TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

# “Can I wear this?” : blending clothing and digital expression by wearing dynamic fabric

*Citation for published version (APA):*
Mackey, A. M., Wakkary, R. L., Wensveen, S. A. G., & Tomico Plasencia, O. (2017). “Can I wear this?” : blending clothing and digital expression by wearing dynamic fabric. *International Journal of Design*, *11*(3), 51-65.

*Document status and date:*
Published: 01/12/2017

*Document Version:*
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

*Please check the document version of this publication:*

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

*General rights*
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

*Take down policy*
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 07. Nov. 2026

# "Can I Wear This?" *Blending Clothing and Digital Expression by Wearing Dynamic Fabric*

**Angella Mackey [1,2,*], Ron Wakkary [1, 3], Stephan Wensveen [1], and Oscar Tomico [1,4]**

[1] *Eindhoven University of Technology, Eindhoven, Netherlands*
[2] *Philips Lighting Research, Eindhoven, Netherlands*
[3] *Simon Fraser University, Surrey, Canada*
4 *ELISAVA, Barcelona, Spain*

We explore the future scenario of wearing garments with digital display capabilities, or *dynamic fabric*, in everyday life. Our study, called *Greenscreen Dress*, investigates the experience of wearing dynamic fabric and how this type of garment quality might alter our daily interactions with clothing and have implications for designers. In the study, we adopt an autoethnographic approach that materially speculates on dynamic fabric by wearing green every day for ten months and using a chroma key ("greenscreen") mobile application to give the garments a digital display. We reflect on the behavioural and mental shifts that emerge from integrating dynamic fabric into one's wardrobe with regards to expression through personal style, fashion design processes for and with digital content, social acceptance of dynamic displays on clothes in mass fashion and engagement with digital media for expressive purposes. Broadly, we argue that exploring wearable technologies through the lens of socio-cultural perspectives and clothing practice, as opposed to material or technological developments, can reveal insights with regards to the opportunities and challenges of blending clothing with smart technologies. More specifically, we explore the future notion of dynamic fabric clothing through the act of *wearing* dynamic fabric in everyday life and an engagement with *digital expression*.

***Keywords*** – Dynamic Fabric, Fashion, Wearable Technology, Smart Fabric, Digital Expression.

***Relevance to Design Practice –*** This article demonstrates through example the importance of including more nuanced socio-cultural understandings of fashion and rituals of dress in wearable technology and smart fabric design disciplines.

***Citation:*** Mackey, A., Wakkary, R., Wensveen, S., & Tomico, O. (2017). "Can I wear this?" Blending clothing and digital expression by wearing dynamic fabric. *International Journal of Design, 11*(3), 51-65.

## Introduction

If garments were to possess a computer screen's ability to dynamically display colours, patterns, and still and moving imagery, what might this experience be in everyday life? The very possibility of integrating "dynamic fabric" into clothing challenges many of the norms of fashion. Key among these is the notion of one garment functioning as multiple garments (Devendorf et al., 2016; Dunne, 2010). In theory, the "ultimate garment" could potentially mitigate the waste and unsustainability of "fast-fashion", that is, the cyclical change of fashion based on trends and seasonal changes of spring and autumn collections (Dunne, 2010). Dynamic fabric offers new forms of expression that combine fashion with digital cultures and which may alter notions of originality, consumption and identity as currently manifest in "non-dynamic" fashion. For example, dynamic fabric could merge the social interactions performed through garments with social media interactions to create hybrid physical and virtual forms of sociality (Berzowska, 2005; Devendorf et al., 2016; Loschek, 2009). In short, wrapping our bodies in dynamic and sophisticated visual digital content could be disruptive for fashion.

The prevalence of dynamic fabric could be equally disruptive for those designing or researching wearable technologies and smart fabrics and also for the broader disciplines of human-computer interaction (HCI), graphic design, textile design, fashion design and social media. It would bring the digital to a new level of intimate, material and social relations with our bodies. As innovations in smart fabrics continue, it will be increasingly important for designers to consider the convergence of the social functions of technology with the social functions of dress (Buechley, Eisenberg, Catchen, & Crockett, 2008; Devendorf et al., 2016; Dunne et al., 2014). Dynamic fabric has the ability to draw from the digital world while existing as worn material in the everyday physical and social worlds. For researchers and designers, this implies that the digital will be brought squarely into the realms of embodiment, daily life, and social and cultural audiences.

It is well-established within fashion that clothing functions as an important and necessary social tool that acts as an interface between our bodies and society (Barnard, 2014), Umberto Eco (1986) writing that, "in imposing an exterior demeanor, clothes are semiotic devices, machines for communication" (p. 195).

**Received** January 9, 2017; **Accepted** July 8, 2017; **Published** December 31, 2017.

***Copyright:*** © 2017 Mackey, Wakkary, Wensveen, & Tomico. Copyright for this article is retained by the authors, with first publication rights granted to the *International Journal of Design*. All journal content, except where otherwise noted, is licensed under a *Creative Commons Attribution-NonCommercial-NoDerivs 2.5 License*. By virtue of their appearance in this open-access journal, articles are free to use, with proper attribution, in educational and other non-commercial settings.

***Corresponding Author:** a.m.mackey@tue.nl

In this light, explorations into dynamic fabric and wearable computing will need to anticipate the socio-cultural implications of identity and audience. Further, the dynamics of daily living on such an intimate basis with digital technology will reveal distinct opportunities and challenges as important as the technological developments that enabled them.

We approach these notions through *Greenscreen Dress*, an autoethnographic study focused on the *wearing experience* of dynamic fabric in everyday life. To approximate this, over a ten-month period the first author incorporated the colour green into her wardrobe on a daily basis and captured still and moving images of the garments inscribed with changing digital content using a live chroma-keying smartphone application (iDevMobile Tec., 2015) (Figure 1). The central activity of the study is wearing visual digital content to "try it on" and through this to explore the interplay of clothing expression and digital expression as it relates to personal identity and style, combined with daily interactions with garments.

**Angella Mackey** is a Marie Skłodowska-Curie doctoral fellow at Eindhoven University of Technology and Philips Lighting Research in the Netherlands. For over a decade, her design practice has investigated wearable technologies in art, research and commercial contexts. She has designed functional garments in a wide range of industries, from medical to space flight, and lectures on the design challenges of integrating electronics into fashion. Most notably, in 2011 she founded Vega Wearable Light, a line of illuminated outerwear for style-conscious cyclists. Mackey's doctoral research explores everyday clothing practice as a means of experimenting within, speculating on and gaining insight into future smart-garment systems.

**Ron Wakkary** is a Professor in the School of Interactive Arts and Technology (SIAT) at Simon Fraser University (SFU) where he established the Everyday Design Studio, a design research studio that explores interaction design. He is a Design United Visiting Professor and Chair of the Impact of Interaction Design on Everyday Life in the Industrial Design Department at Eindhoven University of Technology (TU/e). Wakkary's research investigates the changing nature of human-technology relations through design research in everyday living. He is a member of the editorial boards and steering committees of International Journal of Design (IJD), Tangible Embedded/Embodied Interaction (TEI), and Designing Interactive Systems (DIS). He was co-Editor-in-Chief of ACM interactions from 2010 to 2016.

Dr. **Stephan Wensveen** is a Professor in the department of Industrial Design at Eindhoven University of Technology. He studied Industrial Design Engineering at Delft University of Technology, where he was one of the initiators of the ID-Studiolab design research studio. He began his research on the relationship between emotions, expressivity and product design in 1999. He gained his PhD in 2005, his thesis aiming to bridge the tangible interaction, affective computing and product design communities. His thesis (co)-developed design methods and articles are part of many international design curricula. Since 2005, he has served on multiple conference review committees and was keynote speaker at DPPI'07 (Designing Pleasurable Product and Interfaces conference) and SIDeR'08 (Student Interaction Design and Research conference). His current interests are in using the power of design to integrate research, education and innovation, especially in the areas of textiles and electronics.

Dr. **Oscar Tomico** is head of the Design Engineering Bachelor program at ELISAVA Design and Engineering school, and Assistant Professor at Industrial Design, Eindhoven University of Technology, working on soft interactions for the Wearable Senses Lab. Current projects focus on the textile industry and involve stakeholders during the design process to create ultra-personalized smart textile services in the form of soft wearables. He is involved in research projects like ArcInTexETN (2015), CLICKNL Crafting Wearables (2013), CRISP Smart Textile Services (2011). He has been a guest researcher and lecturer at Textile and design lab AUT (NZ), TaiwanTech (Taiwan), Swedish School of Textiles (Sweden), IAAC (Spain), and Aalto (Finland). He co-organized events like the Waag Careful Designs and Hypercrafting Fashion events (Amsterdam), Baltan Open Lab: Wearable Senses workshops (Eindhoven), Crafting Wearables (Arnhem) and DHUB Smart services, smart production, smart textiles (Barcelona). He curated exhibitions like "Systems Design - Eindhoven School" (DHUB, Barcelona), and "Smart Textiles – Wearable Services" (TextielMuseum, Tilburg).

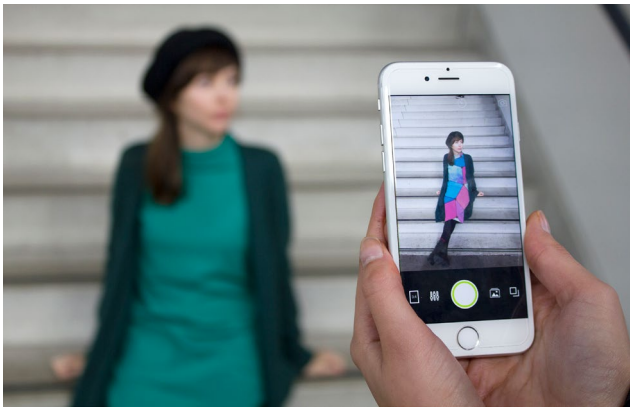

**Figure 1. Live demonstration of chroma-keying smartphone application** (iDevMobile Tec., 2015) **used in Greenscreen Dress:** Here we see composited digital content onto a bright green dress.

Findings from the study are examined through the lens of the researcher's daily acts of *wearing* dynamic fabric, and interactions with *digital expression* (expressive capabilities through digital media). The paper offers several insights. We explore the practical and expressive opportunities and challenges in integrating highly functional fabrics into one's wardrobe, the integral role of an audience in exploring wearable technologies meant for personal fashion, negotiations made between the digital qualities and physical qualities of dynamic fabric, and questions that arise surrounding control and authorship of digital content that is "worn".

In this article, we discuss related research, design and artistic work in the area of dynamic fabric as well as the motivations of our research, which derive more broadly from the practice of wearable technology design aimed at mass fashion. We describe our study and its focus on the first-person accounts and findings of the Greenscreen Dress activity. The study contributes an account of the experience of wearing dynamic fabric situated within a contemporary fashion dialogue. We conclude with a discussion about the body and the act of wearing and the value of exploring future wearable technologies within a social ecosystem rather than from the limited perspective of technologies and materials alone.

# Background

## Related Literature

In this article, we engage with the concept of *dynamic fabric* as a textile with computational input, which enables changes to its visual appearance for aesthetic, communicative and expressive purposes. In 1985, Harry Wainwright developed a sweatshirt with integrated fiber-optics and a micro-processor to control animations displayed on the fabric (Guler, Gannon, & Sicchio, 2016). He went on to hold numerous patents in this area for custom apparel and toys (Guler et al., 2016). In the late nineties and early 2000s, there was significant technological exploration into embedding LEDs and thermochromic inks within textiles and various conductive materials (Berzowska, 2004; Orth, 2004; Orth, Post, & Cooper, 1998; Seymour, 2008). Researchers, artists and designers such as Maggie Orth, Joanna Berzowska and Sarah Taylor created

custom textile swatches, full tapestries and full garments that could change colour and pattern, exploring what was aesthetically and technologically possible. Following these explorations have been further refinements of both the technological and expressive possibilities of these approaches in the form of prototypes and custom textiles (Worbin, 2010), custom-made artistic, high-fashion or entertainment-related animated garments. Examples include the Philips' emotion-sensing illuminated Bubelle dress (Philips Design, 2006), Moritz Waldemeyer and Hussein Chalayan's animated LED Dress (http://www.swarovskicollective.com/hussein-chalayan/), Valerie Lamontagne's (2005) series of colour- and light-changing dresses using real-time weather data and more (e.g., Berzowska & Skorobogatiy, 2009; Rosella & Genz, 2005). There have been numerous short-run or low-volume commercial product releases like the Philips Lumalive e-textile garments (Harold, 2006), illuminated garments by fashion companies CuteCircuit, MOON Berlin and Utope (Berglin, 2013; Rosella & Genz, 2005) and smartphone-controlled animated e-ink shoes and jewelry made possible through crowd-sourced funding websites (e.g., Kovacs, 2015; Coelho, 2016).

Within the last five years dynamic fabrics that combine physical-virtual means, as in augmented- or mixed-reality technologies have appeared in fashion collections. For instance, the design collective Normals in 2012 (http://mixtur.es/apparel/) and designer Marga Weinmans in 2013 (http://augmentnl.com/hyperfabric/) both presented clothing with markings that a smartphone application could recognize to generate large geometrical patterns surrounding the wearer. Also, there have been speculative design films depicting scenes with augmented-reality fashion such as *Song of the Machine* by Superflux (2011, https://vimeo.com/22616192) and *HyerReality* by Matsuda (2016, https://vimeo.com/166807261), which add new possibilities to the concept of state-changing or responsive textiles. The 2002/2003 Bluescreen collection saw the Dutch luxury fashion house Viktor & Rolf project landscapes, street traffic, sky and clouds onto their garments as models paraded on the catwalk (Loschek, 2009). Video-mapping projections have now reached a technical sophistication whereby pop-music celebrities like Carrie Underwood in her 2013 *Blown Away* Tour and Jennifer Lopez in 2015 on the television show American Idol have performed with video-animated dresses. Also, in 2017 companies like Nike are using video-mapping in their live retail experiences by projecting moving images onto running shoes (http://www.smartpixels.fr/).

The common thread linking these examples is the desire to experiment with, develop and speculate on wearable applications for flexible, fabric-like surfaces that can be visually transformed through computation, all valuable contributions to an emerging field that is not yet widely applied. Our research into dynamic fabric does not attempt to make prototypical, artistic or technological contributions, rather we anticipate the wearing experience of dynamic fabric in an individual's wardrobe over time, something not previously undertaken. Differentiating our research from previous work is the aim of Greenscreen Dress to explore the ways in which dynamic fabric might or might not fit into daily life, have implications for mass fashion or the fashion design process.

We see *the everyday* as a space to explore the evolution of new products or systems that could potentially fundamentally change how we already do something, in this case how we wear clothes. We are motivated by the autoethnographic approach and the contribution of Steve Mann (1997) in exploring wearable computers and Andrea Zittel (1991) towards new modes of living with regards to clothing, furniture and food. In terms of HCI, we recognize the value of Neustaedter and Sengers' (2012) concept of autobiographical design, which they define as "design research drawing on extensive, genuine usage by those creating or building the system" (p. 514) and which is exhibited through other works (eg., Desjardins & Wakkary, 2016; Gaver, 2006). We have also been inspired by Hansen and Kozel's (2007) notion of embodied imagination, which is "less concerned with getting input for a concrete design proposal than it is with integrating the body directly into the loop of design iteration in an open ended way" (p. 210), as demonstrated through their project Placebo Sleeves.

The value of considering socio-cultural perspectives of fashion towards personal identity and communication has often been described in academic literature about smart textiles and wearable computing design (Berglin, 2013; Devendorf et al., 2016; Dunne, 2010; Dunne et al., 2014) with very limited exploration into its social reception (eg., Dunne et al., 2014). We draw details and insights from Susan Elisabeth Ryan's (2014) book, *Garments of Paradise*, a critical study of wearable technology that considers the cultural context of and theoretical debates in the field. We highlight the important element of performativity within fashion that Ryan describes and which we demonstrate through this study of use. Furthermore, we frame our findings and discussion within fashion theory as written about by cultural and fashion theorists Malcolm Barnard (2014) and Ingrid Loschek (2009).

We have been inspired by Devendorf et al.'s (2016) concern with the complex nature of personal style within the context of the computer-human interaction field, investigating how clothing and fabrics affect meaning and perceptions of identity among a web of associations with other meaningful things. The novel textile display technology they developed, called *Ebb*, was used as a probe for fashion designers and non-designers to describe how they might integrate dynamic-display textiles into their practices or personal style. Created using traditional weaving and crocheting techniques combined with conductive threads and thermochromic inks, *Ebb* presented a slow, low-resolution color-change in textile swatches, which evoked positive reactions from participants. Interviews with the participants included a variety of unique and detailed descriptions of how this kind of dynamic, clothing-based display could be used in daily fashion. Our research explores similar questions to Devendorf et al. around what it might mean to wear dynamic fabric in everyday life, but differs in its focus on the role of the body, act of wearing, audience and engagement with computer and smartphone screens as conduits for digital expression. This study thus moves into a new space of speculation, whereby the outcome is based on a genuine social context over a relatively long period of time (Mackey, Wakkary, Wensveen, Tomico, & Hengeveld, 2017).

# Greenscreen Dress Study

## Motivation and Context

Our inquiry into what it might mean to wear clothing-based, dynamic display fabric in everyday life was driven by the first author's previous experiences using wearable technologies and smart fabrics in her eight-year practice as a fashion designer. Throughout this time (2007-2015), she observed a predominant techno-centric approach in the industry in the development of such garments. She identified a gap in the understanding of the social ecology of fashion, seeing this as the main reason for relatively low product adoption beyond other commonly cited causes such as production costs and the feasibility of manufacturing (Dunne, 2010; Ryan, 2014). This study began as an experiment to uncover what value can arise from approaching the development of new wearable technologies and smart fabrics with a focus on the act of *wearing in everyday life* with minimal concerns for the technology itself.

Dynamic fabric was chosen as the subject for exploration for this approach, firstly because of its expressive potential and secondly the enthusiasm for it coming from smart fabric communities as outlined in the Related Literature. Without access to this fabric in a form that possesses the visual capabilities of a computer screen, combined with the physical form of a clothing-grade textile, we mimicked these qualities using a "greenscreen" chroma-key system. Other systems were investigated to simulate an experience of dynamic fabric that could be worn every day, such as flexible e-ink displays or interchangeable panels of paper that could be quickly printed on with an inkjet printer. However, these approaches either posed too many practical and technical challenges, or limited the possibilities for interacting with digital content and aesthetics. In wearing green fabric, we were able to collect, design and project digital content (colours, patterns, shapes, text, still imagery and videos) onto a garment's surface quite easily using an off-the-shelf chroma-key application (iDevMobile Tec., 2015) on a smartphone. The application allows for live virtual compositing of any videos and images stored on the smartphone on the green fabric (Figure 1), functioning like many augmented reality (AR) technologies to date. Being able to access *any* digital content capable of being displayed on a smartphone screen broadened the possibilities for digital expression where e-ink, static printed images or LED grids were limited.

Recording this experience using autoethnographic methods over ten months, the researcher incorporated green fabric into her daily wardrobe and regularly changed the digital content of the green clothing throughout the day. She posted the resulting pictures and videos of the digitally-altered garments on Instagram, a social media platform based on image and video exchange and chosen for its popularity within art, design and fashion communities. This choice allowed the digital versions of the garments to be "worn" and have an audience, as well as to exist within a social ecosystem with an established fashion dialogue.

Furthermore, she interacted daily with colleagues and acquaintances who understood the green she wore as "active", or holding the ability to visually present digital content. These interactions lead a small community to participate in the study through workshops, play, discussion, reflection and personal use of the system. The same occurred on Instagram, where a community of 263 followers discussed the videos and pictures she shared. Over ten months, the researcher posted 159 images and videos on Instagram, with approximately 6500 images and videos of garments or digital content left "unworn" on her smartphone.

Throughout this article, we refer to this cycle—the collecting of or assembling of green garments to be worn, wearing these green garments, collecting digital content, "wearing" the digital content, and presenting selected garments on Instagram—as the *greenscreen system*. We refer to the study as Greenscreen Dress, but there is no one dress, nor is it a prototype. Greenscreen Dress is a system for exploiting green garments using chromakey within a digital ecosystem. Greenscreen Dress is a *material speculation inquiry* described by Wakkary & Odom et al. (2016) as "the mediating experience of specially designed artifacts in our everyday world in order to speculatively and critically inquire through design" (p.45). The dynamic fabric is never truly tangible within the study, but an experience of it exists through the greenscreen system. The tension created in the study between the research aims to explore future visions of dynamic fabric without it existing while somehow still living an experience of it in daily use offers a unique perspective from which to speculate (Mackey et al., 2017).

The insights that emerge from the study were extracted and analysed using autoethnographic methods. Autoethnography worked well as a qualitative research approach in its aim to describe and "systematically analyze personal experience in order to understand cultural experience" (Ellis, Adams, & Bochner, 2010, p. 1). By using principles within autobiography and ethnography as a method, results were in both process and product.

As part of the autoethnographic method, over ten months the researcher kept research memos of her experiences using the greenscreen system. She recorded anecdotes, personal thoughts and reflections about the struggle to integrate green into her wardrobe, how others perceived her activities, how she chose to make decisions about what she wore and what elements altered these decisions. The researcher adopted the first-person perspective of a wearer and performed in the role of fashion designer in the creation of some of the green clothing and digital content used in the study. Periodically, she developed high-level reflections from the research memos, followed by group analysis with the second authors to identify themes that provide insight into future implications for dynamic fabric.

These insights and themes are the findings of one researcher and her experience of wearing dynamic fabric in everyday life. The findings provide a qualitative investigation into wearing dynamic fabric with the potential to be *transferable* in qualitative research terms to the future development of dynamic fabric. Our aim is to demonstrate by example the rich detail that this kind of autoethnographic approach can provide for a technology that either does not yet exist or is not yet accessible within mass fashion. We see the most valuable insight to be the potential difficulty in accurately predicting the extremely personal uses

of smart technologies for fashion before it has been adopted over a long period of time as demonstrated by the consistently unexpected outcomes that occurred throughout this study. The findings suggest that personal preference, social interactions, and the repetition and volatility of daily life will ultimately guide the new technology into its final forms.

## First-Person Accounts of Wearing Dynamic Fabric

The following summary of *Greenscreen Dress* is written in first-person by the first author, the content and reflections being extracted and summarized from her research memos written over ten months.

### *Wearing Green Clothes Every Day: The Ultimate Dress*

The study began in February 2016 with wearing the same green dress every day for two weeks. I liked the style of this dress and hypothesized that if periodically washed and dried overnight, it would be "the ultimate dress" (Figure 2a). I imagined that because it could be completely transformed to have a new pattern or colour through the chroma-key app, there would be little reason to consider wearing anything else. However, during the first week of the experiment, I observed that my personal style had been compromised. What I was physically wearing was still based in the reality of clothing situated in the interactions of my daily life at work, in public and at home. I still desired new textures, new silhouettes and other kinds of variety in order to feel "myself." Because an important element of the research was to base the exploration in a real sense of personal style, it was important that what I wore as physically seen by those around me was not seen as a sort of artistic performance, but as a person wearing relatively "normal" clothes. I also observed that being completely covered in the green fabric from my neck to my knees was too strong in that I felt overpowered by the complete digital transformation of most of my body. Some days I only wanted a pocket or collar that was green, a green-striped print or just green pants. I also sometimes wondered if being entirely dressed in such a bright green was conjuring cultural associations with Irish leprechauns or a walking green bean and that no one around me was telling me this.

### *Green Wardrobe*

What followed over the subsequent months was the collection of 20 or more garments—bought new or secondhand—each completely different in texture, style, shade and amount of green (Figure 2b). Each garment reacted differently through the chroma-key application. Some greens keyed-out (were replaced by digital content) seamlessly, creating a flat, one-dimensional interpretation of the digital content. Pastel and dark greens keyed-out in surprising ways that presented the digital content as faded or "grainy." Sheer green fabrics were also able to hold the digital content while still allowing physical artifacts to be seen behind them (Figure 3).

**Figure 2. Samples from green wardrobe: (a) original green dress worn for the first two weeks of study, (b) example of expanded green wardrobe with and without digital content.** Darker greens are shown holding faded versions of the digital content compared to brighter greens. The white shirt with red, blue and green flowers only holds hints of the digital content within the hints of green.

**Figure 3. Sheer, pastel shirt: Examples of a shirt that is made from a sheer fabric.** The shirt is a solid, pastel green colour. The researcher is wearing it over a navy blue dress with white polka-dots. Each of these images shows the shirt with different composited digital content while still retaining it transparency.

The collection of garments not only included the gathering of green garments, but also of other differently-colored garments to provide pieces that paired well with these greens. This meant that many of the garments I already owned could be used to pair with the green, but many could not. Grey, for example, never seemed to "go well" with the bright green colors whereas black and navy

blue did. I thus often paired the green with black and navy blue. With weather changes from winter and spring to summer, I had to find new green clothing to account for seasonality.

To summarize, the task of wearing green daily moved from wearing one green dress for two weeks to collecting, experimenting with and pairing green garments consistently over the remaining nine and a half months. The resulting wardrobe was a product of rebuilding my personal identity through clothing that confronted the constraint of green fabric and allowed for the chroma-keying action to happen. Irrespective of the virtual versions of the garments, the wardrobe was highly sensitive to practical and social elements as physically encountered in my daily life.

### *Wearing Digital Content: Live AR and Selfies*

The chroma-key app worked in such a way that any video or image stored on my smartphone could be used to key-out the green fabric. Still images and videos could be experienced in real-time on the green fabric through the smartphone screen, as in augmented reality (AR). In this way, the system acted like a "live Photoshop." (Figure 1)

In the first few days of the study, I was unsure about how I would frame and plan the pictures of me wearing digital content, but I committed myself to the task of completing at least one picture a day. I also felt uncomfortable with the idea of taking pictures of myself, so I instead approached colleagues using the excuse of demonstrating my experiment to them as a way to take selfies with other people (Figure 4). It took many weeks before I began feeling comfortable taking pictures of myself alone. The digital content I used was the default still images stored on the phone that came with the application. Typically, these were images of trees and sky in landscapes because the application was designed for filmmakers wanting stock backgrounds (Figure 4). To make it more personal, my next step was to search online for images of textile-like patterns. I downloaded sets of graphic patterns I liked, such as black and white polka-dots, rainbow stripes and a houndstooth pattern. After one week of using these two sources for digital content and using them only in this "demonstration-selfie" mode, I felt I was not representing my personal style adequately. I perceived the process mostly as a gimmick or party trick (Figure 4). I was not satisfied.

I next experimented with framing images of my arms, torso and legs, as well as traditional selfies with just myself in the picture. I also experimented with capturing pictures and videos of the physical things surrounding me, such as the texture of a wall, an image from a book, or the moiré-effect of the smartphone camera capturing a computer screen to wear and explore how they appeared on the garments. In an effort to consistently generate interesting juxtapositions for my Instagram posts, I observed that when sitting at my desk, the background of books and cupboards mostly detracted from the overall aesthetic expressions I desired. I felt these backgrounds were ugly. Achieving something I liked with novelty and variation required exploration of my environment, neighbourhood, home city and other cities. Activities such as walking and bicycling, travelling and planned or spontaneous socializing with friends, colleagues and strangers were the best moments to inspire a new digital outfit. I often thought about how I could not get interesting pictures unless I got up from my desk.

Over the following months, these activities led to a heightened skill and understanding of how to use the smartphone camera and the application as a kind of visual- and audio-mixing tool for abstract expressions through the green garments in various environments. As I became better at this system, I became more satisfied with the personal expressions I was posting on Instagram. I began wondering less about what was technically possible to wear using these tools and more concerned with whether I was making the right style choices for myself.

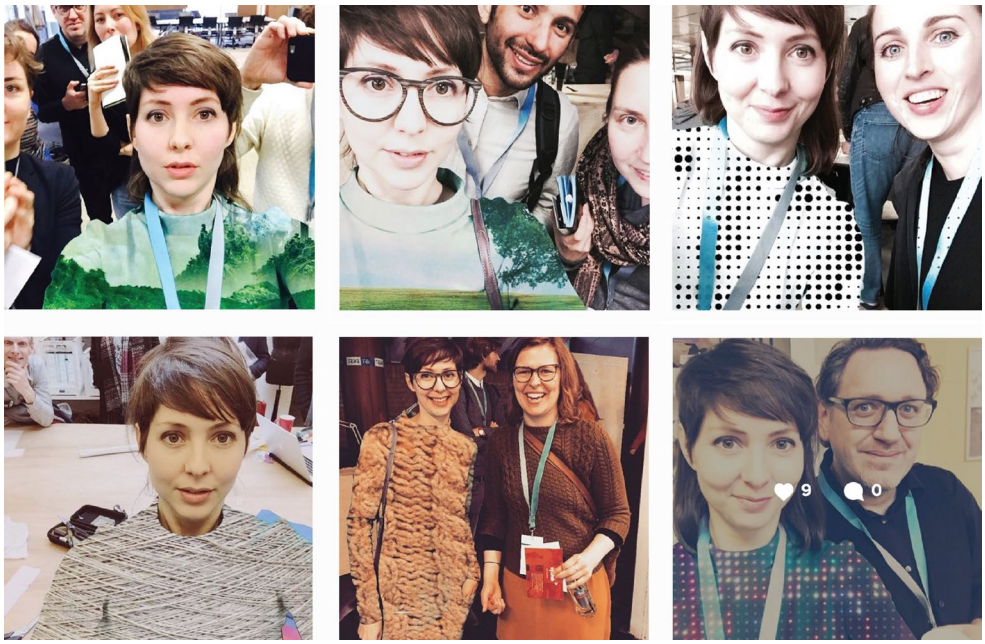


**Figure 4. Selfies: Selected selfies taken with colleagues in the first week of study wearing the same green dress.**

### *Virtual Closet*

I stored the videos and images of "things to wear" in a folder on my smartphone called "Patterns," (Figure 5) because I thought of them in the same way that I thought of patterned fabric. Most of the digital content I wore over the ten-month period came from images and videos in this folder, which contained 1396 files captured from my surroundings. In this way, the folder acted as a digital version of my closet, which held patterns I wore or hoped to wear. Over the entire period, the most I wore repeat patterns on Instagram was three times. The range of time between capturing an image and wearing it spanned from instantly, usually for site-specific images, to many weeks later.

A dominant theme in my personal-style habits was to choose to wear abstract imagery as opposed to representational images. In the beginning, I mostly favoured posting still images of the digital garments, but after several months favoured posting videos—I preferred wearing abstract imagery that was in motion (Figure 5). I felt these expressions were the most interesting for me and others to see. However, in the fourth month I entered a new expressive stage where I wanted to reveal an alternate side of my personal identity and began intermittently posting images that were more representational: screen-like imagery, such as a dancing bunny, blinking eyes or a cowboy riding a horse. Much like wearing a T-shirt with a representational graphic on it, which I rarely did in everyday life, these expressions did not necessarily represent anything specific to me, but were selected as a personal style choice for how I was feeling in the moment. I mostly wore the abstract imagery, but sometimes desired something completely different such as these screen-like expressions.

To summarize, the digital content that I chose to wear went through different stages of trial and error and exploration. Through consistent use, I transitioned from a "gimmick phase" to eventually finding a style that suited my personal tastes (Figure 6) and a method for attaining it. For reasons related to expression and depth of personal identity, I occasionally stepped outside these habits to "try on" new things.

### *Audiences: Wearing within the Social Ecosystem*

Only colleagues, friends and family members intimately aware of this study recognized the greens I wore as "active" and were able to experience the live, AR versions of the clothing through my smartphone. Mostly, this awareness provoked a heightened attention to what I wore each day and sometimes a question like "Oh, you're not wearing green today?" would bring attention to this. I would respond by pointing to the subtle green leaves within the pattern of my shirt, or the green hue in my "blue" pants. Several times, a colleague or friend would comment to me in person that they liked what I wore on Instagram: "That one was my favorite." These kinds of comments could have enormous influence over the future course of my digital dressing. Positive, in-person reactions sometimes led to repeat actions to attain a similar look.

Many of my colleagues had downloaded the same chroma-key application on their smartphone and experimented with the system themselves. One colleague intermittently photographed me when he felt inspired and placed what I perceived as unfavorable digital content on my garments. For example, in one image the colleague "dressed" me in a screenshot of his smartphone home screen, another time in an orange tie-dye pattern and later a

**Figure 5. Abstract patterns in motion being worn by the researcher from "Patterns" folder.** Each image is a still captured from a video: (a) a video of raindrops recorded onto a fabric with green polka dots giving them a shimmering effect. The researcher wears these shimmering polka dots on her shirt three days later, (b) a video of the sky reflecting in the water near where the researcher works. The researcher wears this video in the green stripes of her skirt blowing in the wind the next day, (c) an abstract video mixed on the researchers' smartphone using pink bubble wrap. Three weeks later the researcher attends an art exhibit whereby a green light passes over her face and she "wears" the bubble wrap video on her face using the green light.

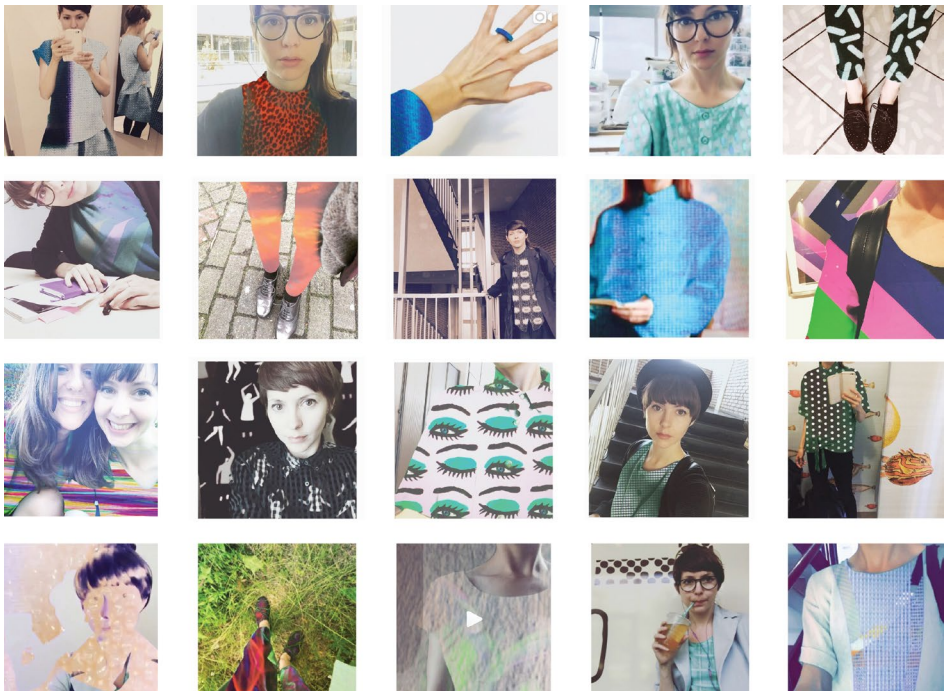

**Figure 6. Selected images and video stills from Instagram of the researcher virtually wearing digital content composited onto her green clothes.**

cartoon monkey (Figure 7). Where I initially thought I would have complete control over what I wore, I experienced unanticipated issues of control through these interactions. I observed that my transition from the original all-green dress to a wardrobe containing varying amounts of green was one way of "protecting" myself from these kinds of "digital attacks." If the green I wore was subtle, or existed only as pieces around my body (a cuff, a scarf, or in a textile pattern of polka dots or flowers), it was more difficult for another person to dress me *entirely* in what they wanted. I also spoke to my colleague about how I did not like the images he was taking of me. From this point onward, he became more sensitive to me and asked before making an image public.

On Instagram, different communities received the garments in a variety of ways. Early in the study when I was unfamiliar with the platform and still attracting followers, I received "likes" and comments from people I already knew in daily life. As time passed, I learned to more intuitively navigate the Instagram social system and find connections with others through my posts. In the circles of users that I followed, I learned how to use a similar tagging language and build upon shared aesthetic preferences. I gained followers from AR communities, digital art, wearable technology, fashion and other special interest groups such as those with similar aesthetic associations to the tags *#spacesynth* and *#glitchart*. Some followers engaged in private discussions with me about whether the fabric I was wearing was "real" and how they could attain it. Other followers started discussions with me about future collaborations, not interested in the technological side of what I was doing, but in the artistic and expressive qualities of the results.

To summarize, the physical and digital versions of the garments were encountered by a variety of people in a variety of contexts. Some interactions involved only the green garments, only the digital garments, or hybrids of both. A general theme for these encounters was the "testing" a look in front of others to see how it was received. Although I never received negative feedback, positive reactions and engagement fed and influenced future choices of dress.

**Figure 7. "Digital attacks": A colleague composites unwanted imagery onto the researcher's green garments without her consent using the chroma-key smartphone application.**

## Findings

In this section, we present a list of findings related to the implications of future dynamic fabric. These findings are outcomes of a qualitative first-person study and are *generalizable* in the sense of qualitative research, meaning that we view them to be *transferable* to similar situations or settings like the possible future of dynamic fabric. They include: 1) Choices that change clothing habits; 2) Need to consider material qualities that are not digital; 3) Social lives of dynamic fabric in social media and everyday life; 4) Digital media curation and control; 5) Wardrobe choices for digital and physical worlds. These insights are grouped under two broad themes: *Wearing Greenscreen Dress* and *Considering Digital Expression*. The goal of presenting the insights under these themes demonstrates respectively the value of *wearing* in the wearable technology design process and the need to consider *digital expression* when working with a technology that uses or draws from digital content.

We arrived at these findings by analyzing the autoethnographic research memos. What emerged were two overarching themes under which the findings have been organised. Additionally, there are different perspectives that could be analysed within Greenscreen Dress. There is the researcher as a wearer and as a designer, and there are the people around her in everyday life and virtually on social media at different levels of engagement. For the discussions within this article, we draw only from the first-person perspective of the researcher as a wearer and a designer.

### Wearing Greenscreen Dress

The activity of wearing in this study sheds light on a useful step in the smart garment design process, revealing opportunities and challenges of a wearable technology concept within clothing practices. Previously, we discussed the theoretical value of taking a body-centric approach—*wearing*—towards exploring the potential of dynamic fabric, or any new smart textile or wearable technology proposed for wear in daily life. What we mean by *wearing* could start with a simple "trying it on", where a considerable amount of knowledge can be gained. But when the process moves into the incorporation of the smart garment into everyday life, new variables are introduced that have undeniable implications for the outcome and understandings of the proposed technology. In the space of *the everyday*, clothing-wearing rituals and personal fashion habits begin to challenge the smart-garment concept. As Ingrid Loschek writes in 2009 in her book *When Clothes Become Fashion: Design and Innovation Systems*:

> [I]nnovations in the audiovisual and electronics media have altered our experience of time and space, but this acceleration and destruction of space have not yet altered the aesthetics of fashion … Wearable electronics, clothes with alternating colours or colours that change with the onset of night-time, real-time projections on clothing, inflatables or other clothes that change their form are largely still perspectives of the future. The question is whether and how rituals and dressing behaviour have altered as a result of the electronic media due to their own temporality, or how much they will alter in the future. (pp. 152-153)

Below we reflect on selected behavioural and mental shifts that took place within the researcher's daily life with regards to her personal style and clothing habits due to the act of wearing dynamic fabric. These reflections attempt to answer the questions *What changes take place in daily life to accommodate these new kinds of garments?* and *What is it like to wear dynamic fabric?*

#### *Choices that Change Clothing Habits*

A finding of Greenscreen Dress was that the experience of dynamic fabric presents wearers with an abundance of choice related to personal fashion. In the study, the researcher was confronted with a new ability—to collect, choose and virtually alter the façade of her green garments at any time throughout the day. Typically, one completes their dressing ritual at the beginning of the day, confirming their choice in a mirror before leaving their home. Rarely is a wearer expected to consider changing their clothes after this.

For the researcher, this new ability confronted her with making many decisions throughout the day about her style. If she could wear anything on the surface of her garments, what would she choose to wear? If she could change it at any time, when would she change it? When would the decision take place? Would she pre-plan her wardrobe ahead of time or would it emerge spontaneously throughout the day? There were no preset social rules for how to react to this onslaught of new wearing choices.

The habits that the researcher settled into were a result of many months of experimentation. To summarize, she negotiated what she wore with the technical abilities of the system (capturing digital content from her surroundings using her smartphone camera or collecting it from the Internet) with her personal preference for abstract imagery and how she felt the outfits worked in conjunction with the aesthetics or context of her surroundings. She carried digital content around with her in a folder labeled "Patterns" on her smartphone and primarily drew from this when composing a new digital outfit. She always allowed inspiration and spontaneity to dictate when a digital version of a garment would occur and never pre-planned them, however committed to generating at least one a day. She discovered that sitting stationary rarely inspired these outfit changes. Therefore, she came to associate activities such as local commuting, long-distance travel, exploration and socialization as prime moments for changing the digital content of her garments and consequently sought them out.

It took many months for the researcher to fall into a cycle where these habits could be identified and acknowledged by the researcher. She describes herself as becoming more skilled with the greenscreen system, suggesting that at some point she reached a comfort level with its integration into her daily life. The long period of time spent wearing dynamic fabric allowed the researcher to enter and leave different phases. For example, the researcher reflects that the beginning of the study felt like a gimmick or party trick. In this phase, she found it difficult to communicate her personal style and use the system as it was intended. Consistent use and exploration brought it to the next phase where she felt her style was beginning to happen. Partly influenced by her own design instincts, the aesthetic sensibilities

of her Instagram audience and the context of people and things physically happening around her, she became more skilled at welding the system to her desires, entering stages of heightened personal expression. The reflection that it took time to make personal sense of and become skillful with the greenscreen system arises from this particular study, however it could be readily imagined in similar navigations of hybrid virtual and physical identities in more everyday contexts.

When the system reached a level of being more intuitive, the researcher describes a mental shift where the main questions she had been asking herself each day changed. Originally, she asked herself, "*What can I do with this?*", meaning *What is possible with this technological system?* Later, as this became clearer, the question she asked was closer to, "*Can I wear this?*" Much as we ask ourselves when standing in front of a mirror at a shopping mall or at home, the system revealed itself to have entered into her subjective, everyday fashion language, this consciously and unconsciously considering what she believes she is communicating to the world through her garments about who she is. Asking, *Can I wear this?* shifts the focus of inquiry from a growing list of what is *possible* to what is *plausible,* given a particular social context and fashion dialogue.

### *Need to Consider the Material Qualities that are not Digital*

Another finding of the greenscreen system is that future versions of dynamic fabric will possess physical material qualities that must be negotiated within different wardrobe contexts. The green fabric within the greenscreen system acted as a stand-in for a constrained set of material qualities that any new smart or technical textile would be subject to. Where the "off-state" of a future dynamic textile could be, for example, the colour white with a thick waffled texture, the colour green in this study was the dominant material quality accommodated by the researcher's wardrobe. If dynamic fabric is envisioned to become an everyday fabric, its physical characteristics will play a role in its success or failure to pair with other garments, textures and accessories in a wearer's wardrobe.

The colour green in this study was considered a wardrobe constraint both fashionably and practically by the researcher. Many items that she previously wore could not be worn in her judgment where they did not pair with green (e.g., the colour grey). Furthermore, the researcher's personal style-needs quickly called for more variety beyond the solid bright green colour she first wore. She desired new textures, shades and varying amounts of green to balance her personal style with her perception of contemporary fashion expectations. The change of seasons also introduced practical concerns related to weather. This required the green garments she wore to pair with functional garments for warmer or cooler climates, or required her to find functional garments in green. The researcher was confronted with these challenges in the relatively short time of two weeks, seeing her change from wearing the original all-green dress to a wardrobe that incorporated green in varied amounts, shades, textures and functionalities. The rapid growth of her wardrobe challenges predictions that dynamic textiles will lead to less consumption of clothes (Dunne, 2010), highlighting our desire for garment material qualities beyond their surface colour or pattern.

The green colour constraints extended beyond the physically encountered versions of her wardrobe. When the researcher states that she often paired black or navy with the greens she wore, this also implies that the digital content she chose to wear must also pair well with these colours. The variety of digital content she could now wear, in theory, also became minimized by the material constraints, in this case pairing with black or navy. At a minimum, these negotiations highlight the complexity of the expectations and language of contemporary fashion. The obstacle of pairing the inherent material qualities of the dynamic fabric with other garments both physically and virtually can help dynamic fabric developers foresee the challenges and opportunities ahead.

## Considering Digital Expression

What does it mean to combine the digital world with the physical world? *Digital expression*, which we loosely define in the context of this article as the individual or collective expression of identity, culture, thoughts, moods or emotions through the use of digital media and computation, has been building a kind of visual and auditory language through its own set of aesthetic references since the dawn of digital machines, gaining momentum in the second half of the twentieth century. It can be thought of as the cultural phenomena that uniquely or predominantly exists through digital media as broad as electronic music or as specific "LOLcat" memes.

When envisioning the adoption of dynamic fabric into everyday dress, it seems unavoidable to imagine a collision of contemporary trends in digital expression with that of the contemporary trends of physically-encountered fashion. If we propose to "plug-in" our garments to the Internet, giving them at a minimum the display capabilities of a computer screen, social acceptance and interactions on both ends will be challenged and renegotiated. Below, we reflect on selected behavioural and mental shifts that took place for the researcher in the Greenscreen Dress study when negotiating her personal fashion with the introduction of digital expression.

### *Social Lives of Dynamic Fabric in Social Media and Everyday Life*

A finding using the greenscreen system is that dynamic fabric social etiquettes will evolve in two worlds—social media and everyday life. As these two worlds continue to blend, etiquettes will adapt. In the paper entitled "I Don't Want to Wear a Screen": Probing Perceptions of and Possibilities for Dynamic Displays on Clothing", Devendorf et al. (2016) conducted interviews with potential dynamic fabric wearers and designers and found that participants had negative associations with screen-based displays. The quality disliked most was the light emission, described as "'jarring' and distracting, like billboards or neon signs" (p. 6034). The dynamic textile they developed, *Ebb*, was seen as successfully avoiding these negative associations because of its non-emitting,

low-resolution and slow nature. Their research suggests that screens are synonymous with speed and high resolution and that these qualities were seen as bad and distracting by potential wearers. As the title suggests, they did not want to wear imagery typically associated with screens.

Greenscreen Dress was not able to directly field-test these findings due to the limitations of the greenscreen system; the researcher could not "wear" digital content in the physical world and therefore could not gauge whether onlookers would find it distracting. However, we can see in her description of the digital content that she chose to wear that she preferred abstract imagery over representational "screen-like" imagery, stating she was influenced by the aesthetics of the Instagram communities posting abstract expressions with the tags *#glitchart* and *#spacesynth*. To a certain extent, this strengthens the argument of Devendorf et al..

However, what we also observe from the researcher's description is that in the fourth month she began diverting from this habit, occasionally wearing representational, "screen-like" digital content such as a dancing bunny. She also states that she switched from favouring still imagery to favouring moving digital content. This demonstrates on a small scale that tastes can shift and change. There will be phases that a wearer will enter and leave, motivated by personal tastes and influenced by the contexts around them. We challenge Devendorf et al.'s message that we do not want to wear screens without considering the process of how fashion trends occur over time, without studying the wearing behaviour of the proposed wearable technology and exposing it to a genuine audience. Loschek (2009) describes how articles of clothing themselves are not "fashion", but rather that it is their acceptance into society or a community which gives them this distinction. She further states:

> The definition of when clothes become fashion originates from the observer. Fashion is defined not by the object, clothing, but by observation — that is, by the signal and the recipient, the observer and the observed. (p. 147)

In this way, we see the act of wearing in front of a genuine audience as the first step for predicting, or trying to understand the potential for something to become part of fashion or not. We argue that it is the nature of fashion for preferences and social acceptance to change or be formed by their social context, making any fixed ideas about future preferences unstable at best.

In Greenscreen Dress, the social ecosystem in which the researcher comfortably wore moving imagery was the Instagram platform, where fast-moving videos presented for personal expression are an accepted activity. Turning down the speed or distraction of this imagery for our contemporary physical world would be a negotiation between the social acceptance and rhythms of this world as it is today and that of the digital world as it is today. If interactions in these worlds begin to blend more seamlessly, through either AR technologies or material-based versions of the Internet of Things, then the preference for slowness and low resolution in dynamic textiles could evolve into more high-speed, high-resolution and "screen-like" versions of digital content over time, then move back again to slowness as fashion trends shift.

It could be argued that slow versions of digital expression combined with physically encountered clothing already exist, laying the groundwork for faster versions in the future with the adoption of smart technologies. These contemporary examples take the form of a T-shirt picturing a gaming icon or a dress depicting a deliberately pixelated textile print. There are also emerging trends that use parametric design to create 3D-printed jewellery or textiles with laser-cut patterns and textures giving them a technological aesthetic. As pointed out by Ryan (2014):

> Wearing technology, say, in the form of a Walkman in the 1970s… or an electronically illuminated gown in the 2000s, does not bring forth a condition of suspended time, nor is it immune to cultural entanglement. These items engage with the complex language of dress, which has in fact always involved technology at some level. To wear technological enhancements or devices is to advance the language of dress in specific ways that converge with the cultural dimensions of technology, and, as a result, to become "culturally seen" within a technologically literate environment. (p.1)

From this, we seek to highlight that our experiences of clothing in physical environments are not void of digital expression, but are currently subject to more traditional, non-digital social rules with respect to everyday fashion. For example, when screen-like fabric is currently worn in the form of LED grids or video-mapping projections, it is usually for entertainment purposes and not day-to-day fashion. If we begin to adopt fabrics with computational abilities in more discreet ways, digital expression as experienced in the virtual world and clothing expression in the physical world might build into new hybrid fashion cycles over time.

### *Digital Media Curation and Control*

Greenscreen Dress reveals the finding that control and curation of personal content created using dynamic fabric will be subject to similar challenges we face today with our personal digital content. When comparing the numbers the researcher gives for her posts on Instagram, 159, with the number of files in her "Patterns" folder, 1396, and photographs of herself on her smartphone in which she did not post on Instagram, approximately 6500, we see that the difference is quite large. We can assume that the 6500 unworn photos and videos on her phone indicate the editing, experimentation and curatorial process behind each outfit, creating a ratio of 1:40 for each digital garment posted.

On further questioning, the researcher felt that this ratio did not accurately reflect her activities. She estimated generating about 6 to 10 photographs or videos per outfit, not 40. The other files in her opinion represented "garbage", failed experiments or ones that she did not feel were good enough to post on Instagram. She stored the unused content anyway and still showed some of it to people casually or in public presentations of the work. She kept these less-valued wearings away from the enduring record of Instagram, or more broadly, the Internet.

There is much to draw from these actions, leading to a larger discussion about the volume of digital content people hoard and what they choose to post on social media. The nature

of connecting our clothing to the digital world opens it up to an irreversible effect that we rarely face with current clothing-wearing rituals. What we wore, for example, two years ago on a Saturday at six o'clock is mostly not documented. We encounter some photos of ourselves from the past, but would dynamic fabric with an Internet connection make us vulnerable to permanent, public documentation of each and every fashion choice we make? The researcher's concern with curating her online digital-fashion presence indicates a desire to control permanent documentations of her image.

In contemporary clothing-wearing rituals, there is a relatively temporal public experience of our clothing choices. When we expect our garments to be documented at a special event with photography, we dress-up, or at minimum consider more deeply the clothing choice for that day. The limitations of the greenscreen system prevented these issues of permanent documentation versus temporal encounters from being fully explored. Because the digital outfits could not be experienced in the physical world, we cannot comment on what the researcher would wear in this context. However, we can infer that because she showed some of her less-favoured outfits in ephemeral settings (for example, presenting images in a slide presentation), she would allow for a less rigorous, sensitive editing process when the threat of permanent documentation was lifted.

Furthermore, the researcher experienced unexpected encounters with a colleague throughout her study whereby he placed digital content she did not like on her green garments. She describes these interactions as "digital attacks" and briefly discussed the coping mechanisms she developed to combat them. The social implications of connecting fabric we wear on our physical bodies to the vulnerabilities we currently experience on social media suggest the potential for loss of control in both realms, a new dimension to becoming "hacked".

### *Wardrobe Choices for Digital and Physical Worlds*

Greenscreen Dress demonstrates the complexity of balancing wardrobe choices for both the digital and physical world. The colour green, used as a stand-in for a constrained set of material properties, became a wardrobe challenge for the researcher as a wearer. As a designer, it was handled as a typical design challenge, but with the added dimension of considering the changing digital content. The green became a stand-in for combining the digital with the non-digital. How should this be handled in a fashion design setting? Who would be responsible for designing the digital content and its interaction with the garments? During the Greenscreen Dress study, the researcher mostly generated her own digital content. She tested out the viability of the digital content by trying it on through her smartphone screen. In a future scenario, who would be responsible for designing the digital content meant for wearing?

Compromises were made in the design process between the *digital* and *material* aesthetic sensibilities of the clothes. The compromises she made allowed the clothing to fit into the social landscapes of both the virtual and physical contexts that she engaged with. This highlights the existence of different languages, tastes and accepted styles in both domains and the need to consider both in designs that propose to engage with both. The act of bringing the digital to the physical is still relatively new, enacted in domains of "wearable" technology, the Internet of Things, tangible computing and mixed realities. In these contexts, the role of 'the digital' may appear immaterial and virtual, but will rely on a system of people and materials to capture its unique abilities and translate them into something people can connect with.

According to Wakkary & Lin et al. (2016) on the frictions generated between material and digital fabrication processes, a similar perspective is offered, suggesting that,

> [T]he digital and its relations to material practices are unique and not like other translations of practice from one craft to another…. The uniqueness of the digital to the material opens up distinct qualities of the digital, human, and automated that can co-exist in a form. (p.1267)

From this, we suggest that form and materiality are part of the interplay in pairing virtual and physical processes, although the digital is, in essence, neither form nor material. We see its expressive abilities as evidence of how it can be harnessed through people and things.

## Discussion

Greenscreen Dress explores the future notion of dynamic fabric by focusing on the experience of wearing dynamic fabric rather than on the development of the technology itself. Broadly, this approach demonstrates the value of *wearing* in the wearable technology design processes and the need to consider *digital expression* when working with a technology that uses or draws on digital content. Below, we attempt to strengthen our argument for this approach by relating it to concepts within cultural theory and fashion ecologies to underscore the study's strengths and limitations.

### The Body and Wearing

What might it be like to wear dynamic fabric and how would this change how we wear clothes? We address these notions by discussing the role of the body in examinations of garment-based displays, or of any digital technology proposing to be worn for personal style. Any artifact placed on the human body takes on social meaning in relation to its wearer (Dunne, 2010; Dunne et al., 2014). Whether it is a hat, a shirt, a watch, or even a tattoo, its position on a specific person and the context in which it is worn each signal *something* to its surrounding audience. As critical theorist Kaja Silverman (1986) is so often quoted for in fashion theory,

> The male subject, like the female subject, has no visual status apart from dress and/or visual adornment…Clothing and other kinds of ornamentation make the human body culturally visible…clothing draws the body so that it can be culturally seen, and articulates it in meaningful form. (p. 145)

Anything placed on the body falls into the spectrum of "fashion" or "style" in some way. Although the term *fashion* is largely ambivalent (Loschek, 2009) and commonly connotes images of models, runways and superficial lifestyles (Barnard, 2014), fashion practitioners generally understand that designing artifacts for the human body involves balancing social meanings with the practicalities of the garment at hand. Theorist Malcolm Barnard states,

> So, there are theories of class, gender and aesthetics underlying and presupposed by all fashion production and consumption, and were it not for artists and designers having an understanding of the elements of those theories, no fashion would get produced or consumed at all. (p. 16)

For this reason, we feel it is important for innovators within wearable technology disciplines to address social meanings and implications for the artifacts and textiles they develop. We feel it is important that they develop *with* fashion designers or those with inherent fashion design knowledge at the beginning stages of technology development.

In addition to working with fashion designers, we feel it is important for innovators to recognise the moment when a technology can be considered "wearable". In the context of fashion, clothing is inseparable from the body. Concepts of style, trends, culture, personal identity and expression are activated or deactivated by the interactions between wearer and garment. Simply put, a garment unworn is static, filled with potential, but is not contributing to a fashion dialogue. The meanings and nuances of what we communicate through dress are, as the term *fashion* suggests, in a constant state of flux (Ryan, 2014). They are reinterpreted and transformed from wearer to wearer, context to context and audience to audience. Loschek writes,

> [Fashion] is negotiated on a communicative basis within society…the social limits of toleration are also being continually renegotiated and are therefore subject to constant change, which is why acceptance of innovative creations and ultimately of new fashions develop at all (p. 142).

Clothing and accessories could therefore be understood as social tools (Barnard, 2014), dynamic in nature and activated by a body and an audience to create fashion. We do not think a piece of clothing or accessory can be fully understood until it enters the space of embodiment and is thus worn.

Within the context of wearable technology, the tension between the enhanced garment or accessory in its static state versus its worn state is evident. Producing prototypes and garment samples for "intelligent" clothing has been relatively easy compared with the struggle to have people actually purchase and wear them (Dunne, 2010). Little is known about a garment's "worn" life in the way that we are already familiar with experiences of traditional clothing in daily life. It could be argued that despite the soft, textile-like form of a digital artifact, it cannot be labeled "wearable" until it becomes part of an individual's wardrobe and is worn in different contexts in front of other people. Loschek (2009) describes this disconnect as the gap between invention and innovation, arguing that it is only the acceptance and adoption by society of a new clothing item that begins to define it as a part of the fashion dialogue.

Ryan's (2014) book speaks at length about the complex and volatile nature of fashion as a type of language and its entanglement with cultural meanings related to technology. She highlights the performative aspect of fashion and proposes the term "dress acts" to describe wearing any garment or accessory intertwined directly with or through historical or linguistic notions of technology. Our study's focus on the activity of wearing in everyday life offers a way to engage with fashion in its natural habitat, moving through time and different contexts as a type of performance. To further examine the possibilities and perceptions of clothing-based dynamic displays, the act of wearing became an action space for observing growth, pattern, variation and transformation of socio-cultural meanings (Harrison & Mackey, 2016).

## Wearing within a Contemporary Social Ecosystem

Reflecting on the broader motivations of the Greenscreen Dress study—to "uncover what value can arise from approaching the development of new wearable technologies…with a focus on the act of *wearing in everyday life* with minimal concerns towards the technology itself."—we see how the approach allowed for the innumerable variables of a social ecosystem to enter the analysis of a future smart textile. Key among these was *time*. The ten-month period allowed growth and change to occur related to a range of situations and contexts. Through issues related to weather, emotion, personal tastes, audience interactions and access to materials, a genuine personal context had effects on the outcomes.

In using a smartphone camera as a tool and Instagram as a platform, the researcher was able to explore aesthetic tastes related to genuine social media users as well as cultural understandings of digital expression like pixelation and digital distortion as in glitch art. The genuine and varied audience surrounding Greenscreen Dress became an ecology. Different people in different contexts had direct influence over the researcher's choices. At each turning point, for example, the decision to post an image or repeat the style of a digital outfit, the researcher's decision related to either an interaction with another person, specific things people communicated to her or her comfort level with how she believed her outfits were being perceived. Her perception that people were observing her, guided each choice. Although her community was relatively small, over the ten-month period her green clothes and virtual clothes became part of a fashion dialogue due to the interactions and perceived acceptance of them within the social contexts involved.

Audience is a key facet within fashion systems. Dress as a communicative tool for identity (Barnard, 2014) depends at minimum on the perception of a social dialogue. It was not important that the researcher wore her digital clothes specifically on the Instagram platform for this study, but rather that she wore the clothes in front of a genuine audience. This made her believe she was accountable for her choices, moving the exploration of dynamic fabric out of pure speculation for what she *might* wear to what she wore in response to genuine social contexts (Mackey et al., 2017). This perceived accountability generated the "*Can I wear this?*" dialogue within her day-to-day life, driving each aesthetic or expressive outcome.

Dynamic fabric, if further developed, will become part of an ecology encountered by varied audiences in varied contexts. In anticipating the implications of dynamic fabric, or any wearable technology meant for personal style, we feel it is important to include explorations in genuine social contexts and within personal clothing practices with generous amounts of time to allow for growth, change and identification of emerging patterns. Adding this approach to wearable technology design processes moves inquiries out of the isolation of technologies, materials and design speculations alone. It adds a perspective that values the varied social ecology of contemporary everyday fashion in terms of wearable technology and smart fabric disciplines.

## Limitations of Greenscreen Dress

The greenscreen system used in this study had limitations with regards to fully realizing a future form of dynamic fabric. Primarily, it lacked the ability for the wearer or audience to experience the digital content "in the real world" to allow them to see and touch the digital versions of the garments without the AR assistance of a computer or smartphone screen. The system also lacked the ability to have dynamic or computational input, such as a live feed from Facebook, weather data, pre-composed visual sequences, body-mapping capabilities or gesture-responsive displays. However, recognizing these and other technical limitations of the greenscreen system, we emphasize that the study aimed to gain insights into the wearing experience of dynamic fabric as it relates to personal identity, expression and clothing habits. The main achievement of this approach was its ability to allow the wearer, the researcher, the capacity to wear fabric that could be transformed with digital content as she went about her daily life. Her awareness of this ability and how it altered her personal style and clothing rituals is the space in which we could draw insights towards future dynamic fabric development. To further clarify, it was not important that her audience perceived her as wearing dynamic fabric, but more important that she perceived the experience of wearing dynamic fabric. It is in the behavioural and mental shifts of her clothing habits that held information about the possible socio-cultural implications of future dynamic fabric.

## Conclusion

In this article, we explored what it might mean to wear dynamic fabric in everyday life. We approached this inquiry by discussing the importance of considering socio-cultural implications of identity and audience as well as changes in daily clothing practices and interactions when designing for wearable technologies. We activated these concepts by introducing the autoethnographic study Greenscreen Dress in which the researcher incorporates green into her wardrobe over ten months and documents changing the digital content of her garments using a chroma key mobile application. The study connects socio-cultural factors in fashion directly to explorations of the social reception of dynamic fabric in garments over time and in everyday contexts. We present findings towards future notions of dynamic fabric as demonstrated through behavioural and mental shifts with regards to her personal fashion identity and clothing-wearing habits. We highlight that the approach of focusing on wearing activities of everyday life and considerations of digital expression can provide valuable insights for future wearable technologies and smart garment concepts that do not yet exist.

## Acknowledgments

This research was supported by ArcInTexETN (European Union Horizon 2020 research and innovation programme under Marie Skłodowska-Curie actions grant agreement No. 642328), Philips Lighting Research, and Eindhoven University of Technology in the Netherlands.

## References

1. Barnard, M. (2014). *Fashion Theory: An Introduction.* London, UK: Routledge.
2. Berglin, L. (2013). *Smart textiles and wearable technology - A study of smart textiles in fashion and clothing.* Borås, Sweden: Swedish School of Textiles, University of Borås. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2:884011
3. Berzowska, J. (2004). Very slowly animating textiles: shimmering flower. In *Proceedings of the ACM SIGGRAPH: Sketches* (p. 34). New York, NY: ACM.
4. Berzowska, J. (2005). Electronic textiles: Wearable computers, reactive fashion, and soft computation. *Textile: The Journal of Cloth and Culture, 3*(1), 58-75. https://doi.org/10.2752/147597505778052639
5. Berzowska, J., & Skorobogatiy, M. (2009). Karma Chameleon: Jacquard-woven photonic fiber display. In *Proceedings of the SIGGRAPH: Talks* (p. 11). New York, NY: ACM.
6. Buechley, L., Eisenberg, M., Catchen, J., & Crockett, A. (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* (pp. 423-432). New York, NY: ACM. https://doi.org/10.1145/1357054.1357123
7. Coelho, D. (2016). *ShiftWear: Customize your kicks.* Retrieved April 22, 2017, from https://www.indiegogo.com/projects/1537724
8. Desjardins, A., & Wakkary, R. (2016). Living in a prototype: A reconfigured space. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 5274–5285). New York, NY: ACM. https://doi.org/10.1145/2858036.2858261
9. Devendorf, L., Lo, J., Howell, N., Lee, J. L., Gong, N.-W., Karagozler, M. E., Fukuhara, S., Poupyrev, I., Paulos, E., Ryokai, K. (2016). "I don't want to wear a screen": Probing perceptions of and possibilities for dynamic displays on clothing. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 6028-6039). New York, NY: ACM. https://doi.org/10.1145/2858036.2858192

10. Dunne, L. (2010). Smart clothing in practice: Key design barriers to commercialization. *Fashion Practice: The Journal of Design, Creative Process & the Fashion Industry, 2*(1), 41-66. https://doi.org/10.2752/175693810X12640026716393
11. Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y. L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction. In *Proceedings of the 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (pp. 4159-4162). Hoboken, NJ: IEEE. https://doi.org/10.1109/EMBC.2014.6944540
12. Eco, U. (1986). *Travels in hyperreality.* New York, NY: Mariner Books.
13. Ellis, C., Adams, T. E., & Bochner, A. P. (2010). Autoethnography: An overview. *Forum: Qualitative Social Research, 12*(1), Art. 10. Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/1589
14. Gaver, W. W. (2006). The video window: My life with a ludic system. *Personal and Ubiquitous Computing, 10*(2-3), 60-65.
15. Guler, S. D., Gannon, M., & Sicchio, K. (2016). *Crafting wearables: Blending technology with fashion.* New ork, NY: Apress.
16. Hansen, L. K., & Kozel, S. (2007). Embodied imagination: A hybrid method of designing for intimacy. *Digital Creativity, 18*(4), 207-220. http://www.tandfonline.com/doi/abs/10.1080/14626260701743200
17. Harold, P. (2006). Creating a magic lighting experience with textiles. *Password: Philips Research Technology Magazine, 28*, 6-11.
18. Harrison, L., & Mackey, A. (2016). Futuring fashion from everyday life. In N. Spurling & L. Kuijer (Eds.), *Everyday futures: Essay collection* (pp. 16-22). Lancaster, UK: Institute for Social Futures, Lancaster University. Retrieved from http://wp.lancs.ac.uk/everydayfutures/essay-collection/
19. iDevMobile Tec. (2015). *ChromaKey studio.* Retrieved from http://www.idevmobile.com/product/chromakey-studio-pro/
20. Kovacs, Z. (2015). *Tago arc: One E-Ink bracelet with endless designs.* Retrieved from https://www.indiegogo.com/projects/tago-arc-one-e-ink-bracelet-with-endless-designs#/
21. Lamontagne, V. (2005). *Peau d'Âne*. Retrieved from http://www.valerielamontagne.com/peaudane.html
22. Loschek, I. (2009). *When clothes become fashion: Design and innovation systems.* Oxford, UK: Berg.
23. Mackey, A., Wakkary, R., Wensveen, S., Tomico, O., & Hengeveld, B. (2017). Day-to-day speculation: Designing and wearing dynamic fabric. In *Proceedings of the Conference on Research Through Design* (pp. 439-454). Edinburgh, Scotland: University of Edinburgh Retrieved from https://doi.org/10.6084/m9.figshare.4747018.v1
24. Mann, S. (1997). Smart clothing: The wearable computer and wearcam. *Personal Technologies, 1*(1), 21-27.
25. Matsuda, K. (2016). *Hyper-reality* [Film]. Retrieved from https://vimeo.com/166807261
26. Neustaedter, C., & Sengers, P. (2012). Autobiographical design in HCI research: Designing and learning through use-it-yourself. In *Proceedings of the Conference on Designing Interactive Systems* (pp. 514-523). New York, NY: ACM. https://doi.org/10.1145/2317956.2318034
27. Normals. (2012). *A P P A R E L.* Retrieved from http://mixtur.es/apparel/
28. Orth, M. (2004). *Dynamic double weave, Fashionable Technology* (p. 75), S. Seymour (Ed.), New York, NY: Springer Wien
29. Orth, M., Post, R., & Cooper, E. (1998). Fabric computing interfaces. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (Summary, pp. 331-332). New York, NY: ACM. https://doi.org/10.1145/286498.286800
30. Philips Design. (2006). *SKIN exploration research - Design probe.* Retrieved from https://www.youtube.com/watch?v=t5h_pGnL5l0
31. Rosella, F., & Genz, R. (2005, August). *CuteCircuit Kinetic Dress.* Presented at SIGGRAPH Cyber Fashion Show, Los Angeles Convention Center, Los Angeles.
32. Ryan, S. E. (2014). *Garments of Paradise: Wearable discourse in the digital age.* Cambridge, MA: The MIT Press.
33. Seymour, S. (2008). The Garment as Interface. In J. Lumsden (Ed.), *Handbook of Research on User Interface Design and Evaluation for Mobile Technology* (pp. 176-186). IGI Global. Retrieved from http://www.igi-global.com/viewtitle.aspx?TitleId=21830
34. Silverman, K. (1986). Fragments of a fashionable discourse. In T. Modelski (Ed.), *Studies in entertainment: Critical approached to mass culture* (pp. 139-152). Bloomington, IN: Indiana University Press.
35. Superflux. (2011). *Song of the machine* [Film]. Retrieved from https://vimeo.com/22616192
36. Wakkary, R., Lin, H., Mortimer, S., Low, L., Desjardins, A., Doyle, K., & Robbins, P. (2016). Productive frictions: Moving from digital to material prototyping and low-volume production for design research. In *Proceedings of the Conference on Designing Interactive Systems* (pp. 1258-1269). New York, NY: ACM. https://doi.org/10.1145/2901790.2901880
37. Wakkary, R., Odom, W., Hauser, S., Hertz, G., & Lin, H. (2016). A short guide to material speculation: Actual artifacts for critical inquiry. *Interactions, 23*(2), 44-48. https://doi.org/10.1145/2889278
38. Weinmans, M. (2013, January). *Wearable augmented reality.* Presented at Amsterdam Fashion Week, Netherlands. Retrieved from http://augmentnl.com/hyperfabric/
39. Worbin, L. (2010). *Designing Dynamic Textile Patterns.* Chalmers University of Technology, Gothenburg, Sweden. Retrieved from http://publications.lib.chalmers.se/publication/121352-designing-dynamic-textile-patterns
40. Zittel, A. (1991, 2014). *A-Z* [Portfolio of work]. Retrieved from http://www.zittel.org/