MASTER THESIS PROJECT

ENHANCING EMOTIONAL DURABILITY THROUGH COLOR CHANGING MATERIAL TRACES IN JACQUARD WOVEN FABRICS

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Abstract

Textile motifs have been an integral part of human culture for centuries, reflecting various artistic, cultural, and social influences. With the advent of technology and the growing interest in interactive and transformative fashion, the concept of dynamic textile motifs has emerged as an exciting and innovative field of exploration. This project delves into this topic, investigating their potential to revolutionize the way we perceive and interact with garments.

The study begins with a comprehensive analysis of traditional textile motifs and the tools utilized in the creation of these. It further focuses on exploring their color-changing capabilities by aging, unveiling the potential of incorporating interactive elements and responsive features into fabrics, such as experimental compositions and new jacquard woven constructions.

The research seeks to enhance understanding and foster new methodologies, enabling unique and engaging experiences for users. Tools like Material-Driven Design, material tinkering, experiential characterization and experience trajectories in logitudinal study revealed to be essential for the findings of the research.

Throughout the study, the topic shifts towards the conceptualization and creation of dynamic textile motifs that respond over time to various stimuli. Weaving, dyeing and ageing tests for discoloration/coloration through different environmental factors are one of the techniques that helped the study to showcase examples of responsive textiles or garments, where motifs adapt to the wearer's actions over time. Moreover, the project emphasizes the importance of sustainability and eco-conscious practices in the development of dynamic textiles. It highlights the potential of utilizing natural dyes, organic materials, and circular fashion principles to ensure the responsible production and longevity of interactive garments.

This thesis also explores the user experience aspect, analyzing how wearers perceive and engage with dynamic textile motifs. By studying user interactions, preferences, and feedback, the abstract addresses the challenges and opportunities in making dynamic textile motifs an enjoyable experience for diverse audiences.

When combining all of the elements of this research creating a new fabric is still not a desirable outcome. If people could reuse existing textiles and a dyeing guide the longevitity and satisfaction from a garment could be highly extended. I believe a product-service system can be created to faciliate such a product.

Finally, this project demonstrates dynamic textiles as an exciting and transformational option in the world of fashion. It emphasizes their ability to break down traditional barriers, improving wearers' self-expression and emotional connection with clothing.

Structure of this thesis

Chapter 2 gives an introduction to the context, explaining which is the connection that links textiles and temporality. Principles like emotionally durable design, material races and slow interactions emerge in this chapter to address and identify the context where the research is diving, especially under a emotional lens.

Chapter 3 provides an introduction to dynamic textile motifs, and then presents an overview of current design practice relating to the use of animated textiles. It also touches on the concept of wear and tear and describes the case studies related to this topic, showing what has been done so far and highlighting areas in which there is more work to be done.

Chapter 4 presents the manufacturing process to make color-changing dynamic motifs, the practice-based research and methodology used in this thesis so as to provide a basis for understanding its structure in relation to design practice. It describes the process with reference to the design of dynamic textile motifs, the factors that influence the color-changing behaviour, the methods used to accelerate the ageing process, the practice of natural dyeing and also the help that PSS can give in this context. In this chapter the first samples made are shown and a series of experiments and ageing treatments used for creating color-changing effect are presented. It also describes how the user tests were conducted, the denim recycled jacquard textile developed with G-Star and the culmination of the findings, thus the design vision of the project and an applicable commercial solution that involves the use of dynamic textile motifs and re-dyeing techniques, for a product-service system focused on extending lifecycle of apparel.

Chapter 5, the concluding part before discussion and conclusions, concerns the embodiment of the product. During this phase, to verify the initial hypotheses of the research, some garments were made using as a basis the samples that performed best during the user tests. The study then ends first with the description of the longitudinal tests (carried out with the garments made to verify the emotional perception of users towards clothes that fade over time) and then with the proposed Design Space.

Acknowledgements

As I come to the end of my academic journey, I am deeply grateful for the incredible experiences and support that have shaped me into the designer I am today. My path led me through three remarkable years at Politecnico di Torino, where I immersed myself in the fascinating world of product design, followed by two transformative years at TU Delft's Integrated Product Design master's. Each step of this adventure at the Industrial Design Engineering faculty has played a significant role in making me a complete designer, and I owe my heartfelt gratitude to all who have been part of this incredible journey.

To begin, I want to express my sincerest thanks to the entire TU Delft community, including the faculty, staff, and collegues. My time here was nothing short of amazing, and the supportive academic environment truly inspired me. I am especially indebted to Holly, my chair, whose introduction to textile design sparked a newfound passion within me. Her mentorship and enthusiasm have been instrumental in shaping my academic pursuits. I must also extend my appreciation to Stefano, my mentor, for generously sharing his expertise on material design and ensuring that the needs of users are at the core of any design process. His guidance and availability to discuss ideas have been invaluable in honing my design thinking.

A special mention goes to Max, my company mentor and friend, who not only provided me with an exciting opportunity to explore fashion design deeper but also imparted practical wisdom and invaluable insights. His mentorship has been an eye-opening and transformative experience.

Moreover, I cannot thank my mom, my dad and my brother enough for their support and belief in me throughout my entire academic journey. Their encouragement and love have been my rock, and I am truly blessed to have them by my side.

Lastly, I want to express my gratitude to all my friends and peers who have shared this adventure with me. Your companionship, shared experiences, and intellectual discussions have enriched my academic and personal growth in immeasurable ways.
You have all played an integral role in shaping the designer I have become, and I will carry the lessons and experiences with me as I embark on my professional career.

Contents

1. Introduction

How do individuals perceive and value the aesthetic transformations that naturally occur in woven textiles as they age? Can these changes be embraced as enhancements that elevate the appeal of the garment? Can the concept of dynamic textile aesthetics, shaped by aging-related color changes, serve as a catalyst for promoting sustainability in fashion consumption by encouraging garment longevity? What are the practical implications and feasibility of implementing color changes in textiles on an industrial scale? How might this integration influence sustainable practices within the fashion industry? To what extent do fabric properties, including characteristics such as the appearance and structure, contribute to the perceived value of garments that undergo color changes over time?

The textile and fashion industry encompasses a vast and intricate supply chain, commencing with agricultural and petrochemical processes for fiber production, extending through manufacturing, logistics, and retail. At each juncture along this chain, there exists a pronounced environmental footprint, stemming from the consumption of water, materials, chemicals, and energy. Notably, many of the chemicals employed in textile production pose significant risks to the environment, factory laborers, and consumers alike. While the brunt of these environmental impacts manifests in the countries where textiles and garments are manufactured, textile waste has become a global concern. The advent of fast fashion has exacerbated material flow within the system, with contemporary fashion brands generating nearly double the volume of clothing compared to pre-2000 levels. Regrettably, prevailing fashion-consumption practices yield copious amounts of textile waste, the majority of which is either incinerated, relegated to landfills, or exported to developing nations. This compounding issue underscores the urgent need for sustainable and responsible approaches within the industry [1].

Designers who work with textiles have a tendency to view woven fabrics as unchanging, or static, materials. However, to truly utilize the benefits of woven fabrics in these systems, designers need to have a deeper understanding of how these textiles can be designed to exhibit responsive behaviors in their use. This involves exploring and utilizing the properties of woven fabrics to create interactive systems that are dynamic and adaptive. Designers can create experiences that engage people on various sensory levels by leveraging the potential of woven fabrics as dynamic elements, increasing the interplay between technology, aesthetics, and functionality. In this way, woven fabrics collaborate to shape the real essence of the designs they are part to, as a system in its own right.

The motivation behind this research is rooted in the recognition that garments, far from static entities, possess the potential to become active participants in the wearer's sensory and emotional narrative. The desire to create garments that not only cover but resonate with the wearer on a profound level, responding to their evolving emotional states and physical needs, has driven me to explore the territory of dynamic textile motifs. The pioneering works of textile researchers such as Rikka Talman have been particularly instrumental in stimulating my curiosity and driving my research for the first findings.

During this research, I delved into the intricate interplay of affection, sustainability, and textile properties within the realm of fashion. The novelty lies not in the aging aspects of garments (eg. leather, raw denim etc.), which has already been widely applied in the industry in recent decades. Rather, the innovation lies in utilizing the consequences of aging, such as fading, as a trigger to create garments that are in a constant state of evolution, but still based on a fixed structure.

One primary objective was to understand how individuals perceive and appreciate the aesthetic changes that naturally occur in textiles over time. This investigation seeked to determine whether these changes can be embraced as enhancements rather than defects by the wearer. The aim was to give clothes a unique character derived from dynamic alterations that comes from changes as they age, fostering a deeper sense of attachment and prolonging their lifecycle. Additionally, this study aimed to promote a sustainable approach to fashion by encouraging users to maintain their garments for extended periods without resorting to replacement or disposal.

Another key goal was to explore the practicality of applying color changes to textiles on an commercial scale. While dynamic textiles have largely remained within the realm of experimentation, this research endeavors to bridge the gap between theoretical exploration and real-world implementation. By assessing the potential for widespread adoption, the aim is to unlock the transformative power of color-changing textiles in fashion and further advance sustainable practices within the industry.

The third objective seeked to unravel the relationship between fabric properties and the perceived value of garments. Specifically, I explored how attributes such as woven structures, compositions, conditions or motifs impact the wearer's appreciation for garments that undergo color changes over time. This investigation aimed to shed light on the significance of these inherent fabric properties, revealing their potential to elevate the desirability of dynamic textiles.

These interrelated research goals constitute the cornerstone of my thesis, guiding my comprehensive exploration of the dynamic intersection between textiles, fashion, and sustainability.

2. Context

2.1. Emotionally Durable design

In the context of sustainable design and the quest for a more environmentally conscious and emotionally fulfilling consumer culture, the concept of emotionally durable design, as articulated by Jonathan Chapman, holds significant relevance. Emotionally durable design represents a departure from the conventional mindset of disposability, advocating for the creation of products that establish enduring emotional connections with users. This design philosophy encourages products to transcend mere functionality and physical longevity, aiming to provide meaningful and lasting experiences. It promotes emotional attachment, enabling users to form personal bonds with their possessions, which, in turn, fosters responsible consumption and a reduced inclination to discard [2]. Emotionally durable design emphasizes the repairability and adaptability of products, allowing them to evolve with changing user needs and preferences. By extending a product's lifespan and enhancing its capacity to elicit positive emotions, designers can contribute to a more sustainable and emotionally enriching consumer landscape [3].
In the realm of textiles, emotionally durable design finds its place in the creation of clothing and fabrics that connect with users on an emotional level, encouraging them to cherish and maintain these textiles for longer periods, thus reducing textile waste and promoting sustainable fashion practices.

Figure 1. Evolving narrative experience by Emma Whiting

2.2. Material Experience, Material Traces

Material traces encompass the idea that the life journey of a product tells a rich narrative. Whether deliberate or unintentional, every crack and scratch that materials manifest as we interact with objects inscribes a story. Interactions with materials result in alterations, imperfections, and ultimately unique objects, which carry traces of time and life [4]. Understanding and interpreting these material traces have become increasingly vital in design practice. Through embracing material traces, designers can create products that users are more inclined to preserve, mend, and care for, thus extending their lifespan and reducing the overall environmental footprint.

Traces not only make a product unique but also impact how objects are perceived and valued over time. They offer an additional layer of communication as they offer a unique experience to the user who serves as the trigger for traces, that evolve therefore based on the person [5]. With textiles, material traces take the form of patina, wear, and aging, which can imbue clothing and fabrics with character and history, contributing to the emotional attachment users feel towards them and encouraging responsible textile consumption and care practices.

Figure 2. Material traces on a wooden seat

2.3. Slow Interactions

The principles of Slow Design and Slow Interactions allign with the ethos of thoughtful and sustainable experiences. Slow Design advocates for a departure from the fast-paced, disposable nature of many product interactions. Instead, it emphasizes a mindful, unhurried approach to design, promoting longevity, sustainability, and a deeper connection between users and product. To inspire designers and stimulate thinking in new ways, Slow Design focuses on 6 main principles: reveal, expand, reflect, engage, participate and evolve [6].
Slow Interactions, an integral aspect of Slow Design, manifest as interactions that unfold gradually, respecting the user's pace and cognitive load. They prioritize meaningful experiences over fleeting engagement and aim to enhance user well-being by encouraging reflection and intentionality in technology use [7]. Slow Interactions, if applied for garments, can involve textile interfaces that respond over time to user input, encouraging a more deliberate and thoughtful approach to clothing choices.

3. Related work

Textiles have the ability to undergo transformations in multiple forms, including alterations in appearance such as changes in color, modifications in touch such (changes in texture), or a combination of both. If these changes have always been perceived as undesigned transformations, during the last years designers started to guide this changes through motifs, by paying more attention to the selection of yarns or to the woven structures used for the textile.
Historically, textile designs have been created to maintain a stable expression, or a static textile motif. This indicates that shape and color scheme, for example, are created to have the same aestethic expression across the motif's estimated lifetime [8]. When contrasting dynamic and static textile designs, the dynamic designs exhibit an innate ability to shift expression during use, from one to another or multiple additional expressions, thus adding functionality to the textile. [9].

3.1 (Traditional) textiles and time

Textile designs and their motifs have historically drawn inspiration from mythological, symbolic, or ornamental decorations based on mythical creatures, and later from Eastern symbols of power, the artistic vocabulary of the Mediterranean region, portrait and figural designs. Richer and more intricate decorations have replaced simpler, geometrical designs as the preferred aesthetic statement in terms of color and style. Usually printed or integrated trough different colored fibers, these motifs are added to a textile's surface for decorative and fashionable purposes, but also to evolve and gain character through frequent use [10].

In this regard, the concept of wear and tear takes on a dynamic dimension in the realm of textiles. The term "wear and tear" describes the deterioration that a material sustains over time as a result of frequent use. Although it might be seen negatively, wear and tear can actually enhance the character and appeal of the clothing in the case of some fabrics.

Dynamic textile design and motifs can be especially intriguing in this situation because they can give a garment more complexity and individuality. For instance, as a garment is worn and washed, the fabric with a subtle geometric pattern might start to show its variations in the pattern, giving the item a one-of-a-kind appearance. Therefore, the natural aging of fabrics can be used in the design process to create dynamic motifs, colors, or structures in textiles in order to link the textile products back to the inherent qualities of materials [11].
Garments made of materials meant to be used for a long time would then improve with age, extending the lifecycle of the product and giving a sense of affection to the wearer. In this way, the user experiences a story around the garment and above all a feeling of wellbeing that can be physical (fabrics can soften over time or create a patina, providing comfort and breathability) or mental (sense of novelty and excitement for the wearer, mixed with uniqueness).

The example of raw denim (or leather), known for its ability to shape and fade and developing unique motifs of wear as it is used over time, exemplifies how clothing can become a textile and fashion narrative, capturing experiences and emotions. Denim clothes act as a canvas on which the wearer's life events are chronicled via deterioration, creating a distinctive and personal story. Warmth, nostalgia, identification, are all emotions that the wearer feels, addressing the idea that clothing may be viewed as a type of textile and fashion narrative in which experiences are captured and mirrored in the garments [12].

Over the decades, the fashion industry has adopted this idea of wear and tear and designers have used methods like pre-fading and distressing to produce a purposefully used-in appearance. This natural process can be also labeled as a dynamic textile process: with denim we see a phenomenon of discoloring (fading), while with natural fibers such as cotton or linen in their ecru/raw state (unbleached and untreated), where changes in color are facilitated and accelerated with exposure to UV lights or moisture, we see a phenomenon of coloring. However, traditional raw fabric has a static color and it's not really used if not been dyed before. For this reason, the way the yarns are woven and the respective motif can serve the material to color change over time and according to conditions and use.

Figure 3. Raw denim fading

Figure 4. Faded leather jacket

An alternative approach to extend the lifes textiles involves exploring repair and re-use practices. Designers have begun to explore the integration of craftsmanship into artifacts, aiming to create long-lasting products that build a sense of attachment over time. Several strategies are being employed in this context, such as integrating the principles of Wabi-Sabi (beauty in imperfection) into the physical design attributes of products to promote "enchantment" or sensuousness, rather than purely functional purposes, and encouraging a shift from mere "users" to active "makers" [13].
Wear and tear, mending and others are all examples of slow fashion, an approach that seeks to extend the life of a product and improve product interaction. Slow fashion garments are intended to be worn for an extended period of time and are manufactured with high quality and ethical principles; englobing durability and sustainable materials.The design is timeless because the styles and colors are timeless, and the materials age well. This has an impact on esthetic longevity [14].

Figure 5. Denim mended with boro stitching

3.2 Animated textiles and dynamic textile motifs

Building upon the exploration of dynamic textile motifs and their transformative potential discussed earlier, the concept of "animated textiles" emerges as a compelling extension, encompassing not only the inherent qualities of textiles but also highlighting their adaptability through physical, digital, and biological means to better fulfill their intended purposes.
The so-called "animated textiles" expand the definition of Smart Textiles, including both the innate properties of textiles and the intelligence of computational or biological components [15]. In particular, the term "animated textile" refers to a growing category of materials with the capacity to adjust to their environment and so better carry out their intended purpose. This idea emphasizes how any substance may have animacy, such as the ability to behave independently or adapt, without the need for computer components. Using this concept as a foundation, the term "Animated Textiles" is introduced as a catch-all term for textiles or textile systems that display animacy using physical, digital, and/or biological means while in use. One-way, two-way, or continuous interactions with animated textiles are all possible [16].
The animation of a textile can be reversible, when the textile changes expression with x number of variations due to environmental or computational stimuli but always returns to its starting point, or irreversible, when the textile changes expression due to environmental or computational stimuli but doesn't return to its starting point.

Figure 6. Smart fabrics by AFFOA

When changes occur in the motif of the fabric, these textiles are commonly referred to as dynamic textile motifs. There are different ways explored to see these changes, through a change in the motif of the textile, through a change in the color of a motif where the motif itself doesn't change or through the texture. For example, together with the work carried out by Talman, particularly relevant for this topic was Koroshnia Marjana's PhD thesis. The textile designer has expanded the potential of leuco dye-based thermochromic inks, using them no longer only as coloring agents but as thermochromic inks printed on fabrics capable of creating a wider range of textile colourchanging effects [17].

Hence, the dynamic textile motifs, as opposed to static textile motifs, play an important role because they can be designed to show inherent qualities to change expressions while used in their lifetime. Moreover, by leveraging their irreversible changes, independently of the time of the change, it is possible to give them meaning while they age over time [18]. In particular, by using a jacquard loom, it's possible to enable the weaving of intricate motifs or compounds. The motifs are formed by the intentional and controlled skipping of warp yarns over weft yarns, and, togheter with colors, are then incorporated into the weave instead of being printed or dyed onto the surface of the fabric. In this way, textiles can gain the ability to be dynamic and age in unique ways depending on their motif and environment.

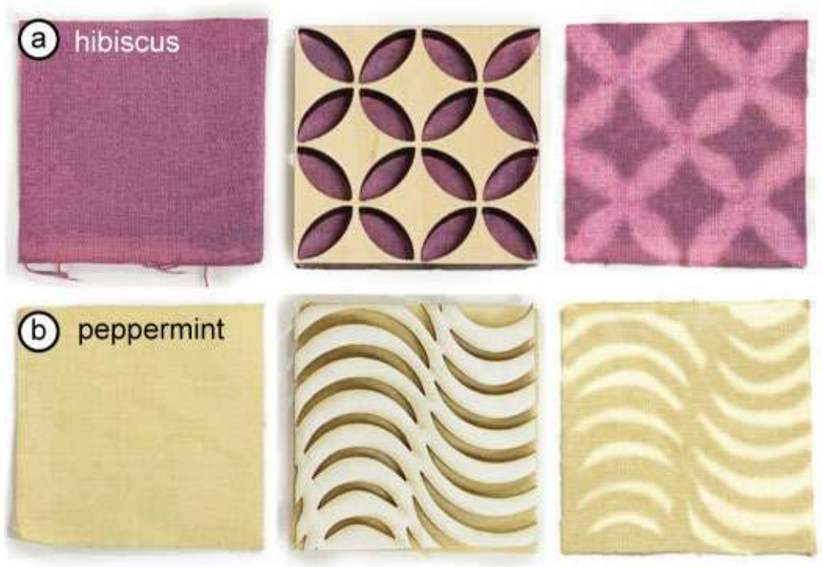


Figure 7. Self-cleaning textiles

The identification and selection of related work were primarily achieved through a comprehensive literature search initiated with the paper by Holly McQuillan on the unfolding of textileness in animated textiles. This initial paper served as a valuale entry point, guiding the search towards relevant studies in the field of dynamic textile expressions. Specific keywords, such as “dynamic textile color changes,” “plant dyeing without mordants,” and “color changes on woven textiles,” were strategically employed to pinpoint studies that explored dynamic color transformations in textiles. Two particularly noteworthy contributions in this area were the works of Linda Worbin and Rikka Talman. Linda Worbin’s research primarily focused on cataloging general changes in textiles over time, supplemented by insightful case studies. On the other hand, Rikka Talman’s work delved deeper into irreversible color changes in textiles, providing a rich foundation for understanding dynamic textile expressions. The other case studies were mainly identified through coach meetings and pertinent online sources about innovation in the use of woven textiles. This approach ensured a thorough examination of apposite sources in articles, journals, books, and conference papers to gather a comprehensive body of relevant literature in the field.

3.2.1 TEXTILES ANIMATED THROUGH COMPUTATIONAL COMPONENTS

Computational materials are used to build fabrics that can react to various stimuli, such as light, temperature, or motion. These fabrics are referred also to as e-textiles.” Electronic sensors, conductive fibers, and microcontrollers are examples of computational materials that may be incorporated into textiles to produce responsive and interactive fabrics. These materials are capable of detecting and processing information from the environment or the wearer’s body and using it to activate certain functionalities, such modifying the color, texture, or shape of the fabric.

3.2.1.1. Dynamic textile motifs - Burning Tablecloth

Particularly relevant to this project was the Worbin’s work “Burning Tablecloth”, example of a design technique that showcases irreversible patterns, displaying color and structural changes in a knitted textile. The aim of this case study was to investigate how dynamic expressions may be made using fabrics and digital technology.
The experiment combined Kanthal wire circuits into conventional textile materials like wool, cotton, and polyester. The Kanthal wire would glow when electrical power was supplied, causing reactions in the materials around it, such as melting in polyester or color changes in cotton, depending on the electrical power level.
The research also explored the interaction of various textile layers, incorporating electrical wires into a woven fabric that was layered beneath a knit top layer. Working with sparks in burnout fabrics also presented control and predictability difficulties. The materials’ reactions to heat varied depending on the design of the textile, the voltage applied, the passage of time, and the oxygen content of the air. Although these factors were challenging to forecast with accuracy, they helped to create the distinctive and expressive qualities of the textile patterns, similar to the uniqueness found in handcrafted fabric and embroidery [19].

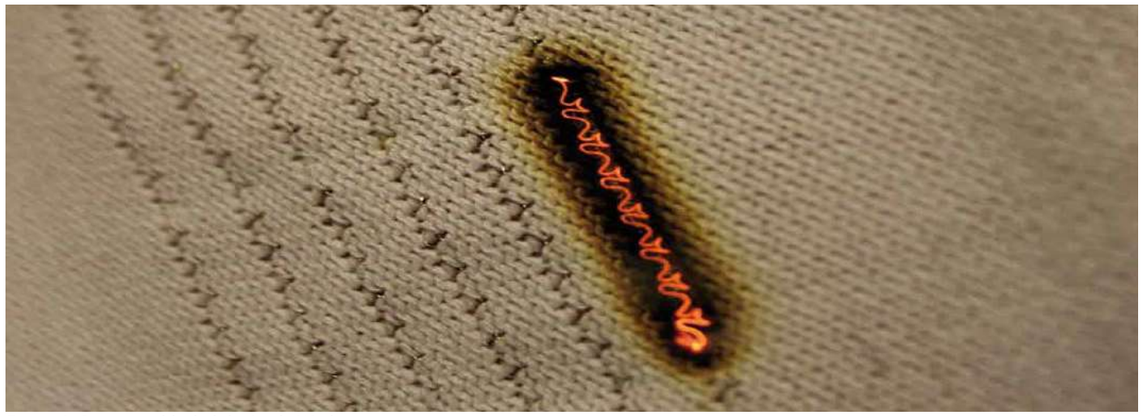


Figure 8. Burning tablecloth by Linda Worbin

3.2.2 TEXTILES ANIMATED THROUGH ORGANISMS

Textiles that are animated by living organisms represent a field of study that merges biology and textiles. Researchers may produce textiles that are self-sustaining and sensitive to their surroundings by incorporating living creatures like bacteria, algae, or fungi into the fabric. This strategy may result in the creation of textiles with the capacity for self-healing, environmental adaptation, and even energy generation. For instance, designers have created fabrics that include photosynthetic algae, which can produce oxygen and absorb carbon dioxide, puryfing the air of the wearer. Similar to real bacteria, textiles may degrade organic material or even generate power using microbial fuel cells.
Even though this field of study is still in its embrional phase, it already demonstrated a promising path toward creating textiles that are more adaptable, sustainable, and attentive to our needs [20].

Figure 9. Biogarmentry by Roya Aghighi

Figure 10. Design to fade by Puma

3.2.2.1. Dynamic textile motifs - Living Pigments

The ongoing project "Growing Patterns. Living Pigments" by studio LIA exemplifies a mission to reimagine fashion and textile design practices for a more sustainable future. By leveraging new technologies, the project seeks to revolutionize traditional dyeing techniques, which are often associated with environmental pollution in the production chain. A key focus lies in bacteria dyeing, offering numerous advantages over conventional methods. This approach aims to expand the application of bacteria dyeing and explore innovative ways to utilize bacteria for fabric dyeing and water filtration post-dyeing. Complementing these efforts are techniques such as UV and 3D printing, laser engraving and cutting, jacquard weaving, silk screening, and more. Through artistic research, the project has successfully guided the growth of bacteria and established intricate pattern designs, positioning bacteria dyeing as a compelling alternative to traditional printing and dyeing methods [21]. These examples illustrate how PSS models and innovative techniques are driving sustainable practices within the fashion and textile industry, aligning with the principles of the circular economy.

Figure 11. Bacteria-dyed textiles

3.2.3. TEXTILES ANIMATED THROUGH SMART MATERIALS

During the last decades, there has been an increase in the use of smart materials in combination with textiles to provide distinctive and responsive behaviors. For instance, materials that respond to temperature (thermochromism), ambient light (photochromism), and electric potential (electrochromism) are all labeled under the name of smart textiles. Additionally, functional fibres, including Shape-Memory Alloys, Shape-Memory Polymers, composite thread actuators, and multi-layer composite fibres, have been woven more and more into textile structures to provide them with shape-changing abilities under thermal or electrical stimuli.

3.2.3.1. Dynamic textile motifs - PhotoChromeleon

Another related system that focuses on object coloration, but not necessarily on textiles, is introduced by the PhotoChromeleon project, an innovative research conducted at MIT. Through the use of specifically designed inks that react dynamically to certain light wavelengths, this technology enables users to alter the color and appearance of objects.
Two essential parts make up the system. The ability to change color when exposed to different light wavelengths, including both ultraviolet (UV) and visible light, is made possible by a group of inks with remarkable photochromic properties. The procedure begins with the application of UV-sensitive ink to the target object's surface, that is then exposed to UV light, while the subsequent addition of a visible-light-sensitive ink on top of the UV-sensitive layer enables the development of complex color patterns. Users can trigger a variety of color patterns and designs by carefully controlling the intensity and distribution of UV light on the object, opening up adaptability in industries like product design, fashion, and artistic expression [22].

Figure 12. Photo-Chromeleon by MIT

3.2.4. TEXTILES ANIMATED THROUGH CONVENTIONAL MATERIALS

Textiles can be animated also trough the use of conventional materials such as paper or polymers. The integration of these materials and their properties allow new responsive behaviours to the textiles, such as the appearance of folds or plies. For example, the thermal expansion of copper, low-boiling point liquids or 3d-printed patterns of inextensible polymer are often used to give shape-changing abilities to textiles.

3.2.4.1. Dynamic textile motifs - Rikka Talman

Very important for the purpose of this thesis was the work done by Rikka Talman, who was the first to experience the color change in fabrics over time. This was possible using different combinations of compositions, woven structures and treatments aimed at accelerating the aging process. The experiments focused on plain woven fabrics and Jacquard-woven patterns to generate multiple expressions from a single starting point.

To create visual changes in woven textiles, two methods were used: dyeing patterns through degradation (burial underground and immersion in saltwater) and adding color or pattern through usage in various contexts.

Two Jacquard-patterned double-face fabrics were woven for the experiments using various materials such as cotton, paper, wool, and polyester. The first fabric had a pattern of multiple triangles, each made of a different material, while the second fabric had two materials combined in each part of the circle pattern. Plain weft-faced satin fabrics were also woven using a variety of materials such as paper yarn, wool, linen, and uncoated copper [23].

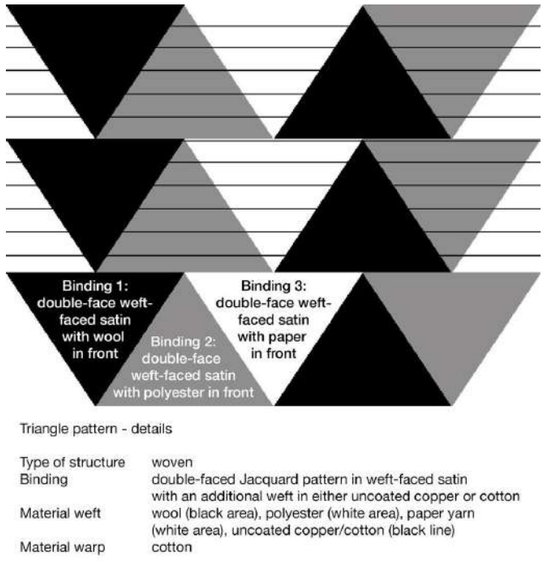


Figure 13. Jacquard woven construction by Rikka Talman

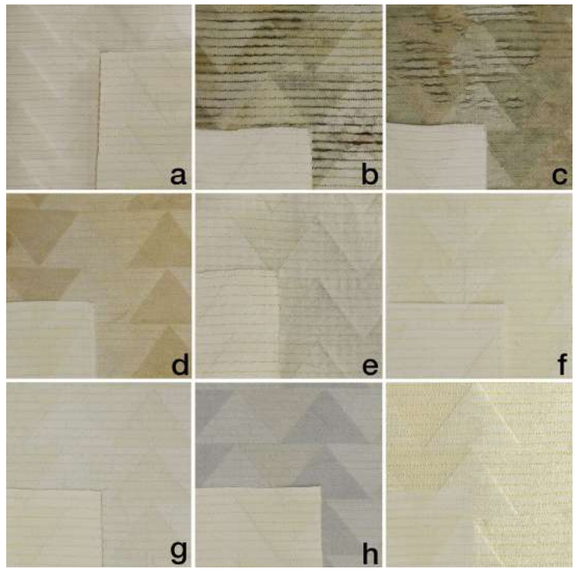


Figure 14. Different color expressions of the same motif

The fabrics were subjected to a variety of treatments, including burial, immersion in the Baltic Sea, and use as everyday textile products such as seat covers and lab coats. To see how the pattern parts were dyed, some fabrics were washed with different colors of laundry detergent. These treatments resulted in a variety of changes in the expressions of all the textiles, including intentional dyeing changes and unintentional changes such as stains and marks caused by use.

The materials used in the experiments reacted differently to stimuli. For example, certain samples revealed that paper yarn absorbed dye more intensely, whereas wool absorbed the most color. Each material's specific shade was determined by the type of exposure it received. Wool, for example, took on a green hue when exposed to sunlight and a reddish-brown hue when immersed in rusty water. Color absorption variations were observed in both outdoor dyed fabrics and samples dyed during washing [24].

3.2.5. TEXTILES ANIMATED THROUGH INHERENT MATERIAL QUALITIES

The physical, chemical, and mechanical characteristics of textiles, known as their inherent material qualities, allow them to be animated. Certain fabrics could have the capacity to alter their color, form, or texture in response to heat, moisture, or pressure. These properties are used to develop textiles that adapt to the wearer's body temperature or movement, resulting in clothing

that fits more comfortably and offers greater support. For instance, natural fibers like cotton, wool, and silk may add special characteristics to fabrics such as breathability, insulation, and moisture wicking, without the integration of any external components.

The graduation thesis of Nikkie Wester, "Beauty Comes With Age", delves into the transformative textiles topic. Made in collaboration with the Textile Museum of Tilburg, the project focuses multi-layered fabrics that reveal hidden layers as they age and get distressed over time. This approach celebrates the beauty of wear and tear and promotes sustainability through revaluation. The innovative and intriguing part of this project is that the irreversible changes are not given by the durability of the fabric or some special pigments, but by the multi-layering of it, giving another interesting point of view [25].
Emma Whiting's concept for Puma explores instead the idea of an 'evolving narrative experience'; a shoe which celebrates the wear and tear and the process of ageing, by accumulating grime. The reactive print on the canvas allows indeed to not let some parts of the motif (in this case the Puma logo) get dirty, revealing the effect with usage [26].
Jane Scott's innovative Responsive Knit combines environmentally responsive wood veneer bilayers with intricate knitted forms to create a diverse range of humidity-responsive textiles. In this way, only trough their inherent material qualities knitted textiles adapt and transform in response to changes in humidity levels, showcasing the intersection of design and dynamic functionality [27].

Figure 15. Beauty comes with age by Nikkie Wester

Figure 16. Knitted structure shape-changing behaviour through water

3.2.5.1. Dynamic textile motifs - G-Star RAW

In 2017 G-Star RAW developed a jacquard woven fabric with a camouflage motif, that has been called Honshu Jacquard. Despite the purpose of this fabric was to reveal the camo motif after dyeing the garment, the properties of this fabric helped me significantly to understand how, depending on the jacquard woven construction and composition used, the fabric gets colored differently, highlighting the different areas of the motif. Moreover, this work got me thinking about using instead irregular motifs on dynamic textile patterns, compared to the regular ones used by Rikka Talman.

Composition	53% PES - Polyester, 47% CO - Cotton
Construction	75Dx60/2, 250x99

Figure 17. Honshu jacquard in raw and dyed states

3.3. Temporality of textiles and Product-Service Systems

In the context of sustainable fashion and textile design practices, the adoption of Product Service Systems (PSS) has emerged as a transformative approach to promoting a circular economy. This paradigm shift moves away from the conventional emphasis on product sales and encourages service provision, thereby extending the lifespan of fashion products. Upcycling and sustainable fashion practices have gained prominence, with both professional designers and DIY enthusiasts engaging in the creative process of revitalizing old or discarded clothing. Recycling efforts encompass repairing and reinventing garments, employing traditional craft techniques like patchwork, reprinting, and embroidery. These methods not only preserve the original materials' integrity but also promote new decorative value into the garments [28].

Nudie Jeans and Patagonia are examples of how brands are already using product-services to reduce environmental impact. Nudie Jeans encourages repairs and recycling, while Patagonia promotes its "Worn Wear" initiative and offers free repair services. In a similar vein, innovative solutions like Biorestore have emerged, offering consumers a means to rejuvenate their worn-out cotton garments with washing. This innovative laundry care product revitalizes textiles by eliminating pilling, restoring color, renewing prints, and reviving their overall appearance and shape. These examples indeed illustrate the adoption of Product-Service Systems (PSS) principles involving ordinary textiles and garments, emphasizing longevity and returning.
However, there are emerging initiatives that specifically target textiles and garments designed for change and return. For instance, Lynn Tallvod's "Made to Fade" collection explores reversibility and ethical fashion, emphasizing the lifespan of garments. Tallvod's innovative approach involves assembling and disassembling garments for re-printing, challenging the traditional fashion system by creating clothing that can be repeatedly reconfigured [29].

Figure 18. Biorestore

Figure 19. Made to Fade by Lynn Tallvod

In conclusion, the findings from the mentioned sources have contributed to the understanding of dynamic textile expressions, discovering the main factors that influence most the realization of the first dynamic motifs, and their application. These insights have not only helped to frame the conceptual work of this research but have also inspired innovative approaches to the design and creation of dynamic textiles, offering a fresh perspective on how textiles can evolve and adapt over time, aligning with the goal of creating more responsive and engaging textile experiences.

3.4. Area of interest

The sustainability aspect of utilizing dynamic textile motifs that change over time is rooted in a profound shift in our understanding of materials and product lifecycles. Traditionally, material selection and design have been primarily focused on creating mass-produced objects that attract consumers with their initial appeal. However, this paradigm ignores the fact that materials and products change over time, responding to use and interaction with the environment. The concept of "graceful aging" or the development of a surface patina on objects can create emotional bonds between users and their belongings. This patina can result from abrasion, polishing, accumulated dirt, oxidation, and other natural processes, and it often makes the object more aesthetically appealing, fostering a deeper sense of attachment.

However, the prevailing industrial design approach tends to produce objects meant to be used in the future, neglecting to investigate how these objects will change over time. As a result, material changes are often perceived as damage or degradation, leading to the premature disposal of products in favor of newer ones.

This phenomenon, known as “cosmetic obsolescence,” contributes to the unsustainable shortening of product lifetimes. Consumers are enticed by the allure of newness and often quickly grow dissatisfied with products that exhibit signs of wear and aging [30].

In response to the negative impacts of the linear “take-make-use-waste” economy, there is a growing emphasis on transitioning to a circular economy. The circular economy aims to reduce both the input of virgin materials and the output of waste by extending the use phase of products, encouraging reuse, repair, and remanufacture, and promoting recycling of materials. To implement circular strategies effectively, designers must consider the role of material change in product design and understand how materials will evolve over time.

Moreover, the circular economy involves the adoption of new “Product Service System (PSS)” business models, shifting the focus from product sales to service provision. These models aim to maintain ownership of products and components, incentivizing designers to create products with longevity and repairability in mind. Consumer behavior plays a significant role in the circular economy, influencing the flow of products, components, and materials [31].

The concept of using dynamic textile motifs that change over time aligns with the principles of graceful aging and emotional durability. By designing textiles that develop unique characteristics as they age, such as changing colors through natural dyeing, designers can promote longer-lasting relationships between consumers and their garments. This approach encourages users to maintain their clothing for extended periods, reducing the need for replacement or disposal.

In conclusion, by designing textiles that age gracefully and foster emotional attachment, we can reduce the environmental impact of the fashion industry and promote more sustainable practices. This paradigm shift in design thinking emphasizes the value of materials and products throughout their lifecycle, ultimately contributing to a more environmentally conscious and socially responsible approach to fashion and textiles.

4. Developing dynamic textile motifs

The literature and case studies analyzed were sufficient to understand the background and to make the first important decisions regarding the project. The aim of the project is to design dynamic textile motifs that can change color over time according to external conditions and that can establish a sense of affection with the user to promote a more sustainable approach to clothes. To do this it was crucial to first analyze the technical domain of the topic, how to understand the main weaving techniques and the factors that influence color change. This was followed by a careful analysis of the strategies to accelerate aging over time, to see the results of change in reduced time, and by the choice of the methodology suitable for the creation of dynamic textile motifs. This is in fact the phase in which the first samples were made and the aging treatments applied. Before arriving at a design vision of the project, the final part of this chapter, user tests were carried out to analyze the relationship between user's emotions and textile that changes.

4.1. Technical domain

4.1.1. WEAVING

In exploring the intriguing concept of "animated textiles" and their responsiveness to wear and tear, it's crucial to grasp the fundamental process of weaving, as it serves as the canvas upon which these dynamic transformations take place. Weaving provides the structural foundation for the dynamic motifs, colors, and structures that can evolve over time, connecting the concept of textile evolution to the very essence of fabric creation.
Weaving is the process of interlacing two sets of yarns or threads at right angles to create a fabric. The process of weaving involves several steps, including preparation of the warp and weft, setting up the loom, and weaving the fabric. The warp threads run vertically or lengthwise on a loom, and the weft threads run horizontally or crosswise, passing over and under the warp threads. By interlacing the two sets of threads, a fabric is created [32].

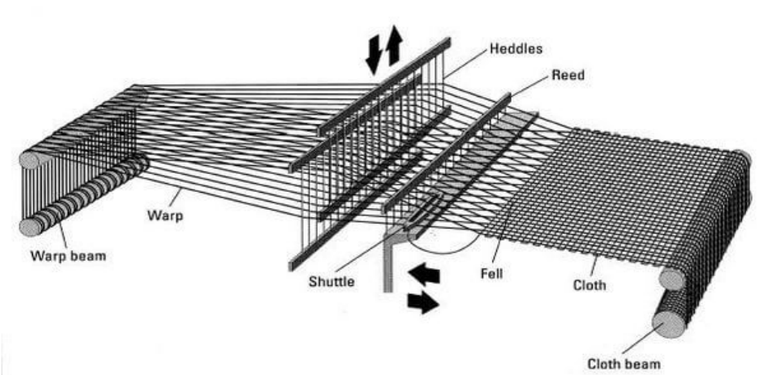


Figure 20. Weaving mechanism in textiles

The preparation of the warp is the first stage in the weaving process. The yarn is measured while wound onto a warping frame, after which it is wound onto a warp beam. The yarn is tensioned and spaced uniformly at this stage.
When weaving, a shuttle or rapier is used to travel back and forth across the breadth of the loom with the weft yarns strung onto bobbins first. The loom is set up once the warp and weft have been prepared. The heddles and reed, two components of the loom, are where the warp threads are passed through. While the reed is used to pound the weft threads into position after each pass, the heddles are used to regulate which warp threads are raised or lowered during weaving. The warp threads are first raised and lowered to form an aperture known as a shed before weaving can commence. The weft thread is then run through the shed using a shuttle or rapier, and a new shed is made with new heddles. Every time the weft thread is passed through, a new row of cloth is produced. After each pass, the weft threads are beaten into position with the reed to create a tight weave and the ideal texture and look for the cloth.
A simple frame loom can be used for hand weaving, or a power loom can be used for machine weaving. The weaving process' speed, quality, and pattern complexity can all be influenced by the type of loom being used.

In general, the factors that influence the outcome of a woven fabric are:

- Type of machine
- Shaft or jacquard loom
- Shuttle
- Width of the loom
- Width and kind of repeat on a jacquard loom
- The density of the warp yarns on the machine (ends/cm)
- The yarn used for the warp (material and thickness)
- The yarn used for the weft (material and thickness)
- The weave structures
- The density of the weft yarns (pick/cm)
- The map of construction

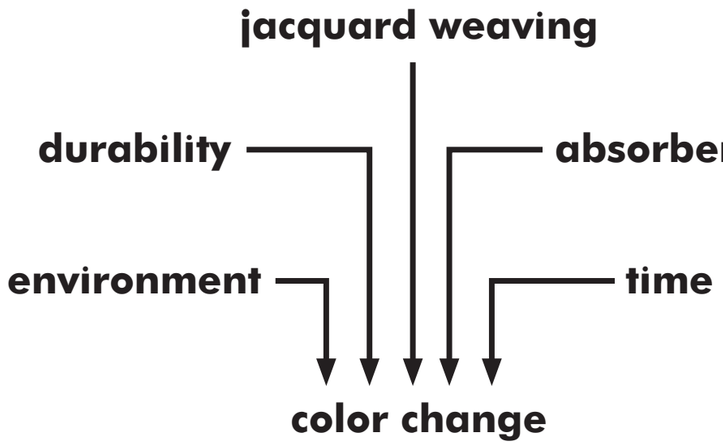
4.1.1.1. Jacquard weaving and loom

The complex weaving technique known as jacquard weave enables the fabrication of elaborated patterns and decorations. Instead of being printed or dyed onto the surface, the pattern and colors are woven into the cloth. This indicates that the yarns used to create Jacquard fabric play a significant role in the fabric's ultimate appearance.
The warp threads are moved using a system of punched cards on jacquard looms, which offers a great degree of personalization and control over the fabric's final pattern. There are several weaves that may be used to create jacquard textiles, including plain weave, twill weave, and satin weave. Brocade, damask, and tapestry are a few textiles that include a jacquard pattern.

Figure 21. Jacquard woven fabric

Joseph Marie Jacquard created the Jacquard loom, a particular kind of mechanized loom, in 1804. The weaving of complex motifs and patterns into cloth is managed using a system of punched cards. The chain of cards is then inserted into the loom after being lashed together. The loom's hooks that lift or lower the warp threads to create the desired design match to the holes in the cards. By permitting the creation of intricate motifs that were previously only achievable with hand weaving, the Jacquard loom revolutionized the textile industry. Additionally, it made it possible to produce textiles more quickly and effectively and to produce materials with greater complexity and finer detail [33].

4.1.2. DESIGNING FOR COLOR CHANGE: COLORING AND FADING



As just seen, although there are different ways to make dynamic changes, in order to allow a textile to irreversibly change color aspect over time (accumulating color or fading), five important factors have been selected: jacquard weaving, durability, absorbency, environment and time. The first factor, already discussed previously, is fundamental for creating complex textile designs with multilayers on which to play with float lengths and concentrate certain types of fibers in specific areas. Durability serves to give longevity to the fabric, which otherwise would not have time to change as it ages, while absorbency ensures that the fabric tends to absorb as much as possible or that it has different areas of absorbency in such a way as to make the motif stand out more. Among the other two remaining requirements, environmental factors (such as weather conditions, light exposure, temperature, and mechanical actions) are essential to comprehensively address the fabric's response to external influences over time, indispensable element for assessing how these dynamic changes evolve and accumulate within the textile.

Color change can be broadly categorized into two main processes: coloring and fading, which occur either slowly or rapidly over time.
In the case of coloring, fabrics, particularly when in their ecru state, possess the ability to evolve and transform over time, influenced by the surrounding outdoor conditions. This natural metamorphosis results in fabrics acquiring unique and distinct hues, giving a sense of character and history.

On the other hand, fading, visible in the vast majority of dyed textiles, but prevalent in natural dyed ones, plays an important role as well. These textiles and their organic dyes, show a gradual fading process with exposure to light and air. While the fading may transpire relatively quickly, each textile's journey unfolds in a truly one-of-a-kind manner, producing a rich combination of colors.

Figure 22. Textiles coloring

Figure 23. Textiles color fading

When Jacquard woven fabrics are integrated, the transformative color changes take on an even more captivating character. Exploiting the programmable patterns of Jacquard looms, the fading and coloring processes become intentionally designed. This link between programming and the natural aging changes let textiles transcending conventional aesthetics.
Both coloring and fading in textiles are fascinating phenomemons that highlight the balance-between time, nature, and design. They show how fabrics keep evolving and changing, becoming more unique over time.

4.1.2.1. Durability

To ensure that the fabric can naturally change by aging and that the textile pattern is dynamic and stands out as the fabric ages, it is necessary to provide an high durability. Making a textile able to resist well over time meets a sustainable approach by avoiding the industrial dyeing, but also by extending the lifecycle of the fabric.
Guaranteeing excellent durability is in fact a fundamental parameter for allowing the fabric to age slowly, and therefore to have time to get changes over time.
For this reason it is important to analyze the most common fabrics designed to ensure durability and resistance to external conditions or mechanical stimuli. Therefore, the most used fabrics in workwear and outerwear are the most fitting for the purposes of this project because they help to understand the ideal compositions and woven structures for the first experiments and to predict the first results.

DENIM

Medium/heavy indigo-dyed fabric mostly used to make jeans. The fabric originated during the gold rush in 1873 as a workwear fabric. It's known for its diagonal surface and for being sturdy and durable due to its weaving structure. It has a lot of different variations like raw denim (unwashed and without shrinkage), washed in different ways or color-dyed.

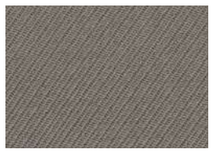
Construction: Twill weave (2x1 / 3x1 / 2x2)
Common fibers: Cotton / PolyCotton
Shininess: Matte
Hand feel: Coarse
Softness: Stiff

CANVAS/DUCK

Light/medium/heavy fabric, commonly used for paintings. Generally canvas fabrics have two variations: plain and duck. It's stiff with a coarse texture and results in durable due to its weaving structure. The duck variation have a basket-weave cotton fabric with two yarns and a single weft: coarser and heavier than canvas. Duck fabrics can be classified by its weight in OZ.

Construction: Pile weave with double piece loom or basket weave
Common fibers: Cotton / PolyCotton / Hemp / Flax
Shininess: Matte
Hand feel: Coarse
Softness: Crisp

CAVALRY TWILL



Medium/heavy right-hand twilled fabric with parallel double ribbed lines. It was designed for military riding breeches of British cavalry officers to be sturdy and durable. It has a smooth and soft surface due to its firmly woven structure.

Construction: Twill weave
Common fibers: Wool / Worsted wool / Cotton / Rayon / Polyblend
Shininess: Matte
Hand feel: Coarse
Softness: Soft

CHINO

Light/medium/heavy fabric with a diagonal brushed or mercerized surface. It was originally used for military purposes and became popular after WWII. It's smooth and soft due to its brushed or mercerized surface, but also durable and abrasive resistant.

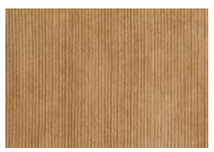
Construction: Twill weave with combed yarn / Ribbed weave
Common fibers: Cotton / PolyCotton
Shininess: Matte
Hand feel: Smooth
Softness: Crisp

SERGE

Medium/heavy double-sided ribbed fabric. often used to make military uniforms. The word "Serge" comes from the Greek word "serikos", meaning "silken". The surface looks textured due to a lower left to upper tight diagonal rib. Besides being sturdy and durable, it's wrinkle resistant and develops shininess with wear.

Construction: Twill weave / Jacquard with extra weft threads
Common fibers: Wool / Silk / SilkWool blend / Other blends
Shininess: Shiny
Hand feel: Smooth
Softness: Crisp

CORDUROY



Medium/heavyweight winter fabric with a soft corded nap on the surface. Previously woven from silk durink the 18th centurt, corduroy started to be made in cotton during the industrial revolution in England, becoming a classic for urban workers' uniform. The cut-pile brushed nap confers smothness and softness, while its weaving structure gives durability. Twill-weave backs are more durable.

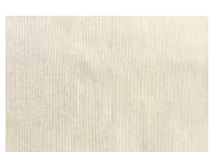
Construction: Jacquard weave / Cut pile weave
Common fibers: Cotton / Wool / Silk / Polyester / Rayon
Shininess: Matte
Hand feel: Smooth
Softness: Soft

GABARDINE

Medium/heavy durable and smooth fabric, suited for outerwear. The name was invented by Thomas Burbery for his iconic trench coat. The shine develops with wear and it is water resistant and windbreaking due to its tight weave. Its weaving structure gives durability and firm to the fabric.

Construction: Twill weave 2x1 / 2x2 with a warp-faced steep twill
Common fibers: Worsted wool / Cotton / Silk
Shininess: Shiny
Hand feel: Smooth
Softness: Crisp

FAILLE

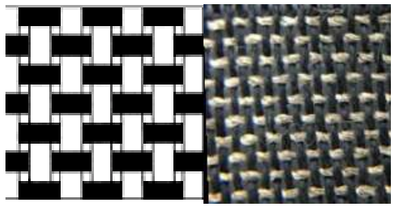


Medium crosswise ribbed fabric, used for formalwear beetwen 40s and 50s. It is slightly stiff and crisp due to its ribbed surface, which gives shiny appearance as well. Moreover, due to its weaving structure and stiff texture, it appears sturdy , wrinkle and tear resistanr

Construction: Ribbed weave
Common fibers: Cotton / Silk / Wool / Rayon / Acetate
Shininess: Shiny
Hand feel: Smooth
Softness: Crisp

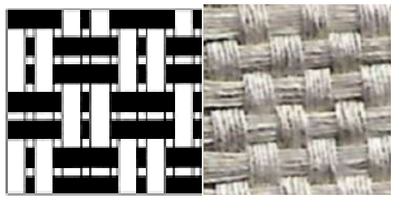
There are several types of weaving, however the durable fabrics mentioned above have most of the times these durable type of weaving: plain weave, basket weave (variation of plain), twill weave, and satin weave. Each type of weaving produces a unique fabric with its own properties and characteristics. The shorter the float links are, the more durable the fabric is.

PLAIN WEAVE



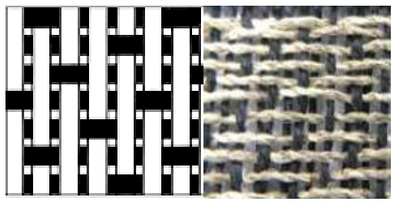
The simplest and most common type of weaving. Each weft thread passes over and under each warp thread (interlacements) in alternating rows, creating a simple, flat fabric with a uniform appearance and a checkerboard-like pattern. Plain weave fabrics are generally lightweight, durable, and easy to care of.

BASKET WEAVE



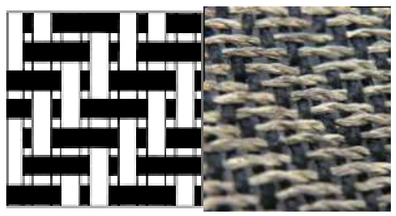
Two or more weft threads passing over and under two or more warps threads, creating a criss-cross pattern that resembles a basket.
This type of weaving creates a sturdy and durable fabric, often used for heavy-duty applications.

SATIN WEAVE



Satin weave is characterized by a smooth surface created by the weft thread passing over several warp threads before passing under one. This creates long floats on the surface of the fabric that catch the light and create a shiny appearance. It has a tighter stacking than twill.

TWILL WEAVE



Diagonal pattern created by the weft thread passing over a certain number of warp threads before passing under the next group of threads. This pattern creates a distinctive texture/appearance allows yarns to more tightly stack atop each other. Twill weave fabrics are generally more durable and less prone to wrinkling than plain weave fabrics [34].

4.1.2.2. Absorbency of fibers

In order for the textile to color itself or to fade as much as possible, their tendency to absorb color, known as absorbency, must also be taken into consideration.
Natural fibers like cotton, wool or linen [35], tend to age well and develop a patina over time [36]. Every natural fiber, depending on the ph, acquires a proper color even if the dyeing is the same. These fibers are also breathable and comfortable to wear, which can be beneficial for a garment that will be worn often. Their yarns share a high absorbency to dye and that is reason why are often a popular choice for manifacturing, especially if bleached before [37]. However, the scope of this project is also to develop a more sustainable approach to use textile in design and that can be possible by trying to avoid the yarn dyeing process and the bleaching before. For this reason, consider using unbleached or undyed yarns, helps to achieve that and also to develop unique colors.

Cotton/ Organic cotton	**Silk**	**Wool**	**Hemp**	**Linen**
				
absorbency • • • •	absorbency • • • • •	absorbency • • • • •	absorbency • • (with high lignin content)	absorbency • • •

Yarns with a slightly different texture or slub than the base fabric should be also considered, in order to create a subtle contrast between the pattern and the background and help the pattern stand out as the fabric ages.
Not all fibers have a high level of absorbency, but some will still be crucial for the changes of the fabric. Some synthetic fibers, like polyester, are known for their strength, wrinkle resistance, shrinking and fading. When blended with natural fibers like cotton, polyester can create a fabric that is more durable and resistant to wear and tear. However, it provides a low level of absorbency, but this can add a certain level of sheen to the fabric, by enhancing its visual effect, especially on a jacquard woven textile. It is worth nothing that adding polyester to a fabric composition can also have some downsides. Polyester is a synthetic fiber that is made from petroleum, which means that it is not a renewable resource and has a higher environmental impact than natural fibers.

4.1.3. STRATEGIES TO ACCELERATE AGEING OVER TIME

In order to measure the effectiveness of changes over time, it must also be possible to take advantage of methodologies and treatments that accelerate the aging process. Not all fabrics fade or take on color quickly, indeed sometimes the first changes appear after a long time, as in the case of raw denim which only starts to fade after 10-12 months.
To overcome this problem, there are various treatments that allow you to simulate in a few days or weeks the transformations that would normally take place after many months [38].
It is possible to categorize these treatments into 3 broad categories: through degradation, through use and through daily care.

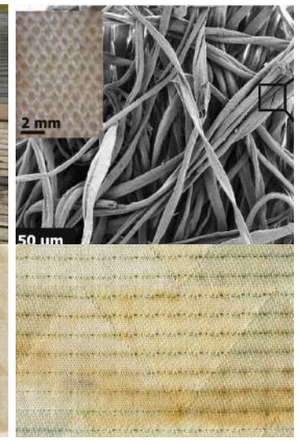
4.1.3.1. Through degradation

Through these treatments that take advantage of accelerated degradation, it is possible to reproduce the outdoor conditions of many years in just a few days, using moisture and UV light.

Aging chamber
(UV and moisture)

Underground
(burying)

Underwater
(salt-water and
iron powder)



Oxydation and
acid-catalysed
hydrolisis

4.1.3.2. Through use

To accelerate instead the texture and color changes (eg. grime accumulation) that usually are provoked by the usage of the fabrics over time, such as distressing, ripping etc. there are some mechanical actions that help achieving this results.

Rubbing and peel-off

4.1.3.3. Through daily care

Even the daily care of a garment and the tools needed to do it, such as the washing machine or the iron, cause fabrics to age, especially if they are then re-proposed in a cyclical and extreme way. For example, a laundry with only black clothes can easily let garments fade at high temperatures, but it can also pass the dye onto other clothes present.

Mixed laundry

Colored laundry (black, blue etc.)

Ironing

4.1.3.4. Natural dyeing (quick to fade)

Using colors derived from plants, roots, leaves, and insects, natural dyeing on textiles is a fascinating method, linked to ancient traditions. This method is not only easy to apply but also environmentally friendly, as it comes from renewable resources. It minimizes environmental damage, is biodegradable, and protects traditional knowledge and culture, among other advantages [39].

To extract pigments for natural plant-dyeing, it is first necessary to collect the plant intended to use and prepare them, by boiling and filtering them. This results in colorful shades, synced with nature's hues [40].

However, it's important to note that while natural dyeing offers numerous environmental and cultural benefits, it often presents challenges related to color fastness. Achieving color fastness (the ability of a dye to retain its color when subjected to various environmental factors such as light, washing, and rubbing) can be a complex process in natural dyeing. Maintaining vibrant and long-lasting colors on textiles while adhering to sustainable and biodegradable principles remains an ongoing area of research and innovation in the field of natural dyeing.

In this project, these challenges are embraced as a unique functional feature of the textile motifs, where the color changes over time become an integral part of the user experience.

Figure 24. Natural dyeing shades

4.2. Methodology

Textiles are frequently treated as materials in industrial design engineering practices, omitting the holistic lens and resulting in unsustainable design outcomes. For this reason, choosing the right methodologies can improve the application of fabrics, giving them new meanings.
This chapter discusses the research's methodological framework, illustrating how the method, involving materials and tests, and the aesthetics are intertwined in the context of sustainability.

4.2.1. MATERIAL DRIVEN DESIGN

As described by E. Karana, the Material Driven Design (MDD) is a flexible, adaptable and iterative approach that focuses on understanding and characterizing materials experience to inform the design process. In contrast to conventional design methodologies, MDD follows a "material-structure-form-function" approach rather than the more traditional "function-form-structure-material." This shift embraces materiality and places a strong emphasis on the value of tangible experiences in addition to technological and performative traits [41].

In contrast to product made by humans, MDD acknowledges that natural artefacts are made of a single heterogeneous material with a variety of properties that enable particular performances in interactions with the environment. The method suggests that materials exist and function within a material system and, since textiles are typically perceived as materials and utilized as substrates, this is essential for developing textile products that include fibers, yarns, and manufacturing techniques innovation. Through the utilization of an MDD approach, designers actively engage in uncovering the inherent possibilities of textiles by immersing themselves in hands-on material exploration, contemplating their findings, and engaging in collaborative knowledge sharing [42].

Additionally, Material Driven Textile Design (MDTD) emphasizes the raw state of materials and explores, translates, and activates them at the level of material science and design [43]. This material process-oriented approach, which emphasizes the interaction between materials and particular systems, is in line with sustainability and circular economy contexts.

Both MDD and MDTD place a focus on the material world while supporting sustainability and the circular economy. They recognize that materials are fundamental to particular systems, denoting the coexistence of numerous viewpoints within these material systems.

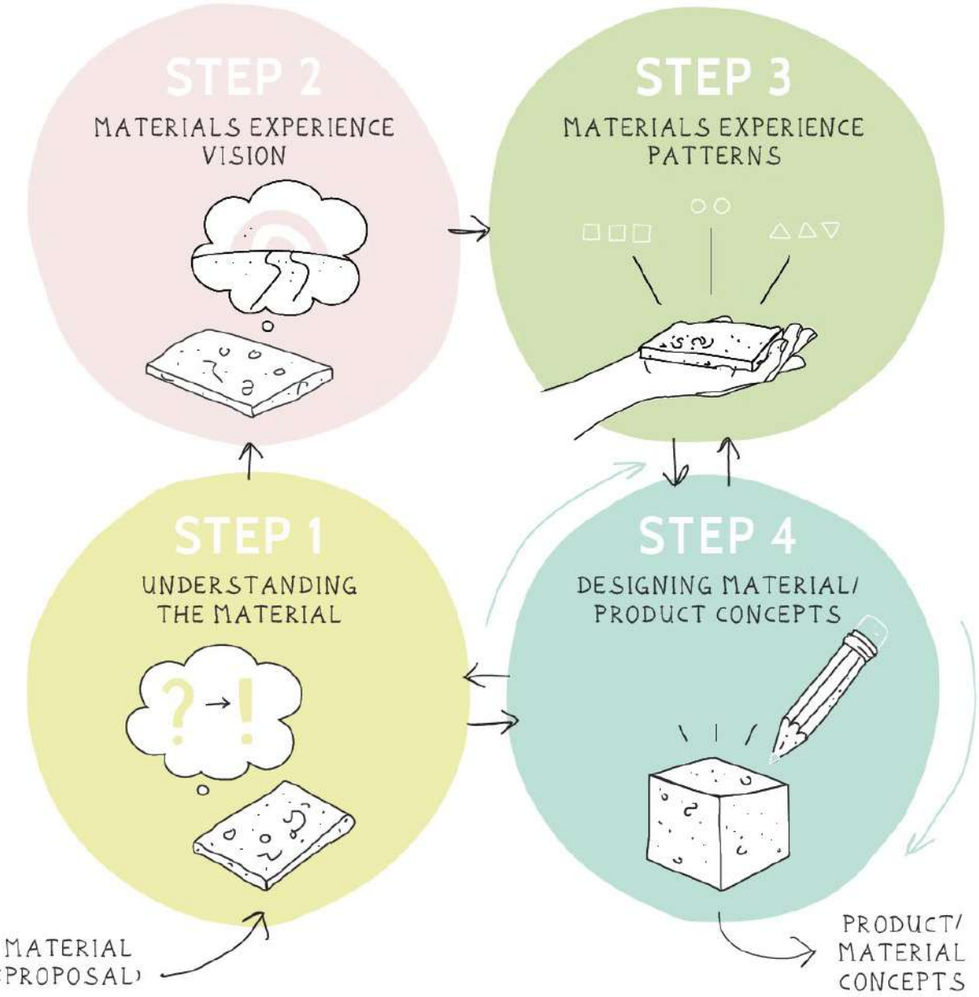
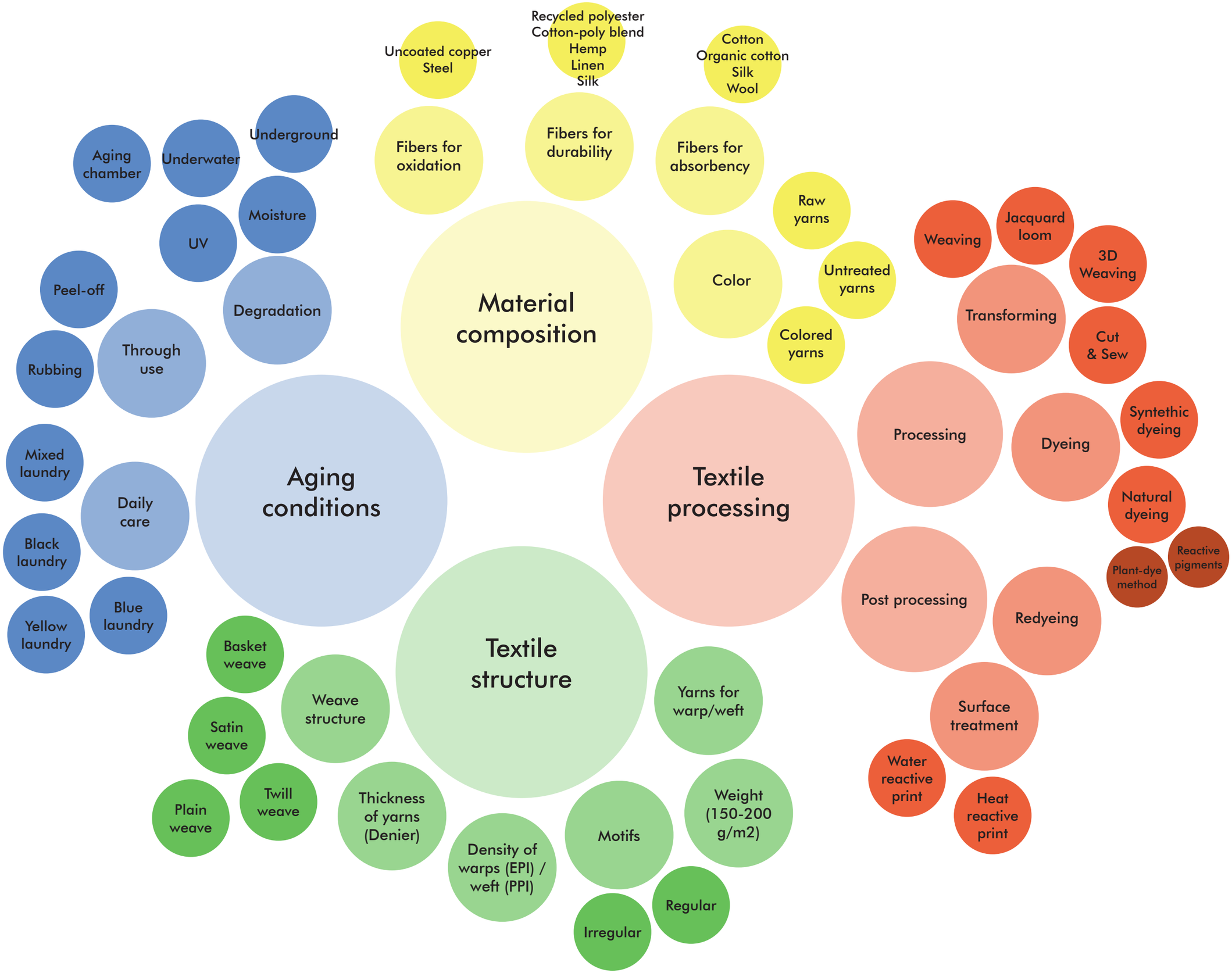


Figure 25. MDD process

4.3. Exploratory Study

4.3.1. MATERIAL TAXONOMY



4.3.2. UNDERSTANDING THE MATERIAL

After analyzing the background of changes over time in textiles and understanding the most suitable methodology to apply, it was vital to apply what was learned on a practical level. This chapter focuses on the design phase of the project, which saw the creation of the first samples and the user tests related to them. It is the phase prior to the vision of the project.

4.3.2.1. Designing the woven construction

The woven constructions of the samples were designed on AdaCAD, a free software used for computational design for weaving. After drawing the motif on illustrator and photoshop, it is imported into AdaCAD where, associating each color with a different construction (jacquard), it is turned into a bit map ready for the loom. The choice of constructions was based on the most durable ones, often used in workwear, but with some variations. For example, the triple twill, although used for resistant fabrics, in this case is revisited with larger float links in three 6x18 layers that allow greater absorption of color and material over time.
Since the works carried out by Talman are with regular and geometric shapes, the motif chosen for the first samples is irregular, a 3-area camouflage. Two combinations of constructions were used for the samples, then repeated for 4 different compositions.

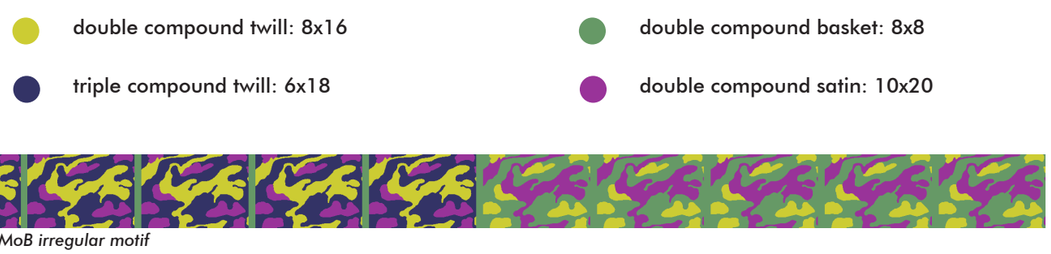
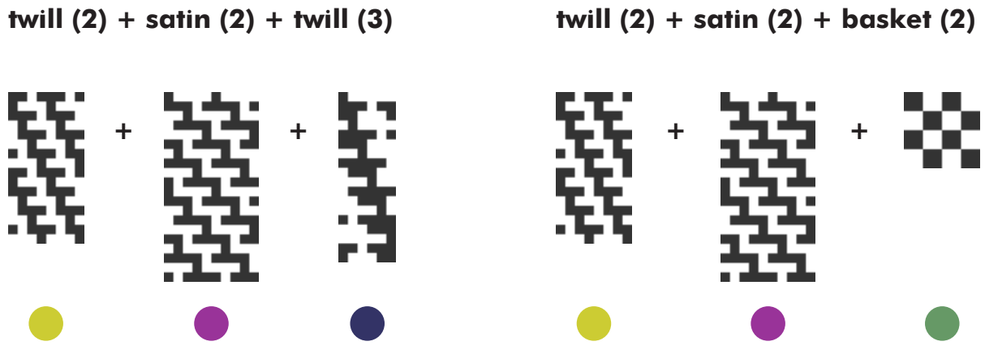


Figure 21. MoB irregular motif



4.3.2.2. Compositions

The choice of yarns to be used as weft for samples fell on those with more absorbency but natural, with the exception of the polyester + rayon combination, in this case selected to test the differences with synthetic yarns if subjected to the same treatments. Note that TC2, the jacquard loom used for this samples, has cotton as a warp. The bitmap was then woven 4 times, obtaining 10 samples at a time.

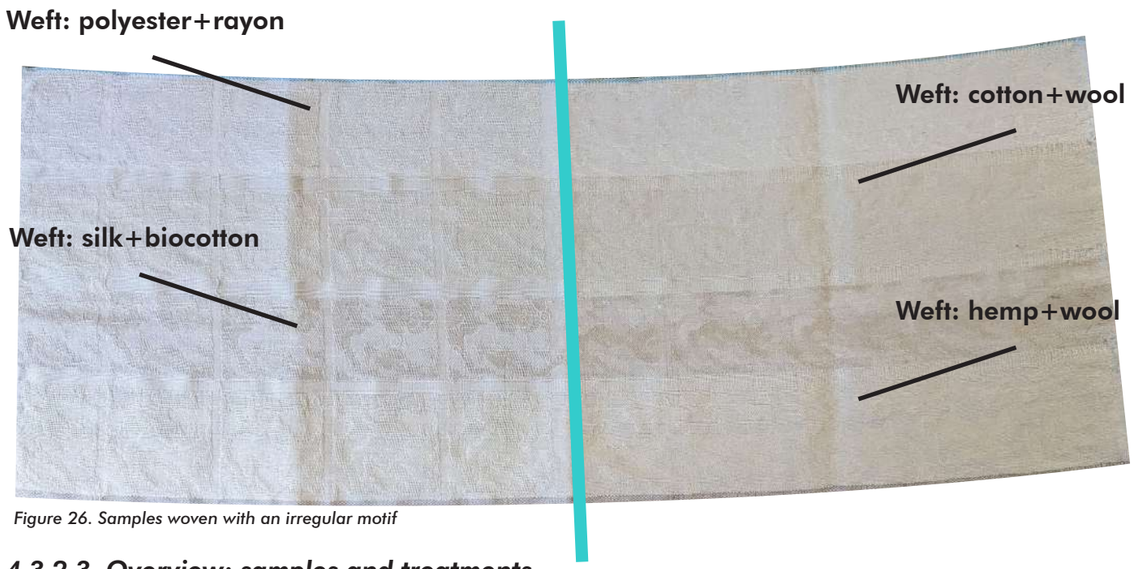


Figure 26. Samples woven with an irregular motif

4.3.2.3. Overview: samples and treatments

Textile material / Ageing treatments	1: initial	2: outdoor	3: burying	4: in use/ daily care	5: natural dyieng
A: camo pattern - basket (2), satin (2), twill (3) - ecru hemp, ecru wool, cotton	A1	A2	A3	A4	A5
B: camo pattern - basket (2), satin (2), twill (3) - biocotton, ecru silk, cotton	B1	B2	B3	B4	B5
C: camo pattern - basket (2), satin (2), twill (3) - ecru wool, ecru cotton, cotton	C1	C2	C3	C4	C5
D: camo pattern - basket (2), satin (2), twill (3) - polyester, rayon, cotton	D1	D2	D3	D4	D5
E: camo pattern - twill (2), satin (2), twill (3) - ecru hemp, ecru wool, cotton	E1	E2	E3	E4	E5
F: camo pattern - twill (2), satin (2), twill (3) - biocotton, ecru silk, cotton	F1	F2	F3	F4	F5
G: camo pattern - twill (2), satin (2), twill (3) - ecru wool, ecru cotton, cotton	G1	G2	G3	G4	G5
H: camo pattern - twill (2), satin (2), twill (3) - polyester, rayon, cotton	H1	H2	H3	H4	H5

Table 1. Overview of samples and treatments applied

Woven samples: 40
Samples at initial state: 8
Samples tested: 32

Treatments applied: 4

4.3.3. EXPERIMENTS

Of the 40 woven samples, 32 were treated to accelerate color changes, while the remaining 8 were kept in their initial state in order to compare them with their counterparts after the changes. 4 different types of treatments were applied: outdoor, burying and in use/daily care to test the coloring over time, while natural dyeing was chosen to verify the discoloration and the speed with which it manifests itself in the different compositions.

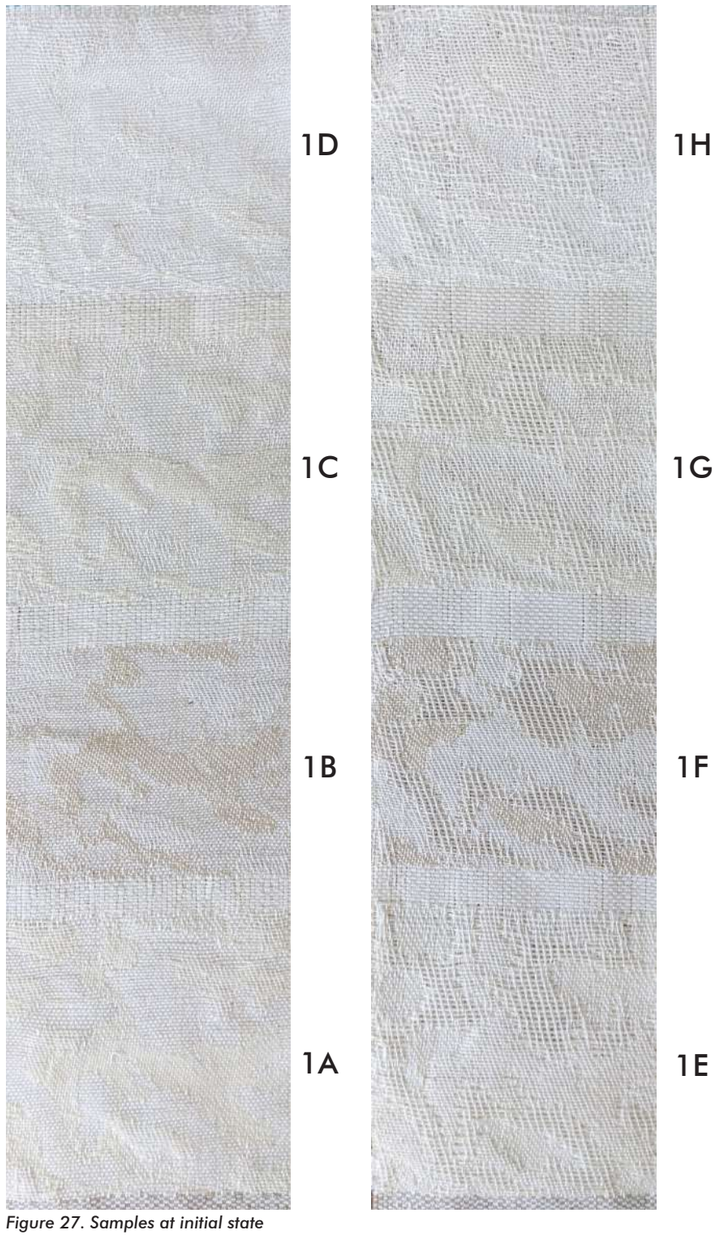


Figure 27. Samples at initial state

4.3.3.1. Outdoor

In our grandparents' houses it is often easy to find old linen fabrics yellowed by time. This type of treatment has been applied precisely to accelerate this change and see how the samples change color according to their composition/structure.

The purpose of this treatment is to reproduce the outdoor conditions that influence a fabric, but on a vastly enhanced scale to reduce time. The process sees two fundamental phases. During the first one, the enzyme artificial aging method is applied, a US patent for articial ageing where the samples are sprayed with laccase (or any other enzime) until humid and then dryed with an hairdryer to activate the compound (60min.) [44]. The second phase is based on an accelerated UV exposure. In particular, the samples are exposed first to sunlight for 72h and then to an UV torch inside a box for 96h. The results were visible immediately and led to a clear yellowing of the samples.

Figure 28. Outdoor dyeing

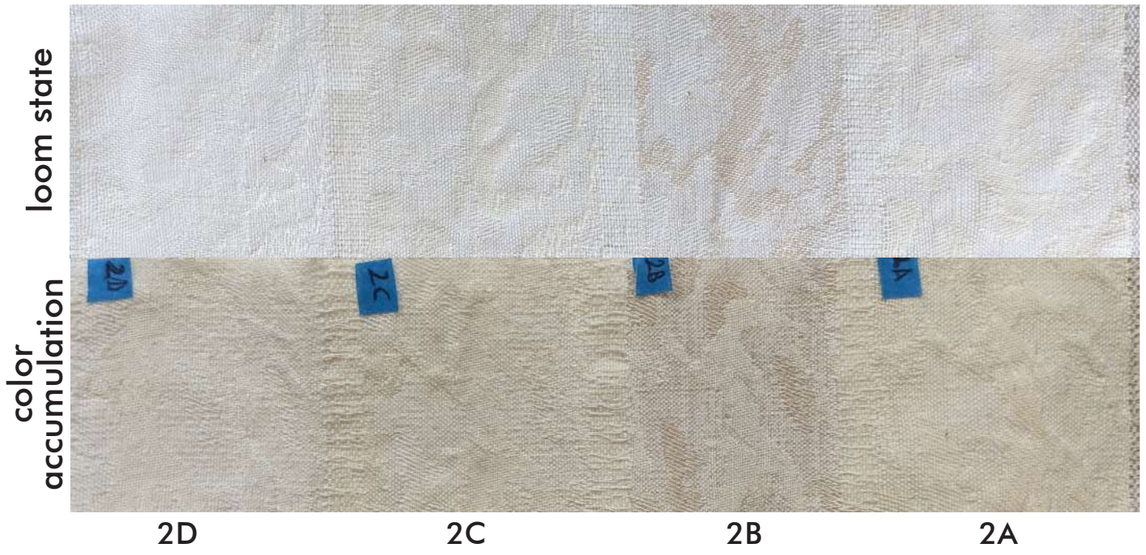


Figure 29. Samples after 169h of outdoor dyeing

Figure 30. Samples after 169h of outdoor dyeing

4.3.3.2. Burying

Based on Talmann's previous work, this burial treatment served to accelerate textile degradation over time. In this case, the samples are buried for 12 days (288h) in a vase filled with natural and humid ground soil. The samples are then rinsed and the impurities are removed. The more the fabric is left in the ground the more visible the changes are, but in this case 12 days were enough to see the first transformations.

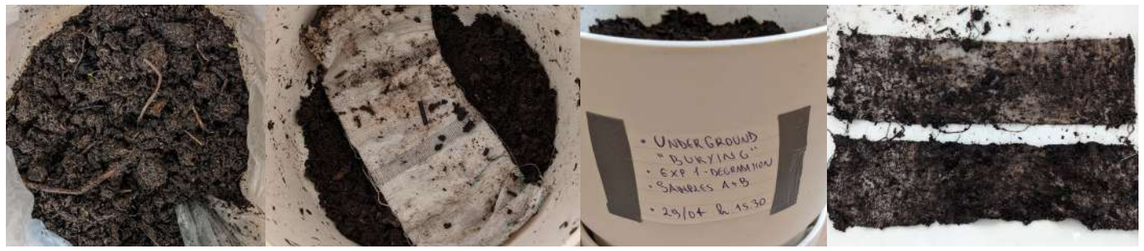


Figure 31. Burying dyeing

Figure 32. Samples after 288h of burying dyeing

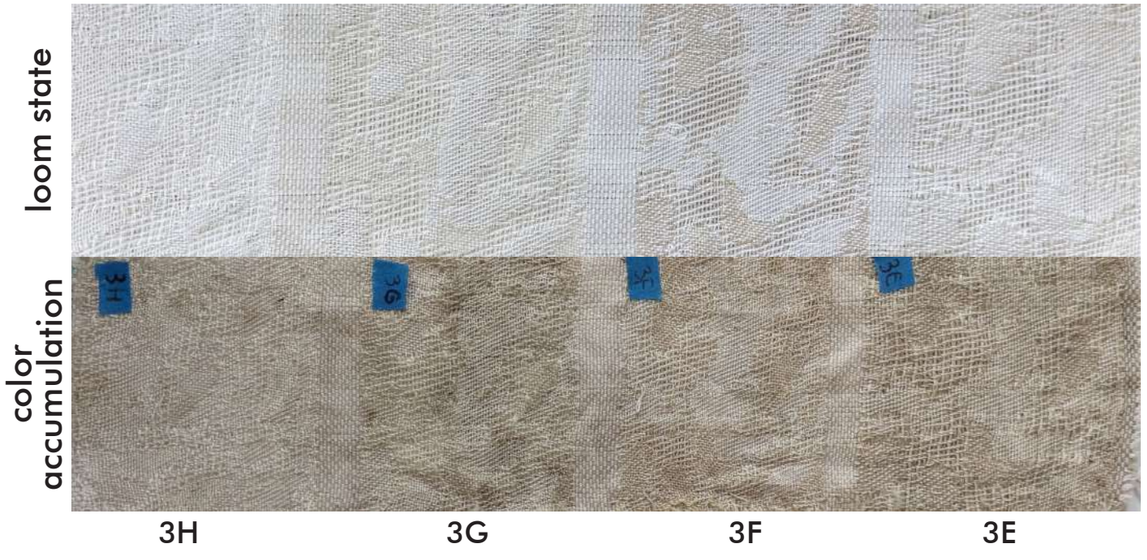


Figure 33. Samples after 288h of burying dyeing

4.3.3.3. In use/daily care

This treatment instead was chosen to understand if the daily maintenance of the garment and its use can give dynamism to textiles. First, the samples are subjected to a series of cycles (90min to 30°) of black laundry, in this case 3 times, to ascertain a possible absorption of black colors. Later, the samples are rubbed with different surfaces (denim, bricks etc.) and fabrics for 60min.

Figure 34. In use/daily care dyeing

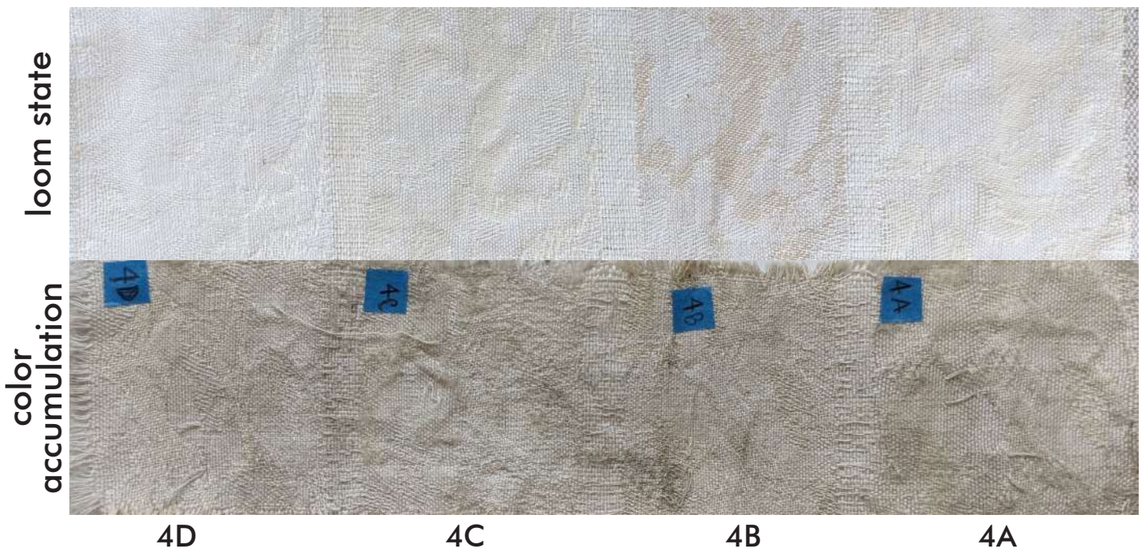


Figure 35. Samples after 1.5h in use/daily care dyeing

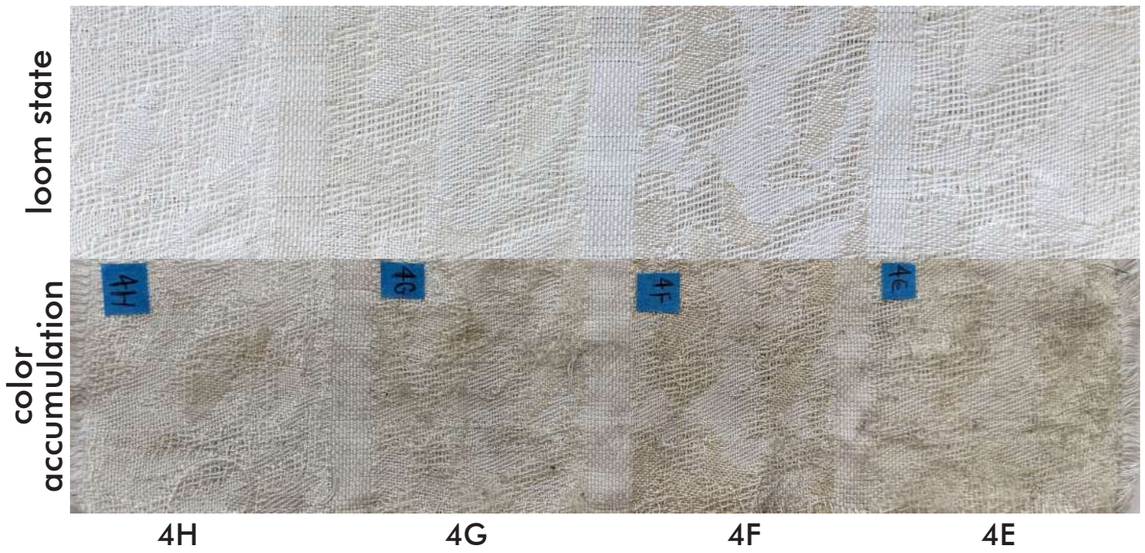


Figure 36. Samples after 1.5h of in use/daily care dyeing

4.3.3.4. Natural dyeing

The treatment of natural dyeing was performed not only to understand how the different compositions and constructions react to natural dyeing, but above all how much they tend to discolor and in how long. The method applied is called plant-dye method and provides that the plant, in this case red cabbage, is boiled for about 1h and then drained and squeezed for about 10min in order to extract the dyeing. Afterwards, the samples are dyed for 72h in a jar and then rinsed. Through this first phase of the treatment it was possible to see how the different yarns of the composition absorb the natural dye in their ecru state. However, in order to see how the colors of the motif areas change over time as they age, the samples were then further washed several times and dried in the sun to accelerate fading and compared to the 2 previous stages.

Figure 37. Natural dyeing with red cabbage

Figure 38. Samples after 72h of natural dyeing and fading treatments

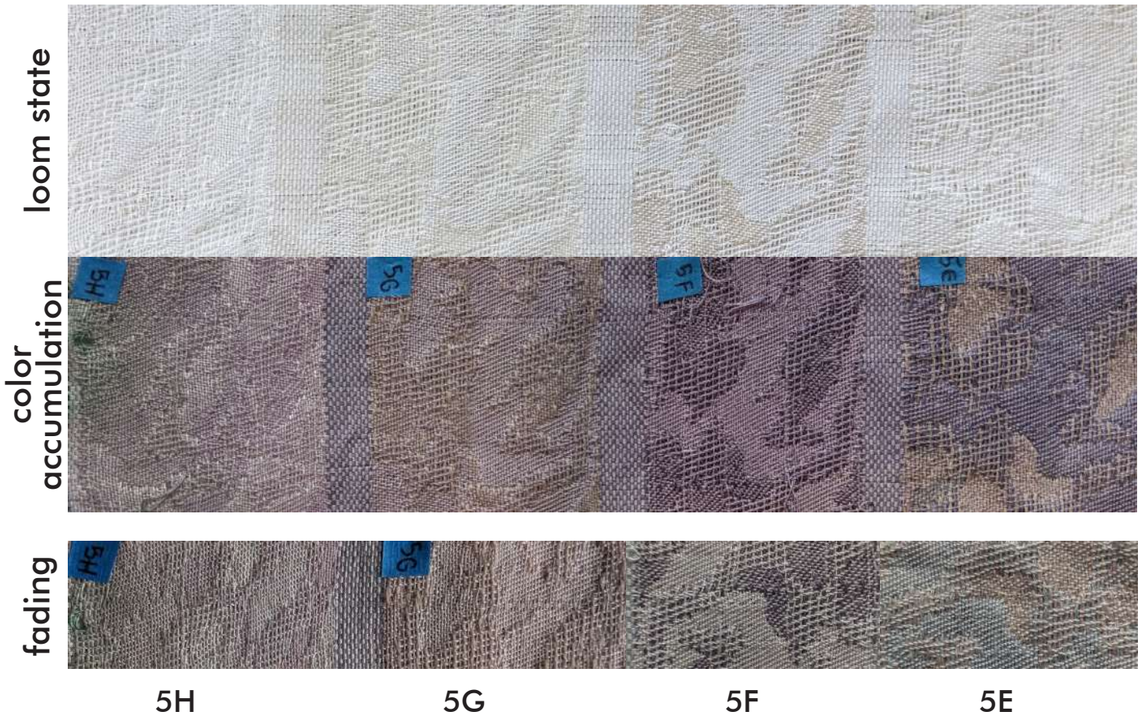


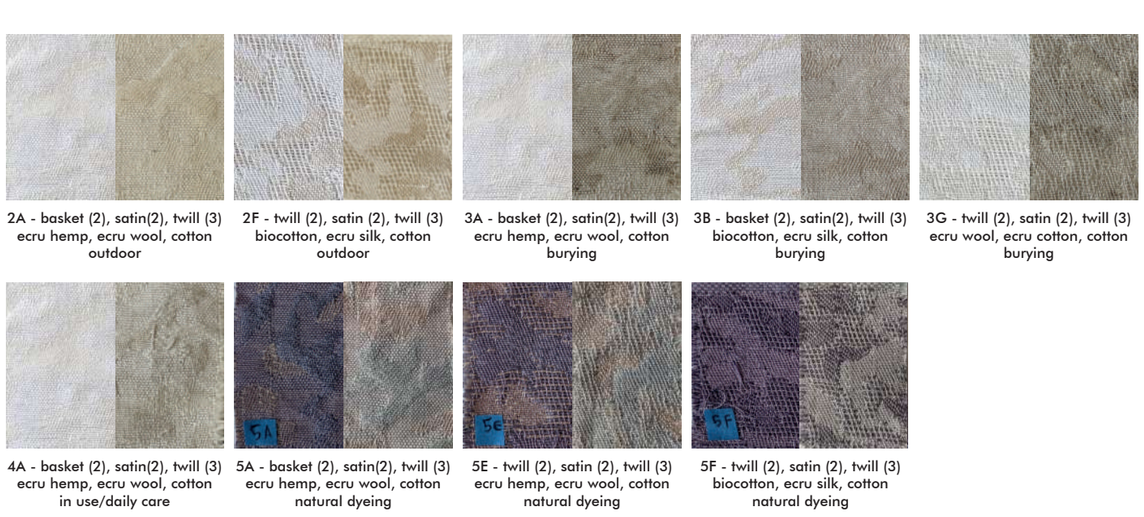
Figure 39. Samples after 72h of natural dyeing and fading treatments

4.3.4. EXPERIENTIAL CHARACTERIZATION

After the realization of the first samples and related treatments, it was crucial to understand how these changes are perceived by consumers and what affection they cause.

4.3.4.1. Aim and setup

To explore the meaning of the samples, understanding how people perceive the emotions that a material transmits is fundamental to giving value to the ageing process of a textile. Therefore, a user study based on the Experiential Characterization method by Camere and Karana [45] and the designed toolkit has been conducted. The results of this study has been fundamental to comprehend which constructions and compositions are more positively perceived, but overall which treatment elicits a greater sense of affection and uniqueness. Moreover, this test has then been useful to narrow down the selection and to find out which treatment fits the most with the realization of the first prototypes.
The test, with a total duration of 45min, was based on an individual session, subjecting 5 participants to the test. Among the 32 samples, 9 were chosen (2A, 2F, 3A, 3B, 3G, 4A, 5A, 5E, 5F) and that is those that showed the greatest changes after the treatments.



2A - basket (2), satin(2), twill (3) ecru hemp, ecru wool, cotton outdoor

2F - twill (2), satin (2), twill (3) biocotton, ecru silk, cotton outdoor

3A - basket (2), satin(2), twill (3) ecru hemp, ecru wool, cotton burying

3B - basket (2), satin(2), twill (3) biocotton, ecru silk, cotton burying

3G - twill (2), satin (2), twill (3) ecru wool, ecru cotton, cotton burying

4A - basket (2), satin(2), twill (3) ecru hemp, ecru wool, cotton in use/daily care

5A - basket (2), satin(2), twill (3) ecru hemp, ecru wool, cotton natural dyeing

5E - twill (2), satin (2), twill (3) ecru hemp, ecru wool, cotton natural dyeing

5F - twill (2), satin (2), twill (3) biocotton, ecru silk, cotton natural dyeing

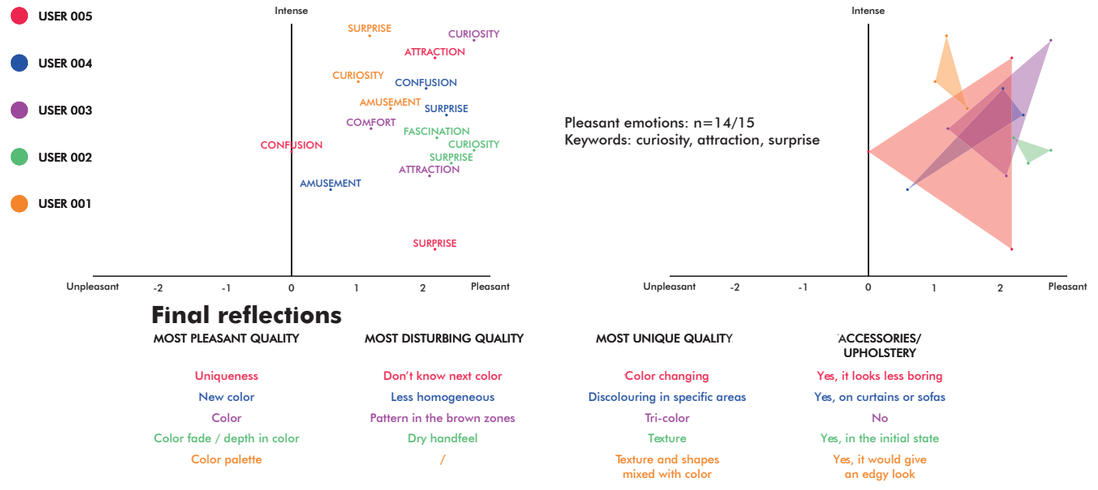
Figure 40. Tested samples

After clarifying from the beginning that the samples are designed to be used for garments, participants were asked to address the affective level they experienced towards the material they were interacting with, by placing 3 emotions among the ones provided on a graph about pleasure (positive or negative) and intensity. Each samples has been always shown together with its initial corresponding state. Then a list of meanings was provided and the participants were asked which associations/meanings are evoked by this experience and why. The test was then concluded with a series of reflective questions regarding the most pleasant, disturbing and unique qualities of the material.

Figure 41. Users interacting with irregular motif samples

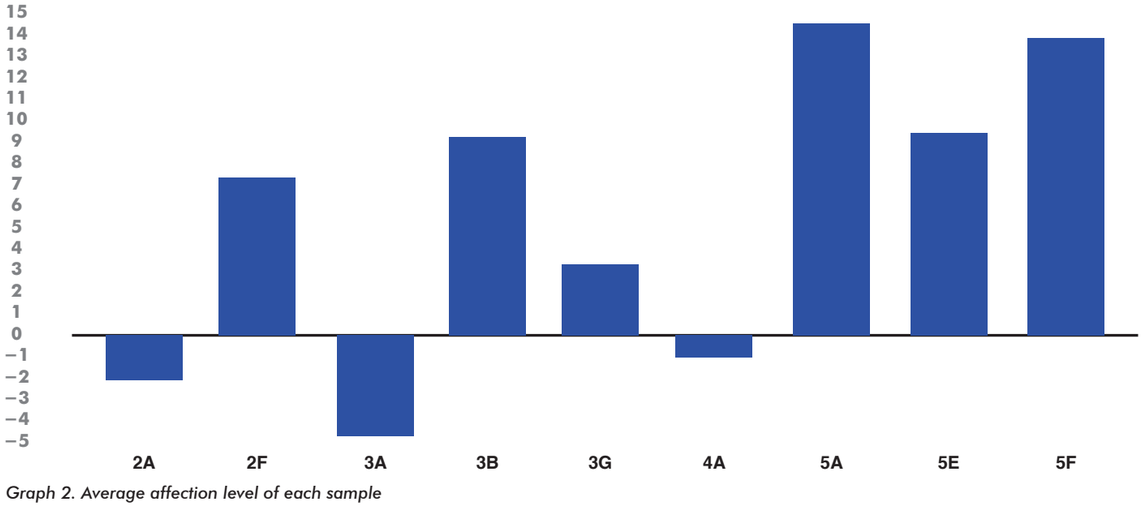
4.3.4.2. Data analysis

The data gathered from participants were analysed in order to find consclusions. In particular, every samples were assessed on a scale of intensity from unpleasent (-3) to pleasant (3) and then visualized on a graph showing the responses of each user. For each of the 3 emotions aroused in the testers, triangles were then obtained to represent the affective average and the general trend of the sample.

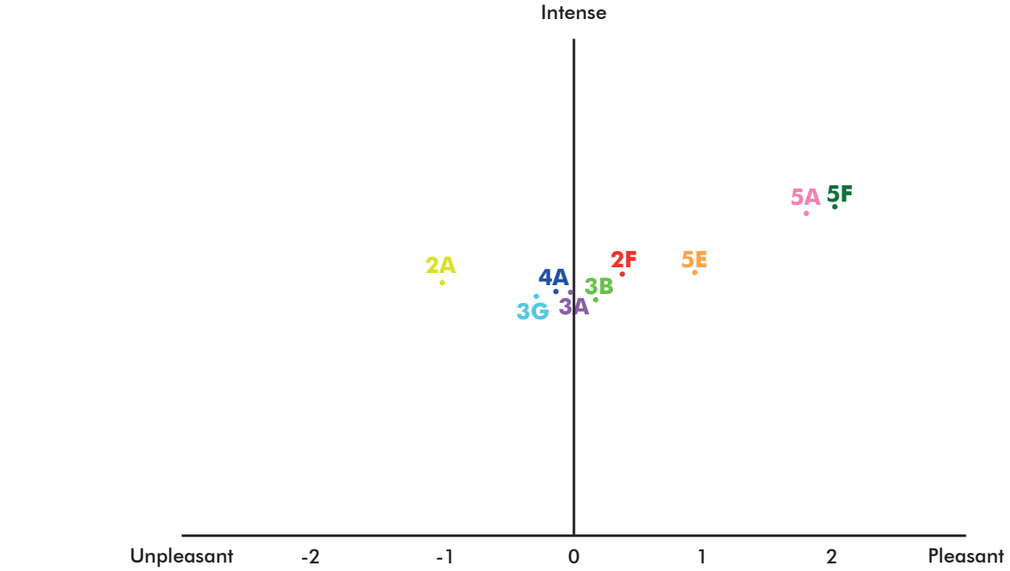


Graph 1. Affective level analysis of sample 5A

Afterward, together first with a barchart, the average score that each sample provoked in terms of emotion has been shown again on a pleasant-unpleasant-intense graph, thus figuring out the most appreciated ones.



Graph 2. Average affection level of each sample



Graph 3. Positive-negative barchartwith the average of the most pleasant samples

By looking at the graph, it apperas clear that the most performative samples are the 5F, 5A, 5E, 2F and 3B. To be specific, the first three mentioned can be categorized as the most appreciated in terms of fading, while the last two in terms of getting colored. However, in order to have even results, the sample 5E, slightly less performative than the other fading ones, has been then excluded.

Instead, to analyze the results of the interpretative level of each sample, the meanings elicited in each user during the comparative interaction were collected in a table which also shows the associations that some users shared during the test. In the case of the 3G and 5E samples there were no common meanings, thus creating conflicting reactions. Also for this reason it was decided to remove the 5E sample from the final selection.

	USER 001	USER 002	USER 003	USER 004	USER 005	
2A	nostalgic / aged / static	aged	natural	static	durable	**AGED / STATIC**
2F	nostalgic / natural	aloof	durable	natural	hand-crafted	**NATURAL**
3A	aged / natural	aged	aged	aged	manufactured	**AGED**
3B	static / aged	aged	nostalgic	aged	natural	**AGED**
3G	strange / permanent	aged	hand-crafted	natural	nostalgic	
4A	aged / handcrafted	aged	strange	aloof	aged	**AGED**
5A	dynamic / futuristic	aloof	futuristic / dynamic	dynamic	dynamic	**DYNAMIC**
5E	unaged / fragile	nostalgic	futuristic	cozy	ntural	
5F	unaged / dynamic / manufactured	nostalgic / hand-crafted	temporary	cozy	temporary	**TEMPORARY**

Table 2. Interpretative level analysis

4.3.4.3. Results

2F - twill (2), satin (2), twill (3) biocotton, ecru silk, cotton outdoor

3B - basket (2), satin(2), twill (3) biocotton, ecru silk, cotton burying

5A - basket (2), satin(2), twill (3) ecru hemp, ecru wool, cotton natural dyeing

5F - twill (2), satin (2), twill (3) biocotton, ecru silk, cotton natural dyeing

Figure 42. Most appreciated samples

The final selection shows the 4 samples chosen to be applied for the embodiment phase. However, as noticeable from the graph shown before, the gap between the coloring samples and the fading ones results in quite large and this suggested new considerations. As a matter of fact, unlike Talmann's work, the woven samples have all an irregular motif, which led the project to consider a new design variable: a regular motif.
At the beginning, the initial hypothesis was to test the samples using only an irregular motif, as it had still not been tested by previous studies and closer to the motifs we see on everyday garments. Regular (or geometric) motifs, especially in the embryonic phase, are extremely helpful to the visualization of changes because they have distinct areas and divided by clearly visible lines. However, since the aim of this thesis is also to make textile motif patterns ordinary and commercial, verifying the effectiveness of irregular motifs was crucial to achieve this goal. Only after analyzing these results, it was discovered that the motif is not a marginal parameter to the interaction with a dynamic motif, but a completely influential factor for the perception of changes, just like woven construction and composition. For this reason it was decided to add this new variable, which was the only one untested, and therefore the only one that could change the scores.

4.3.5. COMPARISON WITH REGULAR MOTIFS

In order to see if the gap beforementioned can be reduced, it became necessary to test again the samples 2F and 3B, but this time with a gemoteric motif, understanding if this factor influences the affection provoked by this samples and shortens the score difference of these two categories. In this case, the motif chosen for the new samples to be compared with the irregulars was the honeycomb, which lends itself well to its geometry. The new samples, in this case renamed 2I and 3L, were then woven with the same compositions/constructions as their counterparts and subjected to the same treatments, respectively outdoor and burying.

Figure 43. MoB regular motif

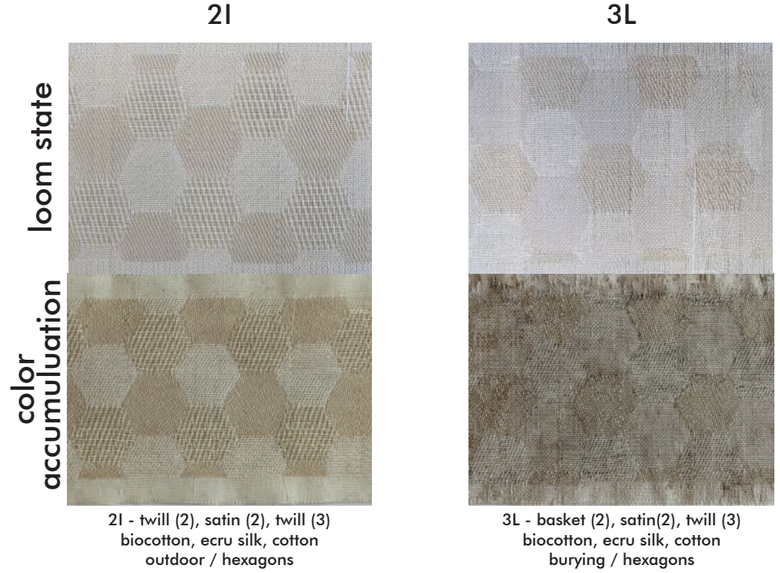
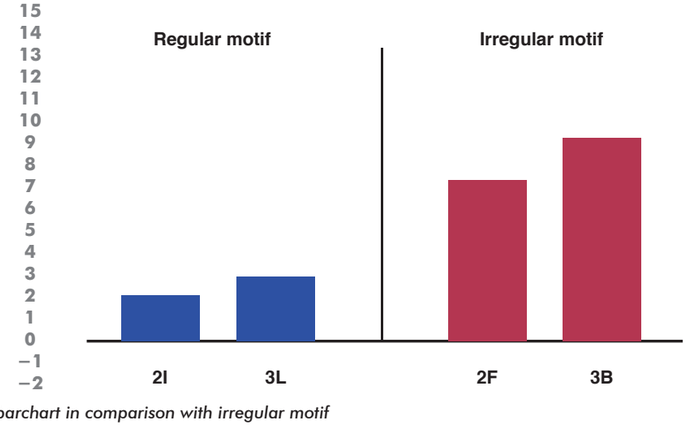


Figure 44. Regular motif after treatments

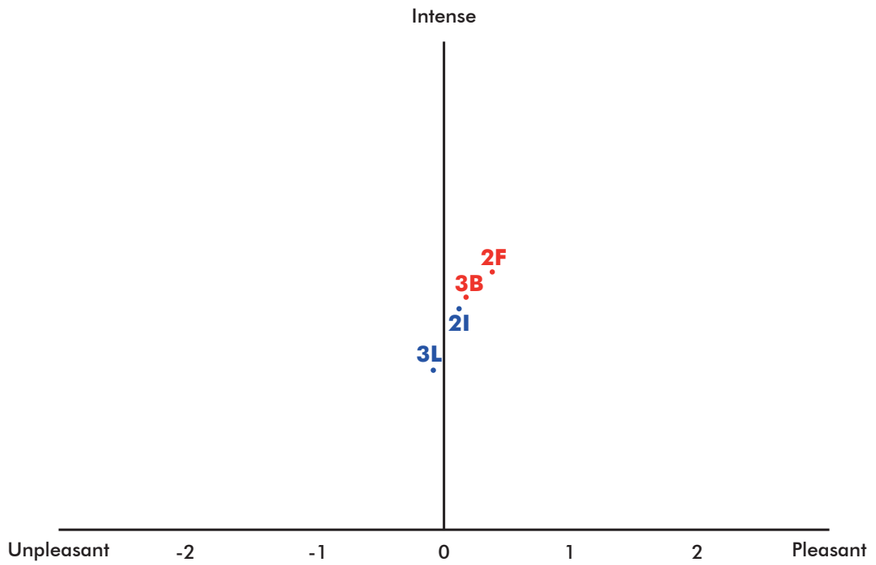
The two new samples were subsequently subjected to a new affective user test, conducted in exactly the same way as the first one and always involving 5 participants for about 17 minutes each.

Figure 45. Users interacting with regular motif samples

The results obtained from the second user test were then analyzed and reinterpreted on the basis of the previous one, in order to have a comparison as objective as possible.
In the following graphs it is possible to observe not only the average score of the two new samples with regular motif 2I and 3L, but also their positioning in comparison with samples 2F and 3B.



Graph 4. Positive-negative barchart in comparison with irregular motif



Graph 5. Average affection level of regular motif samples and comparison with irregular ones

The second test conducted has therefore shown that the regular motif, obviously in relation to the treatments applied and the compositions used, does not perform better than the irregular one, but worse: the reason, which unites most users, is that the observed color changes are basically very uneven, making these defects much more visible, and less appreciated, on a regular than irregular motif, aimed instead at hiding them. Despite this test, the gap between the two categories remained very wide, providing no scientific justification for a possible choice of coloring transformations. In conclusion, it was possible to establish which category of dynamic changes is most appreciated by users, namely fading, thus narrowing the field of action.

	user 001	user 002	user 003	user 004	user 005	
2I	aged	nostalgic	static	hand-crafted	nostalgic	**NOSTALGIC**
3L	aloof	natural	aged	durable	natural	**NATURAL**

Table 3. Interpretative level analysis of regular motif

Even the interpretative level did not show extremely significant associations compared to the samples with an irregular motif, therefore confirming what was seen previously.

4.3.6. G-STAR RAW: RECYCLED DENIM JACQUARD WOVEN FABRIC

After conducting the tests, it became evident that, for the purposes of this project, fading is highly more valued than coloring in textile dynamic changes. The gradual transformation and evolution of colors over time, as seen in faded fabrics, create a sense of nostalgia and character. This preference for fading was attributed to its unique ability to tell a story and add a sense of authenticity to the textiles. In contrast, coloring was perceived as more static and lacked the dynamic allure of the natural aging process. The users' feedback highlighted fading's intrinsic appeal and its potential to evoke emotions, making it a preferred choice for hypotetical consumers.
For this reasons, to allign the project with the purposes of G-Star, client of this research, a new jacquard woven fabric has been developed together with one of its supplier, Nantong Huakai Textile Co. The fabric, characterized by mechanically recycled indigo denim yarns, has an irregular motif (alligned with the results obtained before) of mountains with 3 areas in different blue indigo shades. This allows, unlike raw denim, first of all a programmed fading because each area will fade with different timing, but above all a unique fading knowing that the same areas will discolor one inside the other. Obviously, the fading of indigo yarns generally requires longer times (>8/10 months) [46] than natural dyeing that fades in a few washes, making this fabric much more suitable for commercial purposes.
In technical terms, the fabric is composed of: 50% of recycled indigo cotton yarns (C), 20% of recyled white cotton (RE C) and 30% of recycled polyester (RE PE), melted together with white cotton, obtaining a single ply yarn as warp. It has a weight of 256 GSM and a full width of 55/56.

Figure 46. G-Star recycled denim fabric

Figure 47. Macro of G-Star recycled denim fabric

4.3.7. MATERIAL BENCHMARKING OF CASE STUDIES

In the material benchmarking activity the samples are positioned among the existing related projects from other designer/researchers to understand the material opportunities or gaps they have. The case studies are compared according to two different categories, namely their application and their experiential qualities/problems they present. This phase of the MDD method turns out to be key because, based exclusively on the properties of the material, it leads to more innovative and effective design development. By assessing factors like imperfections, temporality, and authenticity, the benhcmarking helps make informed decisions.

The materials covered by this research, highlighted in blue, have certainly shown great improvements compared to the related works. In particular, a first consideration must be made in relation to their applications, which are generally broader than the other examples. The presence of the irregular motif dictated by the jacquard is in fact not only decorative, because it adds an aesthetic value to a fabric that would otherwise be plain, but also structural because it acts as an engine for dynamic changes considering their heterogeneous composition.
All three materials still have an experimental application, but this does not remove a possible commercial use, as happened for Nike's AF1 or Puma's Living color.
Moreover, thanks to user tests, albeit of limited number, it was possible to understand that sample 5A is not seen as particularly suitable for footwear or accessories, while the 5F, due to the lightness given by silk, and the recycled denim fabric, developed in collaboration with a clothing brand, do not appear suitable for upholstery or furniture at the moment.
Regarding qualitites and issues, all 3 materials provide a natural color that is revealed over time, high authenticity, high naturalness and consequently high imperfections, given by a fading programmed but never homogeneous. This also means that all three materials are highly authentic and unique, with the difference that samples 5A and 5F have a rapid change over time due to natural dyeing, while the recycled denim jacquard fabric is very slow due to indigo and similar to raw denim, therefore slightly more suitable for possible industrial use. In addition, the latter, being more finely woven, is less subject to the presence of visible fibers and is significantly smoother than the samples. Their durability gives also high repairability (wabi sabi) over time.

	Raw denim	Dynamic textiles patterns *R. Talmann*	Burning tablecloth *L.Worbin*	Puma canvas shoes *E. Whiting*	Beauty comes with age *N. Wester*	AF1 tear away *Nike*	Sui bag *Polimi*	Living color *Puma*	Photo-Chromeleon *MIT*	Sample 5A	Sample 5F	Recycled de-nim jacquard woven fabric
												
Applications												
Decorative	yes	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes
Structural	no	yes	yes	no	yes	yes	yes	yes	no	yes	yes	yes
Experimental	no	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes
Garments	yes	no	no	no	no	no	no	yes	no	yes	yes	yes
Footwear/Accessories	yes	yes	no	yes	no	yes	yes	no	yes	no	yes	yes
Upholstery/Furniture	yes	yes	yes	no	no	no	no	no	no	yes	no	no
Experiential qualities & emerging experiential issues												
Natural color	revealed	revealed	recovered	revealed	revealed	revealed	revealed	recovered	revealed	revealed	revealed	revealed
Imperfections	medium	high	high	high	high	medium	high	high	low	high	high	high
Roughness	low	medium	medium	low	high	high	medium	low	low	high	medium	low
Visible fibers	no	no	yes	no	yes	yes	yes	no	no	yes	yes	no
Wabi Sabi	high	high	medium	medium	high	medium	high	medium	low	high	high	high
Standard unique	no	yes	yes	no	no	no	yes	yes	yes	yes	yes	yes
Change over time	yes - slowly	yes - slowly	yes - rapidly	yes - in time	yes - in time	yes - rapidly	yes - in time	yes - slowly	yes - rapidly	yes - rapidly	yes - rapidly	yes - slowly
Authenticity	high	high	high	medium	high	medium	high	high	high	high	high	high
Naturalness	high	high	medium	high	medium	medium	high	high	low	high	high	high

4.4. Vision

The material understanding phase was useful in order to map the findings from the previous studies into a design vision.
During material characterization it was possible first of all to understand which experiments led to the greatest changes. As expected, natural dyeing, compared to aging treatments, was the most visually impactful as the different yarns of the composition were colored differently according to the ph, while in the case of the other results, the changes, although visible thanks to the complex woven construction, were much more moderate and less varied. This clearly was not enough to narrow down the field of study and the first user tests were necessary to filter the first findings.
Particularly relevant to the development of vision was in fact the experiential characterization through which it was possible to discover which of the samples and treatments previously selected were more effective at the affective level. Also in this case, regardless of the regular or irregular motif, the fading of natural dyeing seemed more appreciated than the other changes and this has set the first limits to opt for a service rather than a product. Through the tests, in fact, it has been confirmed that the affection arises from the uniqueness of natural discoloration over time, impossible without good durability, and this concept cannot be satisfied by a simple product that can do it but without the possibility of being recolored.
Adding these considerations to the benchmarking case studies, which are all products, it was decided to decide upon a product-service system, a solution that not only offers the dynamism given by the fading, short or long, of the 3 materials chosen, but also offers the possibility of always giving them another new color once lost, extending its life cycle and, consequently, using a sustainable approach.

4.4.1. DESIGN VISION

Every garment, especially those made with jacquard woven textiles, has its own story, symbolizing the wearer's journey and self-expression. Feeling connected to our clothing is therefore essential for a meaningful and sustainable wardrobe. Following the analysis of the design problem and user's needs, the vision of this project focuses on:
Empowering individuals to extend the life cycle of their garments and embrace a conscious and creative approach to fashion through sustainable redyeing techniques.
By providing accessible resources for self-redyeing or professional assistance, the project aims to promote responsible consumption, reduce textile waste, and encourage a deeper appreciation for the unique character of each garment as it evolves over time. The purpose is to give vibrancy to faded garments and fostering a sense of connection to the clothing that accompanies us through various chapters of life.

4 design insights have been chosen to take into account during the project path:

This vision can be compared to a wall for urban graffiti art: much like how graffiti artists layer new colors and designs on a wall to express themselves and transform the urban landscape, this project empowers individuals to revitalize their garments by adding vibrant layers of color. Each garment serves as a dynamic canvas, eagerly embracing the wearer's creative input and evolving into a unique narrative of self-expression and personal attachment. Every dye application represents an intentional brushstroke, symbolizing a moment in the wearer's life. In the end, just as street art leaves an enduring impression on the urban environment, these redyed garments leave an indelible mark on the wearer's journey, serving as both a testament to our past and a commitment to a more sustainable and creatively vibrant future.

Figure 48. Layers of different graffiti on a wall

4.4.2. PSS: SUSTAINABLE GARMENT REDYEING SOLUTION

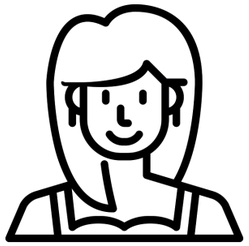
The vision has been translated into a product-service system, in which the user, thanks to the durability of the garment, can re-dye the garment once faded or leave it as it is.

The redyeing process can be done as many times as the user wants during the life cycle of the garment or can just leave it faded. In the case of natural dyed products, the times are much shorter than for indigo ones, but both are anyway suitable for the PSS.

4.4.2.1. User journey

PERSONAS

Sarah



Age: 28

Occupation:
Marketing Executive

Background:
Sarah is a young professional who is passionate about sustainable fashion and eco-friendly practices. She values high-quality, durable garments that align with her personal style and values. Sarah is conscious of the environmental impact of the fashion industry and actively seeks out brands and initiatives that promote sustainability.

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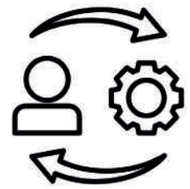
							
	Introduction and Initial Purchase	Initial Use and Monitoring	Decision Point: Faded Garment	Self-Redyeing Option	Redeying Service	Sustainable Practices and Community Engagement	Continuos improvement and Feedback
A	**USER CONTEXT:** Sarah discovers a new product-service system from a big clothing company, aiming to extend the lifecycle of jacquard woven textiles dyed with natural dyes	**GARMENT USAGE:** Sarah starts wearing her new garment, enjoying its design, comfort, and the vibrant colors from the natural dyes.	**USER EVALUATION:** As the garment approaches a nearly white appearance, Sarah reaches a decision point. She contemplates whether to keep her jacket in its faded state, appreciating its uniqueness, or choose to redye it to introduce a new seasonal color	**INSTRUCTIONS:** If Sarah decides to redye her garment, she locates the garment care label or finds instructions provided on the garment packaging. The instructions guide her on self-redyeing techniques	**RETAILER INTERACTION:** If Sarah prefers professional assistance, she visits the partnered retailer or contacts them for a redyeing service appointment	**COMMUNICATION:** Throughout the user journey, the company actively promotes sustainable practices, responsible consumption, and the importance of extending garment lifecycles. They communicate through various channels such as social media, newsletters, and educational content on their website	**USER FEEDBACK:** Sarah, along with other customers, is encouraged to provide feedback and share her experiences with the product-service system. This feedback can be collected through surveys, online forums, or direct communication channels
B	**PRODUCT DISCOVERY:** Sarah visits the brand's website or physical store to explore the collection and shelearns about the unique characteristic of these garments, which evolve over time, fading from their original color	**FADING PROGRESS:** Over time, Sarah notices her garment gradually fading, as the natural dyes undergo their expected evolution process. She embraces this transformation, appreciating how her garment develops a unique character		**GARMENT PREPARATION:** Sarah carefully follows the provided instructions to prepare her garment for the redyeing process. This involves cleaning the garment thoroughly and ensuring it is ready to absorb the new color	**GARMENT ASSESMENT:** At the retailer's location, a trained professional assesses Sarah's faded garment, evaluating its condition and discussing color preferences for the redyeing process. They consider the available seasonal color palette options.	**RECYCLING:** To ensure the responsible end-of-life management of garments, the system facilitates recycling programs, where worn-out garments can be returned for proper recycling or donated to charitable organizations	**ITERATIVE DEVELOPMENT:** The collaboration between the designer and the big company considers user feedback and market trends to continuously improve the product-service system, offering enhanced garment options, more sustainable dyeing techniques, and personalized user experiences
C	**COLOR SELECTION:** Sarah selects her preferred garment, considering the design, fit, and durability. She also chooses a seasonal color palette option from the available choices provided to redye her garment when it fades			**DYE MIX/APPLICATION:** Sarah follows the instructions to mix the natural dye powder with water or any other required ingredients. She immerses the garment into the dye bath, using the specified redyeing technique that suits jacquard woven textiles	**REDYEING PROCESS:** Using their expertise, the retailer performs the redyeing process, following best practices and ensuring the desired color outcome. They apply suitable techniques for jacquard woven textiles		
D				**COLOR INTENSITY:** Sarah monitors the color intensity throughout the dyeing process, adjusting the duration or dye concentration as desired. She then follows the provided instructions to dry and set the garment, ensuring the longevity of the dye	**QUALITY ASSURANCE:** The retailer performs a quality check on the redyed garment, ensuring the color and dyeing quality meet Sarah's expectations. She either collects the garment directly from the retailer or arranges for delivery to her preferred address		

4.4.3. REDYEVOLVE: SELF-REDYEING KIT

The self-redyeing kit, ReDyEvolve, empowers individuals to actively participate in the revitalization of their garment and to foster sustainable fashion. This product, part of the PSS, can be purchased by the user whenever the dyeing of the faded garment wants to be done at home rather than at the retailer. The kit allows users to breathe new life into their jacquard woven textiles, by using natural dyes extracted from seasonal plants. With some essential tools available inside the kit, users can confidently engage in the dye extraction process and create personalized colors, achieving the perfect hue for their clothes. It includes:

- Comprehensive guidebook, that offers step-by-step instructions on plant selection, dye extraction techniques, and dyeing methods for different materials.
- Plant selection chart, thatshowcases seasonal plants suitable for dyeing and indicates their respective color possibilities.
- Airtight recycle bag, to collect the plant materials for dye extraction.

Figure 49. ReDyEvolve front cover mockup

The self-redyeing process is divided into 6 steps, accurately described on the bag, which can be recycled for other future dyes.

1. The first step is to pre-wash (adding white vinegar can help the dye absorption) the faded garment to remove any residues that might interfere with dye absorption. To contribute to the product-service system's community engagement and inspiring others to embrace sustainable practices it is also suggested to take a "before" photo.
2. Subsequently, after identifying in the guidebook the seasonal plant to be used according to the desired color, the user can proceed with collecting plant materials responsibly, ensuring to not harm the environment and adhere to ethical harvesting practices. The amount of material necessary for the dye to be homogeneous must be equal to half the weight of the garment at least. Before moving on to the next step, it is also important to rinse the collected plant materials to remove any impurities.

Figure 50. ReDyEvolve back cover mockup

3. The extraction process involves boiling the plants in a pot containing water over low heat for about 1h (instructions vary according to the type of plant), and then cool the extraction and filter it. Depending on the garment material, the user can choose to mordant the fabric during this phase (with salt, for example) to enhance dye adherence and color fastness. The guidebook provides mordanting options suitable for different fabrics.
4. It is now possible to immerse the garment in the dye bath for 12/24h, allowing it to gradually absorb the natural color. The color intensity of the dye should be monitored periodically to achieve the desired hue.
5. Rinsing and drying the garment to air dry is the last step in the process, avoiding direct sunlight, thus an initial fading of the color. The guidebook also includes aftercare tips and a comprehensive garment care guide to ensure the durability of the redyed garment.
6. Taking a photo "after" concludes the process, encouraging a sense of accomplishment for self-dyeing clothes.

In addition, the user is made aware of trims and stitchings that will not follow the same colors as the fabric: the former, as metal, will remain the same or oxidize, while the latter, often made of polyester, will not absorb the dye or, if they do, will show a different color.
This heightened understanding emphasizes the necessity for a comprehensive approach that not only incorporates the dynamic color fading aspect but also accounts for the impact of the other parts of the garment. A conventional static product would have overlooked these specificities, underscoring how the PSS offers not only dynamic experiences but also accommodates informed sustainability considerations, embracing the entirety and uniqueness of the garment.

In conclusion, this redyeing system promotes sustainable fashion by extending garment lifecycles, utilizing natural plant dyes to reduce environmental effect, and promoting ethical sourcing. Users value personalisation and creativity, which allows them to participate in a circular fashion while also encouraging community engagement and access to educational materials. Overall, the service promotes a conscious and eco-friendly approach to fashion consumption, and it is constantly working to improve its sustainability and user experience.

Figure 51. An example of the plant selection chart

Figure 52. ReDyEvolve airtight bag mockup

5. Toward a Design Space for dynamic textile motifs

5.1. Embodiment study

In the embodiment design phase of the project, the focus shifts towards materializing the conceptual ideas and translating them into tangible solutions. This pivotal stage involves refining and iterating on the selected samples (5A, 5F and G-Star one) taking into account the feasibility of the product-service system ideated. Prototyping plays a crucial role in this phase, allowing for hands-on exploration of natural dyeing techniques and color changes to achieve responsive and visually captivating patterns.
Iterative testing and user feedback are integrated again throughout the embodiment design phase to refine the final prototypes, ensuring that the dynamic textile patterns not only captivate aesthetically but also provide a seamless and intuitive user experience.

To test the PSS and its effectiveness, two bucket hats with the fading fabrics previously chosen have been made. The choice of this garment is simple: it is always in contact with sunlight and above all the pattern does not require an onerous amount, the opposite of a jacket or pants for example, decisively shortening the weaving times at TC2. It was also decided not to make a third bucket hat with the fabric developed together with G-Star for this step, as the timing and discoloration of denim on a garment are far longer. In this case, the goal of embodiment is to test the fading of natural dyeing on a woven fabric jacquard and how much this is appreciated by the user during this phase of the product-service system.

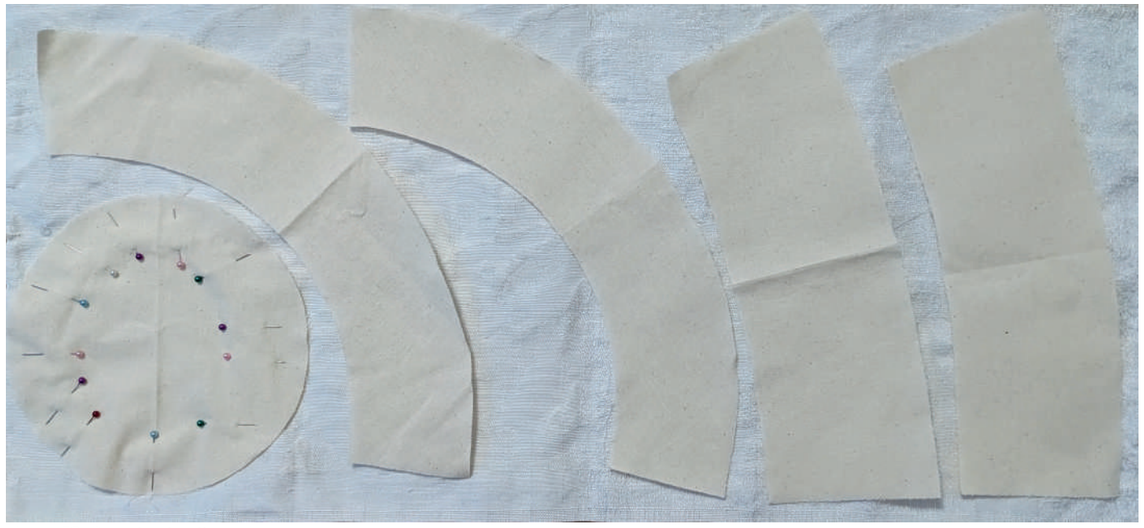


Figure 53. Bucket hat pattern pieces

5.1.1. BUCKET HAT 1 (5A)

The bucket hat 1 was created using samples 5A as a reference, the most appreciated after the first user test. The fabric was rewoven using the same composition and construction, but on a larger scale. It was subsequently sewn and assembled, following a classic pattern for a bucket hat. For each finished hat actually two bucket hats were used, one external, with the fabric of the sample, and one as a lining in ecru cotton to strengthen the garment.

Figure 54. Raw fabric of bucket hat 1

Figure 55. Garment dyeing of bucket hat 1

The choice to garment dyeing and not to dye the fabric before being sewn is to simulate as much as possible the PSS, with the flaw that the dye can be not homogeneous, but certainly unique. The same plant used to naturally dye sample 5A was repurposed for this hat, the red cabbage, able to give this incredible shade of purple/green, depending on the ph.

Figure 56. Bucket hat 1 before and after garment dyeing

Figure 57. Bucket hat 1 on

5.1.2. BUCKET HAT 2 (5F)

The bucket hat 2 was instead made by using samples 5E as a reference and by following the same procedure of the bucket hat 1. As visible from the photos, in this case not only the lining is in ecru cotton, but also the whole brim. Due to its triple twill compound presence in the construction, weaving more fabric it would have taken more time than needed and it would have not changed the results of the study.

Figure 58. Raw fabric of bucket hat 2

Figure 59. Garment dyeing of bucket hat 2

In order to alternate color, the material used for the dyeing of this prototype was turmeric, which gave a consistent golden tone to the hat. The dyeing method followed the same rule: simmering the powder, cooling the pigment and dipping the garment over night.

Figure 60. Bucket hat 1 before and after garment dyeing

5.1.3. LONGITUDINAL STUDY

Longitudinal studies are a potent and versatile observational research methodology that unveils the dynamic evolution of variables over extended timeframes. This method, distinct from cross-sectional studies, involves observing the same individuals or entities repeatedly, allowing researchers to detect changes and developments in both group and individual characteristics. By extending beyond a single moment, longitudinal studies unravel sequences of events and facilitate the identification of cause-and-effect relationships. The scope of these studies offers a more profound understanding of the underlying mechanisms driving change, suggesting causal links that cross-sectional studies might miss [47].

Advantages:

- Real-time insight: longitudinal studies enable researchers to follow subjects in real time, providing a unique opportunity to establish the authentic sequence of events. This grants a deeper understanding of how variables change over time and how they interrelate.
- Causality exploration: with the ability to track variables' trajectories over time, longitudinal studies are better suited to uncover cause-and-effect relationships. By collecting data at multiple time points, researchers can establish temporal precedence, a crucial element in determining causation.
- Individual-level analysis: by repeatedly observing the same individuals, longitudinal studies eliminate the confounding effects of individual differences. This allows researchers to attribute changes in the outcome variable to the intervention or factor being studied rather than individual variability.
- Minimized recall bias: prospective longitudinal studies, in particular, circumvent the issue of recall bias, where participants struggle to accurately remember past events. This enhances the accuracy and reliability of the collected data.

Disadvantages:

- Resource intensive: longitudinal studies demand substantial commitment of time, personnel, and financial resources. The need to collect data from the same participants over extended periods can lead to higher costs compared to cross-sectional studies.
- Time-consuming: the longitudinal nature of these studies means that insights and outcomes may take considerable time to materialize. Researchers must exercise patience as they accumulate data and observe changes unfold gradually.
- Attrition concerns: attrition, the loss of participants over time, is a prevalent issue in longitudinal studies. Participants might drop out due to various reasons, potentially introducing bias and affecting the generalizability of results.
- Validity challenges: the prolonged duration of longitudinal studies can make them susceptible to changes in the research environment, such as shifts in technology or societal norms. This could impact the relevance and validity of collected data over time [48].

While techniques like body maps or somatrajectories offer visual snapshots of bodily sensations [49], they lack the capacity to capture the intricate and evolving essence of emotional journeys, like the affective level of a garment fading on a wearer over time. Recognizing that user responses are not static points in time but dynamic, changing sensations and feelings, this approach serves as a means to articulate these journeys, that are explored, for the purposes of this project, through the lenses of two timeplots: the affection rate and fading rate perception, accompanied by the positive and negative emotions perceived during the time of study (qualitative data). These timeplots offer a framework to analyze and express the design space of the responses, enabling the creation of the trajectories that depict the changing nature of these sensations over time troughout key moments. The unique contribution of the timeplots lies in their ability to articulate user feelings through interactions, accommodating not only physical but also mental responses. The tool designed for this purpose features a flexible framework with an x-axis representing interaction time and a y-axis representing the responses, always expandables to new combinations [50].

5.1.3.1. Aim and setup

The longitudinal study involved two users, one for each natural dyed bucket hat created. The objective of the test, as described in the previous paragraph, was to measure how the user experiences the uniqueness of a jacquard garment that fades over time and if this experience arouses and increases positive emotions.
Considering that the third selected sample, the recycled denim jacquard woven fabric, required longer fading times due to indigo, for the purpose of the study it hase been decided to test only the first two samples, the 5A and the 5F. The test lasted 1 month and the chosen users were people already aware and promoters of sustainable fashion. Each participant was given two tools (google forms) to gather data from their experiences.
The first form, the daily fading bucket hat experience, had the purpose of collecting date, time and activities carried out for each daily use of the hat, whether it was once a day or multiple times throughout the day, as the reflections are fresher if recorded during or immediately after use.
The second form, the weekly fading bucket hat experience, aimed to collect weekly quantitative data, including the extent of color fading, emotions and the affective level they experienced throughout the week. In addition, at the end of each week users were asked to upload one or more photos to see the changes. The emotions provided, 24 positive and 36 negative, were taken from the Emotion Typology tool, developed by the Delft Institute of Positive Design [51].

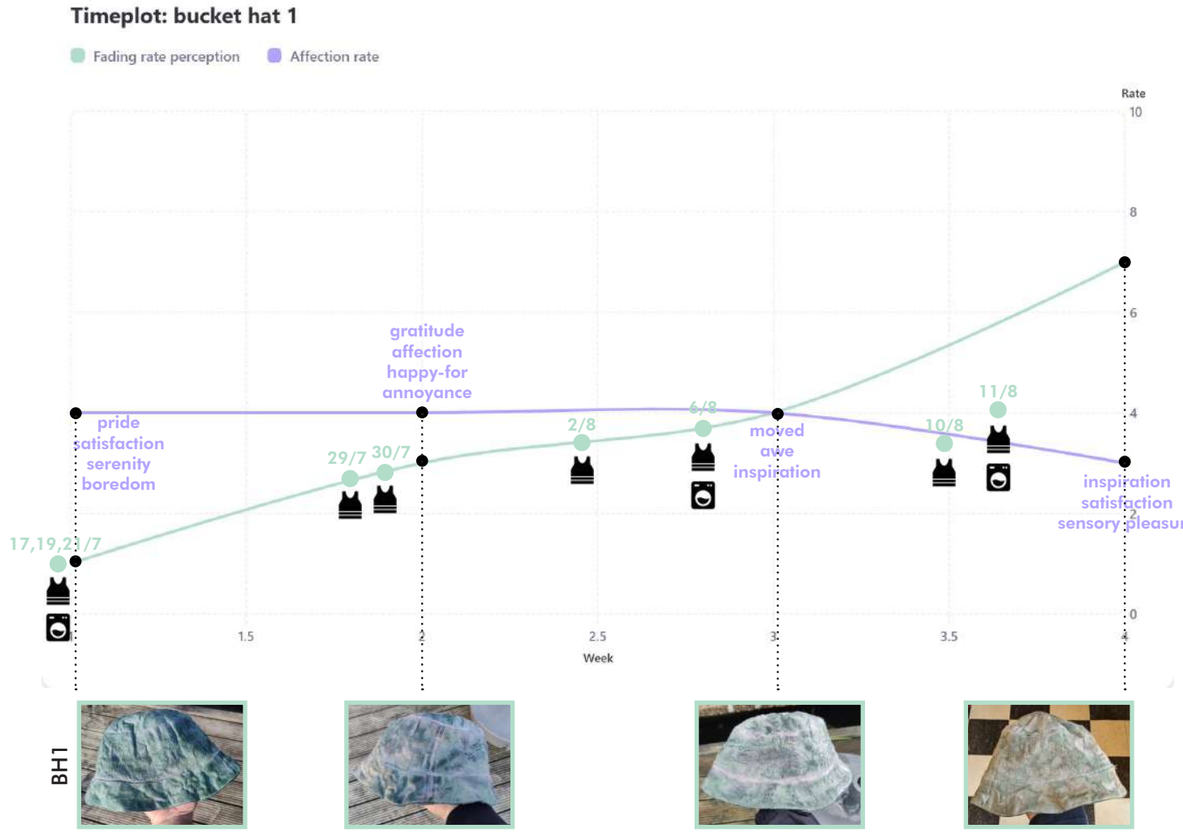
Figure 61. Positive and negative emotions provided

For both tools, it was always recommended to clarify the timeframe of reference for a more accurate evaluation and also to make some actions related to prolonged use of the garment that can accelerate changes, for example washing the hat, hanging out in the sun etc.

5.1.3.2. Data analysis

The data obtained from the two logitudinal tests after one month of wearing were then analyzed and displayed on a timeplot with an x-axis representing the interaction time, in this case of 1 month, and with a y-axis representing the two responses of affection rate and fading rate perception. In particular, the quantitative data of the weekly form were useful to obtain the values, between 0 and 5, of the 2 responses mentioned to trace the curves and follow the trend together with the photos received every week. However, for the fading rate perception, poichè è dato dalla somma del perceived fading (the progress of the curve) and the perceived rhythm of fading (the inclination of the curve in different sections), a cumulative approach has been applied. The data of the daily form, collected in a table, were instead crucial to understand the frequency with which the user interacted with the hat and which were the key moments (rinsing etc.) that most influenced the experience. The starting point of each response was determined after the first week of the test, which therefore provided the first quantitative data then used as initial values of the graph.

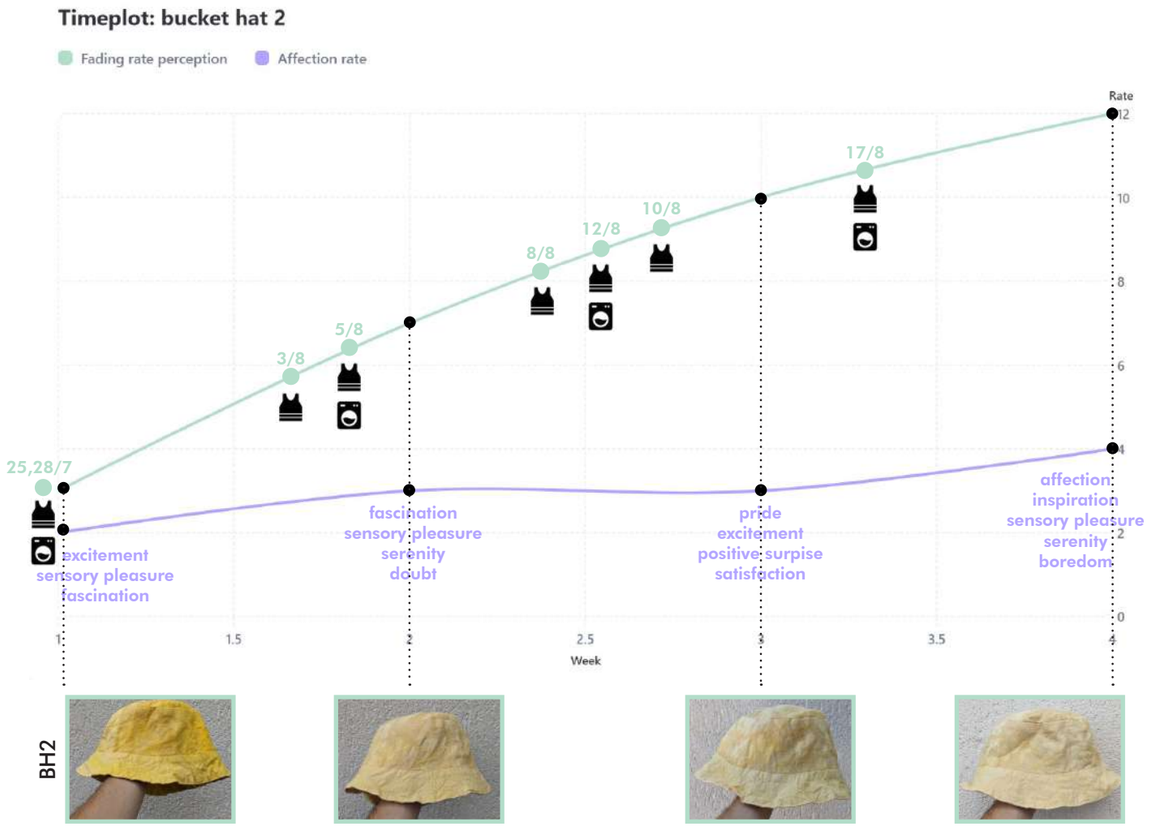
In the bucket hat 1 timeplot, it is visible that the hat 1, based on sample 5A, was worn 9 times over a month and washed 3 times. The fading rate perception trajectory has always been increasing: it increased from value 1 in the first week up to value 3 at the end of the second week. Between the second and third week, however, the increase was minimal (from 3 to 4), but during the last week it was notable, reaching a value of 7, probably due to the very visible fading following the third wash.
Instead, by examining the affection rate trajectory, it is possible to observe the affection level for the hat users exeperienced during the test and the feelings, positive or negative, they experience trough. The affection rate response of the bucket hat 1 remained rather constant (value 4) until the fourth week, where the curve began to partially decrease to the value 3. The user perceived mostly positive emotions: satisfaction and inspiration were the positive feelings that occurred most often, however emotions such as boredom and annoyance were also perceived during the first two weeks, probably because the fading rate was low.
During the wear test of the garment, spanning a duration of four weeks, the user underwent a dynamic spectrum of emotions, mostly positive, that represented their experience. These emotions painted a vivid picture of the user's evolving journey with the garment. In the initial weeks, feelings of pride, satisfaction, and serenity underscored a sense of contentment and fulfillment, mirroring a positive engagement with the clothing. However, as time progressed, a subtle shift in emotions was evident. The emergence of gratitude and affection hinted at a deepening connection, while moments of happiness-for highlighted a sense of empathy or shared joy. Yet, combined with these positive sentiments, traces of annoyance and boredom suggested occasional challenges or fluctuations in the wearer's emotional state. As the study continued, emotions like feeling moved, inspired, or in debt unveiled a more profound layer of the user's experience, suggesting a growing attachment to the garment. The study culminated with a return to positive emotions, marked by inspiration, satisfaction, and sensory pleasure, encapsulating the cyclic and dynamic nature of the wearer's emotional journey throughout the wear test.



Graph 6. Timeplot bucket hat 1

On the other hand, as for the timeplot of the bucket hat 2, based on sample 5F, it is visible that the hat was worn 8 times and washed 4. Comparably to the bucket hat 1, the fading rate response increased drastically during the entire duration of the test, starting from a value of 3 at the end of the first week and increasing first to 7 and then to 10 at the end of the third week. The trajectory reached a value of 12 at the end of the experience, showing that the fading has always been quite perceived.
Concerning the affection rate response, the trajectory of the bucket hat 2 hasn't shown decreasing trends, in fact, increasing until the end of the second week, it stabilized in the third week (value 3), and then reached a value of 4 during the fourth week.
In this case, the emotional journey of this user, overall positive as well, offered another range of emotions that added depth to the whole experience. In the initial stages, emotions of excitement, sensory pleasure, and fascination resonated with a sense of engagement and captivation, highlighting the garment's initial attraction. However, as the weeks progressed, a subtle shift was observed in the wearer's feelings. The persistence of fascination and sensory pleasure suggested an enduring positive connection, while moments of serenity provided glimpses of calm and inner tranquility. Linked with these positive emotions, occasional feelings of doubt hinted at moments of uncertainty or contemplation within the wearer's journey, perhaps due to the color becoming too light.

As the study reached the third week, emotions like pride, excitement, positive surprise, and satisfaction unveiled a more pronounced sense of accomplishment and fulfillment, marking the garment as more impactful. The emotional journey culminated with a blend of emotions, including affection, inspiration, sensory pleasure, serenity, and occasional hints of boredom, reflecting the dynamic and multifaceted nature of the wearer's relationship with the garment.



Graph 7. Timeplot bucket hat2

5.1.3.3. Limitations and results

Clearly, this longitudinal test has some limitations. The first concerns the timeframe of the study adapted to the length of the graduation project: one month is not enough to accurately determine the timing of fading and the sense of affection related to the changes. The actions that users have carried out to accelerate the aging process have proved useful, but at the same time, they have not been an identity of the true naturalness of the fading of a garment, which should therefore be tested for much longer periods. Another limitation concerns the colors and plants used for dyeing. So far only purple/green (red cabbage) and yellow (turmeric) have been tested as discoloring colors, so the experimentation of other colors, and plants, and the respective fading outputs they show, would certainly expand the scope of this test. A third limitation pertains both to the number of users, which may not fully represent the diversity of potential user experiences that could exist in a larger and more varied population, and both the kind of garments tested, which if expanded to new categories such as jackets or trousers, would undoubtedly generate new findings.

However, the two longitudinal graphs made were vital to understand how the two bucket hats performed during the tests. The two users experienced the hats in two different ways. The former perceived an inconstant fading and on values never exceeding 3, but maintained a fairly high sense of affection towards the garment (4 on average) until the end of the month where it decreased by 1 value. The user of bucket hat 2 instead, unlike the first user, perceived a high fading during the first half of the test and then gradually less and less impactful, while the affection felt always tended to grow up to the value 4.
In conclusion, user 1 became attached to the garment when the hat showed much fading compared to the previous color, while user 2, on the contrary, when the perceived fading was low. In both cases, however, the experience was appreciated, demonstrating, in addition to the feasibility of the product-service system, that a garment fading over time can generate affection if conveyed in the correct way.

5.1.3.4. Interviews

With the longitudinal test, the user experienced the fading of the bucket hat for a month. However, during the duration of the study the user was unaware that the experience is only part of a more complete interaction that also includes redyeing. The interviews therefore served to explain the product-service system and, above all, to ask 3 questions similar to those asked during the experience with the garment. In this way, it was possible to understand both if after some time from the end of the test the user's perception has changed, and if being aware of the possibility of redyeing constitutes an added value.

The intervies was structured around three main questions:

1) In one month, you experience the fading of the hat while you were using it. Can you reflect on the past experience with the hat? How did you feel?

After their first reply, the time plot graph with the experience's results was shown and used to stimulate reflection. Questions regarding some specific emotions that are present all the time (e.g. inspiration) or that appear only at the beginning or the end (e.g. boredom, annoyance vs sensory pleasure and satisfaction), or as it started to fade (proud, the excitement/suprise), were also asked, to understand the reasons and the affection curve development (decreasing or increasing).

2) How do you feel if the garment can be redyed?

Participants were asked to articulate about it. This includes their reactions to the redyeing option, whether it impacts their emotional experiences (e.g. less or more inspirational/exciting), when they choose to redye (at different fading stages or after complete fading), their color choices, the influence of external factors on redyeing decisions (e.g. change of season, happening of an event or situation or change of contexts (e.g going back to the school/office, going to a party....), and any perceived added value in terms of sustainability (e.g. emotional bonding, restoring/giving a new apperance...)

3) In one month, you experience the fading of the hat while you use it. I introduce now three potential scenarios after this use: 1. dye it yourself, 2. bring it to the retailer to dye, 3. leave it fading until it is white. How would you assess each one of these scenarios on a scale from 1 to 5?

Participants motivated and articulated their choices, by specifying if they would see the same approach on other type of garments, or not, and why (e.g. scale, frequency of wearing, seasonality, context of use, visibility, value/price etc...)

Participants in the interview provided valuable insights into their experiences with the fading hat and their attitudes towards potential redyeing scenarios.

The participant 1 (bucket hat 1) expressed a strong attachment to the hat, initially finding joy and comfort in its vibrant colorway. As the hat faded over time, this participant admitted to feeling frustrated, as fading is often associated with negativity. Despite this initial frustration, his emotional bond with the hat remained strong, and he found a sense of relaxation when wearing it. The participant's experience aligned with the graph, which showed consistent levels of satisfaction and inspiration throughout the test, reflecting their strong sentiment towards the unique piece. During the interview, the participant also highlighted a moment of annoyance at the end of the second week, which stemmed from the initial fading reaction. Working in quality control, the participant emphasized the importance of color fastness, which typically implies durability and long-lasting color retention.

Regarding the possibility of redyeing the hat, the participant found it to be an exciting prospect, believing that it would breathe new life into the garment and strengthen their emotional connection to it. He noted that this process would make the clothing more sentimental and align with sustainable practices. The participant expressed a preference for wearing the garment until it had completely faded to white, at which point he would choose a new color for redyeing, influenced by seasonal changes and the occasions for which they would use the hat.

When assessing the three redyeing scenarios on a scale from 1 to 5, the participant provided the following ratings:

Dyeing themselves (value 3). This scenario was perceived as an irregular approach, best suited for large batches of items to maximize efficiency.

Bringing it to a retailer (value 4). The participant indicated that he would consider this option only for singular items requiring redyeing.

Leaving the item to fade to complete white (value 2). This scenario was less favorable, as the participant expressed a lack of fondness for the color white.

Overall, the participant's reflections and assessments shed light on the emotional connection individuals can develop with dynamic textiles, the potential for redyeing to enhance this connection, and the various factors influencing their preferences and choices in such scenarios.

The second participant (bucket hat 2) shared his intriguing reflections on his experience with the fading hat and his attitudes towards redyeing scenarios. Throughout the interview, it became clear that the participant formed a deep emotional connection with the hat as it transitioned through various colors during the month of use. He described this transformation as an evolving presence in his daily life, symbolizing his lifestyle and experiences. The participant felt that the hat had become a unique and exciting part of their wardrobe, and this attachment grew stronger as the fading progressed.

His emotional journey, as indicated by the graph, was characterized by a continuous sense of sensory pleasure. The participant explained that the excitement stemmed from observing how different activities, weather conditions, and climates influenced the hat's fading process. This heightened their curiosity and awareness of the garment's dynamic nature.

During the interview, the participant also discussed a moment of doubt at the end of the second week, which was related to the initial visible traces of fading. He noted that wearing the hat made them more conscious of his clothing choices, and it allowed him to stand out from others by wearing something entirely unique in terms of its color evolution.

Interestingly, the participant's fading perception increased steadily throughout the study, aligning with his growing sense of affection for the hat. He described this bond as a responsibility for the hat's fading and transformation, similar to the care he provides to their plants. This connection fostered a deeper attachment and a sense of personal involvement in the garment's journey.

Regarding the potential for redyeing, the participant expressed a strong preference for redyeing the garment after it had completely faded. He viewed this as an opportunity to give the clothing a new life and experience different types of fading and textures. The idea excited them, and they saw it as a way to continually reinvent their personal wardrobe, aligning with his current fashion trends. Additionally, the participant emphasized the sustainability aspect, viewing redyeing as a means of recycling and extending the lifespan of garments.

When assessing the three redyeing scenarios on a scale from 1 to 5, the participant provided the following ratings:
Dyeing themselves (value 5). They considered this scenario highly favorable, emphasizing the enjoyment of being responsible for the garment's aesthetics.
Taking it to a retailer (value 2). While recognizing the advantage of professional service, the participant preferred hands-on involvement and decision-making.
Leaving the item to fade completely to white (value 4). They found this scenario interesting but leaned toward giving the garment a new life with redyeing.

While each participant expressed a strong attachment to the fading garment, their views on the ideal redyeing approach differed.
The first participant appreciated the prospect of redyeing but leaned toward taking the garment to a retailer (rated 4) as the preferred scenario. They viewed this option as practical and professional, highlighting the importance of color fastness. On the other hand, the second participant showed a strong inclination toward a more hands-on approach, expressing a desire to dye the garment themselves (rated 5). They perceived it as a fun and personal way to influence the aesthetics of the garment, closely aligned with their attachment to the hat's evolving presence.
These divergent preferences shed light on the varied ways individuals may engage with dynamic textiles. While one participant favored professional expertise, emphasizing practicality, the other cherished the idea of personal involvement and creative control. Ultimately, both scenarios offer unique benefits, reflecting the dynamic and multifaceted nature of fashion experiences.

5.2. Proposed Design Space

General guidelines to design a color changing dynamic textile motif:
Dynamic textile motifs, as explored in the literature, are an important component for a more sustainable fashion, and beyond, approach. To be able to design for a textile color changing motif using their inherent material properties, designers must first have the right tools to aid them in decision making and product creation. There are some considerations to keep in mind for designers interested in combining jacquard weaving techniques, innovative compositions, and the concept of wear and tear to create animated textiles that change over time.

Understanding Dynamic Textile Motifs:
• Understanding the behavior and constraints of dynamic textile motifs requires a thorough understanding of their various types and operating principles. The desired color-changing manifestation (accumulation of color or fading) and timing for the specific design, as well as the means for ageing the dynamic textiles, must be defined. In case of fading, the initial dye color (natural dye or indigo) should also be defined.
• The woven constructions and compositions of the textile define not only its durability but also its absorbency and aesthetic. The longer the yarn float lengths, the more durable the fabric and the denser the weave structure.
• The dynamic textile motifs do not respond instantly to usage or outdoor conditions; instead, they change color naturally over time.

Weaving Techniques for color–changing motifs:
• The traditional durable weaving structures (satin, twill, basket) are essential for the structure's foundation.
• Taking the next step and developing concepts for 3D weaving structures will provide the visual effects of color change.
• The yarn selection is a critical component for the textile's behavior in producing unique color shades.

Design Considerations for ageing dynamic textile motifs with treatments:
• Accelerate ageing treatments is vital for testing the impact of changes in a short period of time. Experiments frequently do not perform as expected, necessitating either a change in composition or a redesign of the weave structure.
• Core knowledge for color changing motifs can be derived from studies on the behavior of animated textiles in fashion design, product design, material science, and textile engineering.

Practical guidelines for weaving jacquard dynamic textile motifs:
• During the weaving process, the yarn distribution must correspond to the motifs' chosen areas. Accidental textile order or composition can result in no changes.
• Keep in mind any need for post-processing after weaving, such as shrinking with washing or making garments.
• After prototyping, test the samples for color-changing capabilities.

In general, creating dynamic textile motifs is a creative but challenging process. Aside from technical considerations, when it comes to human-product interaction, the user experience is a core value for the design. Studies on people's perceptions of fading garments and their reactions to them are required to inform product qualities. More research and exploration into color changing textile motifs has the potential to revolutionize the way we interact with and experience textiles in a variety of domains.

Design Space for dynamic textile motifs:
The structural considerations are fondamental to make jacquard textile motifs color change over time. This is the most important parameter that enable color change, along with absorption and motif selection. There is an exciting design space for exploring the capabilities of dynamic textile motifs that change in color due to their inherent material qualities, thanks to the unique colors that aging gives to the motif. So, taking into account the main structural aspects of them, as well as design guidelines, will result in unique textile products for our garments. The main parameters for the dynamic textile motif's architecture are the type of pattern (regular or irregular), the woven structures, the composition and the way its color change over time under aging inputs

The outdoor conditions (UV light and moisture), product usage (rubbing), and textile care (washing, sun-drying) are the aging inputs. Furthermore, because of their ability to highlight different areas of the motif, weave structures are crucial to overall structure durability and color changing behavior, making the aging of the textile more appreciated. It is recommended to use short float lengths for durability and longer ones for absorbency.

Two main structures with different compositions and jacquard woven structures emerged for these dynamic textile motifs. One, stiffer, with a double compound twill 8x16, a double compound satin 10x20 and a double compound basket 8x8, the other, softer, with a triple compound twill 6x18 instead of the basket one.

Basic architecture

motif selected

natural dye used

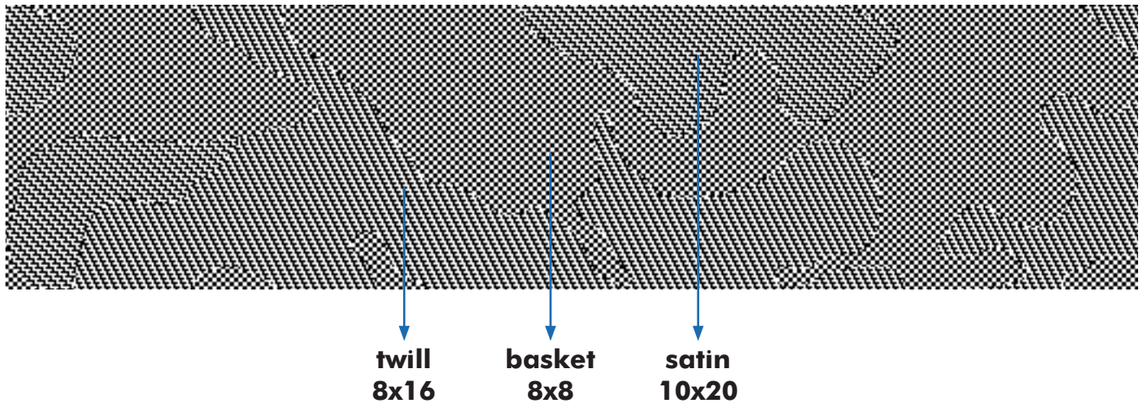
red cabbage

FADE IN

compositions

warp: cotton	weft: ecru wool	weft: ecru hemp
C O L O R S		
light purple	purple grey	dark purple
FADE IN	FADE IN	FADE IN
light green grey	light purple grey	green grey

Weave structures



Twill weave 8x16	Mostly purple grey weft visible Mostly dark purple weft on back side	Front Back
Satin weave 10x20	Mostly dark purple weft visible Mostly purple grey weft on back side	Front Back
Basket weave 8x8	Mixture of dark purple and purple grey Mixture of dark purple and purple grey	Front Back

Color–changing inputs

outdoor conditions | **product usage** | **daily care**

Functional utilities

6. Discussion

This discussion chapter demonstrates that the objectives set forth in the introduction have been effectively addressed and achieved throughout the course of this research.

The first objective centered on understanding how individuals perceive and appreciate the aesthetic changes that naturally occur in textiles as they age. The primary focus was to determine whether these changes could be embraced as enhancements rather than defects by the wearer. Through an in-depth analysis of user experiences and longitudinal studies, it was possible to gain valuable insights into the way people form emotional connections with garments that evolve over time. The findings revealed that, contrary to the conventional perception of fading as a negative aspect, participants often developed stronger attachments to the garments as they changed. This suggests that dynamic motifs can indeed be embraced as enhancements, fostering a deeper sense of attachment and prolonging the lifecycle of garments. The research has successfully contributed to reshaping the way we perceive aging textiles in the context of fashion.

The second objective aimed to explore the feasibility of applying color changes to textiles on a commercial scale. While dynamic textiles have primarily remained within the realm of experimentation, this research started to bridge the gap between theory and commercial application. By assessing the potential for widespread adoption, this project made significant progress in unlocking the transformative power of color-changing textiles in the fashion industry. The development of the ReDyEvolve kit, for instance, represents a practical step forward in enabling users to maintain and rejuvenate their garments, aligning with sustainable fashion practices. This achievement highlights the project's contribution to promoting a more conscious approach within the fashion industry and facilitating the long-term use of clothing items.

The third objective aimed to unravel the relationship between fabric properties and the perceived value of garments undergoing color changes over time. In-depth explorations into woven structures, compositions, conditions, and motifs have provided valuable insights into how these inherent material properties influence wearers' appreciation. The research has illuminated the significance of these attributes in elevating the desirability of dynamic motifs, by understanding the interplay between fabric characteristics and user perception.

In conclusion, the findings not only contribute to a deeper understanding of user experiences with dynamic textiles but also offer practical solutions for integrating dynamic color changes into the fashion industry while emphasizing the importance of fabric properties in shaping user perceptions and preferences.

With this graduation, I had the opportunity to expand my knowledge of woven textiles, understanding their inherent potential, when I can label them as animated and the related production processes. Researching human perception and interaction with variable textiles is also a field in which I gained knowledge during my studies. The life of every human being is surrounded by fabrics and for this reason, I consider the relationship that the user has with their garments over time to be vital. Additionally, I learned about natural dyeing and its unexplored potential. I believe that this project offered many opportunities to consolidate my skills in the textile and apparel world, which I am sure will open my curiosity to new horizons, making me a conscious and eclectic designer.

6.1. Limitations

The research encountered several limitations throughout its course.
One notable constraint was the allocation of time for user tests and experiments, which was adjusted to fit within the confines of the thesis. This time limitation potentially restricted the depth and breadth of the research, hindering the exploration of certain aspects.

Additionally, the participant pool for user tests was relatively small, which could have resulted in a narrower range of emotional and sensory data. Expanding the participant base in future studies would provide a more diverse set of insights.

The textiles used in the research were produced using a TC2 loom, which may produce different results compared to textiles created on industrial looms. This limitation raises questions about the generalizability of the findings to real-world applications.

The research focused on a limited selection of colors and plants for dyeing, which restricted the exploration of potential color changes and plant-based dyeing possibilities. A broader array of color and plant options could offer a more comprehensive understanding of dynamic textile expressions.

Furthermore, the study only tested hats as garments, overlooking the dynamic textile patterns that might manifest in other types of clothing and accessories. This limited scope restricted the applicability of the research's findings to a broader range of garments.

The aging treatments applied in the research were limited to just four variations, potentially neglecting other factors that might influence textile aging and color change.

While the study primarily utilized well-known organic yarns, it did not explore the potential of less common organic yarns. Investigating a wider range of yarn compositions could contribute to a more comprehensive understanding of dynamic textile patterns.

Lastly, the research examined only two combinations of woven constructions. Exploring additional combinations could have yielded valuable insights into the potential variations of dynamic textile expressions.

These limitations underscore the need for future research to address these constraints and facilitate a more comprehensive examination of dynamic textile patterns, encompassing various aspects such as treatments, compositions, and woven constructions.

6.2. Future research

As concluding the current research journey into dynamic textile patterns for color change of jacquard woven fabrics over time, it is essential to outline the avenues for further studies that can contribute to the evolution of this topic. The insights gained from this research provide a solid basis for the future exploration of sustainable fashion practices.
In this context, new areas of investigation emerge as pivotal for future investigations:

- Testing different products: this study would involve examining various types of garments, accessories, and even furniture, to understand how different materials and woven constructions age and fade over time in different contexts. This broader analysis can provide insights into which textiles benefit the most from the redyeing process and how it can be adapted to suit different products.

- User diversity: enriching the user pool with a more diverse and varied demographic, including individuals from different cultural backgrounds, geographical locations, and socioeconomic statuses, can provide a more holistic understanding of the emotional and sensory aspects of self-redyeing.

- Aging machine: using an aging machine would accelerate the natural aging process and can help pinpoint the exact timeframes and conditions under which fading occurs, allowing, for example, more precise recommendations in the self-redyeing kit and more experiments.

- Engineered fading: investigating ways to engineer the fading process to align with the areas of the body where fading naturally occurs more rapidly. This would require a deep understanding of garment patterns and user behaviors to optimize the redyeing process for specific areas, ensuring more uniform results.

- Monomateric composition: exploring the use of monomateric jacquard woven fabric, where only one type of yarn is used. The woven structure would become fundamental without the help of different fibers. This simplification can enhance recyclability and reduce the complexity of the redyeing process, making it more sustainable and efficient.

- Integration of metal fibers: researching the integration of uncoated metal fibers into jacquard woven fabrics and how their oxidation would interact with textiles over time. Understanding the impact of metal fibers, including the formation of rust stains, can inform the development of unique aesthetic possibilities.

- Physical prototype of the self-redyeing kit: creating a tangible prototype of the ReDyEvolve kit, including the packaging, booklet, and instructions. This physical representation can be used for user testing and feedback, refining the kit's usability, aesthetics, and overall user experience.

- User-involved redyeing: extending the study to include the user in the redyeing process will provide valuable insights into their emotions and experiences during the rejuvenation of their garments. Understanding how users perceive and engage with the redyeing process is crucial for optimizing self-redyeing solutions.

- Enhanced plant charts: improving the plant charts by considering factors such as weather, altitude, and regional variations can provide a more comprehensive guide for users seeking sustainable dyeing options. Visual representations of plant locations and harvesting seasons can enhance user experiences.

- Commercial viability: exploring strategies to make the PSS commercially attractive and feasible for the market is essential for widespread adoption. This includes considerations of cost-effectiveness, packaging design, marketing strategies, and accessibility.

- Differential impact of natural dyeing outcomes: investigating how different plants impact fading and users' perceptions can offer valuable insights into the emotional and sensory experiences. This comprehends also more research on how specific yarns react to overdyeing.

- Industry regulations: exploring the legal and regulatory aspects of garment redyeing solutions is critical for their successful integration into the fashion industry. This includes considerations of product durability, labeling requirements, and compliance with environmental standards.

- Communication and transparency: developing effective communication strategies to educate consumers about the outcomes and benefits of self-redyeing solutions is essential. Transparent information about the sustainability, durability, and emotional value of redyeing can empower consumers to make informed choices.

These further studies will enhance the comprehensiveness of the research and contribute to the ongoing development of sustainable garments and self-redyeing solutions.

7. Conclusions

The journey undertaken in this research has illuminated a multifaceted landscape at the intersection of textiles, fashion, and sustainability. The motivation behind this exploration was grounded in the recognition that garments can transcend their traditional roles as static objects, evolving into active participants within the wearer's sensory and emotional narrative. As I delved into this territory, the pioneering works of textile researchers, particularly the contributions of Rikka Talman, served as the catalyst that triggered my curiosity and my quest for knowledge.

This research venture has not merely culminated in the design of a proposed product-service system; it has generated diverse areas of knowledge that have the potential to reshape the textile and fashion industries. At its core, this study has shown a design space where materials, structures, and contexts intertwine to create dynamic textile motifs. The findings extend and build upon Talman's work, offering new insights into the possibilities that exist when dynamic textile expressions merge with new compositions and woven constructions.

Beyond the design field, this research has uncovered different insights into how individuals perceive and value the temporal and fading aspects of color in textiles. It has forged a connection between material and user experience, overtaking the boundaries of fashion into the domains of sustainability, slow fashion, and the significance of material traces. While the study has laid a foundation, it simultaneously recognizes the need for further exploration and investigation in these areas.

One pertinent question arising from this study belongs to its potential implications for the textile design industry. In an industry that often prioritizes color fastness and durability, the dynamic textile expressions uncovered here challenge conventional knowledge. By embracing the changes that textiles undergo as they age, it is possible to shift the focus of the industry from static permanence to dynamic evolution.

The contributions of this project flow across multiple domains. In the area of textile design, it offers a broader canvas for creativity, inviting designers to venture into the field of dynamic textile expressions. The integration of natural dyes, organic materials, and circular fashion principles reinforces the commitment to eco-conscious practices, reshaping the fashion industry's approach to sustainability.

For the relationship between users and their garments, this research accentuates the potential for a deeper connection. Garments cease to be articles of clothing; they become companions in a journey, telling stories through their evolving colors and motifs. This transformative relationship fosters an attachment that goes above the nature of fast fashion, supporting the preservation and longevity of garments.

Material-Driven Design, experiential characterization, and the exploration of response trajectories in longitudinal studies have emerged as essential tools for this project. Their contributions extend beyond the scope of this research, serving as foundational methodologies for future studies in dynamic textile expressions.

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Appendix | project brief

Personal Project Brief - IDE Master Graduation

TU Delft

Dynamic textile patterns for color change in jacquard canvas over time — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 01 - 03 - 2023 — 13 - 10 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Designers who work with textiles have a tendency to view woven fabrics as unchanging, or static, materials. However, to truly utilize the benefits of woven fabrics in these systems, designers need to have a deeper understanding of how these textiles can be designed to exhibit responsive behaviors in their use. This involves exploring and utilizing the properties of woven fabrics to create interactive systems that are dynamic and adaptive, such as Smart Textiles. However, for this research, I consider (smart) textiles animated exclusively through their inherent material qualities, more than considering the application of computational or biological components [1].

Textiles have the ability to undergo transformations in multiple forms, including alterations in appearance such as changes in color, modifications in touch such (changes in texture), or a combination of both. These changes can either be reversible or irreversible. In particular, by leveraging on their irreversible changes, independently of the time of the change, it is possible to give them meaning while they age over time. There are different ways explored to see these changes for example through a change in the pattern of the textile or through a change in the color of a pattern where the pattern itself doesn't change. To allow this process, so-called dynamic textile patterns play an important role because they show an inherent quality to change expressions while used in their lifetime [2].

Garments made of materials meant to be used for a long time would improve then with age, extending the lifecycle of the product and giving a sense of affection to the wearer. Some recent studies have experimented with dynamic textile expressions through colors that change over time, using plant dyeing without the use of mordants [3] or exploring the natural changes in the color on plain and on jacquard-patterned woven textiles [4].
In particular, by using a jacquard loom (Jacquard fabric refers to any textile produced on a jacquard loom), it's possible to enable the weaving of intricate designs such as damasks, stripes, checks, brocades, and tapestries. The patterns are formed by the intentional and controlled skipping of warp yarns over weft yarns, and, togheter with colors, are then incorporated into the weave instead of being printed or dyed onto the surface of the fabric. In this way, textiles can gain the ability to be dynamic and age in unique ways depending on their environment.

The graduation project will be supervised by Dr Holly McQuillan as chair and Stefano Parisi as mentor. Holly McQuillan explores the aesthetic and technical development of systems and methods for zero waste textile forms and multimorphic textiles, while Stefano Parisi explores the material experience in the area of emerging materials, from bio-based to smart materials.
Together with them, I will work also with Maximilian Rabe, senior menswear designer of G-Star Raw who worked also for Aithor Tourpe and Asics and became an expert in woven textiles and now knits.

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Initials & Name G. C. Cimino — Student number 5621194

Title of Project Dynamic textile patterns for color change in jacquard canvas over time

introduction (continued): space for images

image / figure 1: Natural various changes in expression on plain and jacquard-woven textiles (Talmann, 2018)

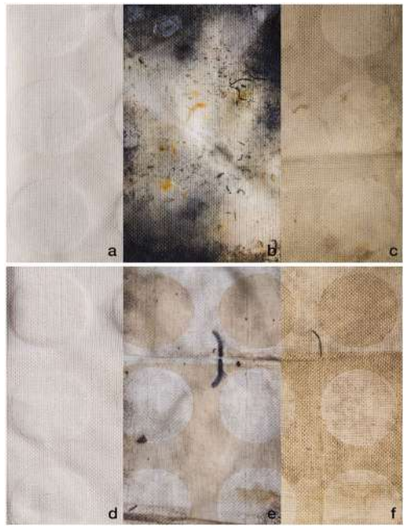


image / figure 2: Natural various changes in expression on plain and jacquard-woven textiles (Talmann, 2018)

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The natural aging of fabrics can be used in the design process to create dynamic patterns, colors, or structures in textiles in order to link the textile products back to the inherent qualities of materials. Naturally, this happens with raw denim: through use and over time, denim shapes and fades depending on the wearer, creating an individual pattern and addressing what is called wear and tear, which adds value and a story to the products [5]. However, even if this process can be labeled as a dynamic textile process, in the case of denim we see a phenomenon of discoloring (fading), involving a dyeing behind. In fact, regardless of whether the dye is natural or chemical, there is always energy consumption involved upstream. The idea, on the other hand, is to let the fabric color according to its use, trying to avoid in this way also the dyeing process at the base.

For this reason, selecting natural fibers such as cotton or linen in their ecru/raw state (unbleached and untreated) facilitates and accelerates changes in color and texture as exposed to UV lights or moisture. However, traditional raw fabric has a static color and it's not really used if not been dyed before. For this reason, the way the yarns are woven and the respective pattern can serve the material to color over time and according to conditions and use.

[5] Townsend, K. 2011. "Denim Garment as Canvas: Exploring the Notion of Wear and Tear as a Fashion and Textile Narrative."

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

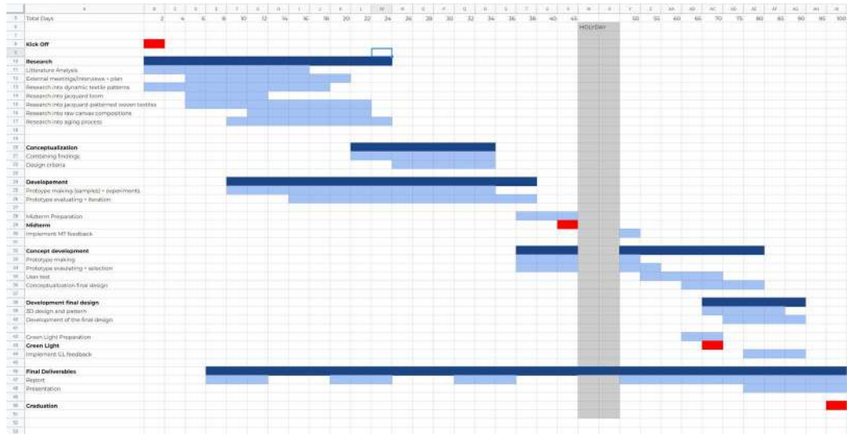
This project aims to explore the potential of using dynamic textile patterns in Jacquard-patterned woven fabrics with raw yarns in different compositions to create a textile that changes color over time through its daily care (washing, ironing) or through outdoor exposure such as rain or warmth.

As the dynamic textile pattern is on raw fabric, the garment will be sustainable as ecru yarns are in their original state: undyed and untreated. The fabric should be durable, strong, and last long. Moreover, breathability and comfort while wearing can bring physical well-being to the wearer. The dynamic pattern can also bring mental well-being to the wearer by providing a sense of novelty and excitement for the wearer, who can also appreciate and value the garment more as it adapts and changes over time. The project's methodology will see first research on existing dynamic textile patterns and their potential for use in fabrics. This step will be followed by conducting a series of experiments to test the color change properties of new dynamic textile patterns, such as camo, in raw fabric under different external stimuli. Given the limited amount of time, these experiments may sometimes involve extreme conditions or processes to accelerate color change (e.g. black laundry, burial, immersing the samples in solutions that contain substances present in some outdoor conditions but in increased quantities). Some examples of treatments can be applied to see changes over time such as coatings that can be activated by different factors (heat, moisture, and UV light), special dyes or pigments that can react to the environment or metallic yarns that can oxidate. The fabric has to act as a white "canvas". An evaluation of the visual appeal and practicality of these dynamic textile patterns will be conducted through user testing and feedback, using first the Material Driven Design method for the first samples and then the Soma Trajectories method for the more advanced prototypes.
At the end of the project, I would like to create a garment that represents the objective of the research and its practical application, through a minimal waste design thinking.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 1 - 3 - 2023 13 - 10 - 2023 end date



MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

This project stimulates my interest in a number of ways. First of all, I believe in the multidisciplinary nature of design and I believe that textiles and clothes must be part of the design baggage that a product designer must have. A garment is a product in all respects because it involves the same industrial processes that can be seen in every project. Since I was a child, garments, especially technical ones, have always fascinated me and since then I have always tried to keep up to date on their design, dyeing, fit, draping, and above all textiles. As a lover of workwear, I have always had raw fabric products at hand, to which I certainly owe a sense of affection given its durability. Moreover, discovering the potential of smart textiles animated through their inherent material qualities and that of dynamic textiles patterns has opened up a range of reflections that I believe, both as a person and as a designer, stimulating and extremely interesting. I understood that textiles must be considered not as a means or a part of the system, but as a system in its own right, capable of bringing by default an infinite potential to its applications. Manufacturing processes in this way can therefore be revolutionized, proceeding more and more toward a direction of sustainability that is difficult to achieve especially in the field of fashion.

During my bachelor's previously and now during my master's, I had the opportunity to be educated in 2 different countries with 2 different design schools, jumping from a more artistic and material-based approach to a technical-scientific and method-driven one. During this heterogeneous academical journey I became a designer that can see the world through both a technical and scientific lens and an artistic and human-centered lens.
Moreover, almost 6 months ago I started my internship at G-Star Raw as a 3D designer and I couldn't have imagined anything better. In fact, it is here that I am consolidating and improving my knowledge in the fashion and textile field. I'm dealing with 3d models, styles, patterns, artworks, fittings, and launches, but above all, being part of the knits department, I'm learning a lot about flat knits and jerseys, such as constructions, gauges, or manufacturing techniques. Now instead, with this graduation I have the opportunity to expand my knowledge of woven textiles, understanding their inherent potential, when I can label them as smart and the related production processes.

Researching human perception and interaction with variable textiles is also a field in which I aspire to gain knowledge during my graduation. The life of every human being is surrounded by fabrics and for this reason, I consider the relationship that the user has with their garments over time to be vital. I would therefore like to learn the behavior of raw canvas understood as a real canvas, where the experience of the wearer influences his aging.

Concluding, I believe that this project offers many opportunities to consolidate my skills in the textile and apparel world, which I am sure will open my curiosity to new horizons, making me a conscious and eclectic designer.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.