Expressive Clothing: Understanding Hobbyist-Sewers' Visions for Self-Expression Through Clothing

Sabrina Lakhdhir
sabrinalakhdhir@uvic.ca
University of Victoria
Victoria, BC, Canada

Charles Perin
cperin@uvic.ca
University of Victoria
Victoria, BC, Canada

Sowmya Somanath
sowmyasomanath@uvic.ca
University of Victoria
Victoria, BC, Canada

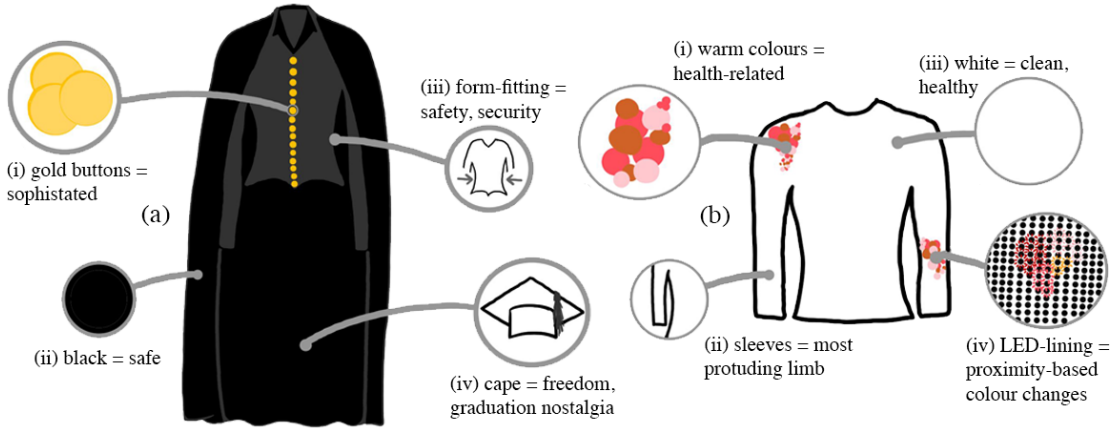


Figure 1: Two participant-created examples of expressive clothing: (a) a personal reflection about transitioning from a student role into a professor role using encodings such as *color* and *garment structure*, and (b) a public, dynamic representation that visualizes the spread of COVID-19 using encodings such as *electronics*, *garment structure*, and *color*.

ABSTRACT

Researchers have found that hobbyist-sewers seek to create new or adapted clothing designs that foster self-expression through communicating ideas, opinions and emotions. Although existing sewing technologies enable designing new patterns, they focus only on the technical aspects of pattern drafting and not on how information can be expressed. To address this gap, we conducted a qualitative diary study with 12 hobbyist-sewers to better understand how they envision creating expressive clothing. From our analysis of the 24 expressive clothing sketches participants created and participant interviews, we identified i) five distinctive multifaceted approaches participants used for self-expression; and ii) four challenges participants identified from their design process. Informed by these insights, we present a set of implications for the design of future technologies that can better support hobbyist-sewers in designing and creating expressive clothing.

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05
https://doi.org/10.1145/3613904.3642338

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

self-expression, communication, e-textiles, fashion and clothing, hobbyist-sewers, design, storytelling, tools for storytelling

ACM Reference Format:
Sabrina Lakhdhir, Charles Perin, and Sowmya Somanath. 2024. Expressive Clothing: Understanding Hobbyist-Sewers' Visions for Self-Expression Through Clothing. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3613904.3642338

1 INTRODUCTION

Clothing serves as an expressive medium facilitating the communication of ideas, opinions, emotions, and cultural narratives [11, 47, 59, 75, 76, 88]. Within this context, the practice of creating clothes as a hobby has existed for a long time [88]. Individuals, ranging from professional designers to hobbyists [88], engage in the art of sewing clothes as a means of personal expression [11, 47, 59, 75, 76]. Over centuries, the evolution of technology, including looms, programmable machinery, and contemporary software such as pattern drafting tools [5, 69, 98, 122], simulation tools [8, 127], and brainstorming and showcasing tools like Etsy, Pinterest, and Instagram,

has played a pivotal role in scaffolding, and enabling people in making clothing [95, 125, 126].

Despite the wide array of tools available to the public, the primary emphasis within these technologies often centers on facilitating technical aspects of sewing clothes, such as pattern drafting [8, 127] and outcome visualization [5, 69, 98, 122]. As such, aiding the more creative facets of information communication and expression, such as exploring how forms, fabrics, or notions can be employed to enhance how concepts can be conveyed, or how modern elements like e-textile components could be harnessed to weave richer narratives are left out from tool design and deferred to individuals acquiring knowledge over time. In the existing literature on technologies for sewing-related activities, while e-textile constructionist kits [3, 4, 21] have been proposed to empower self-expression, there is limited understanding of how individuals can be effectively guided through the creative process of articulating their concepts and ideas. To fill this gap, in this research we focus on understanding how hobbyist-sewers want to express information through clothing, and identifying opportunities for designing new technologies to support such creative pursuits.

Hobbyist-sewers are individuals who enjoy sewing and engage in making clothes for a variety of purposes, like striving to express themselves [47, 59], making statements [88], and raising awareness about the world around them [11, 75, 76]. Researchers have found that hobbyist-sewers aspire to go beyond mere replication of clothing patterns, aiming to conceive, materialize, and wear clothes that convey personal [11, 47, 59, 75, 88] and social narratives [11, 47, 59, 75, 76]. In the public sphere, there are numerous examples of such expressive clothes [10, 29, 30, 51, 71, 103], demonstrating this inherent desire to communicate messages through clothing. Within HCI, understanding the concept of communicating information through clothing presents implications such as enabling the development of connections with spectators [32, 55], serving as extensions of oneself, one's ideas, and one's identities [55, 56], and augmenting and impacting one's experiences and interactions [32, 51, 55]. Inspired by this, we conducted a qualitative study, seeking to understand how hobbyist-sewers envision conveying information via the medium of clothing. Our study probed into our participants motivations that informed the type of expressive clothes they wanted to create, their preferences for the types of materials they wanted to utilize, spanning conventional fabrics and notions to contemporary e-textile elements, and how they wanted to communicate information and express themselves.

To gather data, we used the diary method [17, 26, 36, 45] and asked our participants to sketch prototypes of expressive clothes for conveying personal and societal concepts. We also conducted semi-structured interviews to better understand the rationales that shaped participants' ideas. We qualitatively analyzed 24 sketches and 12 hours of interview transcriptions, to learn about the multifaceted approaches adopted by hobbyists to design and create expressive clothes.

The contributions of this paper are twofold: firstly, we describe five distinctive approaches that hobbyist-sewers took to express information using clothes as a medium, including the challenges participants envisioned encountering if they were to sew these clothes in real life. Secondly, we discuss a set of implications for the design of future technology that can address the identified challenges and foster an enriched creative process in the domain of crafting expressive clothing.

2 BACKGROUND AND RELATED WORKS

Our research draws on works that aim to explore fabric as a medium for communication.

2.1 Past and Current Practices of Information Communication with Fabrics

The clothes we wear are often meant to be telling of a part of who we are [47, 59, 88], or are worn with the hopes of provoking certain feelings or emotions in ourselves and in those around us [11, 47, 59, 75, 111]. By studying examples, Martindale et al. and Goffman determined that clothes are often embedded with social meanings such as messages about gender, social roles, and group membership [47, 75]. Similarly, Kaiser and Goffman discussed how an individual's clothing is one of the fundamental ways in which impressions about them are formed, including how individuals judge one another [47, 59]. Through artifact analysis, Banim et al. found that clothes in the fashion industry innately embody some meaning (e.g., wearing a suit often leads to perceptions of being smart; wearing clothing by designer labels symbolizes status) [11]. From their analysis, they also discuss how individuals often perceive that they must select clothing from this already defined industry, leading to the clothing's innately embodied meaning being transferred onto the individuals wearing them [11]. Prior literature within HCI has also more broadly discussed the communicative nature of clothing, highlighting how it is a medium used for self-expression [19, 55], supports communications with spectators [32, 55], and enables the development of communities [19, 32, 55].

At a more social level, initiatives such as *Threads*, a mobile sewing circle, have shown how the use of a sharing circle can encourage communication via self-created clothing and shared lived experiences [73]. This highlighted triggers of reflection and conversations, which led to psychological and social benefits for those involved. Fashion has also recently been used to understand storytelling as it relates to fashion technology on the runway [90], as well as a medium for raising awareness about social issues [30, 84, 89, 128].

When considering costume design, Tanenbaum et al., Lamerichs, and Goffman discuss the role costumes play in altering or formulating the character an actor portrays [47, 67, 109, 110, 112]. In both theater and cosplay, costumes allow individuals to transform into the character they are portraying [67, 109]. This demonstrates the abilities for clothes to carry and portray meaning, whether it be to the wearer or to an audience.

2.2 Audiences For and Purposes Behind Information Communication with Fabrics

Throughout history, stories have been told using fabric-based mediums for a variety of purposes [88]. For example, to pass knowledge and stories to new generations within a culture or community, *huipils*, as worn by the Guatemalans, share cultural folklore and stories through the inclusion of embroidered imagery on panels that make up a single item of clothing. *Huipils* were often created for the purposes of educating one another, passing down knowledge, and demonstrating group associations [88]. Clothes have also been

used for self-expression or demonstrating belonging. For example, many Africans wear *kente* cloths, a cloth with a distinctive and recognizable print, to convey a sense of pride and their relationship to their origin and background [88]. Traders, dressmakers, and tailors in Europe in the mid 1900's also used clothes as a medium for broadcasting information by using their individual creations to complement one another, thereby formulating and circulating collective statements and knowledge [28].

Within HCI, Bolesnikov et al. conducted a qualitative body mapping study with queer populations to understand their perceptions towards wearables, generally, and found that queer expression was a particular desire that remained somewhat unfulfilled [19]. However, they highlight how the personalization of aspects of wearables, such as where they are worn, what they look like, and what types of information they convey and to whom, can greatly impact someone's desire to use them [19]. Similar findings are discussed when considering social wearables - devices that augment co-located experiences - for more general populations [32, 55]. From these examples, we gain insights regarding how fabric-based mediums can be used for communication with varied purposes, and towards different audiences.

2.3 Encoding Mechanisms for Information Communication

In *Through the Wardrobe* and *The Fabric of Civilization*, Banim et al. and Postrel, respectively, discuss the various methods by which meaning is encoded onto, or portrayed by clothes [11, 88] through the exploration of multiple examples. In some cases, clothes inform others about the wearer. For example *traje* are traditional Guatemalan ensembles [88] that are recognizable through their bright colors and prints, and can therefore tell viewers about the background and culture of the wearer. In other cases, clothes are meant to portray a particular message. For example, wax printed cloths worn in Africa – *ankaras* in the West and *kitenges* in the East [88] – often convey their region of origin by showcasing local stories through the use of imagery and icons. Banim et al. further discuss the difference between being impacted by the innate meaning embedded in clothing, versus the consciously embedded meaning that is added into clothing by their wearers or creators [11]. They discuss encodings in a general sense, where color is commonly used to convey emotion on clothes, while garment shape or structure can represent professionalism, or a lack thereof [11].

Within the scope of HCI, patched textiles (i.e. visibly mended or repaired textiles) have been explored as a way of introducing encodings onto cloth [15, 57]. While patches themselves do not serve as encoding mechanisms in this particular case, the individuals wearing patched textiles often value the personalization and uniqueness that such visible mends bring to their clothes through the introduction of different elements like color and pattern [57].

When it comes to dynamic or interactive encoding mechanisms, the HCI community has recently pushed towards exploring interactive textiles (for example, interactive embroidery [52] and shape-changing fabrics [121], among others [26, 62]), and introducing toolkits for low-barrier of entry wearable electronics [1, 2, 21, 44, 46, 58, 60, 80, 81, 85, 115]. Devendorf et al. explored the integration of sensing and actuation components into fabrics and weaving in order to create textiles that can respond to touch [38], and further, integrated sensors to create *A Fabric that Remembers* – a fabric that can remember where and how it was touched [34, 37]. Similarly, Posch discussed the creation of textile books, making use of snaps, buttons, zippers, and other textile accessories for interactions such as attaching, opening, moving, and rearranging, as well as making use of electronically enhanced pop-up elements such as activating sounds, color changes, vibrations, or movement when touched [87]. Interactive textiles and wearable toolkits present an avenue by which primarily traditionally static encodings (i.e., color and pattern for example) can become interactive and highlight an opportunity to leverage dynamic encoding mechanisms, whether they are also tactile or not, in future expressive clothes. Moving beyond interactive textiles, on-body robots as wearables have also been explored more recently as a mechanism for collecting and communicating information beyond the wearer's body [35, 96].

Each of these examples and discussions demonstrates the breadth of encoding options that are available when using textiles as an interface for communication. Like other mediums, textiles allow for both, static and dynamic encodings, as discussed above. However, unlike other mediums such as paper, textiles present affordances such as how they drape and different textures [7, 47, 88]. Such affordances and options with additional characteristics provide a wide range of approaches towards encoding various information-related attributes such as the audience it is meant for, the purpose behind communication, and the type of information being communicated.

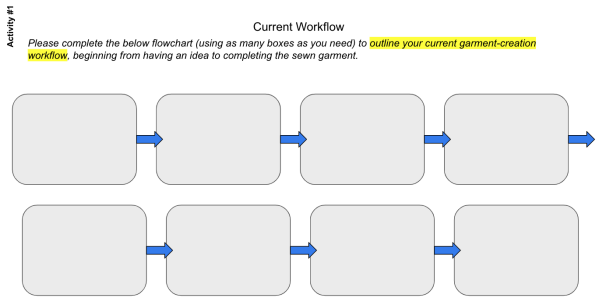
Through this project, we aim to understand desires and approaches towards communicating information via clothing. In particular, we want to understand how hobbyist-sewers envision their clothes containing embedded meaning, what encoding mechanisms they employ for this purpose, what information they choose to portray, why they choose to portray that, and what overarching characteristics can be identified amongst different types of information being communicated. Building on the body of work discussed in this section, we continue to explore the use of different methods for communicating meanings and messages. We expand on current findings by aiming to understand the motivations behind using specific methods to communicate information through clothing.

3 METHODOLOGY

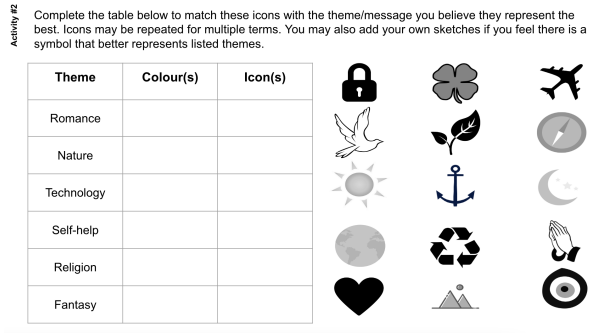
To better understand hobbyist-sewer's thoughts and ideas regarding designing clothes that communicate information, we conducted a remote five-day three-phase study. We employed semi-structured interviews on the first and fifth day, and asked our participants to collect information using an activity workbook provided to them with a set of prompts and questions (see Figure 2).

3.1 Study Procedure

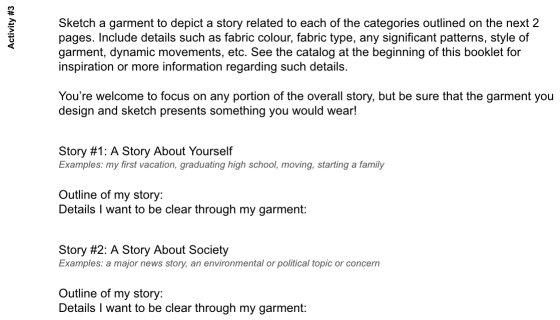
Our study was broken into three phases: a pre-interview, an independent activity workbook, and a post-interview. Our study procedure was inspired by other, similar design and diary studies that collected design ideas from participants using workbooks [17, 27, 36, 45] in which participants created sketches, annotated them with some additional details, and then engaged in an interview to answer questions related to their ideas, design rationales, and overall impressions regarding the concept (i.e. communicating via clothing).



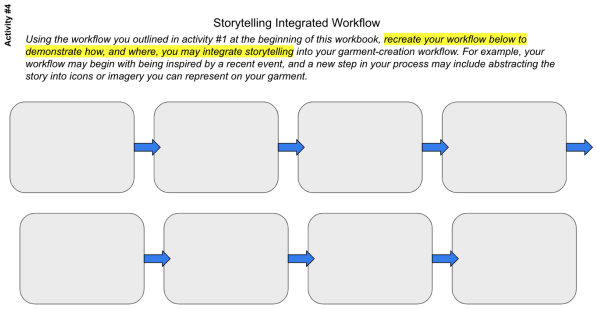
(a) Activity 1 asked participants to outline their current sewing workflow.



(b) Activity 2 asked participants to map textual themes to visual representations.



(c) Activity 3 asked participants to sketch two expressive clothing designs.



(d) Activity 4 asked participants to outline an updated sewing workflow that considers the inclusion of communicating information through designs.

Figure 2: The activities that participants were provided in the workbook.

We opted for a sketching activity over a physical making activity for pragmatic reasons surrounding time frame and available resources. Given the role sketching and doodling already has in sewing activities [49], we considered it to be a reasonable pathway for achieving our goals. This was later validated when 7 out of 12 of our participants explicitly noted sketching being part of their regular sewing workflow. The interactions between the participants and the researcher (i.e., pre- and post-study interviews) were 1-1 and all participants underwent the same procedure. The study procedure was approved by our university ethics board.

Phase 1: pre-interview. During this phase, participants were asked to share their sewing experiences and background in the context of communicating information through clothes in a semi-structured interview. Participants were asked guiding questions such as *"How do you make your creations your own?"*, *"Do you, or have you, considered communicating information through your clothes?"*, and *"Is this a practice that is of interest to you?"*. Participants were also encouraged to elaborate as they felt necessary [14]. The goal of the pre-interview was to understand the user's level of knowledge of, and experience with sewing clothing, and gauge any initial thoughts or experiences regarding the idea of communicating with self-sewn clothing.

Phase 2: independent activity workbook. During this phase, participants were asked to engage with a workbook that contained four activities (Figure 2) related to their own methods of sewing and communication, for a minimum of 30 minutes per day over a three-day period. During this period, participants were welcome to ask the research team questions via email if they faced any confusions. The three-day period was selected to give participants time to engage with, and reflect on, each of the activities presented to them [25]. Using the workbook approach also allowed us to gather information regarding participant workflows and processes while they were immersed in their sewing environments, whereas having a researcher present in real-time during the data collection process could have influenced or hindered their workflow [18, 24]. Participants later discussed how some activities required them to spend some time thinking about them before returning to, and completing them, thus validating our decision to give participants more time to engage with their booklets. The goal of the workbook was to gain insight and reflection into participants' existing processes, while also encouraging them to explore a design space that was outside of their comfort zone. The workbook and its associated set of activities are described in the next subsection and a copy can be accessed via supplementary materials.

Phase 3: post-interview. During this phase, participants discussed the activities that they had completed in the workbook over the course of the independent study phase and reflected on how

they could envision technological tools supporting their design process. This was once again done through a semi-structured interview where a set of predefined questions was used to begin conversations, and participants were encouraged to expand and reflect upon their experiences with the workbook [14]. For example, we asked participants to walk us through the idea they wanted to convey in the article of clothing, and the design decisions they made accordingly in order to depict that idea on their design. Similarly, participants were asked to reflect on whether they could see themselves wearing their designed clothes in public, why they chose to communicate their selected idea, and how they imagined using technology in their overall process. The goals of the post-interview were 1) to gain an understanding regarding the participant's openness towards the concept of communicating information through the clothes they create after having had time to reflect on the idea, 2) to understand what encodings and thresholds (i.e. at what point they draw the line for various practices such as their willingness to share personal stories or personal imagery) they primarily incorporated in such expressive clothing designs, and 3) to gain insight towards key points in their workflows where technology may be able to support their design process.

3.2 Workbook

Our workbook consisted of a set of four activities (see Figure 2), with each activity leading the participant to consider the idea of communicating with clothing on a deeper level. Below, we describe each activity and its rationale.

Activity 1: The goal of the first activity was for participants to identify the various stages they currently go through when approaching a sewing project such that it would provide a baseline for future reflection. This activity asked participants to define and reflect on their current sewing workflow (see Figure 2a). Upon understanding their workflows, we could then apply that knowledge towards understanding how their process changed when communication was incorporated, and how and when technological tools could provide benefits.

Activity 2: Often, specific encodings such as images, colours, and symbols are employed to communicate information visually [47, 54, 57, 88, 97]. To familiarize our participant's with this notion, the goal of the second activity was to encourage participants to begin thinking about how themes or higher-level genres could be externalized using encodings such as shapes, icons, and colors [54, 97] (see Figure 2b). To get them warmed up, we asked participants to engage in an example wherein they mapped a set of icons and colors to a predefined set of themes (romance, nature, technology, self-help, religion, fantasy). The presented set of themes were selected based on common contrasting genres that exist within writing and literature [116]. We chose themes from writing and literature to build off ideas of storytelling such that the themes would be familiar, and would likely spark instant thoughts for mappings.

Activity 3: The goal of the third activity was to understand how individuals envision communicating information via their clothing, and what encodings they use to do so. This activity asked participants to engage in sketching activities wherein each sketch they created reflected an expressive item of clothing [24] (see Figure 2c). This activity consisted of two parts. The first part prompted participants to select a personal idea or concept (e.g., a vacation, a favourite memory, graduation, etc.), and map it to an item of clothing of their choosing, in any manner of their choosing. The second part followed the same structure, but was about society (e.g., something related to culture, the environment, current events, etc.). We decided to include both personal and more public-facing prompts as they are the two main high-level purposes behind storytelling and information communication broadly [93, 111]. Participants were given the choice to select any type of encoding they considered meaningful. To give participants an idea of what might be possible and informed by literature [20–22, 88], we included examples of not only traditional, fabric-based encodings such as color, icons, and patterns, but also included more contemporary encoding mechanisms such as electronic modules and smart materials such as motors and LEDs. Looking at participants choice of encoding mechanism allowed us to gain insight towards what information participants want to communicate through their clothes, who their intended audiences would be, what their intended purposes would be, how they abstracted textual ideas, specifically, the mappings that they used, and where and when they would opt to select particular encodings.

Activity 4: The goal of the fourth activity was to provide a comparison point against Activity 1 from which we could understand where and how participants' sewing workflows changed (if at all) in order to incorporate a communication aspect. This activity asked participants to revisit their sewing workflows from Activity 1, and adapt them accordingly such that it supported the incorporation of communication (see Figure 2d). Finding these points in the workflow allows us to gain insight towards where in the process technology could provide support.

3.3 Participants

Fifteen participants who self-identified as hobbyist-sewers were recruited, of which twelve participants completed our study (all women; aged 21-59, m=32; see Table 1). We recruited our participants from advertising our study details on a variety of sewing-related social media groups and local sewing and fabric stores. Our participants had prior experience sewing clothes such as t-shirts, leggings, skirts, dresses, slippers, and jackets. They all mentioned primarily sewing for themselves. Participants were compensated with a $30 gift card for their help with our study.

3.4 Data Collection

Participant data was collected in the forms of audio- and video-recorded pre- and post-interviews, a demographics questionnaire, and a digital workbook that consisted of sketches and completed activities as described above. This led to the collection of 12 hours of recordings and 12 workbooks, each consisting of two sketches (24 sketches in total), two workflow definitions (24 in total), and one conceptual mapping (12 in total).

3.5 Data Analysis

We took a two-pass approach to analyze the gathered workbook and interviews data. In the first pass, we open-coded [9, 79] the data through three rounds of iterative coding. We coded for the components that constituted the information being conveyed such

Participant Number	Age	Years of Experience	Profession
P1	34	6-8	Graduate Student
P2	30	3-5	Graduate Student
P3	29	11+	Graduate Student
P4	25	3-5	Makeup Artist and Professional Trainer
P5	59	11+	Retired
P6	40	3-5	Musician
P7	31	11+	Instructional Designer
P8	47	3-5	Project Manager
P9	41	6-8	Operations Manager
P10	29	3-5	Graduate Student
P11	42	11+	Office Administrator
P12	21	11+	Undergraduate Student

Table 1: Overview of study participants.

Category	Concept	Properties and Dimensions
Stories and Storytelling	Interpretation *What is being communicated through the garment and to who?* *What emotions are present in the garment? Who is the audience? What is the purpose of the garment?*	Garment purpose is spreading a general knowledge message
		Garment purpose is an educational tool
		Garment purpose is data tracking
		Garment purpose is providing comfort or reassurance
		Garment purpose is self-care
		Garment purpose is self-expression
		Garment purpose is gaining an understanding of one another or the world
		Garment purpose is simply aesthetics

Figure 3: A subset of concepts, properties, and dimensions belonging to the *Stories and Storytelling* category.

as contextual information, if there were any specific characters in the information being communicated, and the overarching theme of the information being communicated. From this coding process we developed a code book of 263 codes (an example shown in Figure 3) and gained an overview of how our participants envisioned communicating information through their clothing. Then we collaboratively discussed the codes to develop a set of themes related to the multifaceted approaches participants took to develop expressive clothing (an example shown in Figure 4).

3.5.1 Positionality Statement. All three authors were involved in the data analysis. We have a range of experience when it comes to sewing, designing clothing, and HCI research. One author has never sewn or designed clothes, and has over ten years of information visualization research experience. The other two authors have prior sewing experience (three years and five years), and are experienced HCI researchers (over ten years and four years, respectively). None of the authors have previously developed technologies for sewing or its related activities.

4 RESULTS

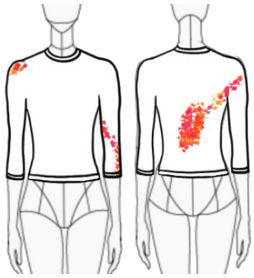
Overall, we found that all our participants were interested in embedding meaning into the clothes they created. More specifically, we gained rich insights into how individuals envision the concept of information communication on clothing. Informed by this understanding, in this section we expand upon a set of five approaches that we identified our participants employing when designing expressive clothing. We also discuss a set of challenges they faced during this process.

4.1 Clothing-based Communication Approaches

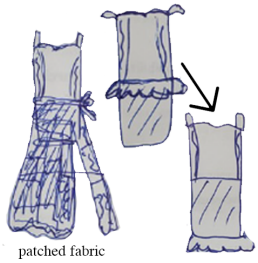
From our data analysis, we identified a number of linkages between how hobbyist-sewers wanted to communicate information on their clothing (i.e., using what encodings), what information they wanted to communicate, and why they wanted to communicate it. Based on these linkages, we organize this first section of our results into a set of unique approaches through which participants expressed their ideas, emotions, opinions, and thoughts using clothing. These approaches were named and characterized based on attributes our participants highlighted while explaining their examples. In some cases, the sketches demonstrated the application of multiple communication approaches. However, aiming for brevity and narrative clarity, we first describe such examples in the category of communication approach we think it primarily exemplifies. In this section, we first describe the individual approaches, and then briefly summarize the examples that apply multiple communication approaches.

Phenomena	Conditions/Context (codes)	Action/Interaction Strategies (codes)	Consequences (codes)	Participant Examples
Evolutionary Storytelling *Telling a story that builds on the garment overtime, or changes as data changes*	Inspired from past experiences User sharing a somewhat personal message through the garment	Garment purpose is data tracking/Garment purpose is self-expression/Garment purpose is simply aesthetics	The physical garment doesn't make sense when simply viewing it	P13, Sketch 1 P3, Sketch 2
	The story is based on user data but is not interactive	Plot is encoded with color, plot is encoded with pattern, plot is encoded with fabric type, etc.	The physical shape of the garment respects natural body movements Story influence material choice/material choice defines the story that is being conveyed	
	Story audience is the public	Participant struggled with displaying a complex story on the garment Struggled to connect practicality with self-expression Participant felt the process led to increased reflection and introspection on the garment design	Participant feels they lack the necessary sewing skills to successfully undergo this process on their own	

Figure 4: An example of one of our axial codes which enabled categorization of expressive clothing creation approaches.



(a) P3b: a proximity sensor based shirt to demonstrate the spread of COVID-19.



(b) P7b: a convertible patchwork dress to spread a message about textile waste and the effects of the fashion industry on the environment.

(c) P10a: a pair of pants that showcase all the hikes the participant goes on - each time they go on a hike, they add an embroidered or ink trail line on the hem of the pants.

Figure 5: Examples of expressive clothing that demonstrate the *evolutionary* design approach.

4.1.1 Evolutionary. From our analysis, we found three sketches (see Figure 5) that demonstrated an approach wherein an idea or concept was conveyed over time. These designs often encoded social, or public, information about current events through encodings such as *electronics* and *fabric type*. This strategy was commonly observed in the cases of expressive clothes that were meant to change. Informed by these characteristics, we name this approach *evolutionary*. *Evolutionary* clothes were observed using two techniques: *manual evolution* and *automatic evolution*.

Manual evolution can be seen in cases where data is manually encoded onto the article of clothing to develop information over time as it is worn and used. Two examples of *manual evolution* were observed in our participant's sketches. One example is P7's dress where the *garment structure* and *fabric type* (i.e., jean scraps) are used to communicate the idea of sustainable fashion. In this example, the entire structure changes to evolve the concept (e.g., *"The idea is that it's convertible. So it's never the same dress twice, there's all these little pieces that you can mix and match."* [P7]; see Figure 5b). A second example is P10's hemmed pants where the article's visual appearance changes as information is collected and added to it (e.g., *"I could put that like onto fabric and I think, as they accumulated and you had like dozens of those lines..."* [P10]; see Figure 5c). P10's hemmed pants demonstrates the use of *decorative notions* (particularly embroidery), as an encoding for an evolutionary dataset with the intention of record-keeping and demonstration.

Automatic evolution was seen in just one design, where the information embedded in the item of clothing changed over time through interactions with other individuals and the wearer's surroundings (see Figure 5a). In this example, information was encoded using *electronics* for dynamicity and *color* for awareness and relation (e.g., *"as the day continues for example, they continue to kind of like spread through the garment to symbolize and certify the spread of the virus"* [P3]; see Figure 5a).

4.1.2 Minimalistic. From our analysis, we found seven sketches (see Figure 6) that demonstrated an approach wherein simplistic information was conveyed through the inclusion of fewer, and more subtle encodings. These clothes were meant primarily for self-expression, and encouraged the user to incorporate subtle encodings as a way of embedding details about themselves onto their clothing. These designs encoded both personal and public information about current events or personally-relevant experiences that were meant for others to recognize through encodings such

(a) P4a: a design about self-love and personal growth.

(b) P6a: a dress shirt encoding character that demonstrates the participant's love for animals.

(c) P8a: a muted (color and pattern-wise) shirt to convey emotions about a potential promotion and needing to dress more professionally.

(d) P8b: a jumpsuit expressing emotions surrounding stepping out of your comfort zone and trying new things.

(e) P9a: a pair of pants with semi-colon grommets to represent pauses or struggles in life.

(f) P9b: a hoodie that incorporates recycled masks to demonstrate the feelings of comfort and protection they provide.

(g) P12a: a skirt encoding character that reflects the participant's Dungeons and Dragons character - a strange, yet colorful and spirited personality.

Figure 6: Examples of expressive clothing that demonstrate the *minimalistic* design approach.

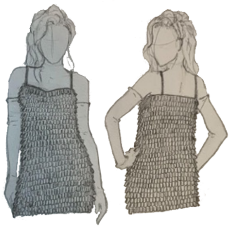
as *garment structure* and *decorative notions*. Informed by these characteristics, we name this approach *minimalistic*.

Two examples can be seen in P8's designs wherein while they have integrated a series of encodings such as *garment structure* and *color* to provide subtle context of their concept, the clothes themselves looked like everyday wear items that did not contain any embedded meaning (e.g., *"something that's more subtle or more normal... I don't want it to be obvious"* [P8]). In their particular examples, they used *garment structure* and *color* to depict emotions about a pending job promotion (see Figure 6c), and encodings such as *garment structure* and *decorative notions* to depict emotions about stepping out of their comfort zone (see Figure 6d).

4.1.3 Conversation-Starter. From our analysis, we found twelve sketches (see Figures 5a,b and 7) that demonstrated an approach wherein clothes intentionally caused confusion or presented controversial opinions in order to encourage audience engagement. These designs typically communicated information about ongoing current events and aimed to raise awareness. Therefore, these designs often used more elaborate or obvious encodings in order to catch attention while maintaining a static nature through encodings such as *pattern*, *color*, and *decorative notions*. This strategy was commonly observed in the cases of more public-facing expressive clothing. Informed by these characteristics, we name this approach *conversation-starters*.

For example, P7 intentionally created a patchwork dress to abstractly represent sustainable fashion in order to intrigue viewers and encourage their engagement with the wearer (e.g., *"I would like people to see it and be like, why, when you see it, why is it like that."* [P7]) through encodings such as *fabric type* and *garment structure* (see Figure 5b). Similarly, P3 incorporated interactive, proximity-based encodings in order to create a shirt containing state changes to catch viewer's interests and inform them about the spread of COVID-19 (e.g., *"...changes and it kind of gets your attention"* [P3]).

4.1.4 Allusive. From our analysis, we found five sketches (see Figures 6a,c,e, and 8a,b) that demonstrated an approach wherein individuals' feelings or emotions were embedded through smaller, less noticeable details. These clothes employ deliberate subtle details that, while remaining unnoticed by a broader audience, are known about and act as reminders for the creator and wearer. These designs often incorporated encodings such as *electronics*, *color*, and *garment structure*, with the end goal of self-care, self-help, and providing comfort to the creator through the making process, and were meant primarily for their own knowledge. This approach was commonly observed in the cases of more personal expressive clothing. Informed by these characteristics, we name this approach *allusive*.



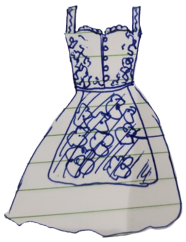
(a) P2b: a 1920's style cocktail dress made out of cigarette butts with dynamic LED lighting underneath to mimic wildfires and shed light on the cause of many wildfires.

(b) P4b: a jumpsuit highlighting how everything in the world stems from nature.

(c) P5a: a jacket encoding setting by showcasing the participant's new home following a move.

(d) P5b: a tunic that raises awareness about consequences of the logging industry.

(e) P6b: a dress that raises awareness about climate change using regional climate strips.

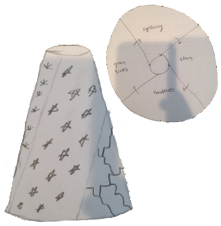


(f) P7a: a dress that merges the participant and their partner's backgrounds - a traditional German dress with Mexican embroidery.

(g) P10b: a thrifted jacket with a personalized back panel to raise awareness about climate change.

(h) P11a: a jacket visualizing the participant's feelings towards going out during the pandemic.

(i) P11b: a hoodie to raise awareness about the #MeToo movement.



(j) P12b: a skirt inspired by a song about the course and evolution of human history.

Figure 7: Examples of expressive clothing that demonstrate the *conversation-starter* design approach.

For example, P3 created a coat that was representative of their transition from a PhD student into a professor, where they incorporated a series of encodings such as using the *colors* black for safety and gold buttons for sophistication. They reiterated how each of these design choices was intentional, however, they aimed to make the encodings either not understandable by public audiences, or not noticeable altogether (e.g., *"all of my design choices were very deliberate [...] there are clear emotions for me behind all of them or clear reasons"* [P3]; see Figure 8b). Similarly, P9 created a pair of pants where the sole encoding was on the drawstring grommets to ensure their emotions were embedded into the article in a more intimate, private manner (e.g. *"I'd rather wear something that most people would look at and not even realize that there was any sort of meaning behind it."*[P9]; see Figure 6e).

4.1.5 Understanding. From our analysis, we found five sketches (see Figures 5c, 6c,g, and 8c,d) that demonstrated an approach wherein clothes aimed to support or increase what viewers understood either about the creator, others, or of the world. These designs primarily encoded information through *decorative notions*, and communicated both personal and public information about topics such as how things work and how things could be perceived. Informed by these characteristics, we name this approach *understanding*.

For example, P1 created an algorithmic shirt to help them visualize and understand the cookies that are tracked about them on various sites (see Figure 8c). This shirt showcases personal data in an aesthetically pleasing manner, making it understandable for the individual it is relevant to, but like a piece of abstract art or a statement to others viewing it. Similarly, P12 designed a pair of pants that visualizes their game character, thereby providing a method by which viewers can attempt to relate to the character (e.g. *"something that shows these key characteristics "* [P12]; see Figure 6g).

4.1.6 Applying Multiple Communication Approaches. From our analysis we identified seven examples that applied more than one communication approach (see Figures 5 and 6a,c,e,g) .

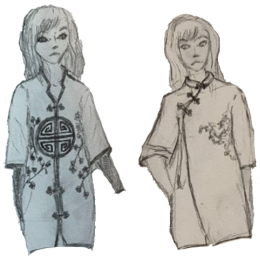
Figures 5a and 5b show examples of designs that apply the *evolutionary* and *conversation-starter* communication approaches. These approaches can be seen through the inclusion of dynamic encodings that were geared towards encouraging audience engagement.

Figure 5c shows an example of a design that applies the *evolutionary* and *understanding* communication approaches. These approaches can be seen through the inclusion of subtle, yet dynamic encodings that showcased information that, through engagement, could help audiences learn something about their wearer.

(a) P1a: a representation of the participant's emotions regarding a miscarriage.

(b) P3a: an emotional reflection about the transition from a PhD student into the role of a professor.

(c) P1b: a dynamic shirt demonstrating the tracking of cookies by various sites online.



(d) P2a: a dress encoding character and setting that reflects the participant's favourite trip.

Figure 8: Examples of expressive clothing that demonstrate the *allusive* (a,b) and *understanding* (c,d) design approaches.

Figures 6a, 6c, and 6e show examples of designs that apply the *minimalistic* and *allusive* communication approaches. These approaches can be seen through the inclusion of subtle encodings that are inconspicuously integrated onto the garment so as to embed information, but remain unknown to audiences.

Figure 6g shows an example of a design that applies the *minimalistic* and *understanding* communication approaches. These approaches can be seen through the inclusion of deliberately placed *decorative notions* that maintain subtlety while also ensuring they guided audiences towards some level of understanding regarding the encoded information.

4.2 Challenges Faced While Designing Expressive Clothing

Through our study, participants also highlighted a set of challenges that they faced when tasked with designing expressive clothing. These challenges are largely related to different aspects of encoding mechanisms, as that is the main consideration when designing expressive clothing. In this section we expand on these challenges, and later in this paper we discuss a series of implications, guidelines, or approaches that might be employed to help hobbyist-sewers overcome these challenges when designing expressive clothing.

The first challenge noted by participants was related to determining which mappings were best suited for their topic and idea of choice. P3, P4, P5, P6, P7, P8, P9, and P12 mentioned how mapping galleries might benefit their process (e.g., *"different examples of what these different, you know, fabrics and colors and things like that can convey"* [P3]), as well as how receiving automated suggestions for encodings based on user-chosen themes might simplify their visualization approach (e.g., *"some sort of symbolism bank [...] if you had an idea but you weren't sure how to do it, you could look it up and then it would show you"* [P9]). They imagined these to be beneficial for determining recognizable encodings (P8) and ensuring they were portraying accurate meanings (P5).

Second, P3, P4, P5, P6, P10, and P11 noted that visualizing their designs can be a challenge at times when relying on sketching and physical materials. This was of particular importance when the encodings of *fabric type* or *garment structure* were used, due to the nature of fabrics where different types drape differently, or complement one another differently. P6, P10, and P12 discussed how they struggle to visualize the transition from a 2-dimensional sketch to a 3-dimensional article of clothing, while P11 mentioned the advantages of being able to visualize a design when it is placed on a human figure. Some participants (P3, P7, P11, and P12) discussed creating mock-ups of their designs before cutting into their real fabric as an attempt to simulate how the fabric would drape, and how the completed item would look. Further, three participants (P1, P2, and P3) identified the particular case of electronics-embedded designs, wherein visualizing multiple states of a motor or shape-memory alloy might become significantly more complex, and thus lead to states of frustration or confusion. For example, P1 reflected on their prior experiences stitching clothes that had "trains" (long fabric piece that is attached to the back of a garment and trails behind the wearer) (e.g., *"That's like quite frustrating and difficult to do in sketches I find, like, this is my, you know, the servos so the train is down, the servos so that train is now up, you have to sketch it like five times and that's kind of a pain"* [P1]).

Third, eight participants (P1, P2, P4, P5, P6, P7, P11, P12) noted that they currently use Pinterest as a tool for gathering ideas and inspiration for future projects. However, they discussed facing challenges when it came to combining their found ideas into a single, unique piece of clothing, and in organizing their workspace when using such search and ideation platforms. As such, these participants were interested in ways to combine various unique elements in order to create cohesive stories (e.g., *"now I'm like okay I have a story in my head, I have a picture over here, I'm feeling this in my heart, and outside it is happening like this. So, I would like [...] something where you could put everything in one place"*[P4]). Further, they speculated that simulations could help them visualize their designs (e.g., *"I could pretty easily pull the elements that are key to that story and then it was sort of difficult to translate them into something [...] it would have been helpful to have a tool that could do that part."* [P12]) or help them mix and match elements to visualize unique combinations for their given purposes (e.g., *"...you can just pick and choose from like a catalogue of tops and bottoms, [and] so you can mix and match, so you can see, and you can change the color, you can add the fabric"* [P6]). Generally, participants found

that this further extended to also considering how they could combine various elements to satisfy their vision while maintaining an aesthetically appropriate demeanor.

Lastly, P5, P6, P11, and P12 discussed a lack of knowledge regarding where and how they could create personalized encodings. For example, P6 and P12 required very customized prints for their proposed designs (see Figures 7e, 7j), but had very little knowledge of how to produce them themselves.

5 DISCUSSION AND IMPLICATIONS FOR DESIGN

Based on our findings, in this section we revisit each of the aforementioned approaches and challenges, and discuss implications for designing new technologies to support hobbyist-sewers in creating expressive clothing. While our results are based on participant's envisioned ideas rather than direct practice [83], we find that our insights are aligned with current practices seen in fashion and costume design [23, 31, 67, 109, 110, 112], and previously highlighted understandings in HCI research [6, 7, 19, 32]. Our communication approaches can serve as starting points, or methods of categorization, from which hobbyists can develop narratives and embed information onto clothing based on determining the audiences and purposes behind their desired communications. In this section, we organize our implications in the following order: 1) gathering inspiration and breaking down the information they want to communicate, 2) taking the individual parts of the information they want to convey and selecting appropriate encoding mechanisms, 3) thinking about how information can be organized aesthetically, and 4) avenues for producing expressive clothing. Our discussion focuses on breaking down the four challenges we identified and on drawing relationships amongst these four challenges and the five communication approaches that emerged from the study results. We also provide examples of how such implications can be applied to other industries like fashion, theatre, and costume design.

5.1 Gathering and Visualizing an Idea

From our study, we learned that our participants currently use online tools such as Pinterest and home-sewer blogs as avenues for finding project inspiration. While these existing tools enable sewers to gather a multitude of project ideas, they fall short of supporting sewers in collecting materials in a single location from which they can adapt aspects of them into their own designs. We also learned that based on these broader forms of inspiration, our participants wanted to convey information that varied in complexity. While some had more elaborate ideas, others had more specific concepts they wanted to convey. However, despite this variation in complexity, breaking down an idea to specific pieces of information that could eventually be encoded was a challenge. Sewing-related technologies can be designed to address this challenge.

Storyboarding [61, 100, 118], an approach commonly taken in film and writing, could be adapted to support the design of expressive clothing. This support could be twofold: by encouraging brainstorming and the generation of multiple ideas or options over time and by enabling visualization of multiple states. Our participants specifically discussed the benefits of being able to visualize multiple states of expressive clothes that incorporate programmable encoding mechanisms, such as those designed using the *evolutionary* or *allusive* design approaches, that may be more difficult to sketch manually, or track imaginatively. For example, the Illuminated Jacket [51] demonstrates an example of a jacket that engages with multiple inputs and outputs. Its designing required a gallery of sketches to highlight each of the different states it might embody for all such input-output combinations [51], illustrating the difficulty presented by such dynamic designs. Such challenges have also been found in costume and fashion design, wherein complex narratives are being conveyed through clothing (e.g., [31, 89, 90, 109, 110, 112]).

A related challenge to visualizing an idea was creating a representation of it. For example, some of our participants mentioned sketching some ideas such as conveying emotions can be difficult. To this end, adapting and proposing new tools, especially geared more towards hobbyist-sewers who include people with limited design skills, can be useful. Such a tool might aim to support expressing a concept or idea entry using a range of input modalities. Techniques from artificial intelligence, machine learning, and graphics can be leveraged to help convert inputs such as text-based data entry (e.g., journals written by the sewer could be used as input to create clothing representations that convey emotions or other semantic interpretations), rough sketches (e.g., rough sketches that a sewer can create could be used as input and improved upon algorithmically), or externally sourced materials (e.g., online found images could be used as an input to define a new clothing pattern and design) into clothing-based designs.

5.2 Determining Mappings Between Ideas and Encodings

From our study, we learned that the encoding mechanisms participants wanted to use varied for representing different types of information varied (i.e., they wanted to use *color*, *pattern*, *icons*, *garment structure*, *fabric type*, *electronics*, and *smart materials*). However, as discussed by our participants (P3, P4, P5, P6, P7, P8, P9, and P12), a corresponding challenge is in determining the best-suited mapping for a given concept or piece of information.

To address this challenge, there is no straightforward solution and therefore there is an opportunity for future technologies to explore different possibilities. At the basic level we think one approach towards supporting hobbyist-sewers in determining mappings could be providing users with avenues through which they can explore possibilities and in turn learn from those explorations to make appropriate choices. For example, an encoding could be selected based on some form of search and filtering system, wherein input keywords such as a specific theme (e.g., hiking) can be matched to examples of existing clothing, color palettes or visual representations that correspond to that specific theme. Such approaches are currently used in the domain of costume design wherein character outfits are often designed based on existing contexts in order to allow costumes to portray some level of information about the character to their audiences [23, 31, 67, 109, 110, 112]. For example, when portraying royalty, costumes often integrate details such as gold and silver notions, chains and cuffs, and richer fabrics such as leather and velvet [31]. Similar practices can be seen in fashion wherein designs, such as Orange Culture's Peacock Riot collection [30], use avenues like *color*, *embellishments*, and *silhouettes* to

design *conversation-starting* garments representative of isolation, dignity, and inclusiveness, as it relates to social unrest and protests in Nigeria [16]. As demonstrated by these examples, we envision such approaches being particularly beneficial towards applying the *conversation-starter*, *understanding*, and *allusive* communication approaches due to their increased use of encodings that are capable of embodying a range of attributes such as *colours*, *icons*, and *patterns*.

Similarly, for the particular encoding mechanisms of *garment structure* and *fabric type*, as most commonly used in the *evolutionary*, *minimalistic*, and *allusive* communication approaches, existing pattern drafting tools can be extended such that sewers can upload a pattern they have selected to create and easily alter that pattern by trying out different visual aspects of article shape, such as necklines, sleeve types, and hemlines. Such changes, once applied to the article, can be further experimented with by applying to the virtual article of clothing other variables such as different fabric types and colors, and simulated for parameters such as movement [105, 127] to further encourage the exploration of mapping ideas to encodings and enable users to explore and apply multiple communication approaches as desired.

Encodings selection might also be impacted by the goals creators want to accomplish using their expressive clothing. For example, if the goal is to increase notice, encodings such as *electronics* could be suggested as possible materials for experimentation. In contrast, when designing expressive clothing which share more personal ideas or emotions, creators might want to experiment with more subtle encoding options such as using fabric properties.

Lastly, the approach taken (i.e., *evolutionary*, *understanding*, etc.) might also play a role in informing encoding selections. For example, when designing an *evolutionary* article of clothing, an individual could be given suggestions that prioritize an opportunity for growth overtime. This could mean opting to select articles of clothing that offer more surface area to support the addition of materials or information in the future, or using electronics that can more easily be activated and scaled over time. In contrast, when designing a *minimalistic* or *allusive* article of clothing, an individual could be given suggestions to experiment with removable encodings that can allow them to perform alterations in the future.

5.3 Designing for Aesthetics and Social Acceptability

While our participants were able to present complex expressive clothing designs, they highlighted that they struggled with selecting or combining unique encodings that would lead to an aesthetically pleasing item of clothing. We learned that while interested in wanting to use different encodings, a level of consciousness concerning the wearability [40, 41, 56, 78, 82, 104] and social acceptability [47, 59, 63, 64, 101, 106] of their final design remained (a topic also often discussed in wearables literature [39, 89]). For example, when designing clothing using the *evolutionary* or *conversation-starter* communication approaches wherein more public-facing information was being conveyed, we found that our participants were increasingly concerned with the design's aesthetics and noticeability, but were also increasingly willing to create more apparent communicative designs. This presents an opportunity for future technologies for supporting the design of expressive clothing while maintaining the item's aesthetic appeal.

Psychology studies have provided insights towards how people perceive encodings such as *patterns*, *shapes*, and *colors* [43, 72, 77, 107, 114, 117, 120]. Examples of the application of such knowledge in fashion can be seen in designs such as through Wanda Lephoto's Gaze collection [71], wherein encodings relating to *color*, *line patterns*, and *texture* are used to emphasize and express South African identities and past livelihoods [16]. Such knowledge can be leveraged to design new systems that offer guidance on using more subtle or obvious encodings to convey information while also meeting requirements for social acceptability. For example, drawn lines that can be translated to fabric patterns can express various feelings and emotions based on the shapes and movement that they can convey [117], and this has been commonly applied and analyzed in similar social-facing practices such as typography [53] and architecture [102].

Additionally, a similar guidance can be offered for the integration of electronic encodings which may impact wearability, washability [13, 68, 99, 113], durability [91, 99], and overall aesthetics. For example, the system may suggest options such as how and where to place the electronics as well as which type of electronics to use (e.g., biomaterials-based electronics [12, 65]). By experimenting through such options, sewers may also be encouraged to experiment with more contemporary types of encodings such as *electronics* rather than limiting themselves to traditional encodings such as *color*, *notions*, and *fabrics*.

Such guidance can also be further extended to help sewers explore interactions with electronics and other materials, which may contribute to addressing social acceptability, and can expand the encodings toolkit that is applied towards more subtle communications as explored in the *minimalistic*, *understanding*, and *allusive* communication approaches. For example, by helping design fabric-based interactions (e.g., [86, 87]), participants may find more creative ways to express themselves in appealing manners. These forms of guidance and exploration can further be extended to, and adapted for, all industries that involve sewing by collecting, demonstrating, and sharing practices towards embedding information in visually appealing and socially acceptable manners, such as through online craft, hobbyist, or professional communities.

5.4 Creating Personalized Encodings

In the results, we highlighted participants' desires to obtain personalized encodings such as custom-printed fabrics (as discussed by P5, P6, P10, and P11), particularly for designing *allusive*, *minimalistic*, *understanding*, and *conversation-starter* expressive clothes. The ability to create and acquire personalized encodings broadens the scope of what hobbyists can create, what information they can convey, the audiences they can interact with, and through what means they can do so. Within HCI research, we have seen examples of embedding augmented-reality (AR) markers onto garments as a method towards expressing more information through clothes in less obvious manners [50, 94], such as is the case for the *minimalistic*, *understanding*, and *allusive* communication approaches. This presents an opportunity for future technologies when it comes to supporting the design and fabrication of customized elements,

materials, or encodings, whether through techniques such as custom physical components, AR-markers, conductive elements, or dynamic encodings. Participants mentioned that this step can be difficult due to a lack of knowledge or expertise regarding available avenues for creation.

Many easy-to-learn and easy-to-access avenues exist for creating physical artifacts, which we have not yet seen used to their full extent in domains such as theatre [109, 112], and we think they can be extended to support the design of expressive clothing [21, 46, 57, 58, 80, 81]. By leveraging existing tools for fabrication such as fabric printing [42, 108, 119], CNC machines, 3D printers [108], and tools such as knitting and embroidery machines [33, 48, 70, 74], and developing tools corresponding to notion designs or clothing structure design, individuals can create their own personalized encodings and convey more particular information to their audiences. For example, CNC machines present opportunities for cutting and imprinting onto fabrics in particular shapes that support the creation of multi-layer fabrics, or the creation of cut-out decals. Similarly, with the use of moldable filaments and fabric-based printing, 3D printers can offer personalization avenues when it comes to creating unique buttons [108], soft printing [66, 108], and printing details directly onto fabrics [66, 108, 124].

In terms of designing future tools, supports can be created to make the design process more accessible to a broad range of designers with varying levels of design expertise. For example, for designers who are new to digital fabrication tools, future technologies could incorporate features that convert sketches into fabrication-ready files. Systems that offer tutorials on using a range of fabrication tools may also be helpful for those more interested in creating the necessary materials by themselves

6 LIMITATIONS

Our case study aims to understand the design of expressive clothing from the perspective of hobbyist-sewers, and our work offers insight towards five approaches taken by individuals when designing expressive clothing. We also highlight four challenges faced during this process, and discuss a series of implications that can guide creators in designing tools to support the designing process. However, our study also presents limitations that need to be considered in the future. First, while we provide insights into various wearability aspects of these articles of clothing (such as a user's willingness to wear it and a user's comfort level regarding what imagery or encodings they are comfortable sharing with more public audiences), our results could be more reflective of perspectives belonging to female-identifying sewers. Second, in our study, participants ages ranged from 21-59 years and while we did not observe or note any explicit mentions of age-related preferences regarding expressive clothing, specific demographic considerations such as age could be a factor to explore in future studies. Third, reflective studies, such as our own, have limits when it comes to evaluating practical metrics related to wearability and social acceptance [83]. Fourth, our study also did not consider cultural aspects that may impact the uptake of designing and wearing information-communicating clothing such as their integrations within different societies and customs. Finally, while we introduce novel communication approaches for designing expressive clothing, our set of five approaches is not exhaustive. Given the existence of expressive clothes, such as those we explored within the fashion [7, 47, 90], costume design [23, 31, 67, 112], and hobbyist-sewers industries [47], we assume these limitations do not impact the validity and usefulness of our current findings. However, we do think they offer some important avenues for future considerations that we discuss in the following section.

7 FUTURE WORK

Through this work, we hope to inform future projects regarding communicating information through clothing. As the next steps, it would be beneficial to consider a broader demographic of participants (across age, gender, socio-economic status, cultures and others) to gain a more comprehensive understanding of the design space for these articles. Informed by such an understanding, we see value in the development of software tools that would support the design and creation of expressive clothing by a wide range of audiences. For example, we believe our found approaches can be applied to industries that rely on sewing articles of clothing, such as costume design, to evaluate their validity and coverage because such industries already engage in the practice of embedding information into clothing. We also think that there is more to be uncovered in terms of how expressive clothing can be physically created (i.e., the process that is undertaken in order to translate a sketch or idea into a physical piece of clothing), communication approaches, support tool recommendations, and the introduction of dynamic encoding mechanisms such as electronics into the sewing workflow for novice tinkerers. We also envision the exploration of creating such clothes with a broader set of encodings. For example, traditional encoding mechanisms such as *color* and *pattern* can also be programmed through the use of materials such as thermochromic pigment and LCD screens. Future studies might aim to take a materiality approach towards considering how we can support the integration of more computational materials, while building upon the foundational blocks of clothes [92, 123]. Lastly, evaluating systems and processes that can support the creation and use of expressive clothing could also offer deeper insights into practical considerations such as their wearability, washability and social acceptability.

8 CONCLUSION

In this paper, we presented an initial understanding of hobbyist-sewers' desires to use fabrics and clothing as a medium for communicating information. We extend these understandings to place a focus on how we can design tools to support this practice. Based on our findings, we discussed: 1) a set of five distinctive approaches that hobbyist-sewers took to express information using clothing, 2) a set of four challenges that participants either encountered in their design process, or envision encountering if they were to physically create these clothes, and 3) a set of implications for the design of future technologies that can address the identified challenges, thereby fostering an enriched creative process in the domain of sewing. We hope our efforts will inform future studies to gain a deeper understanding of individual's desires to integrate information or expression into their clothing, as well as guide the design of future supporting hardware and software tools.

ACKNOWLEDGMENTS

We would like to thank our participants for their valuable feedback. This work is supported by NSERC grant RGPIN-2018-05950.

REFERENCES

[1] 2022. *Arduino projects.* https://create.arduino.cc/projecthub
[2] 2022. *Fun Electronic Projects.* https://learn.adafruit.com/guides/projects
[3] 2022. *Home.* https://www.arduino.cc/
[4] 2022. *Home.* https://www.adafruit.com/
[5] 2023. https://www.adobe.com/ca/
[6] 2023. How Fashion Meets Culture. https://artsandculture.google.com/story/how-fashion-meets-culture/gwLyN_zp-PN1Lg
[7] 2023. What is Fashion? https://artsandculture.google.com/theme/hwKSYSaJMOwAKA
[8] Neeharika Adabala, Nadia Magnenat-Thalmann, Guangzheng Fei, and CH1211 Geneva. 1995. Real-time visualization of woven textiles. *Journal of Textile Institute* 86, 4 (1995), 635–648.
[9] Anne Adams, Peter Lunt, and Paul Cairns. 2008. *A qualitative approach to HCI research.* Cambridge University Press, 138–157. https://doi.org/10.1017/CBO9780511814570.008
[10] Chloe Angus. 2022. *Chloe Angus Design.* https://www.chloeangus.com/
[11] Maura Banim, Eileen Green, Ali Guy, Claudia Mitchell, Jacqueline Reid-Walsh, Walt Mueller, Thomas H Wheeler, and Chris Baker. 2001. Through the wardrobe. *Women's Relationships with their Clothes* (2001).
[12] Fiona Bell and Mirela Alistar. 2022. Designing with Alganyl: A Hands-on Exploration of Biodegradable Plastics. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 56, 5 pages. https://doi.org/10.1145/3490149.3503669
[13] Mary Ellen Berglund, James Coughlin, Guido Gioberto, and Lucy E. Dunne. 2014. Washability of E-Textile Stretch Sensors and Sensor Insulation. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers* (Seattle, Washington) *(ISWC '14)*. Association for Computing Machinery, New York, NY, USA, 127–128. https://doi.org/10.1145/2634317.2634326
[14] Ann Blandford, Stephann Makri, and Dominic Furniss. 2016. *Qualitative HCI research: Going behind the scenes.* Morgan & Claypool Publishers.
[15] Shunying An Blevis and Eli Blevis. 2022. Visible Mending. In *Nordic Human-Computer Interaction Conference* (Aarhus, Denmark) *(NordiCHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 87, 13 pages. https://doi.org/10.1145/3546155.3547291
[16] Wanique Block. 2023. The art of storytelling in fashion. https://guap.co/the-art-of-storytelling-in-fashion/
[17] Mark Blythe, Enrique Encinas, Jofish Kaye, Miriam Lueck Avery, Rob McCabe, and Kristina Andersen. 2018. Imaginary Design Workbooks: Constructive Criticism and Practical Provocation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3173807
[18] Kirsten Boehner, Janet Vertesi, Phoebe Sengers, and Paul Dourish. 2007. How HCI Interprets the Probes. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '07)*. Association for Computing Machinery, New York, NY, USA, 1077–1086. https://doi.org/10.1145/1240624.1240789
[19] Adrian Bolesnikov, Karen Anne Cochrane, and Audrey Girouard. 2023. Wearable Identities: Understanding Wearables' Potential for Supporting the Expression of Queer Identities. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 393, 19 pages. https://doi.org/10.1145/3544548.3581327
[20] Leah Buechley. 2010. LilyPad Arduino: Rethinking the Materials and Cultures of Educational Technology. In *Proceedings of the 9th International Conference of the Learning Sciences - Volume 2* (Chicago, Illinois) *(ICLS '10)*. International Society of the Learning Sciences, 127–128.
[21] Leah Buechley, Mike Eisenberg, Jaime Catchen, and Ali Crockett. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy) *(CHI '08)*. Association for Computing Machinery, New York, NY, USA, 423–432. https://doi.org/10.1145/1357054.1357123
[22] Leah Buechley and Benjamin Mako Hill. 2010. LilyPad in the Wild: How Hardware's Long Tail is Supporting New Engineering and Design Communities. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (Aarhus, Denmark) *(DIS '10)*. Association for Computing Machinery, New York, NY, USA, 199–207. https://doi.org/10.1145/1858171.1858206
[23] Jessica Bugg. 2014. Emotion and memory: Clothing the body as performance. In *Presence and absence: The performing body.* Brill, 29–52.
[24] Bill Buxton. 2011. *Sketching user experiences: Getting the design right and the right design.* Morgan Kaufmann.
[25] Scott Carter and Jennifer Mankoff. 2005. When Participants Do the Capturing: The Role of Media in Diary Studies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Portland, Oregon, USA) *(CHI '05)*. Association for Computing Machinery, New York, NY, USA, 899–908. https://doi.org/10.1145/1054972.1055098
[26] Amy Chen. 2020. The Design and Creation of Tactile Knitted E-Textiles for Interactive Applications. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 905–909. https://doi.org/10.1145/3374920.3374959
[27] Janet X. Chen, Francesco Vitale, and Joanna McGrenere. 2021. What Happens After Death? Using a Design Workbook to Understand User Expectations for Preparing Their Data. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 169, 13 pages. https://doi.org/10.1145/3411764.3445359
[28] Norma Clarke. 2020. The stuff of life: Work, loss, tradition, storytelling; how fabric can help to remake communities. *TLS. Times Literary Supplement* 6092 (2020), 20–21.
[29] Elise Dee Co. 2000. *Computation and technology as expressive elements of fashion.* Ph. D. Dissertation.
[30] Orange Culture. 2023. Peacock riot - SS22. https://www.notjustalabel.com/collection/orangeculture/peacock-riot-ss22
[31] Rebecca Cunningham. 2019. *The magic garment: Principles of costume design.* Waveland Press.
[32] Ella Dagan, Elena Márquez Segura, Ferran Altarriba Bertran, Miguel Flores, Robb Mitchell, and Katherine Isbister. 2019. Design Framework for Social Wearables. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 1001–1015. https://doi.org/10.1145/3322276.3322291
[33] Hong Dai. 2021. Comparison of Traditional Manual Embroidery and Computer Machine Embroidery in Dress Design in Internet Age. In *The Sixth International Conference on Information Management and Technology* (Jakarta, Indonesia) *(ICIMTECH 21)*. Association for Computing Machinery, New York, NY, USA, Article 156, 5 pages. https://doi.org/10.1145/3465631.3465826
[34] Sasha de Koninck, Laura Devendorf, Chad Di Lauro, Emma Goodwill, and Shanel Wu. 2021. *A fabric that remembers.* https://www.colorado.edu/atlas/fabric-remembers
[35] Artem Dementyev, Hsin-Liu (Cindy) Kao, Inrak Choi, Deborah Ajilo, Maggie Xu, Joseph A. Paradiso, Chris Schmandt, and Sean Follmer. 2016. Rovables: Miniature On-Body Robots as Mobile Wearables. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 111–120. https://doi.org/10.1145/2984511.2984531
[36] Audrey Desjardins, Cayla Key, Heidi R. Biggs, and Kelsey Aschenbeck. 2019. Bespoke Booklets: A Method for Situated Co-Speculation. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 697–709. https://doi.org/10.1145/3322276.3323311
[37] Laura Devendorf. 2020. A fabric that remembers. http://artfordorks.com/a-fabric-that-remembers/
[38] Laura Devendorf and Chad Di Lauro. 2019. Adapting Double Weaving and Yarn Plying Techniques for Smart Textiles Applications. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 77–85. https://doi.org/10.1145/3294109.3295625
[39] Laura Devendorf, Joanne Lo, Noura Howell, Jung Lin Lee, Nan-Wei Gong, M. Emre Karagozler, Shiho Fukuhara, Ivan Poupyrev, Eric Paulos, and Kimiko Ryokai. 2016. "I Don't Want to Wear a Screen": Probing Perceptions of and Possibilities for Dynamic Displays on Clothing. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 6028–6039. https://doi.org/10.1145/2858036.2858192
[40] Lucy E. Dunne. 2019. Intro to the Human Body: Wearability and Human Factors of Wearable Systems. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–3. https://doi.org/10.1145/3290607.3298822
[41] Lucy E. Dunne and Barry Smyth. 2007. Psychophysical Elements of Wearability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '07)*. Association for Computing Machinery, New York, NY, USA, 299–302. https://doi.org/10.1145/1240624.1240674
[42] Esraa El-Sayed, Hanan Othman, and Ahmed Hassabo. 2022. A Short Observation on the Printing Cotton Fabric using Some Technique. *Journal of Textiles, Coloration and Polymer Science* 19, 1 (2022), 17–24. https://doi.org/10.21608/jtcps.2021.86368.1077

[43] Adam K Fetterman, Michael D Robinson, Robert D Gordon, and Andrew J Elliot. 2011. Anger as seeing red: Perceptual sources of evidence. *Social psychological and personality science* 2, 3 (2011), 311–316.

[44] Yanglei Gan, Tianyi Wang, Alireza Javaheri, Elaheh Momeni-Ortner, Milad Dehghani, Mehdi Hosseinzadeh, and Reza Rawassizadeh. 2021. 11 Years with Wearables: Quantitative Analysis of Social Media, Academia, News Agencies, and Lead User Community from 2009-2020 on Wearable Technologies. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 5, 1, Article 11 (mar 2021), 26 pages. https://doi.org/10.1145/3448096

[45] William Gaver. 2011. Making Spaces: How Design Workbooks Work. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 1551–1560. https://doi.org/10.1145/1978942.1979169

[46] Caglar Genc, Oguz 'Oz Buruk, Shiva Jabari, Lee Jones, Kirill Ragozin, Kate Hartman, Johanna Virkki, Kai Kunze, Oskar Juhlin, and Jonna Häkkilä. 2022. Toolkits & Wearables: Developing Toolkits for Exploring Wearable Designs. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI EA '22)*. Association for Computing Machinery, New York, NY, USA, Article 111, 5 pages. https://doi.org/10.1145/3491101.3503715

[47] Erving Goffman. 2021. *The presentation of self in everyday life.* Anchor.

[48] Bruna Goveia da Rocha, Oscar Tomico, Panos Markopoulos, and Daniel Tetteroo. 2020. Crafting Research Products through Digital Machine Embroidery. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 341–350. https://doi.org/10.1145/3357236.3395443

[49] Camilla Gåfvels and Viveca Lindberg. 2021. Theorising craft practices through sketching: The case of Swedish post-compulsory floristry and textile education. *FormAkademisk* 14, 2 (May 2021). https://doi.org/10.7577/formakademisk.4206

[50] Jonna Häkkilä, Ashley Colley, Paula Roinesalo, and Jani Väyrynen. 2017. Clothing Integrated Augmented Reality Markers. In *Proceedings of the 16th International Conference on Mobile and Ubiquitous Multimedia* (Stuttgart, Germany) *(MUM '17)*. Association for Computing Machinery, New York, NY, USA, 113–121. https://doi.org/10.1145/3152832.3152850

[51] Jonna Häkkilä and Paula Roinesalo. 2017. Enhanced Through Clothing. https://www.hcilab.org/wp-content/uploads/2017/04/AmplifyCHI17_H%C3%A4kkil%C3%A4.pdf

[52] Nur Al-huda Hamdan, Simon Voelker, and Jan Borchers. 2018. Sketch&Stitch: Interactive Embroidery for E-Textiles. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3173574.3173656

[53] Sarah Hyndman. 2019. How typography impacts your mood. https://shyndman.medium.com/how-typography-impacts-your-mood-5bbc3386de03

[54] Sarah J Isherwood, Siné JP McDougall, and Martin B Curry. 2007. Icon identification in context: The changing role of icon characteristics with user experience. *Human Factors* 49, 3 (2007), 465–476.

[55] Pradthana Jarusriboonchai, Felix A. Epp, Thomas Olsson, Andrés Lucero, Oscar Tomico, Eric Paulos, and Jonna Häkkilä. 2019. Beyond Individuals: Exploring Social Experiences around Wearables. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers* (London, United Kingdom) *(UbiComp/ISWC '19 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 454–456. https://doi.org/10.1145/3341162.3347754

[56] Pradthana Jarusriboonchai and Jonna Häkkilä. 2019. Customisable Wearables: Exploring the Design Space of Wearable Technology. In *Proceedings of the 18th International Conference on Mobile and Ubiquitous Multimedia* (Pisa, Italy) *(MUM '19)*. Association for Computing Machinery, New York, NY, USA, Article 20, 9 pages. https://doi.org/10.1145/3365610.3365635

[57] Lee Jones and Audrey Girouard. 2021. Patching Textiles: Insights from Visible Mending Educators on Wearability, Extending the Life of Our Clothes, and Teaching Tangible Crafts. In *Creativity and Cognition* (Virtual Event, Italy) *(C&C '21)*. Association for Computing Machinery, New York, NY, USA, Article 36, 11 pages. https://doi.org/10.1145/3450741.3465265

[58] Lee Jones, Sara Nabil, Amanda McLeod, and Audrey Girouard. 2020. Wearable Bits: Scaffolding Creativity with a Prototyping Toolkit for Wearable E-Textiles. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 165–177. https://doi.org/10.1145/3374920.3374954

[59] Susan B Kaiser. 1985. *Social psychology of clothing and personal adornment.* Macmillan.

[60] Majeed Kazemitabaar, Jason McPeak, Alexander Jiao, Liang He, Thomas Outing, and Jon E. Froehlich. 2017. MakerWear: A Tangible Approach to Interactive Wearable Creation for Children. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 133–145. https://doi.org/10.1145/3025453.3025887

[61] Joy Kim, Mira Dontcheva, Wilmot Li, Michael S. Bernstein, and Daniela Steinsapir. 2015. Motif: Supporting Novice Creativity through Expert Patterns. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1211–1220. https://doi.org/10.1145/2702123.2702507

[62] Konstantin Klamka, Raimund Dachselt, and Jürgen Steimle. 2020. Demonstrating Rapid Iron-On User Interfaces: Hands-on Fabrication of Interactive Textile Prototypes. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '20)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/3334480.3383139

[63] Marion Koelle, Susanne Boll, Thomas Olsson, Julie Williamson, Halley Profita, Shaun Kane, and Robb Mitchell. 2018. (Un)Acceptable!?! Re-Thinking the Social Acceptability of Emerging Technologies. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3170427.3170620

[64] Marion Koelle, Thomas Olsson, Robb Mitchell, Julie Williamson, and Susanne Boll. 2019. What is (Un)Acceptable? Thoughts on Social Acceptability in HCI Research. *Interactions* 26, 3 (apr 2019), 36–40. https://doi.org/10.1145/3319073

[65] Andreas R. Köhler. 2013. Challenges for eco-design of emerging technologies: The case of electronic textiles. *Materials & Design* 51 (2013), 51–60. https://doi.org/10.1016/j.matdes.2013.04.012

[66] Mikahila L. 2022. 3D knitwear: How 3D printing is revolutionizing the fashion industry. https://www.3dnatives.com/en/3d-printing-knitwear-220720215/

[67] Nicolle Lamerichs. 2011. Stranger than fiction: Fan identity in cosplay. *Transformative Works and Cultures* 7, 3 (2011), 56–72.

[68] Paul Le Floch, Xi Yao, Qihan Liu, Zhengjing Wang, Guodong Nian, Yu Sun, Li Jia, and Zhigang Suo. 2017. Wearable and Washable Conductors for Active Textiles. *ACS Applied Materials & Interfaces* 9, 30 (2017), 25542–25552. https://doi.org/10.1021/acsami.7b07361 _eprint: https://doi.org/10.1021/acsami.7b07361.

[69] Mackenzie Leake, Kathryn Jin, Abe Davis, and Stefanie Mueller. 2023. InStitches: Augmenting Sewing Patterns with Personalized Material-Efficient Practice. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 267, 14 pages. https://doi.org/10.1145/3544548.3581499

[70] Yi-Chin Lee and Daniel Cardoso Llach. 2020. Hybrid Embroidery: Exploring Interactive Fabrication in Handcrafts. In *ACM SIGGRAPH 2020 Art Gallery* (Virtual Event, USA) *(SIGGRAPH '20)*. Association for Computing Machinery, New York, NY, USA, 429–433. https://doi.org/10.1145/3386567.3388575

[71] Wanda Lephoto. 2022. Gaze. https://wandalephoto.com/portfolio-item/gaze/

[72] Rebecca Lin, Muhammad "Tuan" Amith, Chen Liang, Rui Duan, Yong Chen, and Cui Tao. 2018. Visualized Emotion Ontology: a model for representing visual cues of emotions. *BMC medical informatics and decision making* 18 (2018), 101–113.

[73] Kristina Lindström and Åsa Ståhl. 2010. Threads - a Mobile Sewing Circle: Making Private Matters Public in Temporary Assemblies. In *Proceedings of the 11th Biennial Participatory Design Conference* (Sydney, Australia) *(PDC '10)*. Association for Computing Machinery, New York, NY, USA, 121–130. https://doi.org/10.1145/1900441.1900459

[74] Yiyue Luo, Kui Wu, Tomás Palacios, and Wojciech Matusik. 2021. KnitUI: Fabricating Interactive and Sensing Textiles with Machine Knitting. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 668, 12 pages. https://doi.org/10.1145/3411764.3445780

[75] Addie Martindale and Ellen McKinney. 2020. Self-sewn identity: How female home sewers use garment sewing to control self-presentation. *Journal of Consumer Culture* 20, 4 (2020), 563–577.

[76] Addie Martindale and Ellen McKinney. 2020. Why Do They Sew? Women's Motivations to Sew Clothing for Themselves. *Clothing and Textiles Research Journal* 38, 1 (2020), 32–48. https://doi.org/10.1177/0887302X19872552 arXiv:https://doi.org/10.1177/0887302X19872552

[77] Arlen C Moller, Andrew J Elliot, and Markus A Maier. 2009. Basic hue-meaning associations. *Emotion* 9, 6 (2009), 898.

[78] Gianni Montagna and Cristina Carvalho. 2016. WearAbility. In *Advances in Design for Inclusion*, Giuseppe Di Bucchianico and Pete Kercher (Eds.). Springer International Publishing, Cham, 247–256.

[79] Michael Muller. 2014. Curiosity, Creativity, and Surprise as Analytic Tools: Grounded Theory Method. In *Ways of Knowing in HCI*, Judith S. Olson and Wendy A. Kellogg (Eds.). Springer New York, New York, NY, 25–48. https://doi.org/10.1007/978-1-4939-0378-8_2

[80] Sara Nabil, Lee Jones, and Audrey Girouard. 2021. Soft Speakers: Digital Embroidering of DIY Customizable Fabric Actuators. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 11, 12 pages. https://doi.org/10.1145/3430524.3440630

[81] Sara Nabil, Jan Kučera, Nikoletta Karastathi, David S. Kirk, and Peter Wright. 2019. Seamless Seams: Crafting Techniques for Embedding Fabrics with Interactive Actuation. In *Proceedings of the 2019 on Designing Interactive Systems*

Conference (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 987–999. https://doi.org/10.1145/3322276.3322369

[82] Érica P. das Neves, Aline C. Brigatto, and Luis C. Paschoarelli. 2015. Fashion and Ergonomic Design: Aspects that Influence the Perception of Clothing Usability. *Procedia Manufacturing* 3 (2015), 6133–6139. https://doi.org/10.1016/j.promfg.2015.07.769

[83] Jakob Nielsen and Jonathan Levy. 1994. Measuring Usability: Preference vs. Performance. *Commun. ACM* 37, 4 (apr 1994), 66–75. https://doi.org/10.1145/175276.175282

[84] Johanna Okerlund, Madison Dunaway, Celine Latulipe, David Wilson, and Eric Paulos. 2018. Statement Making: A Maker Fashion Show Foregrounding Feminism, Gender, and Transdisciplinarity. In *Proceedings of the 2018 Designing Interactive Systems Conference* (Hong Kong, China) *(DIS '18)*. Association for Computing Machinery, New York, NY, USA, 187–199. https://doi.org/10.1145/3196709.3196754

[85] Luis Paredes, Caroline McMillan, Wan Kyn Chan, Senthil Chandrasegaran, Ramyak Singh, Karthik Ramani, and Danielle Wilde. 2022. CHIMERA: Supporting Wearables Development across Multidisciplinary Perspectives. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 5, 4, Article 174 (dec 2022), 24 pages. https://doi.org/10.1145/3494974

[86] Irene Posch. 2017. Crafting Tools. *Interactions* 24, 2 (feb 2017), 78–81. https://doi.org/10.1145/3038227

[87] Irene Posch. 2021. Crafting Stories: Smart and Electronic Textile Craftsmanship for Interactive Books. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 100, 12 pages. https://doi.org/10.1145/3430524.3446076

[88] Virginia Postrel. 2020. *The fabric of civilization: How textiles made the world*. Basic Books.

[89] Sydney Pratte. 2022. Designing Fashion Technology Garments for Awareness. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 46, 6 pages. https://doi.org/10.1145/3490149.3503580

[90] Sydney Pratte, Anthony Tang, Shannon Hoover, Maria Elena Hoover, Matt Laprairie, Catherine Larose, and Lora Oehlberg. 2023. Towards a Design Space for Storytelling on the Fashion Technology Runway. In *Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction* (Warsaw, Poland) *(TEI '23)*. Association for Computing Machinery, New York, NY, USA, Article 36, 15 pages. https://doi.org/10.1145/3569009.3573899

[91] Kopo M. Ramokapane, Dirk van der Linden, and Anna Zamansky. 2019. Does My Dog Really Need a Gadget? What Can We Learn from Pet Owners' Amotivations for Using Pet Wearables?. In *Proceedings of the Sixth International Conference on Animal-Computer Interaction* (Haifa, Israel) *(ACI'19)*. Association for Computing Machinery, New York, NY, USA, Article 6, 6 pages. https://doi.org/10.1145/3371049.3371054

[92] Erica Robles and Mikael Wiberg. 2010. Texturing the "Material Turn" in Interaction Design. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction* (Cambridge, Massachusetts, USA) *(TEI '10)*. Association for Computing Machinery, New York, NY, USA, 137–144. https://doi.org/10.1145/1709886.1709911

[93] María Teresa Rodríguez, Sérgio Nunes, and Tiago Devezas. 2015. Telling Stories with Data Visualization. In *Proceedings of the 2015 Workshop on Narrative & Hypertext* (Guzelyurt, Northern Cyprus) *(NHT '15)*. Association for Computing Machinery, New York, NY, USA, 7–11. https://doi.org/10.1145/2804565.2804567

[94] Paula Roinesalo, Juho Rantakari, Lasse Virtanen, and Jonna Häkkilä. 2016. Clothes Integrated Visual Markers as Self-Expression Tool. In *Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct* (Florence, Italy) *(MobileHCI '16)*. Association for Computing Machinery, New York, NY, USA, 617–620. https://doi.org/10.1145/2957265.2961832

[95] Aidin Salamzadeh, Samira Sadat Mortazavi, and Morteza Hadizadeh. 2022. Social Media and Digital Technologies Among Pottery Makers and in the Sewing Sector. In *Artisan and Handicraft Entrepreneurs: Past, Present, and Future*. Springer, 217–238.

[96] Anup Sathya, Jiasheng Li, Tauhidur Rahman, Ge Gao, and Huaishu Peng. 2022. Calico: Relocatable On-Cloth Wearables with Fast, Reliable, and Precise Locomotion. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 6, 3, Article 136 (sep 2022), 32 pages. https://doi.org/10.1145/3550323

[97] Karen B Schloss, Laurent Lessard, Charlotte S Walmsley, and Kathleen Foley. 2018. Color inference in visual communication: the meaning of colors in recycling. *Cognitive research: principles and implications* 3, 1 (2018), 1–17.

[98] Seamly. 2023. . https://seamly.io/

[99] Mohammad Shak Sadi and Eglė Kumpikaitė. 2022. Advances in the Robustness of Wearable Electronic Textiles: Strategies, Stability, Washability and Perspective. *Nanomaterials* 12, 12 (2022). https://doi.org/10.3390/nano12122039

[100] Yang Shi, Nan Cao, Xiaojuan Ma, Siji Chen, and Pei Liu. 2020. EmoG: Supporting the Sketching of Emotional Expressions for Storyboarding. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376520

[101] Kristen Shinohara and Jacob O. Wobbrock. 2016. Self-Conscious or Self-Confident? A Diary Study Conceptualizing the Social Accessibility of Assistive Technology. *ACM Trans. Access. Comput.* 8, 2, Article 5 (jan 2016), 31 pages. https://doi.org/10.1145/2827857

[102] John Ormsbee Simonds. 1983. Landscape architecture: a manual of site planning and design. (1983).

[103] Yolonda Skelton. 2022. *Yolonda Skelton - Sugiit Lukxs designs*. https://www.sugiitlukxsdesigns.com/

[104] Andreas Sonderegger. 2013. Smart Garments – the Issue of Usability and Aesthetics. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication* (Zurich, Switzerland) *(UbiComp '13 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 385–392. https://doi.org/10.1145/2494091.2495969

[105] Tatjana Spahiu, Ermira Shehi, and Erald Piperi. 2014. Advanced CAD/CAM systems for garment design and simulation. In *6th International conference of textile*. 1–6.

[106] Tali Stolovy. 2021. Styling the Self: Clothing Practices, Personality Traits, and Body Image Among Israeli Women. *Frontiers in Psychology* 12 (2021). https://doi.org/10.3389/fpsyg.2021.719318

[107] Ilya A Surov. 2022. Quantum core affect. Color-emotion structure of semantic atom. *Frontiers in Psychology* 13 (2022), 838029.

[108] Haruki Takahashi and Jeeeun Kim. 2019. 3D Printed Fabric: Techniques for Design and 3D Weaving Programmable Textiles. In *Proceedings of the 32nd Annual ACM Symposium on User Interface Software and Technology* (New Orleans, LA, USA) *(UIST '19)*. Association for Computing Machinery, New York, NY, USA, 43–51. https://doi.org/10.1145/3332165.3347896

[109] Joshua Tanenbaum, Nicole Crenshaw, and Karen Tanenbaum. 2016. "Its'a Me, Mario!": Costumed Gaming's Effects on Character Identification. In *Abstract Proceedings of the First International Joint Conference of DiGRA and FDG, Digital Games Research Association (DiGRA)*.

[110] Theresa Jean Tanenbaum. 2011. Being in the story: readerly pleasure, acting theory, and performing a role. In *International Conference on Interactive Digital Storytelling*. Springer, 55–66.

[111] Theresa Jean Tanenbaum and Karen Tanenbaum. 2011. The Reading Glove: A Non-linear Adaptive Tangible Narrative. In *Interactive Storytelling*, Mei Si, David Thue, Elisabeth André, James C. Lester, Theresa Jean Tanenbaum, and Veronica Zammitto (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 346–349.

[112] Theresa Jean Tanenbaum, Karen Tanenbaum, Katherine Isbister, Kaho Abe, Anne Sullivan, and Luigi Anzivino. 2015. Costumes and Wearables as Game Controllers. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction* (Stanford, California, USA) *(TEI '15)*. Association for Computing Machinery, New York, NY, USA, 477–480. https://doi.org/10.1145/2677199.2683584

[113] Xuyuan Tao, Vladan Koncar, Tzu-Hao Huang, Chien-Lung Shen, Ya-Chi Ko, and Gwo-Tsuen Jou. 2017. How to Make Reliable, Washable, and Wearable Textronic Devices. *Sensors* 17, 4 (2017). https://doi.org/10.3390/s17040673

[114] Chloe Taylor and Anna Franklin. 2012. The relationship between color–object associations and color preference: Further investigation of ecological valence theory. *Psychonomic bulletin & review* 19 (2012), 190–197.

[115] Jan Thar, Sophy Stönner, Florian Heller, and Jan Borchers. 2018. YAWN: Yet Another Wearable Toolkit. In *Proceedings of the 2018 ACM International Symposium on Wearable Computers* (Singapore, Singapore) *(ISWC '18)*. Association for Computing Machinery, New York, NY, USA, 232–233. https://doi.org/10.1145/3267242.3267280

[116] Tonya Thompson. 2021. *144 genres and subgenres for fiction writing*. https://www.servicescape.com/blog/144-genres-and-subgenres-for-fiction-writing

[117] Laura Trautmann. 2021. Emotions evoked by geometric patterns. *J* 4, 3 (2021), 376–393.

[118] Khai N. Truong, Gillian R. Hayes, and Gregory D. Abowd. 2006. Storyboarding: An Empirical Determination of Best Practices and Effective Guidelines. In *Proceedings of the 6th Conference on Designing Interactive Systems* (University Park, PA, USA) *(DIS '06)*. Association for Computing Machinery, New York, NY, USA, 12–21. https://doi.org/10.1145/1142405.1142410

[119] Heather Ujiie. 2006. *Digital printing of textiles*. CRC Press.

[120] Lewis William Robert Urquhart, Andrew Wodehouse, et al. 2017. The emotive qualities of patterns: Insights for design. In *DS 87-8 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 8: Human Behaviour in Design, Vancouver, Canada, 21-25.08. 2017*. 109–118.

[121] Daniela Ghanbari Vahid, Lee Jones, Audrey Girouard, and Lois Frankel. 2021. Shape Changing Fabric Samples for Interactive Fashion Design. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 14, 7 pages. https://doi.org/10.1145/3430524.3440633

[122] Valentina. 2023. . https://smart-pattern.com.ua/en/valentina/download/

[123] Anna Vallgårda and Johan Redström. 2007. Computational Composites. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '07)*. Association for Computing Machinery, New York, NY, USA, 513–522. https://doi.org/10.1145/1240624.1240706

[124] Adrian Wagner, Paul Miles Preuschoff, Philipp Wacker, Simon Voelker, and Jan Borchers. 2023. FabricFaces: Combining Textiles and 3D Printing for Maker-Friendly Folding-Based Assembly. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 135, 7 pages. https://doi.org/10.1145/3544549.3585854

[125] Corinne Weisgerber and Shannan H Butler. 2011. Social media as a professional development tool: Using blogs, microblogs, and social bookmarks to create personal learning networks. In *Teaching arts and science with the new social media*. Emerald Group Publishing Limited, 339–363.

[126] Theresa M Winge and Marybeth C Stalp. 2014. Virtually crafting communities: An exploration of fiber and textile crafting online communities. (2014).

[127] Ying Yang, Nadia Magnenat Thalmann, and Daniel Thalmann. 1992. Three-dimensional garment design and animation: A new design tool for the garment industry. *Computers in industry* 19, 2 (1992), 185–200.

[128] Clint Zeagler, Jaye Lish, Edie Cheezburger, Max Woo, Kathleen L Tynan, Elise Morton, Simrun Mannan, Eva L Christensen, Jordan Eggleston, Paige Greenfield, Chloe Lynne Choi, Axel Gustafsson, Jonatan Holmgren, Aparna Iyer, Michael Chi, Maribeth Gandy, Laura Levy, and Jay David Bolter. 2021. YOU BETTA WERK: Using Wearable Technology Performance Driven Inclusive Transdisciplinary Collaboration to Facilitate Authentic Learning. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 3, 12 pages. https://doi.org/10.1145/3430524.3440622