"It's Being Unmade!": Reflections on the Unraveling and (de)fabrication of Machine-Knit Textile Tapestries

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Figure 1: The *Unraveling* series unraveled machine-knit panels as individuals walked by. Photos courtesy of Niki Boytchuk-Hale.

Abstract

This paper explores how people experience public displays that take apart machine-crafted items, as a design resource. We use the affordance of knitting as an ephemeral fabrication method (that can be gradually pulled apart and unraveled) as a way of understanding how individuals feel about unraveling crafted textiles in public. We designed machine-knit panels as tapestries, and developed an interactive yarn winder that unravels those panels as individuals pass them. This resulted in a textile-based artwork series *Unraveling* (2022-2023), and we present two iterative public installations, and results from a user study. Our study findings highlight users' empathy toward others and mindful interaction: being aware that defabricating a piece is finite. Insights also revealed tensions between admiring playful sustainable practices and feeling guilty of destruction.

CCS Concepts

• **Human-centered computing** → **Human computer interaction (HCI)**.

Keywords

unmaking, ephemeral design, ephemeral fabrication, knitting machines, machine knitting, textile fabrication, digital fabrication

1 Introduction

Digital fabrication enables individuals to produce physical objects without, or with reduced, manual intervention [26]. Alongside this ability, there are increasing sustainability concerns about how we can further re-use or re-purpose these objects [78]. As a result, researchers are turning their attention to the user experience of unmaking and taking things apart [73]. In this paper, we use a participatory and interactive artwork to explore how individuals feel about unraveling digitally-fabricated textiles as well as the social dynamics that arise when doing so in public. We take knit

tapestries, which are usually precious, and with audience participation unravel them for re-use. In previous work, the context of art has been a useful entry point into exploring novel interactions, especially for probing interactions without a set task to accomplish or evaluate [10, 23, 80, 81].

1.1 The *Unraveling* series

The artwork series *Unraveling* combines two elements: (1) digitally-fabricated, machine-knit textiles, and (2) a yarn winder that unravels the textiles when individuals walk by (Figure 2).
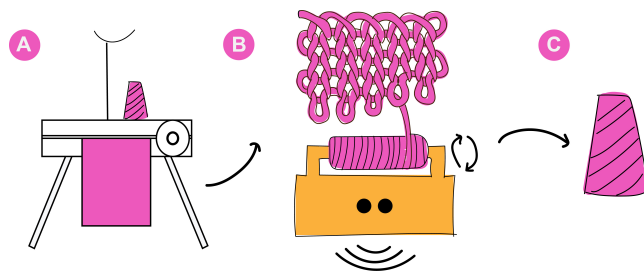

Figure 2: The *Unraveling* system leverages how knit items are made with a single interlooping yarn (A). As a result, when the yarn is pulled on, it can unravel the item for reuse (B+C).

1.1.1 Machine knit yarn panels. We used digital fabrication to knit panels with an adapted Brother knitting machine (Electroknit KH-950i) with img2track software, which translates image files into a compatible knit pattern [17]. Once the knits were layered on canvases, the yarn could be pulled to unravel the textiles both manually and with automatic sensors. As a result of the knit structure, a textile pattern can be created by machines, and we were motivated to explore how people feel about it unraveling. A hand-knit textile takes a long time to create, and the human effort involved makes it precious. In contrast, creating a machine-knit textile is a much faster process.

1.1.2 Automatic yarn winder. Yarn winders were created with an Arduino Uno connected to an ultrasonic sensor and a continuous servo motor. Ultrasonic sensors can measure the distance to an object, so as individuals walked by the ultrasonic sensor this would trigger the servo motor to spin, which would wind up the yarn and unravel the knit panels. The resulting interaction was that as individuals stood in front of the installation (i.e. looking at the textile panels) their presence would unravel the panels.

1.2 Three iterative implementations

We worked with three art organizations in Canada (Union Gallery in Kingston, Video Pool Media Arts Centre in Winnipeg, and ArtEngine in Ottawa) to iteratively design *Unraveling* and explore how individuals felt about taking apart machine-crafted textiles in public. The first implementation was a one-day pop-up in a public park, the second was a three-month installation in an art gallery, and the third was a formal user study with 10 participants (see Figure 3).
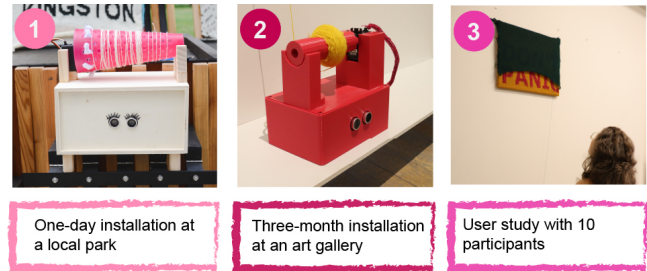

Figure 3: Three project phases: a 1-day park installation, a 3-month art gallery installation, and a user study.

1.2.1 Research questions. We explored 2 research questions:

RQ1: How do individuals respond to unraveling machine-crafted textiles?

RQ2: What are the social dynamics that arise when unraveling in public?

1.2.2 Research through Design. For this project we used a Research through Design (RtD) approach that involved exploring and speculating [22] through physical implementations and design iterations (see Figure 3). This 2-year longitudinal exploration [91], involved documenting our design process [3, 92] to get at unexpected outcomes [64]. We learned from each iteration through several methods including photo documentation, self-reflection and note-taking, and getting user feedback from a qualitative user study. By placing the work in a variety of locations for different lengths of time (i.e. in an outdoor park installation for 1 day, and an indoor art gallery for 3 months) and in a formal user study, we aimed for a diversity of outcomes [35].

1.3 Contribution

We provide the following insights from our iterative deployments:

1. Unraveling in public is uncomfortable: In all three installations our participants required encouragement to engage in unraveling. Though after interacting with the installation we heard comments that it was "satisfying" or "fun", in all cases unraveling was initially experienced as uncomfortable. As a result of this initial discomfort, it became that much more important to make the unraveling interactions "smooth" - i.e. for yarn not to get caught up, or bobbins to fill up, or any interruptions to the unraveling interaction.

2. Bigger is more observable: Throughout our three iterations we found that the size of the panel to be unraveled had an impact on how individuals experienced the installation. Interactions with larger panels were more observable by audiences, who could view the interaction before engaging. Similar to research on public displays, we found that enabling individuals to observe the unraveling process before participating encouraged more unraveling.

3. Small creates concerns for sharing and scarcity: Participants had concerns about taking "too much" of the unraveling time and concerns around fairness, especially when unraveling a small object and therefore a scarce resource. Smaller panels were experienced as creating scarcity and participants brought up concerns

around turn-taking and limiting their interaction due to worries of taking more than their "fair share" of the unraveling.

2 Related work

This artwork series was motivated by the rise in textile digital fabrication and the ability for knitting to act as ephemeral fabrication [78], where an item can be created, edited, and taken apart.

2.1 Unmaking and destruction as interaction

HCI researchers are increasingly exploring the processes of taking things apart, unmaking, and destruction [73]. For example, researchers have explored using disposal as a method of grieving and letting go [74], how destruction can be an enjoyable activity [19], and how unmaking can be used as a way of questioning norms [71, 72, 79]. Destruction can also create feelings of risk if it is irreversible [68], and can be felt negatively [51], but taking things apart, and looking "under the hood" can also help us understand how things work [58, 59]. Many disassembly explorations have sustainability goals, such as creating things that are designed to eventually disappear [78], things that can be deconstructed for re-use [36, 41, 43, 52, 53, 53, 54, 89], things that can be repaired as they break down [34], or things that change over time [76]. Destroying or taking things apart can be a way to remove technologies with negative impacts [50, 62], while creating space for new things [61].

Though some of the user studies in unmaking have had practical tasks, for example exploring the user experience of taking something apart for re-use [41, 51], or learning from the approaches of e-waste practitioners [43], we situate our work among those working in a more speculative space, rather than giving users a practical task to complete. For example, several projects have used destruction as a way to explore novel interactions. Destructive games was a series of games where a laser cutter was used to destroy or damage physical objects, for example a virtual tug of war that would create cut lines in a competing player's monetary bill [19]. In this case, destruction of something of value created excitement in the game, and a memento to show and share the experience with others afterwards [19]. Similarly, in the project *Point of No Undo*, the authors developed three material speculations to explore irreversible destruction [68]. They found that irreversible interactions forced participants to reflect on what they were doing, and some participants were hesitant or refused to participate (for example in the case of breaking a robot's legs) [68]. Both of these examples show how destruction can give an added weight to an interaction, either excitement through increasing the stakes [19], or feelings of guilt or loss in destruction [68].

2.2 Ephemeral design

In contrast to the concepts of unmaking and deconstruction, which focus on taking something apart or destroying it, ephemeral user interfaces are those that are designed from the beginning to last only a limited amount of time [18], for example, designing interfaces with ephemeral materials like ice [49], bubbles [75], or food [20, 57]. In the realm of digital fabrication and textile fabrication, most of the work in HCI has focused on degradation, bio-designing objects and textiles that are only meant to last a specific amount of time, and will disappear or decompose afterwards [6, 7]. For example, fabric stains that will disappear when exposed to light [9], or using biodegradable plastics [44] and "leather" (such as scoby [8], alganyl [5], biofoam [48], and mycelium [24, 87]) to craft "textile" objects. Similarly, researchers have explored how we can "grow" devices that will decompose later on [60]. More recently, HCI researchers are focusing on this at the yarn level by developing biodegradable yarns [47, 90]. At the same time, one of the benefits of traditional textiles is their durability, flexibility, and launder-ability, so degredation isn't always desirable. In this project we explore how we can use traditional yarns for strength but (de)fabricate textiles (leveraging their fabrication structure) when we want them to be taken apart for re-use. In this way the (de)fabrication is caused by the end-user.

2.3 Knitting as a (de)Fabrication method

Knitting supports ephemeral fabrication [78] where a textile object can be made, edited, and unmade. Knitters frequently use this affordance to fix mistakes, alter a garment's length, or re-purpose yarns for another project. Knitting is a fabrication method where yarn is continuously looped to create a textile. In HCI, we have leveraged this affordance for digital fabrication, and to ***create*** knits, rather than using these features for unmaking or unraveling knits. For example, digital fabrication has enabled researchers to explore how to augment knitting to encapsulate memories into textiles [65–67], and how to use knitting machines as a way of physicalizing memory storage [63] or to visualize our own personal data [29, 40] or community data [37–39]. Researchers in HCI are increasingly working to support digital fabrication with knitting creativity support tools, languages, and software [2, 30–33, 84–86]. Overall, knitting as a digital fabrication method is a rich resource for tangibilizing and physicalizing data.

When a knit textile is created "fully fashioned" (i.e. made with one continuous yarn) it affords the ability to be unraveled back into a spool of yarn, a process called "frogging" in knitting communities [1]. This affordance has been leveraged by artists as a method for re-using materials [89], such as Germaine Koh's *Knitwork* (1992-ongoing) [4, 45] where the artist reuses yarn from 100s of used sweaters to hand knit one continuous fabric. Artists use machine unraveling to create tension between humans and machines, such as Laura Splan's *Material Expressions No.2* (2016) [77] where the artist is continuously stitching a knit item that is being unraveled on the other end by a machine. Knitting is an interesting use case for ephemeral fabrication because though knitters are aware of this affordance (the ability to "frog" a piece of knitting for editing or re-use), those who do not knit might view it as a static and permanent object. There might also be tensions among knitters (and hand-knitters especially) who are aware of the amount of work and time that goes into creating a knit. Here we explore how audiences feel about taking apart knits, and compare with previous work on destruction as an interaction.

3 Implementation 1: 1-day park pop-up

For our first implementation of *Unraveling*, we collaborated with Union Gallery to create a 1-day pop-up installation for their Wandering Art Station, a "gallery on wheels" that could travel and

"pop-up" in public spaces. This iteration was used as a way of testing the initial concept in-the-wild with members of the public, and gaining insights for future iterations.

3.1 Preparation

The Wandering Art Station (WAS) was developed in response to pandemic constraints with the goal of enabling individuals to interact with art in a safe way (outside, physically distanced, etc). As the first artists to activate the WAS, we decided to use this opportunity to reflect with the community on their pandemic experience. To inform the design of the knit panels (i.e. the content of what would be unraveled), we sent out a survey to Union Gallery's community newsletter with questions on how Kingston has changed during the pandemic. These community responses were turned into icons and images and translated using img2track into knit patterns for digital fabrication [17]. The resulting panels were layered on top of each other (each 3 layers deep), so that once one panel was unraveled it would reveal the next one. We then used an Arduino, ultrasonic sensor, and servo motor (as described in 1.1.2) to create the *Unraveling* system. To prototype the housing of the yarn winder, we used a wood box and connected a yarn cone to the servo motor so that the yarn could be would up for re-use. Alongside the automatic unraveling with the yarn winder, we also included panels that could be unraveled by hand.

Figure 4: Unraveling a layer of knitting to reveal the next. Photos courtesy of Niki Boytchuk-Hale and Talib Ali.

3.2 Installation reflections

Unraveling was placed in a busy park on a Saturday. We placed the WAS at a sidewalk intersection and near park features (baseball diamond, tennis court, playground, and water park) to get foot traffic. During the installation we had support from 4 gallery volunteers, 1 videographer, and 1 photographer. We had an A-frame board explaining the project and that the installation was being documented. The researchers paid attention to the *Unraveling* process, with crafting tools (like scissors and string) on hand to make quick fixes as needed, and to answer questions from the public. Immediately after the *Unraveling* installation, the first two authors noted the changes needed for the next iteration.

3.2.1 What we saw. During the installation (Figure 5), we noticed that individuals tended to unravel passively with the machine before actively unraveling the works by hand. The machine seemed to give them permission to unravel, showing what interactions were allowed in the space. We noticed that children seemed less self-conscious when causing the work to unravel, and they approached it freely and expressed delight in the process of destruction. Adults

Figure 5: The participatory installation at a local park. Photos courtesy of of Niki Boytchuk-Hale and Talib Ali.

often started unraveling but expressed hesitancy to *"unravel too much"* and to *"save some for others"*. One group of knitters that passed by refused to unravel saying it *"hurt"*, and reflecting on the effort involved in creating their own hand-knit pieces. After being encouraged to unravel the panels (as we often found ourselves reassuring participants that it was okay to unravel them), some individuals found the process oddly satisfying. We heard individuals say things such as *"I feel like I could stand here doing this forever"*. We also heard reflections on sustainability, and appreciating that the wound-up yarn could be re-used. This public display of *Unraveling* highlights some of the felt discomfort in taking things apart, and watching a crafted item disappear, but also the positive and satisfying feelings the process can evoke.

Figure 6: At the beginning of the installation, and at the end.

3.2.2 What we learned. We learned that we needed to make several changes to the physical design of the installation. Due to the vast amount of people that came by, the knit pieces were unraveled quite quickly (all 9 panels completely unraveled within four hours), and at times the maintenance was difficult to keep up with. There were 2 events that would cause the unraveling machine to jam (and as a result make participants concerned whether they had broken something), so we wanted to avoid those unintended interactions in future iterations.

1. Two-colour knit creates jams: In our knit designs we used a 2-colour design with "Fair-Isle" knitting, where the unused colour of yarn creates strands on the back. In our tests, when we needed to switch the colour this required a bit of manual intervention on the part of the researchers, but with many people using the installation during the pop-up, these colour changes would cause the unraveling machine to knot and jam. As a result, we learned that we needed to use a solid colour design for the layer to be unraveled to ensure that it could be taken apart without supervision.

2. Not enough room on yarn cone: With the amount of people that interacted with the installation, the yarn cone on the yarn winder filled up too quickly, and once full of yarn the machine would stop working. As a result, we learned that we needed a thinner cone so we could wind up complete panels without maintenance.

3. Small size impedes observation: From the documentation photos we noticed that if someone was interacting with the installation it was difficult for passers-by to observe what was happening. As a result, for future iterations we decided to explore how we could make the process of unraveling more observable, and whether this would help ease the discomfort individuals felt towards unraveling. This would enable us to leverage HCI concepts from public displays such as the "honeypot effect" where seeing others interact with a display encourages further interaction by audiences [25, 88].

4. Machine unraveling is better unraveling: While the machine unraveled the panels in a controlled way that would enable the yarn to be re-used, the hand unraveling was less organized. Participants would pull on the textile panels creating runs and tears in the textile and resulting in yarn that was completely unusable afterwards. Machine unraveling supported our sustainability goals of making the yarn re-usable for ephemeral fabrication [78].

4 Implementation 2: 3-month exhibit

In our second implementation, we wanted to further explore whether we could improve the experience of unraveling. To do so, we wanted to make unraveling more observable for bystanders by increasing the size and the height of the panels to be unraveled, and to fix previous issues we experienced with the winder jamming.

4.1 Context: Reflections on an arts organization

Video Pool Media Arts Centre commissioned the authors to work with them to reflect on their 40th anniversary and to map out where they want to go in the future. The project lasted six months with the first three in preparation, and then the next three for the installation. During the planning phase we created questionnaires for staff to answer and held virtual workshops using an online whiteboard[56]. The questions asked were meant to be surprising and to get at the personality of the organization, for example, what type of sweater they would be, their astrology sign, their biggest challenge, and their favourite moments. Their responses were knit into panels (see Figure 8) and included examples like the personality of an 80s sweater, being Capricorns (work hard, play hard), the time their building got graffiti to (F)ArtSpace, the challenge of being on the second floor of the building and up an elevator, and being Winnipeg's best kept secret.

4.2 Designing for reduced maintenance

For this iteration of *Unraveling* we created a more robust yarn winder (see Figure 7) that could continuously wind up yarn over the three-month installation period (and avoid "jams"). The adaptions we made included 3D printing the yarn bobbin and making a thinner bobbin so that more yarn could be wound, resulting in less maintenance. The yarn bobbin clipped into the servo motor so that if there was any tension, or a row of stitches was stuck, the winder was sturdy enough to continue to wind it up. The goal of our design was to create a winder that would address the concerns from the previous installation, where the machine stopping, filling up, or jamming would cause users to hesitate and feel like they had broken something.
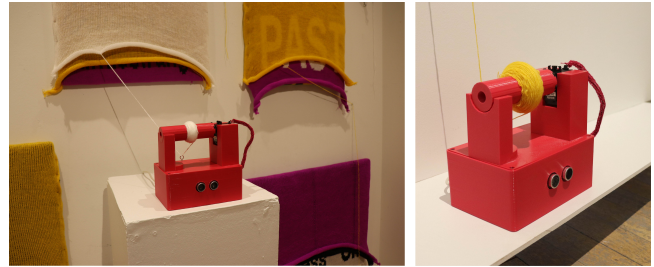

Figure 7: The updated yarn winder design. We presented two winders in different rooms with panels of different sizes.

4.3 Making it observable

4.3.1 Providing a preview. The second decision was to add visual instructions informing viewers how to unravel. We created a looping video of a panel being unraveled, knit up again, and unraveled once more. This looping video quickly showed the cycle that each piece was to go through, giving participants a preview of the interaction they would be participating in.

4.3.2 Making the process viewable to bystanders. For this installation we made panels that were bigger and stacked vertically. This enabled bystanders, who weren't yet interacting with the process of unraveling, to see the process before participating. In comparison to the park installation, where the crowd gathering in front of the installation blocked the view, with these larger and vertical presentations onlookers could see the process before engaging in the activity.

4.4 Installation

The yarn winders were installed in two different rooms. The first was a small alcove that visitors walked through immediately when they got off the elevator (see Figure 8). This area had 10 artworks to unravel, and one in the centre that was unraveled by machine. The artworks were stacked vertically so onlookers could see the works being unraveled, and the machine was placed in front so approaching participants would trigger the sensor. To the right of the alcove was the door to a second room where we had three artworks that were much larger. The one on the left was to be unraveled by hand, the one in the middle was a looping video showing a panel being unraveled, reversed (stitched up again), and unraveled continuously, and the one on the right was unraveled by machine (see Figure 9).

4.5 Exhibition reflections

The opening happened on a Friday, coinciding with a city-wide art crawl, and Video Pool invited their mailing list from their online newsletter, and placed posters throughout the city. Attendees included members of the organization's board, founding members, staff, and the arts community of Winnipeg. During the exhibition opening, we had 1 photographer and 1 videographer to document the event and visitor interactions with the installation. The researchers were present to answer questions and provide support.

Figure 8: Vertical panels in the alcove before the opening (left), and after (right). Photos courtesy of Karen Asher.

Figure 9: In the second room we had three panels. One unraveled by hand, one looping video preview, and one unraveled by machine. Photos show the installation before the opening (left), and after (right). Photos courtesy of Karen Asher.

Figure 10: The larger panels made the interaction observable to bystanders. Photos courtesy of Karen Asher.

4.5.1 What we saw. The changes to the unraveling machine design had the intended result. During the opening the unraveling machines worked with reduced maintenance or intervention. Overall, we noticed different interactions between the two rooms suggesting the impact of panel size. The room with the larger panels beside the rapid preview video were quite quickly unraveled. We even noticed moments of participants competing against each other, seeing which layer could be unraveled fastest. Overall, the larger panels afforded more group interactions as people worked together to unravel, whereas the smaller panels in the alcove were worked on individually. The second room also had the benefit of more space around each work, and we noticed that individuals often watched others unravel before approaching the panels to participate themselves (see Figure 10).

4.5.2 What we learned. Based on the differences between the two rooms we provide the following recommendation:

Bigger is Better: We noticed more engagement with the larger panels placed within the larger room (where there was space around the installation to observe). Individuals were able to watch others unraveling, and the unraveling preview video, and this appeared to increase their comfort level with getting involved. We noticed new interactions, such as "racing" to unravel.

5 Implementation 3: User study

To more formally understand the experience, we invited 10 participants (P1- P10) to explore *Unraveling*. All participants were museum goers and were recruited based on registering an interest in previous studies on textile fabrication. Participants spent a few hours at ArtEngine and experienced unraveling as a group and individually. For this implementation, we created a solid first layer of green yarn, and then the layer below would reveal the words "PANIC" before "DON'T PANIC", playing on our feeling of taking things apart (see Figure 11). We chose a small panel that could be completely deconstructed by a small group in a short period, and installed the artwork above eye level.

Figure 11: During the study the panel unraveled to reveal "PANIC" before "DON'T PANIC".

5.1 Method

5.1.1 Interviews. After participants spent time with *Unraveling*, we interviewed each individual participant separately through a video call. Each semi-structured interview was approximately 30-45 minutes long and the data collected included the video recording and transcripts. Participants were asked questions such as: their impression of what was happening, how it felt to interact with the installation, and how it felt to watch others interact with the installation. This study was approved by our institutional research ethics board.

5.1.2 Analysis. Data analysis began by comparing the transcripts to the videos. We then used Braun and Clarke's reflexive thematic analysis [11–13] due to the exploratory nature of the study, and due to our interest in gathering initial impressions and future directions rather than evaluating the usability of a specific task. This involved reading through the transcripts for familiarity, and then line-by-line coding. Our codes had a particular focus on recommendations for future directions of the project. We then grouped the codes into central organizing concepts to create themes. We include participant quotes to illustrate our themes.

5.2 Findings

5.2.1 Discomfort in unmaking. Participants expressed discomfort in taking the knitted textile apart. Part of this was a feeling of surprise or panic in the item coming undone, as P6 described: *"There's this feeling of 'Oh, my God!' [facial expression of surprise] It's being unmade!"*. Things coming apart is often associated with feelings of frustration. For P7, this resulted in feeling *"a little bit of I would say discomfort. You're not used to seeing things unravel, not used to seeing things come apart like that on purpose. Having a family of knitters and crafters, I completely appreciate when you have to backstitch, or you have to take out a whole row of stitches, how frustrating that can be"*.

Participants discussed how undoing is not an action we are used to performing, since there is a general expectation to be productive, to keep moving forward, and to finish a task. As P3 summarized: *"We're always constructing things. We don't do a lot of deconstruction [...] you're generally almost always working towards something to be finished, to have that finished product"*. In contrast, our design challenged that norm: *"It's the opposite of what you would expect"* (P8). Defabrication, for some, was not just novel but rather provocative as having a *"machine pulling it apart this way [was] slightly unsettling"* (P2).

5.2.2 Empathy and mindful Interaction. Similar to the feedback we gathered at the public installation, individuals expressed feelings of not wanting to take apart too much and wanting to save some for others. As P2 summarized: *"I wanted to be cautious and just take my turn"*. P6 expressed a similar tension around wanting to unravel the work and see the end result, but also not wanting to take more than what they perceived as their fair share of the unraveling: *"I had the feeling that I didn't want to stay too long [in front of the sensor]. I wanted to see the message, I wanted to activate the sensor, but I didn't want to hog this space and be there for too long"*. As a result of this uneasiness around taking too much, participants mentioned that they at times felt more comfortable being *"just a spectator"* (P5) rather than owning the action of unraveling or feeling selfish, greedy, or guilty of destruction. As P2 stated: *"I think I probably enjoy watching others do it more than doing it myself"*. Participants were conscious of the finiteness of the knits and that made them more mindful and respectful, taking turns approaching the sensor: *"That was really fun. Everybody took turns"* (P7). While *"some people didn't really want it to unravel"* (P10), others felt joy and playfulness – *"It kind of brings out the child in you"* (P8).

5.2.3 Big reveal. Aligning with the public installation, participants valued the sustainability angle of unraveling. As P4 summarized: *"I thought it was pretty cool how it would wind up a whole new cone of yarn which makes it sustainable [...] so I can take this cone and make another piece and continue to do that over and over again"*. At the same time, there were also limitations to the use of a single colour for the top layer. For example, it took individuals longer to understand what was happening. As P5 stated, *"It took me a while to understand that it was unraveling a message"*. Once they started to see the text panel underneath, individuals began rushing to get to the end due to the *"mystery"* (P3) and *"curiosity of what's behind"* (P6). P3 expressed feelings of anticipation: *"Let's get on with it. Let's*

see what it's gonna be [...] that feeling of like just wanting to see the end of it".

In comparison to the public installation, our study participants discussed how the single colour top layer changed the purpose of the installation into a "big reveal" rather than the previous focus on taking something apart. As P2 stated: *"It was exciting to see it unraveling to have a bit of a reveal"*. Similarly, P1 said: *"People were really interested in the reveal"*. It created more of a rush to an end point when the reveal would happen, as P3 summarized: *"I just got impatient. I just wanted it to happen"*. They felt that their interactions would get them there, as P6 stated: *"If you're not interacting with it, it's not delivering its message, so in a sense that was really interesting too. You want to interact with it. You want to see it unravel to see the final message"*. The reveal added *"a little bit of novelty. What does it say underneath? What is it? Is it a word? What color is it? Is there some special meaning in this word?"* (P7).

The single layer also felt less destructive than previous iterations where the panels of text were being unraveled. P1 called the top layer a *"veil"* and discussed how with the first iteration in the park it felt more *"transformational"*. In the previous park iteration, *"instead of having a blank layer on top, you're unraveling the actual image. It's sort of new where you've got a veil, and then you're revealing what's behind the veil. When I see the other work, the words are unraveled and it changes, there's this transformation, and [...] the veil didn't offer that same transformation for me"*. This reduced the risk involved in unraveling. *"The veil felt more like opening a present to see what's inside, but the gift wrapping isn't that important"* (P1). As a result, in future iterations, we would like to explore how to unravel the actual textual panels while also enabling them to be re-used.

6 Discussion: Tensions and opportunities for unraveling

Our iterations of *Unraveling* explored different contexts with different rules of engagement (such as how a stand at a park might encourage tangible engagement, whereas this is typically not permitted in an art gallery). Rather than generating generalizable findings, this RtD material exploration aims to highlight the insights from the design iterations, and we frame our journey as generating opportunities and tensions to consider in designing for unraveling.

6.1 Unraveling experienced as destructive

Throughout the installations, participants were initially hesitant to unravel, echoing frictions experienced in previous work on interactions with 'no-undo' [68]. In all instances we had to verbally encourage individuals to unravel and provide reassurance that taking the textiles apart was the intended interaction. In coming up against this friction, this research also highlights and brings forward the unspoken social rules we have around destruction. In this way our research unintentionally emulated the work of breaching experiments from sociology [21], where individuals performed behaviours they were not used to in order to bring forward unconscious or unexpressed social rules [21, 28], but in our case in a visual art and textile fabrication context. Our study findings and installation reflections bring up the value individuals prescribe to

crafted items, even when they have been fabricated by machines, and even when the knitted textiles were designed to be unraveled.

HCI researchers have argued that new technologies in themselves can be breaching experiments and are especially useful when there is an absence of practice to inform social norms [16]. For example, early explorations into wearable technology, like Steve Mann's *Sousveillance* performances, helped participants to imagine how they might feel about wearing new technologies like wearable cameras [55]. We were surprised how folks hesitated to take the textiles apart, because in comparison to previous work (with activities such as breaking the legs of a robot or shredding a photo [68]) we saw unraveling textiles as a less emotionally-charged activity.

6.2 Sharing the unraveling and scarcity

Our first and third installations brought up feelings of unraveling and fairness, and it's interesting to note how this concern came up in settings where the panels to be unraveled were comparatively small. Due to our installations occurring in a group setting, individuals expressed not wanting to take more than their "fair share" of the interaction, and there was uncertainty and ambiguity about what that was. As a result, participants also brought up feeling more comfortable in the position of spectator, rather than being the individual triggering the machine to unravel. In the position of spectator they expressed that they wouldn't have to worry about hogging the space or taking up too much of the experience. In this way, their responses highlight how the size of the item to be unraveled could have an impact on how precious it is, i.e. with smaller objects there's more awareness that unraveling is a finite resource. To correct for this, and make participants more comfortable in the role of unraveler, future work could explore how we can remove this ambiguity from unraveling by for example designing the interaction of a "turn" for each participant so each person is perceived as getting their fair share of unraveling time. It would also be interesting in future work to explore unraveling as a solo activity, where participants do not need to be concerned about saving part of the interaction for others.

6.3 Scale and learning from public displays

Of the three iterations, the second was the most self-sustaining, in that once participants saw others unraveling they joined in with less verbal instruction. The second iteration also had more cues to unravel with the added looping video showing the unraveling process. The scale of the work, and the resulting ability to observe the interaction of unraveling before participating, could have contributed to what other researchers in public displays have termed the "honeypot effect" [14, 88], where audiences are able to learn and get comfortable with performing interactions by watching others perform them first. Previous work has discussed how it is easier to see what others are doing on large displays compared to smaller ones [82]. By having observable interactions, this enables audience members to decide if they want to engage in an informed way, and avoid potential concerns of embarrassment. This was echoed in the formal user study, where participants said they were more comfortable in the "observer" role, or in watching others unravel. Being able to see the interaction could also be important due to

animation, and how movement draws our eyes and increases engagement [27, 42, 46]. Being able to see the movement of unraveling could draw more interest in the interaction than if obstructed.

6.4 Unmaking as a fun activity

Once participants got over the initial hesitation in unraveling, many described the activity as satisfying and fun. This relates to previous work on gamifying destruction, where the act of permanently destroying something added a level of excitement or "stakes" to the interaction [19]. In the larger second installation we saw individuals, without prompting, gamifying the process of unraveling and competing on who could unravel a knit layer faster. Participants in our third installation, the user study, also discussed wanting to unravel faster in order to reveal the result underneath. These two examples suggest the potential for unmaking to be gamified - rather than just being just used to destroy [19]. Future work could explore developing games with destruction for re-use.

6.5 Opportunities for ephemeral fabrication

In our installations *Unraveling* explored how knits afford the ability to be (de)fabricated, but knitting also allows other aspects of ephemeral fabrication [78], where knitters can edit, remix, and re-use. For example, hand knitters can currently use knitting as a form of mobile fabrication [69] knitting, editing, and undoing mistakes on the go. These forms of re-mixing have been explored in HCI with 3D printing, and how printed items can be re-mixed and re-used in new prints [70, 83], but in the realm of knitting this might alter how individuals feel towards unraveling. For example, if individuals not only saw the knit being unraveled, but also that yarn being re-purposed, how might that change how they feel towards unraveling? In this case, unraveling would not just be a form of (de)fabrication, but also allow for the creation of something new. In this current work, responses to *Unraveling* emulated those found in previous work on destruction [19, 68] due to the limited aspects of ephemeral fabrication [78] shown in these installations. In future work it would be interesting to explore how individuals feel towards the destruction of a knit item when there are further opportunities for remixing the item, or re-using the yarn, within the same setting.

7 Conclusion

Socially engaged art practices can be a useful way for encouraging public engagement in HCI topics [15], such as digital fabrication, hybrid crafts, and un-making. This work intertwines participatory art and HCI textile fabrication (and defabrication), and uses the context of art in order to engage the public in interactions that though not usable in the typical HCI sense are still enriching to explore and hold meaningful design values. It is unusual to interact with a computational device that takes something apart, but our findings show how –depending on the application– this concept makes users conscious of the finiteness of interaction bringing the latter to a more mindful state. We found that participants experience discomfort when unraveling, wanted to "save some for others", and that the design of the textile display can either create urgency and excitement to reveal the end result or induce guilt. We see this *Unraveling* project as furthering explorations in how art practice

can inform HCI research [10, 80, 81] in general and textiles and wearable applications in particular [41, 89].

Acknowledgments

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