjorth et al's mapping, "techniques" refer to methods, "translation" to the shift of ideas across multiple forms and "transmission" to the act of communication itself. This offers a way to consider the sustainability of research outcomes, for example the slide decks produced for the workshops are widely shared. The multi-sector nature of the collaboration drove the adoption of mixed methods from a range of domains, from the commonplace (questionnaires and observation) to a more novel centring on 'play as a research method' to underpin workshop development and knowledge mobilization goals.

In Hjorth et al's approach, play is a mechanism for transmission that involves the public in social spaces as a way to extend the reach of research to a wider-than-typical audience. Our partnership and emphasis on playful presentation of material is similar in ambition. Material play is central to the physical experience of making, and haptic and multi-sensory feedback core to both learning and developing e-textile and wearable technology projects. Participants play with materials, technology and concepts to create their work. As a unifying metaphor, play holds the potential to disturb the inevitable power dynamics whilst inviting active engagement. As a mode of inquiry the research team were explicitly playful in the development of learning materials, setting of workshop space and in dialogue with the participants.

WORKSHOP OVERVIEW

A total of five workshops were offered, all focused on the creation of alternative game controllers using textile sensors and microcontrollers. Workshops were held on weekday evenings, typically 3 hours in length, attendance ranged from 6 to 21 participants at various levels of experience. Each workshop explored different topics, materials, methods, and game types. Workshops were designed and announced one-by-one rather than as a series. This was the product of funding but served as an opportunity for iterative development. Because of the short duration of the workshops, time was devoted to the teaching, designing, and crafting of a game controller rather than a game itself. While select participants designed small game sketches or interactions, more typically the controllers produced in the workshop were used to control existing games.

Workshop development tended to follow this process:

- Internal discussion and brainstorming on format, theme, technique, and approach between project partners (academic and community organizers), including outcomes of prior workshops
- Research into material availability and costs; techniques, including existing learning resources and learning curve; feasibility of overall approach; and safety aspects
- Development of functional game controller prototype(s) for demonstration purposes
- Development of custom learning resources and supporting materials including physical samples, circuit diagrams, example code, photographs, videos, and slides
- Preparation of physical materials for workshop participants
- Planning for workshop space setup including room layout and methods for material distribution

The approach to preparation of physical materials advanced with each workshop and came to include pre-cutting most materials, pre-programming microcontrollers and placing materials at participants' stations before they arrived. This was to reduce time from the start of the workshop to the moment when participants had their first experience of seeing something they had made work. Each workshop included a lecture that introduced concepts, tools, materials, and techniques followed by time for hands-on experimentation and prototyping. Efforts were made to improve quality and clarity of supporting materials so that more time could be devoted to hands-on work. In early workshops, structured time for 'show and tell' was included at the end, however it was found that participants enjoyed a more relaxed approach to sharing their work with each other.

In later workshops, 'play test' time was introduced so as to provide tactile engagement early on with physical work samples [11]. Supporting resources were shared via live slide deck so that materials could both be displayed via projector and participants could flip through slides at their leisure. Because slides were shared as a living document, facilitators were able to update them with answers to questions or clarifying details as they came up in the workshops. Four facilitators were present to provide one-on-one support, answer questions, and discuss ideas. Participants were encouraged to interact with and help each other and to document their creations through photographs or video clips either independently or with the help of a facilitator.

#	Workshop Name	Topic	Sensing Methods & Materials	Type of Game	Total # of Participants
1.	Intro to Textile Game Controllers	overview of textile sensing possibilities for game controllers	capacitive sensing with Makey Makey; digital fabric switches; analog fabric sensors	screen-based	21
2.	Body-Centric Game Controllers	sensors meant for larger body movements	analog sensors w/ velostat	screen-based	15
3.	Wearable Game Controllers	sensors designed to be used on or between bodies	digital switches with iron-on conductive fabric	screen-based	11
4.	Stitch and Stuff: Making Embroidered Games	self-contained hand-held game	capacitive sensing with embroidery	hardware-only	6
5.	Fun with Felting	hand-held game controller	capacitive sensing with felting	screen-based	20
Jam	Game Jam	Textile game controllers	All of the above	DIY game	24

Table 1: Workshop overview

Workshop 1: "Introduction to Textile Game Controllers

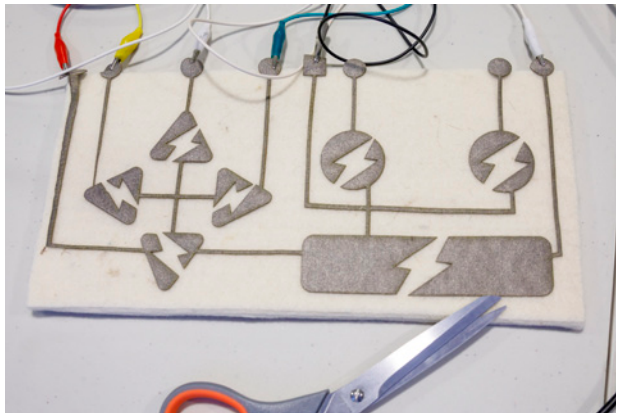
Workshop 1 introduced a curated selection of material and prototyping methods to gauge interest in topics for future workshops. Three sensing methods were introduced: capacitive sensing, digital switches, and analog sensors, all made with conductive textiles. The first method used e-textiles connected to the Makey Makey [1], a prototyping board often used to create DIY interfaces for games. This exercise proved to be clear and easily accomplished, both because of the simplicity of the sensor construction and the beginner-friendly design of the board.

The other methods were used with the Arduino Micro board [36] which was chosen because of its ability to behave as a keyboard. The digital switch activity mapped conductive fabric switches to key presses, thus enabling the textile switches to control browser-based games on a USB -connected laptop. The analog sensor example utilized serial communication between a customized Arduino sketch and customized game made in Processing [38]. This second approach proved to be far too complex for the time allotted.

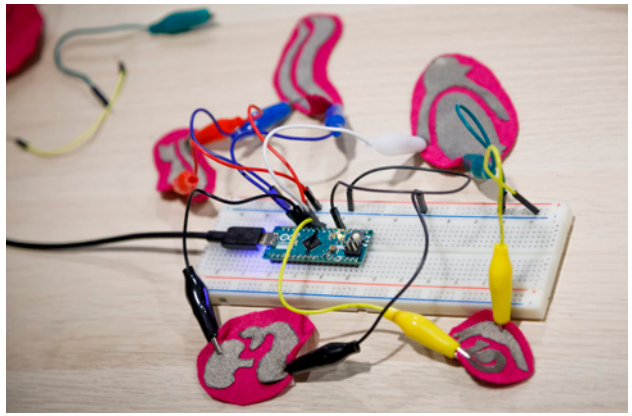
[B] E-textile techniques were introduced in a lecture format and participants were encouraged to work together in smaller groups to follow along.

[C] Conductive fabric sensing pads were cut in creative shapes and attached to a felt subtrate with iron-on adhesive.

[D] These sensing pads were then connected to the Makey Makey boards to act as a touch interface. Participants were encouraged to demonstrate their work to others.



[E] Physical examples were provided for participants to test and examine construction techniques. This photo shows a more complex set of conductive fabric digital switches meant to be closed with an additional piece of conductive material.



[F] Digital switches were then connected to the breadboard using alligator clips and hookup wire.

Workshop 2: “Body-Centric Game Controllers”

In Workshop 1, we learnt participants were interested in the analog sensor technique introduced towards the end, but few had time to use this technique in a controller. Adjusting our approach, Workshop 2 participants were offered a deep dive into creating game controllers using analog sensors. With this analog sensing approach, sensors are created with conductive fabric and resistive plastic sheeting - a method introduced and popularized by the collaborative team Kobakant (Hannah Perner-Wilson and Mika Satomi) [24]. This technique was introduced within the framing of “body-centric controllers”.

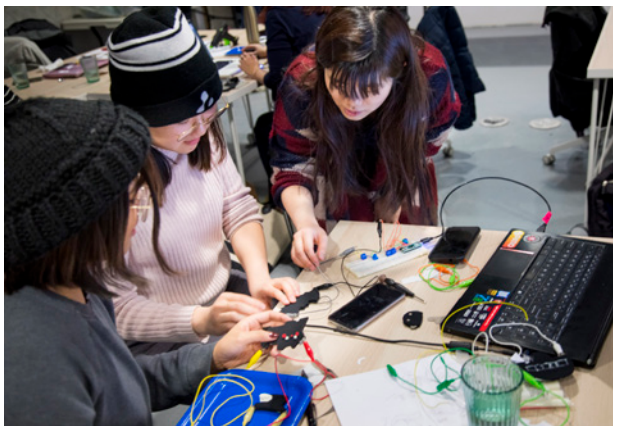
Participants were encouraged to create pressure-sensitive textile buttons designed for particular parts of the body. As a way to enable participants to quickly test their sensors as soon as constructed, a pre-wired and pre-programmed Arduino board with alligator clip connections was made available at the front of the room. It was connected to a game displayed on the projector so as to provide visual and auditory feedback to let the participants know their sensors were working. Once they had a working sensor they could then work to assemble their own circuit and craft additional sensors. While there was great success with participants making functional sensors, the intended body-centric aspects were less realized. Participants tended to focus more on the design of the sensor itself rather than its placement or intended use.

[G] Lecture demonstration of how to design and fabricate analog sensors.

[H] Analog sensor sample constructed with conductive fabric, Velostat, and industrial felt.

[I] Constructing the analog sensor

[J] Completed sensor



[K] Connecting the sensor to the breadboard

[L] Testing the sensor with a screen-based game.

Workshop 3: “Wearable Game Controllers”

Workshop 3 returned to the concept of digital switches but focused on a more complex implementation of them. Rather than a “bridge switch” technique (two pieces of conductive fabric on a flat surface being bridged by a third piece of material) [10], this workshop introduced the idea of “social switches” [10] - switches that were closed or completed by multiple bodies. With this approach a piece of conductive fabric on one person’s body part making contact with conductive fabric on another person’s body part will close the switch and make the electrical connection, thus “pressing the button” of the game controller to initiate an action within the game. Due to the workshop date being before Halloween, the team created playful costume-themed examples, using capes, hats, bunny ears, and wands as the base for wearable social switches.

A focus was placed on multiplayer and/or collaborative games. Participants were also provided with costume themed props to modify with conductive fabric in order to create social switches. The mix of themed and example projects seemed to more clearly communicate the idea of wearable game controllers than Workshop 2. Participant projects took the form of witches hats, gloves, ties, and angel halos, thus bringing the physical interaction of the game controller out of a hand-held format and to different parts of the body and different physical interactions.

[M] Example projects were developed to demonstrate at the workshop. Game control interactions that were demonstrated included jumping, hip bumping, standing back-to-back with a fellow player, and a tap with a magic wand.

[N] One group created a digital switch using a costume halo with wire wrapped around the outside, and a costume witch’s hat with a conductive fabric digital switch. When the halo is place on top of the hat, a key press is activated.

[O] Another participant used conductive fabric to create a game controller comprised of a costume necktie and glove. Each connection between glove finger and the associated contact point on the tie activates a different key press on a screen.

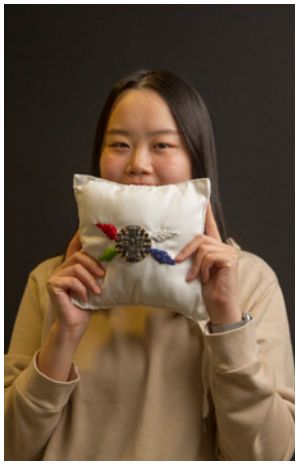
Workshop 4: "Stitch and Stuff: Making Embroidered Games"

Workshop 4 focused on the creation of capacitive sensors using embroidering techniques with conductive thread. Upon recommendation from the community organizers, this workshop differed from others in that it took a hardware-only approach to making a textile game controller, meaning the game does not rely on a screen-based device. After much research, an e-textile interpretation of a Simon-style example found in the Adafruit Learning system [22] was developed.

This workshop proved successful because participants could test and play the game as the game controller prototype was being developed by touching the Arduino board directly. Because it was a screenless game, the gameplay and feedback lived within the controller itself. In terms of sensing techniques, the simplicity of capacitive sensing was well-received and quickly understood by the participants. It had been the easiest and most successful example of Workshop 1. In this iteration it was tested with a more complex method of crafting the sensor (embroidery) and with a more multifaceted microcontroller. Embroidery was a more challenging construction technique, but it worked because enough time was allotted for participants to sit together, sewing, chatting, helping each other, and sharing tips and tricks as they worked. This made the workshop feel less rushed and opened up more opportunities for peer learning.

[P] Beginning with Workshop 4, the Adafruit Circuit Playground [19] became the microcontroller of choice. Using a circuit board designed for connections to be made with conductive thread allowed for simpler, easier to understand, and more reliable connections to be made to the microcontroller. In addition, this controller features onboard components including LEDs and a speaker. This allows for local feedback via light or sound for troubleshooting or even gameplay purposes.

[Q] In Workshops 4 & 5 the room layout for the workshops was changed from a lecture-style arrangement (facilitators at the front and participants in rows or clusters) to a sewing circle or round table style of layout. This was meant to encourage movement, conversation, and sharing amongst all workshop participants, and proved to be successful.



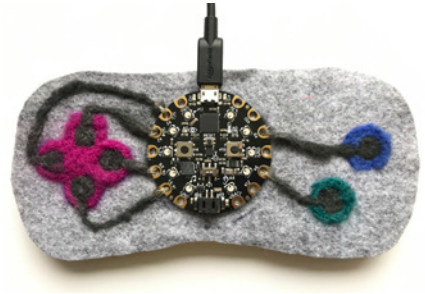
[R] A new documentation practice was introduced in Workshop 4 & 5. In addition to having a roaming documentarian take photos and video clips, a photobooth-style set up was installed in the room where participants could stand in front of a backdrop, hold up their prototype, press a button and a series of images would be taken of what they had created. This allowed for more agency and playfulness in the documentation of the game controllers.

Workshop 5: “Fun with Felting”

Workshop 5 utilized the same sensing technique (capacitive) with a different crafting technique - felting. There was a significant jump in registrants for this last workshop. One community organizer speculated that it was due to the image used to advertise the event. Compared to previous workshops, the example game controllers looked the most like consumer game controllers. The positive response to this was interesting because it was something that had been deliberately avoided in previous demonstrators. This led to the realization that starting out by making textile game controllers that looked like traditional game controllers was a promising way to bridge the gap and clearly communicate the affordances of the textile sensors for the game community in the initial stages of learning. Participants first needed to use the sensors in a familiar format before branching out into new conceptual models and mappings for what a bespoke alternative game controller could be.

Felting proved to be a playful and accessible method for crafting sensors using steel fiber and wool roving. Animated gifs in the slide show helped to clearly demonstrate the necessary techniques. A base template of industrial felt constrained the controller designs to a reasonable size and shape. Due to the refinements to the material preparation, topic, learning and support materials, room layout, and schedule, Workshop 5 proved to be the most streamlined, playful, and collaborative of the overall workshop series.

[S] Animated gifs were added to the instructional material to better demonstrate techniques.



[T] Felted Game controller examples that were shared via social media prior to the event.

[U] On board LEDs allowed connections to be tested throughout the prototyping process.

[V] Participants collaborating and prototyping their felted game controllers

WORKSHOP REFLECTION

Application of Hjorth et al's heuristics here allows the identification of dynamic processes aimed at improving participant experience. Two main techniques were added to our initial set of methods: a photobooth for the participants to self-document and 'live' presentation materials were introduced to rapidly respond to participant needs whilst the sessions were in progress. Looking to translation; significant work was put into improving workshop materials. In the final workshops, participants left with sample code, materials, connectors, technique tutorials, and a microcontroller.

In response to challenges observed in Workshops 1, 2, and 3, workshop topic and content was radically simplified for Workshops 4 and 5, focused on a single material and sensing technique. Complete, functional examples were provided that clearly showed how concepts and techniques could be combined. Participants who needed significant guidance could follow the instructions provided with the example, while those who were ready to branch out creatively or technically were able to do so. Physical worksheets were provided for participants to sketch out circuit and sensor placement and design. Participants generally embraced a research creation-influenced approach, where the controller's development altered course in response to discovery and inspiration that occurred while making.

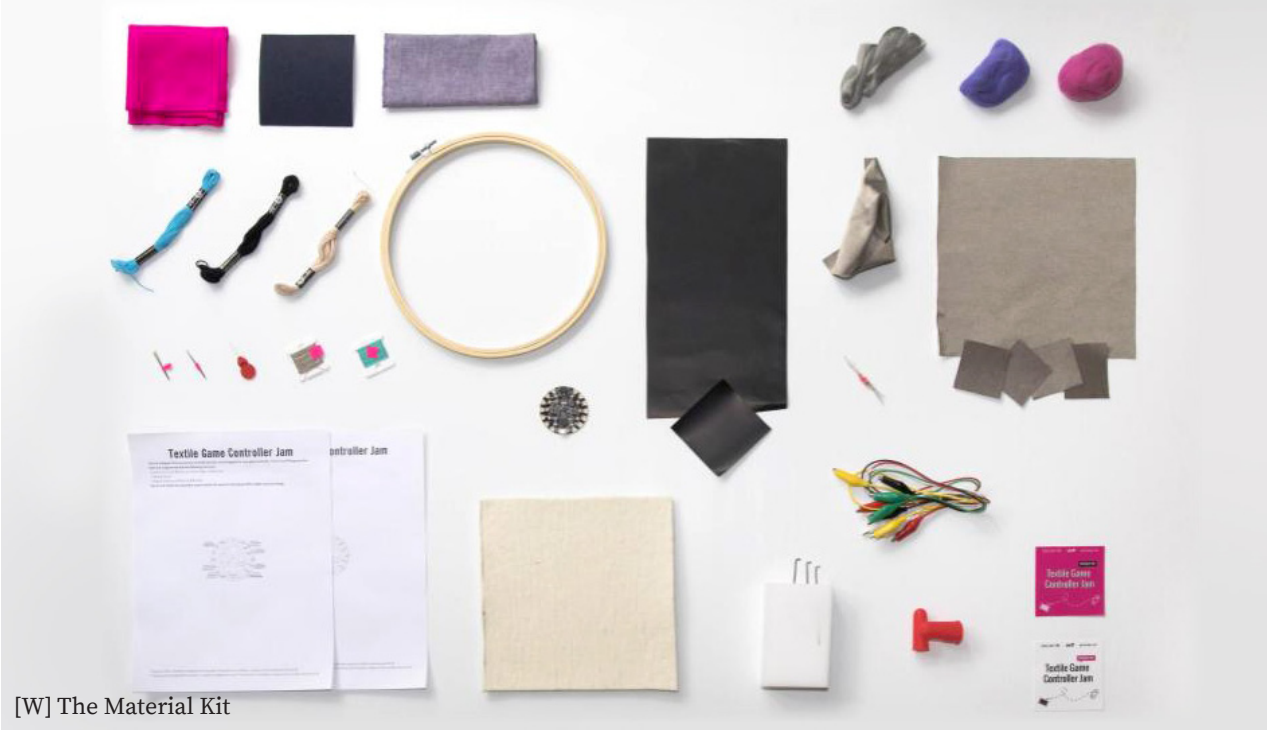
The ongoing simplification of focus and increase in quantity of supporting materials offered multiple ways to engage as well as persistent resources beyond the workshop; communication was vital, e.g. the recruitment materials were especially important in both attracting participants and setting expectations, especially relevant given the goal of bringing distinct communities together. Transmission shifted across the workshops meaningfully, both by increasing the amount of making time each participant had and by changing the physical layout of the space to emphasize participation.

GAME JAM PREPARATIONS

Although originally scheduled as a weekend-long in-person event, the resulting game jam was pivoted to a remote format in response to COVID-19 closures. Nevertheless, learnings from the five workshops were applied to the format and preparation of materials for the online game jam. We used what we had learnt through the workshops to prepare both physical and digital materials for the game jam. The game jam was carried out via video conference and Slack where participants, researchers and DMG hosted game jam activities remotely over an extended period of two weekends. A key early success factor here lay in the preparation and delivery of game jam material kits from the researchers on bicycle, many participants commented on the pleasure involved in receiving their materials in this way.

Physical Materials

A materials kit was developed and distributed to all game jam participants to allow them to participate from their homes. The kit contained all materials and tools required for the sensing and crafting techniques that were introduced in the five workshops. The kit contained the following items: conductive materials, including conductive thread, fabric (with and without adhesive), and fibre; resistive material (Velostat); non-conductive materials, including cotton thread; cotton fabric, craft felt, and industrial felt; electronics supplies including the Adafruit Circuit Playground Classic, alligator clips, USB cable, and resistors; felting supplies including felting needle, sponge, finger protectors, and wool fibre; embroidery supplies including needles, embroidery hoop, and embroidery thread; and printed worksheets for circuit planning.



[W] The Material Kit

Digital Materials

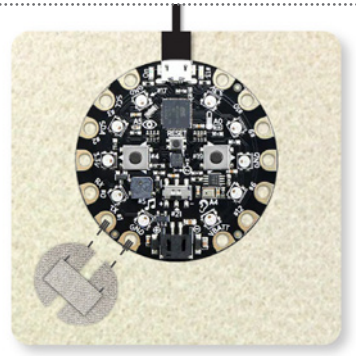
Based on the questions, experiences, and observations generated from the five workshops a new set of digital materials were developed to support the game jam, including diagrams, video tutorials, and code examples. This allowed game jam participants to review demonstrations asynchronously as needed, better supporting self-directed learning. This approach proved to be especially successful for the online format of the game jam and in allowed participants to gain a more in-depth understanding of the e-textile sensing techniques.

Embroidery

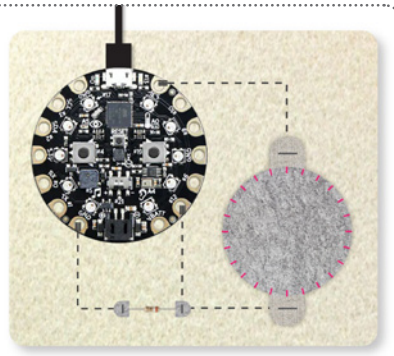
Felting

[X] Additional video tutorials were provided to demonstrate more in-depth crafting techniques such as embroidery and felting.

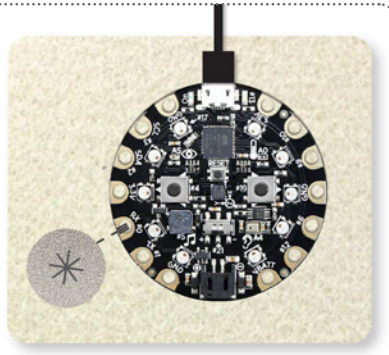
Digital



Analog



Capacitive



[Y] Video tutorials and corresponding diagrams were designed to support consistency across learning resources.

GAME JAM RESULTS

The Game Jam took place across two Saturday meetings and a final community Show-and-Tell on the following Thursday, with both synchronous and asynchronous support offered between meetings. The following examples demonstrate the ways in which e-textile sensing techniques were applied in the creation of alternative game controllers. While capacitive sensing was the most commonly used technique, digital and analog sensing techniques were used as well.

Capacitive Sensors

[Z] "Soft Paw Controller" uses wool fiber and conductive fiber to create buttons that could be activated by a cat. Prototype by Elizabeth Chan and Jordanne Chan.

[A1] This "3D Whack-a-Mole" game invites players to handle and rotate the triangular pyramid to find the "mole", and touch conductive filaments around the lit LED once found. Prototype by Maria Yablonina.

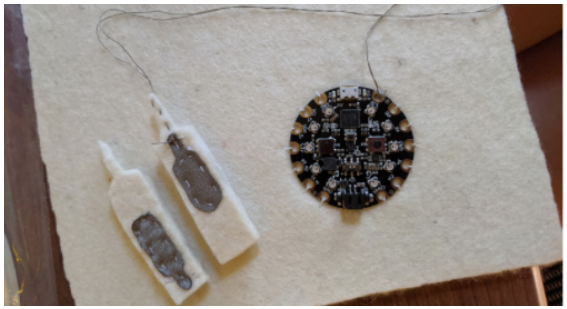
[B1] "Map Game" uses capacitive sensing to let players encounter enemies by touching different parts of the map. Pressing buttons on the Circuit Playground activates a simulated dice-based combat encounter. This game forgoes the use of a computer screen in favour of the LEDs on the Circuit Playground. Prototype by Kezia Adamo.

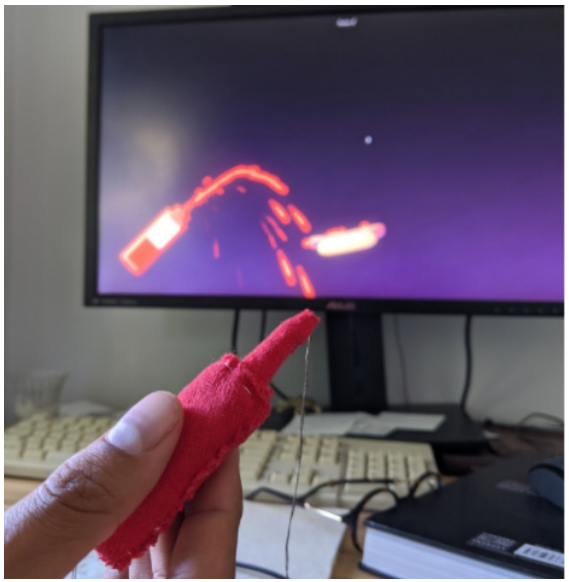
[C1] "OK Soundz" invites players to explore a variety of tactile sensations, triggering sounds as a result. Conductive fibre, fabric and thread connect to capacitive touch sensors on the Circuit Playground. Prototype by Bonnie Yau.

Digital Sensors

[D1] "Folded" is a folding controller and microgame designed to simulate the process of sizing and cutting fabric. It uses a series of digital switches to detect the action of folding felt. Prototype by Kaelan Doyle Myerscough.

Analog Sensors





[E1] "Sauce yer Dog" is a game in which the distance of the ketchup squirted on the screen is controlled by how hard a plush ketchup bottle is squeezed. The intensity of the squeeze is detected through an analog sensors. Prototype by Coley Caverley & Nathan Powless-Lynes.

CONCLUSION

Returning to Ørngreen and Levinson's [34] framing of research workshops as a means, as practice, and as methodology, it is possible to see how these structured and time-delineated sites of making offer rich opportunities to research, communicate and synthesize creative approaches to material and sensate experimentation with technology. The workshops described in this paper acted as spaces to enable material development (whether of workshop supplies, teaching materials or participant projects) as well as a way to share skills and domain knowledge across partners and participants, whether of working with e-textiles, wearable game controllers or of running workshops. Teaching materials and process documentation were produced, shared and published and research iteration allowed the team to explore approaches to support rapid learning and experimentation. Most importantly, in their responses via making the DMG community members were able to demonstrate ways in which the e-textile techniques were or were not translated effectively for use in making alternative game controllers.

Findings were carried forward from the five workshops to scaffold the culminatory game jam. We learnt that careful preparation of both physical (e.g. pre-cut and coded materials) and digital (e.g. video tutorials and live presenter notes) material was essential to support the creativity of participant projects. The structured game jam sessions introduced techniques and discussed work-in-progress. Importantly the partners built an online community on Slack for the game jam that facilitated social moments in which researchers, organizers and participants supported each other both creatively and personally. It is notable that many of the changes introduced during workshop design iteration addressed multiple goals, for example the production of tutorial materials helped prepare for the game jam and also increased research reach through wider public sharing via a range of channels (partner websites, YouTube, etc.). Due to the production of projects taking place in domestic environments the resulting game controllers tended to be smaller and handheld whereas under the originally intended circumstances we had hoped for more full-bodied interactions. There are many nuances of the resulting artifacts to be explored, though a detailed analysis of the game jam is beyond scope for this paper and will be covered in future publications. However, as evidenced by the resulting prototypes shown above, it can be summarized that the transmission of e-textile techniques to a game jam context was successful, including all three sensing techniques (digital, analog, and capacitive); assorted assembly techniques (stitching, gluing, felting); as well as use of conductive and resistive materials (conductive thread, fabric, fibre; and Velostat). As such it can be surmised that the intersection of these two making practices, alternative game controllers and electronic textile (e-textile) sensors, holds rich potential for further creative and critical inquiry. Our research workshops deployed Hjorth et al's heuristics for mobilizing research knowledge across multiple communities to meet our research objectives. By developing methods that shifted ideas across the groups involved; from researchers to participants and back again, in a way that was responsive to our embodied contexts of making, we developed techniques that facilitated translation of concepts that were then transmitted to multiple publics.

RESOURCES

Circuit Diagrams, Code, Video Tutorials, Materials List, and other resources generated through these research activities can be accessed here: http://socialbodylab.com/textile-game-controllers/

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