

Alternative Presents for Dynamic Fabric

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ABSTRACT

In this paper we investigate how a combination of “speculative” design methods can be used to generate theoretical understandings for dynamic, colour-changing fabrics for garments. Specifically, we combine a first-person, autobiographical, research through design (RtD) approach that draws strategies from speculative design. We call this approach *alternative presents*, inspired by the work of James Auger, and explore it as a way to generate theoretical propositions for dynamic fabric that emphasize the lived experience over technological innovation. The contributions of this framing are twofold. Firstly, we offer a theoretical contribution to the literature on dynamic fabric. Secondly, we make a methodological contribution for how autobiographical design and RtD can be oriented speculatively to generate intermediate knowledge, with particular emphasis on social-technical aspects.

Author Keywords

Speculative Design; Material Speculation; Research through Design; Smart Textiles; Wearables

CSS Concepts

•Human-centered computing~Interaction design~Interaction design process and methods

INTRODUCTION

Dynamic, colour-changing fabrics have played an active role in smart textiles and wearables discourses in both commercial and research contexts for almost two decades. Poised as a futuristic but realisable textile, it has been suggested that colour-changing fabrics can help mitigate fast fashion [17,21], and generate new fashion expressions that combine digital and physical experiences. The fashion industry has been increasingly shifting towards digital experiences to support fashion-based activities for styling, branding and retail, though not for computationally dynamic fabrics.

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Figure 1. Wearing dynamic fabric using a chroma-key app and green-coloured dress.

Barriers to the adoption of wearables products and smart textiles have been attributed to a mix of technical, production-oriented, and socio-cultural challenges [21,57]. In particular, researchers coming from fashion practise are signalling a disconnect between the prevalent techno-centric approach to wearables, on the one hand, and fundamental fashion and design-related concerns on the other [43,46,66]. In the specific area of dynamic, colour-changing textiles there have been several material- and design-centric works exploring new concepts for interactive colour-changing garments [17,26,40,76], but details of their lived, everyday experience are still unknown, or based on conjecture.

In this paper we introduce *alternative presents*, an autobiographical, research through design (RtD) approach that draws from speculative design. Through living and designing with a simulated version of dynamic fabric over a long period of time, we examine, not the *imagining* of a speculative future, but the *experiencing* of a speculative present. Up until this point it has been an underlying assumption that once a high-fidelity prototype or commercially-viable fabric has been developed, design considerations can be more thoroughly examined in its context of use [17], that is, as a wearable garment. However, we invert this assumption through an RtD, speculative engagement with the concept that lets the lived experience and design activities of one researcher co-generate the fabric experientially, with minimal concerns for its underlying technology or technological development.

To summarise, the first author of this paper wore and worked with real-time, wearable greenscreen garments over three

years to mimic a dynamic, colour-changing effect. Through two case studies, she explored the *personal experience* of having colour-changing garments in her wardrobe, and also the *designer's experience* of working with these fabrics to create a fashion line. From these case studies, insights were gathered through reflective analyses in several papers describing the design implications, creative techniques, unexpected outcomes and questions that emerged from these processes for wearing and working with the fabric [44–47]. In this paper, we re-examine the body of work as a whole. We track the changed understanding of dynamic fabric through these studies, and offer three differing propositions (*before, during* and *after* the case studies) to express this. From here we contribute an expanded understanding of dynamic fabrics, and begin the methodological framing for how RtD can be speculatively oriented.

RELATED WORK

In this section we describe the related work that has inspired our inquiry into dynamic colour-changing fabrics. This includes first-person perspectives in wearables, autobiographical design in HCI, research through design, methods from speculative practices in HCI, and literature on dynamic fabric.

First-Person Perspectives in HCI & Research through Design

Wearables and smart textiles are ripe areas to engage first-person, auto-ethnographic exploration in design processes and research. Researchers have the opportunity to *wear* or *live with* the technologies they examine, and gain rich experiential understandings [45,65,69]. Wearable computing was arguably pioneered through this approach with Steve Mann's decades-long commitment to exploring augmented reality (AR) headpieces by wearing one himself since the 1980s [48]. From a feminist perspective, the activity of *wearing* wearable technologies to understand them makes explicit their inescapable role as mediators of social activity when placed on the body, brought to our attention by the pioneering work at Joanna Berzowska's XSLabs [6,7], and also Kate Hartman's Social Body Lab [81].

Embodiment, as a closely related conceptual framing, has become an important part of wearables discourses [65,66,78]. Our interest in using first-person accounts in our research—through wearing the technology—veers slightly away from body-felt notions of embodiment, and towards those that predominantly seek socio-cultural understandings. We have been interested in the social ecology that might surround a technology-enhanced garment, and have found that this can be brought forth by the activity of *wearing it in daily life* [44,45].

In terms of HCI, we see overlap in our approach with Neustaedter and Sengers' [49] notion of *autobiographical design* which attempts to formalise the often undisclosed practise of using oneself as a user in design explorations over long periods of time [e.g. 22,23,51]. Several works have engaged this approach more explicitly since then [e.g.

11,16,31] and what we see is that using *oneself* is a way for the researcher to navigate and tune their design sensibilities to the nuance of the experience over time. This can lead to more sensitive, thoughtful, and thorough examinations of new technologies than can be achieved through observation and interviews with others. Certainly, this approach has its limitations and requires “careful, critical reflection on one's work processes.”[49]

Further to this, we also highlight our use of the *researcher as an instrument* [75] in the data collection of our research. The first author of this paper engaged herself at the centre of the inquiry, using her everyday life to explore the wearing experience of the dynamic fabric. Her skills and experience from practice in fashion design and wearables have offered a valuable lens from which to view the experience and unpack the intricacies involved.

Finally, we draw attention to the overall approach of our research, which falls under the umbrella of research through design [80]. Our inquiry into dynamic fabric was mostly open-ended, in that we let design methods, curiosity, instincts and reflexivity lead us through the process of discovery with the artefacts we created and interacted with. As RtD functions in this generative way, it is the glue that binds the combined methods described in this paper.

Speculative Practices

A driving force of our inquiry into dynamic fabric has been to explore it from a socio-cultural perspective without having to make any technological advancements. Dynamic fabric, as we understood it—a colour-changing textile embedded with electronics, that can be readily cut and sewn into garments—did not exist. So, we engaged an RtD approach with a speculative orientation to accomplish this.

In HCI, speculative design in varying forms [1,20,22,60,71] has served to highlight new socio-cultural perspectives on emerging technologies. In the words of James Auger, speculative design “incorporates a sociocultural element—the role of fashion, trends, and human behaviour in shaping everyday life. [It aims]...to place emerging technologies into real-life contexts, communicating how these would be manifest through tangible evidence such as props, videos, images, scenarios, vignettes, and stories” [2]. Mainly serving to provoke discussion, inquire into, or expand the design space of future technologies beyond conventional, uncritical trajectories [1,20], speculative design discourse intersects with discursive design [64], critical design [3,19], design fiction [9,60,63], and design probes in HCI [10].

Within the large scope of speculative practises taking place in HCI we highlight *material speculation* [71,72] and *speculative enactments* [22] as closest to our aim of generating experiential understandings of a future technology. Material speculation is the crafting of *counterfactual artefacts*, or, material things designed to be from a possible world yet placed in the actual world of today. The artefacts [e.g.30,73,74] are ideally situated in the

“everydayness of our world” [71] where the inquiry can then play out. This, as described by Wakkary et. al, offers “a new ontological perspective that over time makes more visible assumptions, implications, and possible change.”

Speculative enactments can be seen as a more performative version of material speculation, mainly inspired by Candy and Dunagan’s *experiential futures* [12]. Participants in a speculative enactment are invited to immerse themselves in the social interactions of a possible future in a way that is *consequential* to them. For example, in the project *Abacus Datagraphy* [23], couples consult with a “wedding datagrapher” to collect quantifiable data about their actual wedding, such as their heart rate while kissing, or the volume level of “peak laughter” at the reception. The information gathered was then published as part of a concept brochure for Abacus, and made public.

Related to material speculation and speculative enactments, we also highlight Hansen and Kozel’s *Placebo Sleeve* [28] and Wilde and Andersen’s *OWL project* [77], which both engaged participants to wear things (a sleeve, and other undefinable objects) as technology “placebos”. Wearers were asked to spend time wearing the placebos and reflect on how they related to them as technology. In *Placebo Sleeve*, participants kept a diary of this experience for one week. Although these projects were brief explorations in comparison to the other long-term work we highlighted, they intersect with the speculative orientation of our research by placing *the idea* of a technology on the body to *be with it* and *think with it*. We have been inspired by their use of wearing, imagination and reflexivity to generate and envisage narratives for technologies that do not essentially “work”, or exist.

From this prior work, we hope to highlight the use of *present-day situations* to feed speculative scenarios, and essentially bring them to life. This notion has been fundamental in our examination of a future-based technology, as we strove to examine it in context, without prescribing the details of its use or implications. We sought a situation that would allow the technology to *reveal to us* how it might exist, and to do so in a way that was *more consequential* to participants than previous approaches demonstrated in speculative design.

Literature on Dynamic Fabric

State-changing and colour-changing materials have a rich history in fashion dating as far back as Tutankhamun (“King Tut”) whose garments were adorned with shiny gold discs [59]. Jumping to the 20th century, it became possible to mimic shimmering jewels and precious metals using sequins, glitter, plastics and imitation gold leaf. In the latter half of the 20th century several products with thermochromic characteristics went to market, notably the “mood ring”, and in 1991 the faddish Hypercolor T-shirt [40]. Shortly thereafter, a radical shift began in the area of colour-changing textiles [79] as computational materials became smaller, more powerful, flexible, and more accessible to designers and researchers.

In the early 2000s, several novel explorations of thermochromic printed textiles and electronics emerged [4,51,55] as well as illuminated textiles using various materials to achieve animated displays on garments [8,13,29,50,52,56]. Several of these experiments intersected with art and design, and have become iconic exemplars in wearables discourses, such as the Philips’ *Bubelle* dress [53], designed to change colour according to a wearer’s mood, or dresses from Valérie Lamontagne’s *Peau d’Âne* [42] that responded to moon cycles, sunlight and wind patterns.

Throughout the last 15 years there have been a string of niche and novelty products on the market, emerging from these explorations using light to animate the surface of garments for personal fashion [e.g. 27,79,80]. We have also seen several high-fidelity prototypes using thermochromic dyes, photochromic dyes, and e-ink for garments, shoes, make-up and bracelets [e.g. 14,33–35,38,81].

Beyond this, several researchers have taken more in-depth, material-centric or fashion-centric investigations into the techniques and expressive possibilities for colour-changing textiles. Linda Worbin [79], for example, articulated some of the variables involved for controlling dynamic textile expressions such as *time* and *the surroundings*, as well as novel qualities a textile designer must grapple with, such as a *dynamic line* or *dynamic form*. Marjan Kooroshnia, in her investigation of leuco dye-based thermochromic inks, explored interactive spaces for colour-changing dresses [39]. In one exploration she describes that the interaction between two wearers “created patterns which were unique but wild, messy, uncontrolled, impossible to reproduce, and temporary.” We see related articulations coming from other designer-oriented explorations of colour-changing garments such as *ambiguity* [17], *volatility* [17] and *irregularity* [76]. We too have been motivated to uncover and articulate designerly qualities of dynamic fabric.

In terms of everyday fashion, the colour-changing feature of garments, accessories and other adornments has been widely described as being an expressive feature for its wearer. Through a variety of exemplars and examinations, more precise ideas for this expressive quality have been described, such as mood expression [38,53,62], provoking intrigue in situated social interactions [17,27,34,70], having many garments in one garment [17,21], expressing data from remote sources [17,42], poetically and materially expressing time [5,17,43], providing safety (e.g. with light) [18,26], expressions of body movement [8,50,76], responses to situated environmental triggers (e.g. rain, sound, heat, or light) [26,34,36,38], or contextual colour and pattern changes (e.g. matching the surroundings) [26,38,76].

However accurate these use-scenarios prove to be, they are still initial concepts and not something that can be claimed from long-term, daily usage. In the words of Devendorf et al. [17], who share our curiosity for the everyday experience of dynamic fabrics, “While HCI has explored domain specific and conceptual proposals for clothing-based displays, very

little is known about the way such displays would be perceived and utilized within everyday life, beyond runways and outside of galleries.” Our work attempts to make contributions towards this concern.

METHODOLOGY

In this section, we summarise the way we have brought together several research through design methods and oriented them towards strategies from speculative design. We call this approach *alternative presents*, inspired by James Auger [1,2], and have used it to generate theoretical propositions for what dynamic fabric is or could be.

Alternative Presents

As we briefly outlined so far, our research combines first-person, autobiographical design and RtD methods to pursue a speculative inquiry into the future concept of dynamic fabric. To summarise the logic behind this approach, we felt that to understand the fabric from a socio-cultural perspective we should explore it through wearing it as a garment over time in the context of everyday life. Because dynamic fabric did not exist in a form amenable to wearing it in this way, we had to mimic its colour-changing abilities through a greenscreen system (green fabrics combined with real-time chroma-key apps) (Figure 1). This made the exploration *speculative*, as we did not see this greenscreen system as meeting key requirements of the future fabric, other than its colour-changing capabilities. More specifically, we saw it as a limitation that this effect was mediated by a smartphone, and that the dynamic patterns were not physically tangible. Our views on these limitation, however, changes throughout the case studies.

Over time we found that, having placed the greenscreen system so deeply into the life of the researcher, many aspects originally perceived as simulacra of dynamic fabric became perceived as real and authentic. From here, the inquiry moved into a space we found difficult to articulate at the time—a space between real and not-real, but still part of the researcher’s actual world and lived experience. We now call this space an *alternative present*. In the case studies where this played out, Greenscreen Dress and Phem, alternative presents were experienced by the same researcher navigating from different perspectives. For Greenscreen Dress it occurred primarily through the wearing experiences of the dynamic fabric and for Phem through engaging it as a fashion material in a design process. The two perspectives blend and overlap but the shift of experiencing an alternative present occurred somewhere in Greenscreen Dress and carried over to Phem.

To elaborate further on this notion of an alternative present, we describe it as the unfolding of palpable experiences within the context of a speculative engagement. In our case, the first study began as an experience prototype that used smartphone mediation to mimic colour-changing textiles, and then matured into an experience that more fluidly blended dress and technology. As time went on, the distinct technological forms and features became less important to

our understanding of dynamic fabric. We experienced the dynamic fabric instead through the social ecology that grew around it and the encountered digital phenomena. These experiences left us with drastically different concepts of dynamic fabric than the one we started with. In this paper, we use the accounts of these alternative presents to derive three propositions for what dynamic fabric is before, during, and after the case studies. These propositions act as the broad strokes of our changed understandings over time.

Intermediate Knowledge

From here we are left with the question for what kinds of knowledge these alternative presents can contribute. The paradox of this approach—exploring a possible future by allowing it to unfold in the present—brings a tension when framing and contextualizing the outcomes. As a possible future, are the insights speculative if they occurred in “real” life? Is the Greenscreen Dress a prototype for the future or a product for the present? Why not examine the greenscreen system more explicitly as an AR-fabric instead of dynamic fabric? In previous papers [44–47], each case study was individually examined according to different research questions. Now, we look at this body of work anew and turn to discussions of intermediate knowledge in interaction design to frame their potential theoretical contributions towards understandings of dynamic fabric.

Drawing from *conceptual constructs* [61], *strong concepts* [32] and *bridging concepts* [15], we propose that alternative presents can play out in a back-and-forth manner between theory and practice, generating *theoretical understandings* about the technology in question backed by the empirical evidence of the autobiographical accounts, design activities and artefacts that were produced. In our case, we engaged in a speculative inquiry that allowed us to *formulate propositions* for what dynamic fabric is, in an iterative manner. In other words, we first proposed a description of dynamic fabric based on existing literature and exemplars, then altered them twice based on insights from our two case studies. As first-person accounts of the dynamic fabric are the backbone for the rationale behind these new propositions, they are best understood when taken as a narrative of sorts—consumed chronologically so that readers can follow the logic of the changed understanding as they unfolded for the researcher herself.

We suggest that these propositions live as theoretical, intermediate knowledge that can be used to feed and inspire future designs and development for dynamic fabrics and, as we hope to argue in this paper, expand understandings for what dynamic fabric could or will be beyond current mental models.

PROPOSITIONS FOR DYNAMIC FABRIC

In this section, we present our three propositions for dynamic fabric. The first was extrapolated from prior work on dynamic colour-changing fabrics. The second and third propositions were formulated through reflective analyses on the case studies Greenscreen Dress and Phem. The first-

person accounts from each study describe the alternative presents as experienced by the researcher. Greenscreen Dress acts as an alternative present where dynamic fabric is worn in daily life, and Phem acts as an alternative present where dynamic fabric is engaged in a fashion design process to create a contemporary fashion line.

Notes on terminology

Over the three-year timeline of this research the terminology we have used to describe the materials and tools being worked with has changed to accommodate our changed understandings and efforts to communicate these understandings in scholarly contexts. In other research, we have seen dynamic, colour-changing textiles referred to in a variety of ways suitable to the context, such as *animated textiles* [4] or *dynamic display fabric* [17]. To be clear and consistent throughout this paper, we have chosen the following terms to describe the focal points of our inquiry: dynamic colour- and pattern-changing fabrics will be referred to as *dynamic fabric*. Garments that incorporate dynamic fabrics will be referred to as *dynamic garments*, and the animated imagery that these garments display will be referred to as *dynamic patterns*. When a dynamic pattern is composited into a fabric's surface we will refer to the fabric as being *active* or *activated*, and *static* when it is not.

Before the case studies: Extrapolating a proposition of dynamic fabric from existing research

Our research was initiated in late 2015. We wanted to explore new design approaches for wearables products, and were inspired by several of the exemplars described in the section Literature on Dynamic Fabric (with more recent works included for this paper). Based on the large body of work in wearables and smart textiles that explore illuminated and thermochromic textiles, we conceived an idea for what a future dynamic fabric might look like, or, the requirements that would make it wearable as a garment. From this we extrapolated the following proposition for a dynamic fabric that could be wearable in everyday life. It is not meant to be comprehensive, but a reasoned extrapolation from the prior works.

Proposition 1

Dynamic fabric is a clothing-grade textile or textile-like material that can change colour and/or pattern using embedded electronics. It can dynamically display and change imagery like a computer screen in response to situated input from a body, the surroundings, and/or other kinds of remote data.

This proposition includes nearly all the prior work on dynamic fabric listed in the Literature on Dynamic Fabric section, with no technical limitations. It is what we interpret as an idealised or aspirational form of dynamic fabric based on the trajectory of prior work. What we mean by “clothing-grade” is that all practical issues have been overcome, resulting in a fabric that can be readily constructed into a garment. This garment is comfortable, washable, durable,

and practical for everyday wear—things cited as necessary for wearables adoption [21].

Case study 1: Greenscreen Dress

Our first case study began as a speculative inquiry into the lived experience of dynamic fabric as it is described in Proposition 1. This study was explicitly undertaken to generate socio-cultural understandings of dynamic fabric as opposed to technical knowledge, and was conceptually framed at the time as a *material speculation* [46]. The main question being asked throughout this study was *What would it be like to wear dynamic fabric in everyday life?*

We now switch to the first-person voice of the first author of this paper to summarize her activities and reflections on Greenscreen Dress. This summary has been derived from her auto-ethnographic journal. Video documentation can be seen here: vimeo.com/284999343

Setting up the case study

I wanted to wear dynamic fabric, but did not have access to an all-in-one, clothing-grade dynamic fabric. After exploring several ways to create this (e.g. weaving strips of e-ink), I discovered I could use a live chroma-key app to change the surface of some green fabrics, like a live wearable greenscreen. I constructed a entirely green dress and wore it for one week with an app called Chromakey Studio Pro [33]. This app allowed me to composite any image or video stored on my phone into the green hues of any fabric in real-time.

Commitments for Greenscreen Dress

In following the question *What would it be like to wear dynamic fabric in everyday life?* I needed to qualify *everyday life* and *everyday wearing* through some commitments. I committed to wearing the fabric for one year, which I believed would deeply embed it into my personal life. I would wear green fabric in conjunction with the chroma-key app every day, including weekends, everywhere I went. Secondly, I would record myself activating the dynamic garments once a day, at minimum. Because I did not know when, why or how many times I would want to activate it, this commitment ensured that the experiment persisted stubbornly, irrespective of my motivation. As the documentation describes, in practise I activated the fabric several times a day up until the last months of the study.

Thirdly, because the system I had created worked like AR, with the activated garments appearing on my smartphone, this meant I was typically the only person seeing them. Therefore, I chose to present the dynamic garments on social media regularly, via Instagram, to have an audience. This allowed the dynamic garments to be “worn” by being seen. It made me accountable for the choices I made, as one typically is when wearing clothing outside their home.

Finally, I committed to regularly documenting my thoughts and actions throughout the year in an auto-ethnographic journal. This allowed me to track patterns and changes in my behaviour over time.

Description of the lived experience wearing dynamic fabric
 As described in greater depth in previous papers [45,46] the first weeks of Greenscreen Dress revealed several challenges for integrating dynamic fabric into my wardrobe. For example, after two weeks of wearing the same green garment, I found I wanted a greater variety of green garments (or rather, a greater variety of *dynamic fabric* and ways to wear it). I found garments with checkered green patterns and green leaves (Figure 2); I found garments with dark green hues which had a “muddying” effect on the dynamic patterns. I also needed practical green garments such as cardigans for warmth. Furthermore, only certain items and accessories in my wardrobe could be worn with the new dynamic garments. For example, things that were black or navy could easily be styled with the dynamic garments in both their active or static (green) states, but few things that I owned in pink worked stylistically.



Figure 2. Fabrics from the researcher’s green wardrobe



Figure 3. Examples of wearing dynamic fabric

It took several weeks, but I soon began to find a personal style for wearing the dynamic patterns. I drew inspiration from “glitch art” and exchanged ideas about this with followers on Instagram. I wore pixelated animations and made dynamic patterns by capturing videos of things like clouds and blowing grass. Sometimes, I mixed dynamic patterns by layering them (e.g. chroma-keying videos of grass into each other) to create abstract animations that had strange video artefacts.

Several months into the study something unexpected happened while wearing a dynamic garment. The large throne-like chair I was sitting in was green. Consequently, my dynamic patterns blended into the chair and also became activated (Figure 3). Followers on Instagram really liked this effect, as did I, and I searched for more green things to blend with such as plants and art (Figure 3). These unexpected moments of discovering new expressions happened often throughout the study.

In terms of *when and how many times* I chose to change the patterns on my clothing each day, I found these moments to be largely influenced by mood or inspiration from my surroundings and social interactions. This rarely occurred at

my desk, and I quickly understood I must leave my desk to instigate these moments. The frequency with which I activated my garments changed throughout the year—ranging from once a day to ten or more depending on inspiration from my surrounding situation.

In general, most of the people around me understood the significance of the green I wore each day, seeing it as “active” with the ability to change. One colleague installed the same chroma-key app on his phone and dressed me with his own patterns, which I did not like. I counteracted this by dressing in green patterns—such as green stripes instead of an entirely green garment—to derail this hack, as the images would be broken up and become unrecognisable. I reflected in my journal on how fragile my control was over the dynamic patterns I wore.

To sum up, I posted 160 dynamic garments online in one year, with more than 6500 left “unworn” or “tried-on” on my smartphone. In general, I navigated choices for what to wear publicly between my personal tastes and perceptions of other people’s appreciation of them.

When wearing dynamic fabric became tiresome

About eight months into the study, major changes in my routine affected my motivation for wearing the dynamic fabric: I began commuting long distances for work and was newly pregnant. Often feeling over-tired and physically uncomfortable, I did not want to present myself on Instagram. Also, despite continuing to interact with specific audiences in person and online, I started to feel unsatisfied with the community engagement surrounding the work. There was no reciprocation for wearing dynamic fabric. To sustain an enthusiastic engagement, it would have required that other people wear their own versions of dynamic fabric with and around me. Despite these drawbacks, I continued to wear it every day for a full year. Outside adding new green garments to accommodate pregnancy, there were few experiences in the final four months that generated novel insights beyond these last reflections.

Reflective Analysis of Greenscreen Dress

We now switch back to the third-person voices of the authors of this paper.

Several insights into the wearing-experience of dynamic fabric were extracted from Greenscreen Dress, described in detail in previous publications [45,46]. To summarise, they include the insight that although the dynamic fabric generated *many garments in one garment*, the researcher still felt the need to gather several garments to accommodate other practical and expressive concerns. This challenges the notion presented in literature that a dynamic garment would help mitigate fast fashion [17,21]. There were also issues of *control over the dynamic patterns* relating to when her garments were hacked; *the influence of digital aesthetic sensibilities* such as glitch art from online communities; issues around balancing an *abundance of wardrobe options* in *both the physical and digital experiences* of the garments;

wearing the dynamic patterns in unexpected ways such as *blending with the surroundings* (Figure 3) or discovering new material expressions by *using the chroma-key app in unintended ways*.

Moreover, we would like to offer an additional reflection on this study which we could only identify with time, after Greenscreen Dress had ended: *the memories the researcher retains for wearing the dynamic fabric are visceral ones*. The long amount of time she committed to wearing the dynamic fabric caused it to deeply permeate her lifeworld. She still perceives green-coloured things as dynamically “active”; she has personal meanings attached to certain wearing experiences documented on Instagram, and memories that include corporeal experiences of feeling the fabrics while wearing them amongst the sights, smells and sounds in her environment. She retains a collection of dynamic patterns on her phone which she feels a fondness for as if they were cherished textiles such as bed sheets or an old T-shirt. To contextualise this post hoc reflection, the researcher did not experience the greenscreen system in *the same way* as traditional clothing fabrics, but was surprised by the extent to which the dynamic patterns became part of the green garments to the point that throughout and after the study the combination was as much a part of her personal style and history as any items in her wardrobe.

Changed understanding of dynamic fabric

With these reflections in mind, we re-examine the initial intention to have mimicked dynamic fabric, where Greenscreen Dress is seen to be an incomplete realisation of Proposition 1. In her account, the researcher experienced the greenscreen system as a functioning form of dynamic fabric. It functioned to change the surface patterns of her garments, it reasonably fit into the practical and social dynamics of her daily life, and became personally expressive for her. Moreover, she formed an intimate relationship with the dynamic garments as part of her wardrobe despite their mediated form.

Consequently, we believe the greenscreen system in combination with her daily activities created a new form of dynamic fabric. In essence it was *co-generated* with her everyday life, put together through variables of different dimensions such as the influence of Instagram followers, situated social interactions, her surroundings, textile qualities of the green fabrics, technological constraints of the greenscreen system, and her changing moods, motivations, and personal tastes. We see that the intermingling of social and technical aspects over time brought forth a new perception of the dynamic fabric, with a reduced emphasis on its technical abilities. We thus propose the following second proposition of dynamic fabric:

Proposition 2

Dynamic fabric is a social-technical system of textiles that interact with augmented reality and other digital media to change the surface colour and/or pattern of the textiles involved.

To unpack this, the focus here is on the fabric as a *social-technical system* to emphasise its social fit into the wearer’s life instead of it being a “clothing-grade fabric”, as described in Proposition 1. In Greenscreen Dress, the system of green garments with the chroma-key app alone was not considered dynamic fabric, but became so in conjunction with varying social situations. The distinction as a social-technical system also calls attention to the social ecology of the technologies involved, and not only to the social ecology of dress. In the study, examples of this are the creative influence of glitch art communities online, the app working in unintended and unexpected ways, and the anecdote of being hacked. The technologies involved did not only allow the fabric to change colour, but also added their own set of social considerations and unique character.

As to it *interacting with AR and other digital media*, this part of the proposition comes with the inference that *dynamic fabric does not require digital technologies to be embedded into it*. This is a leap from Proposition 1, where dynamic fabric is described as an all-in-one technology-embedded textile. As described at the start of Greenscreen Dress, the green garments and chroma-key app were originally used to approximate a tangible, technology-embedded future fabric. However, through the process of co-generation with the researcher’s everyday life, it began to achieve all the social functions of a garment fabric, such as being personally expressive in social situations and an ability to be styled with other items in a wardrobe. This inverts assumptions that colour-changing technologies must physically integrate with textiles for them to be studied as garments [17], and opens up a discussion on the blurred boundaries of mixed-reality technologies, and whether or not they qualify as “wearables”.

Case study 2: Phem

Our next study, Phem, takes a different perspective from Greenscreen Dress. Here the researcher investigates the fashion designer’s autobiographical experience of designing garments with dynamic fabric. The main question being asked throughout Phem was *What would it be like to design garments with dynamic fabric in a present-day fashion context?*

We now switch back to the first-person voice of the first author to summarize the activities and reflections on Phem.

Setting up the case study

After Greenscreen Dress, I felt that I had found a form of dynamic fabric to explore designing with. At the time, AR seemed the closest technical description of it, but it did not feel right to articulate it in this way. The term “AR-fabric” did not encapsulate all that I was experiencing. I moved forward with the notion that I was working with dynamic fabric in the way that it presented itself to me, without being able to precisely identify it technically.

Commitments for Phem

In the same way that I used my everyday life in Greenscreen Dress to explore concerns from everyday life, I set the stage

for Phem by immersing it in a fairly traditional fashion-design process. I had practised as a fashion designer for many years with my own business, and treated Phem as if it were to become a new independent fashion line. I aimed to produce a series of garments for a fashion film, which is a widely-used format in the fashion field [67]. I collaborated with Club Futur (clubfutur.nl), a local branding and styling consultancy, and engaged in the entire process of creating moodboards, designing garments, commissioning a logo, and collecting content for an eventual social media presence. Finally, I produced the main artefact, the fashion film, which can be seen here: vimeo.com/312729991.

Description of designing with dynamic fabric

As described in greater detail in other publications on Phem [44,47], I drew from the material explorations of Greenscreen Dress and then went deeper into the ways that green-coloured (and also blue-coloured) fabrics could interact with chroma-key apps to achieve different visual effects. For example, I experimented with custom printed fabrics and laser-cut shapes to study my control over the placement of the dynamic patterns on a garment. I played with transparent and shiny materials to achieve different effects. I also found by playing with colour-half-tone tools in Adobe Illustrator, that I could reduce solid green and blue colours into gradients of dots that were not quite green or blue when viewed up close. This confused the chroma-key app. Fabrics printed with these dots would be active at a distance, but inactive when the smartphone moved close. I imagined scenarios where the wearer could exhibit some control through their proximity to the digital devices.

Over six months I designed 12 garments. They included custom-printed fabrics, hand-sewn embellishments and various other materials to produce a variety of effects. However, only six were featured in the final cut of the film due to iteration on the brand feel. I also created sets of dynamic patterns with a shimmering quality. I made them using an online glitch-generating tool [85] to create animations that I would film via a computer screen to collect screen-artefacts (Figure 4). This resulted in hundreds of dynamic patterns that I categorised under different names such as the “rainbow holographics” or the “silver statics”.

Shooting the fashion film took place over one day. We shot two kinds of footage—footage with a smartphone depicting the model in real-time wearing active dynamic garments, and footage with a digital SLR camera where she wore static versions of the garments. The shoot brought many challenges, but the most significant was that the dynamic patterns I had pre-chosen were not working stylistically with the atmosphere on set. I felt I had brought the “wrong” dynamic patterns with me, with no time to generate new ones. I also struggled with the idea that I could not tangibly fiddle with the dynamic patterns to reposition and style them in a better way. I decided to rely on the footage from the digital SLR camera and instead activate them in post-production with more time to judge these details.



Figure 4. Making dynamic patterns for Phem

During post-production I made new sets of dynamic patterns that worked better in the context of the film. I also iterated further on *when* the dynamic patterns should be activated in the flow of the film. I reflected that my sensibility for this was tied to the way I would style sparkling fabrics, aiming for the shimmers to appear in a fortuitous manner.

To sum up, the creative techniques I implemented to bring the film to its final form came from improvisation with the digital tools I worked with. For example, during post-production I chose to activate the garments in the raw SLR footage via the smartphone apps, via the computer screen (Figure 5) instead of using the chroma-key effects in the video-editing program. As I described in my journal, this activity, as well as several other improvisations, felt “like painting” with the dynamic patterns onto the garments.

When the film was complete I felt that the dynamic fabric had come to life in the film. Moreover, I felt it had come to life through my efforts to mould it throughout the process.

Reflective Analysis of Phem

We now switch back to the third-person voices of the authors of this paper.

Several insights into the experience of designing with dynamic fabric were extracted from Phem, described in richer detail in [44] and [47]. For example, the material explorations revealed several interesting interactive effects that could have been more explicitly shown in the film. However, from a fashion design viewpoint, we chose to focus on the fabric’s expressive qualities in ambiguous ways than to demo its interactive capabilities.

We also found that strategies for *blending the dynamic patterns with the qualities of the physical textiles* (e.g. texture, drape, surface pattern) yielded the most favourable results in terms of generating a convincing form of dynamic fabric. In short, this allowed the dynamic patterns to be perceived as fabric or as part of the garment as opposed to as video clips, which they technically were.

There was also a strong frustration voiced in the researcher’s journal about not being able to touch the dynamic patterns because they were mediated through the smartphone screen.

Thinking about how a materials-based designer operates in a garment-design process—ripping, folding, or scrunching fabrics to have a dialogue with them—it became clear why this aspect felt lacking. For her, pliable exploratory actions with a fabric often dictate the next moves in her design process. Closer to the end, she expresses ways she overcame this challenge.



Figure 5. Activating the dynamic fabric via the chroma-key app via the computer screen

To summarise, she found that *interacting with the dynamic patterns in embodied and situated ways* enabled her to affect the fabric akin to manipulating it by hand. It was not as sensorial as hand manipulation, but more sensorial than navigating a screen-based interface. As craftsmanship is strongly tied to tacit knowledge, her body movements for wielding the smartphone around the garments and various screens began to feel “like painting”. She was not able to handle the dynamic patterns but she could *skilfully affect them* by navigating other unstable aspects in the moment (e.g. the lighting, wind, garment movements). She expressed needing multiple attempts to get one of these moments right, and we suggest that *drawing strategies from time-based arts*, such as dress rehearsals, could have allowed her to further develop this craft for mixing dynamic patterns in situ, similar to the skills of a DJ or VJ.

Changed understanding of dynamic fabric

With these reflections in mind, we re-examine our understanding of dynamic fabric at the beginning of this study. In the beginning the researcher expressed working with a form of dynamic fabric that she could not articulate in technical terms. She also expresses frustrations with not being able to touch the dynamic patterns, although this is later overcome. This paints a picture of the dynamic fabric as something elusive, yet we see it has brought certain aspects to the forefront.

First, it shows us that the dynamic fabric cannot be described in technical terms because it was not bound to any one digital tool. It included all the digital technologies involved at different times, in different ways. The dynamic fabric was something that *appeared in certain moments in certain configurations of tools, materials, people, and environments*. And secondly, she was partly able to overcome frustrations

with the intangible, mediated aspects of the dynamic patterns *via* these configurations. For example, she could affect the expression of the fabric by manipulating the lighting, directing the model’s movements or repositioning the camera. She improvised with these configurations until she found ones that for her felt “like painting”.

Furthermore, in addition to experiencing the dynamic fabric in this way in the design process, the researcher expressed seeing it “come to life” in the final film itself. In the scenarios depicted, the dynamic fabric seemed to naturally express itself. With this and all that we have previously described, we postulate that *the existence of the dynamic fabric is conditional*. Phem did not result in dynamic fabric at the end, but in instances of it. We are left with the researcher’s accounts of working with it, and the film as an exemplar of it. Moreover, the film arguably acts as an alternative present that can be experienced by others.

With this we propose a third proposition of dynamic fabric:

Proposition 3

Dynamic fabric is a material state that blends physical textiles with uniquely digital phenomena. This state occurs conditionally and temporarily and extends to both digital media and situated contexts.

In this final proposition, we take several steps away from the dynamic fabric being a technology-embedded textile, and veer slightly away from it being a social-technical system. The design activities in Phem generated a new kind of intimate relationship with the fabric for the researcher in the role of designer. She engaged it in a material-exploratory manner, which largely included digital phenomena from all the tools she worked with. For example, she could style and create dynamic patterns *after* the film shoot (Figure 5) which brings into question whether the model herself ever wore them? She also made and activated the dynamic patterns using a layering of screens technique (filming the computer screen) (Figure 4) to generate digital artefacts, and was challenged by the intangibility of the dynamic patterns. If dynamic fabric of any form is to be worked with as a fashion material it is beneficial to recognise that it will carry uniquely digital material qualities along with its garment form. In the case of Phem, this included it having a temporal form [68], a mediated or intangible form, an ability to be in two places at once, and display uniquely digital artefacts (e.g. pixellation) as part of its expression.

DISCUSSION

By describing two alternative presents for dynamic fabric, we offer an expanded understanding of dynamic fabric meant for everyday fashion. To summarise, we first described it as *a colour-changing textile embedded with electronics*, then as *a social-technical system interacting with digital media*, and finally *a temporary material state that blends physical textiles with digital phenomena*. Below we reflect on our approach and discuss modes of activating this expanded understanding for designers.

Reflections on Alternative Presents for Dynamic Fabric

This research took place between 2016 and 2019, yet we have not been able to articulate the two case studies in this way, as alternative presents, until now. With distance, we saw the opportunity to examine them together and focus on our changed understandings. As we cannot offer a formula for the method we undertook, we can offer the following ingredients which we believe contributed to the outcome of this research: (1) choosing a technology that was widely-explored, though had minimal socio-cultural understandings, (2) taking an RtD approach (3) drawing strategies from *material speculation*, and (4) using a researcher with a means and capacity for unconventional commitments and personal investments in the inquiry.

Dynamic fabric, as an emerging technology, was a good subject for this approach because of the considerable amount of prototypical work produced in the area with little understanding for how it might integrate into an everyday fashion ecology. The door was open for us to explore the mundane and intimate details of its integration into a person's wardrobe. We could also extend the exploration to include a designer's perspective, addressing concerns for how materials-based designers might adapt their process to working with digital phenomena. Some of these things have been addressed in other literature on wearables, but our approach generated detailed anecdotes to support or challenge them, and unpack the nuance involved.

We recognize that a challenge of our approach is how to account for the subjectivity of the researcher in forming knowledge contributions. Insights from these studies are not generalizable, but transferable as intermediate knowledge meant for practitioners working with dynamic fabric. Articulating these insights as overarching propositions allowed us to add a second layer of reflection, acting as the broad strokes of what occurred throughout the research. We see that this approach could be of benefit to other topical areas for DIS. Moreover, we believe that taking a first-person perspective and situating speculative technologies in context allows for an increase in the ecological validity of a process that normally happens in a lab.

Expanded Understandings of Dynamic Fabric for Designers

The three propositions we have offered in this paper are theoretical constructs for dynamic fabric. We do not propose that any one is definitive or incontestable. What we propose is that they can be each be applied differently to frame design goals for dynamic fabric.

Designing towards Proposition 1, for example, suggests a focus on technological developments for it to become wearable as a garment. Proposition 2, on the other hand, puts emphasis on the social ecology of the fabric, prompting questions such as *can other items in a contemporary wardrobe be styled with it?* or *how will the speed of a dynamic pattern be interpreted?* Arguably this is a natural approach in fashion design, but we hope to highlight the

inclusion of the social dimensions of the digital technologies in this process.

Furthermore, Proposition 2 also describes *interacting with AR and other digital technologies*. This paints AR in a new light, a technology that in our view has not been seriously considered as a viable form of dynamic fabric. Moreover, it invites further interrogation of other technologies such as real-time Instagram filters, holograms or mapped video projections as dynamic fabrics currently in use. We draw attention to some recent examples of this in fashion design such as Johanna Jaskowska's *Beauty3000* Instagram filter [35] and Amber Jae Slooten's explorations of VR garment designs and wearing them as holograms [58].

Finally, Proposition 3 emphasizes the *blend* of physical textiles with digital phenomena to create an entirely new material state. This allows us to see dynamic fabric's ability to extend beyond the tangible, material experience of the textile it is part of—such as being on our body but also on a screen. We hope that this view of dynamic fabric, then, invites textile and fashion designers to explore digital phenomena materially in the same way they might engage fabrics—in boundary-pushing and improvisational interactions with them to uncover their unique qualities.

Furthermore, we wish to make explicit that dynamic fabric can and presently does exist as we understand it from this third proposition. We do not think it requires further technological developments for a designer to be able to engage it, nor for them to collaborate with an engineer to create it. Designing with dynamic fabric as a combination of textiles and digital phenomena is achievable in a variety of unorthodox ways. The implications of this challenges fashion designers but also opens dynamic fabric to a wider research agenda where other kinds of DIS researchers can explore the social-technical aspects of dynamic fabric, the role of AR in fashion, digital media and software tools, new design methods, and approaches.

CONCLUSION

In this paper we have described two case studies that explore living with and designing with dynamic fabric over three years. These studies use an approach we call *alternative presents*, which combines first-person, autobiographical, RtD methods with speculative design practises. From this we generated three propositions for dynamic fabric summarised as (1) *a colour-changing textile embedded with electronics*, (2) *a social-technical system interacting with digital media*, and (3) *a temporary material state that blends physical textiles with digital phenomena*. These propositions act as theoretical knowledge for dynamic fabric discourse and design practise.

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