PREVENT WORK TECHNOSTRESS THROUGH BIOMIMICRY SMART WEARABLE

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SCUOLA DEL DESIGN

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Master’s Degree Course

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To follow I thank Pauline Van Dongen, who with her professionalism and skill allowed me to enter in her studio and discover a world in which technology and fashion meet to create sensational experiential garments. In addition to her highly established figure in the field, her hospitable and kind personality, along with that of her assistants, Anna Jos Wetzel and Ellen Britton, made me feel at home during an experience that will remain forever in my memory.

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ABSTRACT

Background Scientific Research

The concept of **Biomimicry Wearable project** starts from the correlation between the introduction of computers in the workplaces with the increase of employers' stress and anxiety. In fact, several studies (Bradley, 1989), (Westlander, 1994), (Aronsson, 1989), (Stellman et al., 1985), (Carayon-Sainfort, 1992) have shown that the introduction of technology has resulted in significant change in the type and content of job responsibilities, social interactions, management style, and the work process. While some of these developments were advantageous, many also had negative consequences on people's physical and mental health as a result of people losing touch with their surroundings and becoming less focused. Environmental psychology research demonstrates that restorative contexts not only allow, but actually encourage recovery from attention deficit disorder, increased physiological arousal, and negative emotions linked to acute stress and exhaustion (Hartig et al., 2014), (Berman et al., 2008). Exposure to natural stimuli, in particular, has been shown to promote relaxation, boost wellbeing, and raise work satisfaction (Korpela et al., 2010), (Bowler et al., 2010). The main goal of Biomimicry Wearable is therefore to **reconnect people** to these stimuli arising from nature, in order to prevent situations of mental breakdown favoring a working climate as serene as possible in the long term. Technology, design, nature and fashion can create a network of interactions such as to collaborate as a single entity that aims to be human centered and no longer based on mere technological innovation, perceived by the majority as cold and detached from peoples' needs.

Research Issue

Smart wearables, in this thesis intended as **smart watches** and **smart wristbands**, have recently captured a lot of consumer interest (Chawla and Amist, 2021). From the IDC data (2019) is expected by 2023 that 302.3 million smart wearables will have been shipped worldwide. Despite studies indicating rising demand for those devices, nowadays these technologies still have a poor acceptance and diffusion rate (Adapa et al., 2018). Early wearable tech sought ways to "wear" computing tools on the body, while contemporary design problems are focused on i**ncreasing social acceptance** and, in particular, cultural significance (Tomico et al., 2017). Starting from the previous studies that confirm the natural stimuli as a means of relaxation during the breaks of the working day, the thesis proposes the creation of a smart wearable that is able to stimulate the user through technology, to recreate that feeling of well-being, otherwise difficult to achieve in a closed environment. The interaction with the natural world is essential to human life, a sustainable lifestyle requires striking a balance between individual consumption and the natural environment's potential for regeneration. However, we frequently behave as though we are independent of nature and that we can survive without it. Indeed, the constructed environment acts as a barrier between people and their surrounding natural ecosystems, people are separated from nature by offices, schools, houses, vehicles, restaurants, and a variety of other indoor habitats (Schultz, 2002). How to create a smart wearable that **stimulates the user** through technology to recreate that feeling in parallel with the ethical respect of how technology should not be the substitute of nature, but incentivize the person to **take care of themselves** and embrace that world again, will be the main question explored in this paper.

"Our clothes connect us to the world. They are not a surface we interact with; they are embodied and become an intimate part of us. Since they are such a prominent part of our everyday practices, our clothes can contribute to societal challenges related to vitality, human resilience and empowerment. They enable us to explore the soft, emotional and subjective sides of technology".

Van Dongen, P. V. D.

ISSHO jacket, Pauline Van Dongen, 2017

Methodology

This thesis explores the design of a smart wearable based on the fashion-tech methods through a desk and case studies research concerning the biomimicry in the fashion field. This will lead to a design in which iterative phases of ideation and reflection will be alternated. The next steps will require to proceed with the phase of experimentation, textile laser cut, Arduino circuit implementation and a first prototype. Afterwards, a user centred test will be necessary for the validation and verification of initial assumptions and consequently, the collection of feedbacks and a final design will take place. The different stages of the process demonstrate how the digital fashion design practices are still a field in which the research can open a wide perspective of possibilities and improvement, under a social point of view, of what is already in the market.

Results

Biomimicry wearable is a system that interacts with the person reconnecting it with nature, especially designed for people working indoors in front of a computer screen, detached from the real world. The garment contains inside an Arduino circuit connected in real time with a software that extrapolates the angle, direction and intensity of the **wind**, which has been chosen as natural stimulus because it affects as many **human senses** as possible, touch and hearing through the vibration of the air in contact with the body and sight through the movement caused by the pressure of this on the objects. Depending on the wind data, the piezoelectric motors return to the end consumer vibrations more or less intense, regulated by more or less rapid intervals, starting and ending in different directions. The person will be "distracted" by his/her workflow and intrigued by the interaction of the smart wearable, which is no longer an inanimate surface to wear as protection from the outside but, on the contrary, a dialogue with what exists beyond the office walls. The people who become aware of what happens in real time outside are encouraged to get out, breathe fresh air and immerse themselves in the surrounding environment. As a result, on re-entry they will have benefited from the positive effect of natural stimuli that relax the mind and allow greater concentration. This initial hypothesis has been summarized into a prototype realized in the studio of **Pauline Van Dongen**, through the Ftalliance project, through the guidance of the head Pauline Van Dongen, her assistants Anna Wetzel and Ellen Britton and the supervision of Professor Daria Casciani. Later the prototype was subjected to extensive tests on several targets, which through the questionnaires to collect data and information useful for the realization of the final wearable. The union of new technologies with the natural world in a human centric and design driven vision, can open up new avenues in the fashion industry and in the field of **mental well-being** through constant experimentation.

Keywords:

Smart wearable; nature; technology; mental well-being; wind; fashion-tech design; biomimicry;

1. INTRODUCTION AND THESIS STRUCTURE

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The thesis was developed across several stages (**Figure 1.**), from which crucial data was gathered in the development of the Biomimicry Wearable project. Each stage was broken down into seven chapters, starting from the literature review and ending with the proposal's testing.

In **chapter 2:** ***"Smart Wearable for Wellbeing"***, a review of the **literature on smart wearables**, **biomimicry, and wellbeing** was conducted on books, periodicals, papers, and web pages. It was declared that the adoption of new technology has shown an important increase in the last years, and has led to the creation of smart wearables. Those, which can be described as electronic devices that can be worn, are subdivided into three main fields, according to their final application and objectives: market oriented, specific purpose and research driven. In parallel, another concept was analyzed, the **biomimicry**, which is the **innovation inspired by nature**, composed by structural, morphological, texture and functional inspiration. The bridge between smart wearables and biomimicry is the increase of **technostress in the workplaces**, due to the introduction of tasks performed on the laptop. The natural stimulus has been proven to relax the mind and prevent stress. For this reason, the paperwork starts from the initial premises of developing a smart wearable functional biomimicry inspired, in the research driven field of application, based on people's future needs, the mental well-being care.

In the next step, **Chapter 3:** ***"Idea"***, all those concepts were deeply examined to understand the possibilities and solutions that led to this increasing technostress among workers. In fact, its prevention will be the main thesis scope. As follow, the section describes the project paths, whose objective is to **reproduce the natural stimulus of the wind**, an intangible external element, to help people in **taking care of their own mental health.** These feelings will be provided by a smart wearable that produces both the **tactile and visual outputs** of the external air.

The outline of the project has been carried out in Pauline Van Dongen studio, which is analyzed in **chapter 4:** ***"Field Research"***. The company's areas of research are mainly three, which are design oriented, so based on emergent human needs: Solar Cells, Haptic Technology and Shape Changing Materials. The intersection between the thesis and the Dutch reality felt inside the sphere of **haptic technology**, through the reproduction of the tactile output of the wind, and s**hape changing material**, linked to the visual movement caused by the pressure of air on objects. Defined those two design paths, the analysis of several case studies was fundamental to take inspiration for the methodology, materials, and sensor location for the prototype design. The **wind's two quantifying characteristics, the intensity and the direction**, are translated into different interactions of both the smart wearables. Indeed, the data extrapolated from a real time weather condition website, will pass through a circuit, integrated inside the devices, and **converted**, thanks to the Arduino software, **into vibrations and texture movements.** The tactile experience will be provided by a **wearable on the wrist area**, whereas the visual interaction will be located over the **surface of a laptop bag**.

The next stage requires a more practical approach, described in **chapter 5**: ***"Experimentation and Fi-***

nal Prototype". **Several tests** were carried out by the **laser cutting machine, circuit construction and fabric implementation**. Has shown from the trials steps, the initial hypothesis of the **laptop sleeve** has been rejected due to s**ustainability, technology and materials limit**. Whereas, for what concerns the **vibrational smart wearable**, it was possible to give a physical shape to the initial assumption, creating a **prototype**. The final steps after the experimentation have been summarized until the last product.

Having obtained a prototype, the **verification of its functionality and user perception**, has been checked through the **chapter 6**: ***"Users' acceptance and feedback tests"***. The test was performed on different people that had in common the laptop application during their daily routine, the device was worn for eight hours while the user had received several information and tasks. **The survey objective** was to **collect the effect of biomimicry wearable on well-being** and the general considerations on design and ergonomics. **The results** showed how the prototype **perception of wind** and **relaxing outcome** happen only while the person takes a **break outdoor**, which seems to **bring a more beneficial effect on people's productivity and relaxation in the workplace**. In addition, the user suggested location of the vibrations is mainly the upper back, while for the ergonomic design, the device's tactile interaction is felt different depending on the wrist size of the interviewed. For what concerns the aesthetic, the colors which unconsciously remind the wind are shades of blue, grey, white and green.

All those survey inputs were examined and transformed into new possible redesign in **chapter 7**: ***"Results and discussion"***. The users feedback were developed as a **new proposal**, taking into account also the **future possibilities**, the **social relevance of wellbeing** and the **sustainability impacts**, linked to the product disassembly ability and maintenance.

In the end, in **chapter 8:** ***"Conclusion"***, it is declared that the **design research should be oriented to the human well-being**, rather than work productivity, since it responds to the emerging needs. The Biomimicry Wearable project opens up several possible new paths in this field, in combination with the social and environmental sustainability assumed improvement, due to potential new and more performing technology and materials.

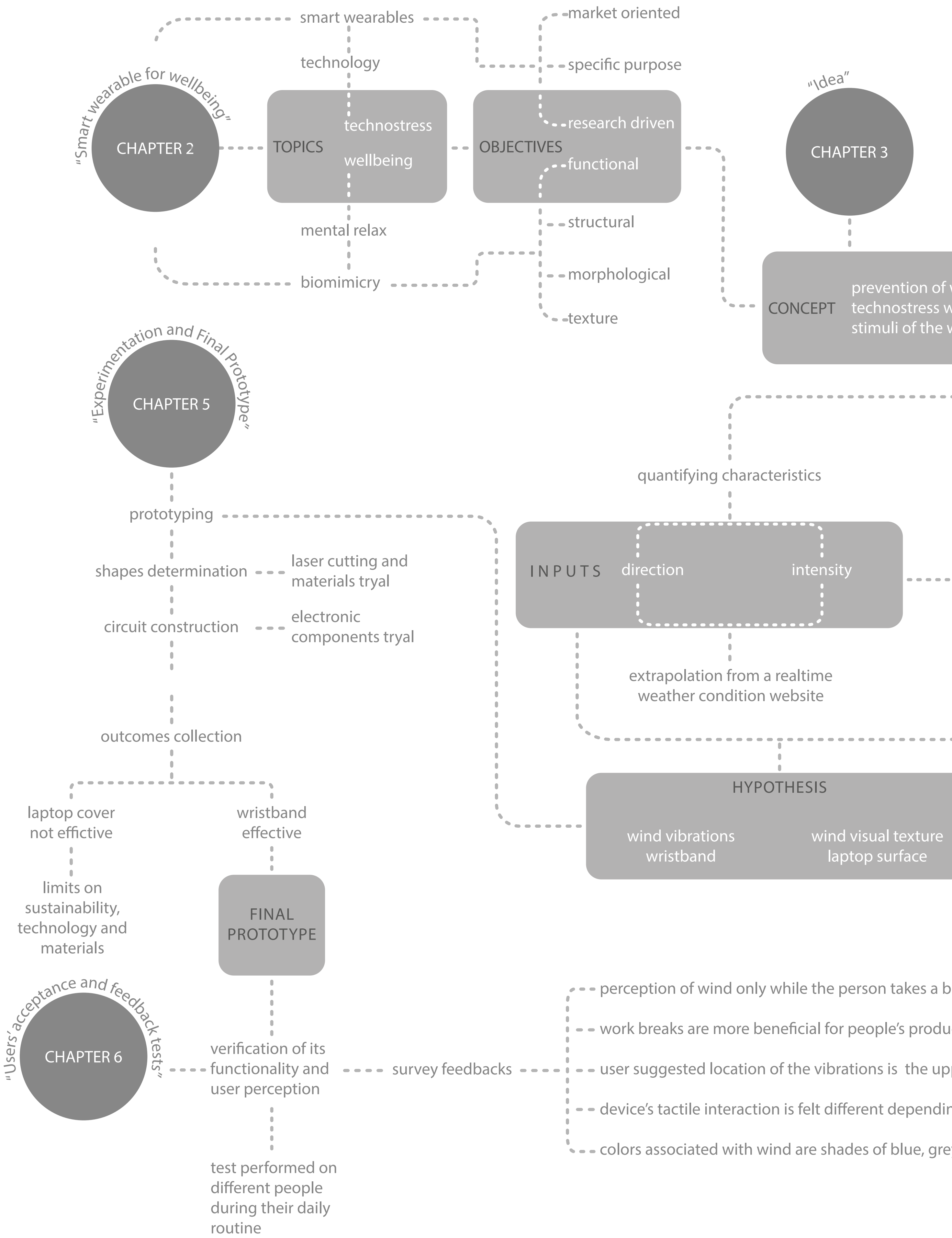
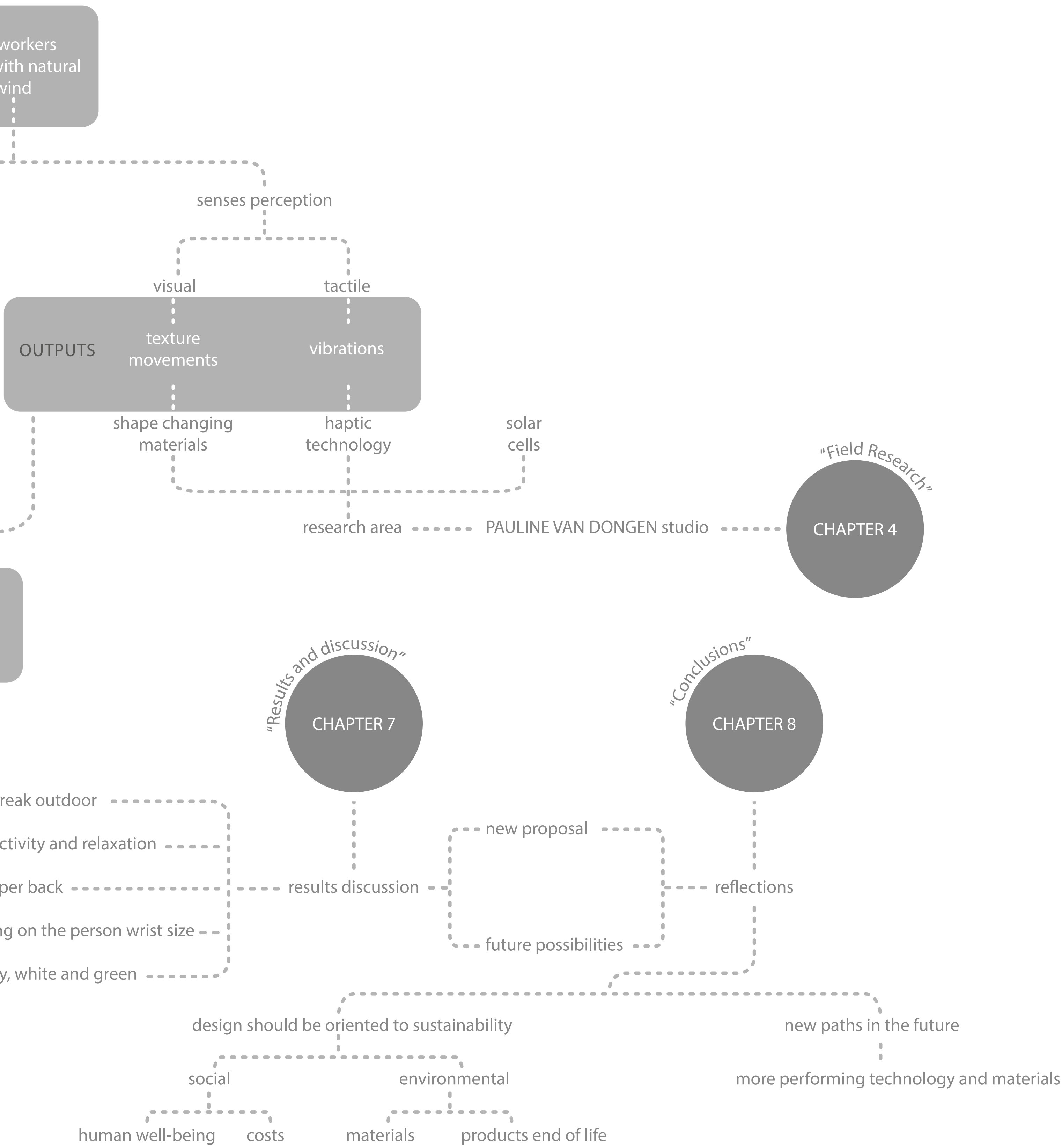


Figure 1. Development of the Biomimicry Wearable project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2. SMART WEARABLE FOR WELLBEING

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2.1 Defining Smart Wearable

Over the past ten years, **consumer involvement with technology and artificial intelligence has grown** significantly, users' adoption of wearable technology is a component of the current technological revolution (Ameen et al., 2021). Wright and Keith define **wearable technology,** also known as wearable devices or just wearables, a**s intelligent computers integrated into various accessories, such as consumer-worn apparel, fashion accessories, and other common objects** (Wright and Keith, 2014). The smooth, integrated solutions that people have come to expect from computers will be delivered by these devices. Modern goods with a combination of sensors and computing devices incorporated in clothes and fashion items, such activity monitoring bracelets or smart watches, have rapidly increased the launch of new computer wearables (Friedman, 2017), (Nieroda et al., 2018). Analyzing the different papers on the smart wearable theme, is evident that those during the last century have expanded in **several fields of applications**. Wearable technology was mostly employed for military purposes before it entered the civilian market, whereas nowadays is present in the healthcare and fitness fields (Jhajharia et al., 2014). Another domain of interest in smart textile technology concerns the one of astronaut space missions (Dalsgaard and Sterrett,2014), video games (Salomoni and Prandi, 2015), human needs centered, infotainment, customer service, prototyping test, fashion glamour (Çiçek, 2015) and speculative design (Dunne and Raby, 2013). In order to achieve a better visual organization of those fields, they can be subdivided into three main categories as shown in Figure 2.: **Market Oriented, Specific Purpose and Research Driven.**

Figure 2. Smart Wearable Fields of Application.

2.1.1 Market Oriented:

This sector involves all wearable electronic devices that are the product of **customer demands** and recognized needs being the main priorities.

Healthcare and Medical: It is increasingly common to use wearable electronics to check one's health. People's heart rates, calories burned, steps done, blood pressure, biochemical release, exercise duration, and physical effort may all be tracked with these devices. In addition to detecting changes in health, mood, and stress, they are helpful for monitoring conditions. In fact, the progression of chronic illnesses and the vital characteristics of individual patients can be kept under control by the ongoing study of vital signs.

Fitness and Wellness: In this area it is possible to outline the essential tools for analyzing the different key metrics required to assess a user's performance or general well-being. There is a constant desire for better athletic performance in the realm of sport. Athletes and coaches may now analyze the effectiveness of training plans and fine-tune them to maximize performance thanks to technological advancements in physiological monitoring and motion surveillance.

Infotainment: Describes all smart wearables that deliver real-time information in a way that interacts with the user, such as a set of smart glasses that can detect a driver's level of weariness or sleepiness and notify the other car, increasing road safety (Chang et al., 2018)

Custumer service: including in the sphere of smart wearable all the electronic devices that can be worn over the body or embedded in clothing powered by microprocessors, all the smart devices as smartphones, computers and tablets, should be taken into consideration. These tools allow to collect and transfer data in the people daily life. Indeed, bluetooth, WiFi, GPS and all the other technologies embedded in those devices are used for a wide variety of purposes as transportation, communications, education, security and so on.

2.1.2 Specific Purpose:

Within this category fall all those products born already for a **specific purpose and application** field, which therefore require certain technical characteristics and performance outlined immediately.

Military: Organizations and other law enforcement agencies rapidly realized the potential uses of wearable computers in the military. Infantrymen will be able to employ digitally distributed commands, maps, and information with the aid of smart wearable computers. Much of the research on wearables in the military has been kept private, but however, there are instances of collaboration with non-military researchers in the United States, Australia, the United Kingdom, and Singapore.

Space: For manned space missions, the European Space Agency (ESA) is still making investments in smart textile technologies. The device they are creating is intended to assist in addressing some of the health issues astronauts deal with as a result of lower gravity forces in space.

Video games: The new technological era has had an impact on the gaming experience through the use of virtual reality, as shown by the rise of new wearable that give the user the impression of being immersed in a parallel reality through physics simulation, that includes object properties like mass, inertia, barycenter, joint constraints, restitution, surface friction and others.

Glamour: Several designers are still making their impact in the wearable technology fashion industry, this field covers all the clothes that are designed with the intention of being worn as accessories, some examples include: clothing that responds to light and has sound animation.

2.1.3 Research Driven:

Finally, the third sphere of smart wearable includes all those projects born not following an analysis of the current market, and therefore based on the now recognized needs of users, but by a design based on the desire to improve what already exists. In order to achieve this condition it is necessary to analyze the problems not yet evident and the **central needs for the human being**, whose existence has **not yet been perceived**.

Solar windbreaker, Pauline Van Dongen, 2016

Test prototyping: It represents all the devices that are new prototypes and systems to evaluate user behavior, preferences and requirements. There are several instances where smart wearables are utilized to assess things like stress levels or the user's emotional state in a particular setting. The results are often applied to enhance a wearable, system, product, or interaction.

Human needs centered: In this section the activity of the designer is based, which must be the figure able to capture the future needs of the people and based on an ongoing or expected change of society, context or human relationships. These smart wearables are therefore not concerned with monitoring a heartbeat or allowing a gamer to play better, but is based on a deeper attention on the social condition through research and experimentation.

Speculative design: Includes all the smart wearables designed to test theories, or the applicability of technology from a social and cultural perspective. The aim of this research field is to provide fresh perspectives on nowadays "*wicked issues*," encourage discussion and debate about alternative ways of present existence, basing the research this on imagination. Design speculation have the potential to inspire a change in how people view reality.

2.2 Thesis Objectives Orientation

The aim of this thesis is to **focus on smart wearable research driven**, the one underlined in **Figure 3.**, in particular, on human needs centered, it also partly involves the areas of healthcare and wellness, especially in terms of **mental well-being** and **through a process** that also includes the use **of prototyping testing and the speculative design approach**. The design intent therefore starts from an analysis of what are the changes in society, to then move to an experimentation through semi-final products and evaluate the experiences of users. Finally, if in the future the result of this project will meet the market, the transition from research driven to market oriented will happen, and the design process will start all over again. Human society is in fact constantly changing, requiring a new analysis of the current and future situation for each new project.

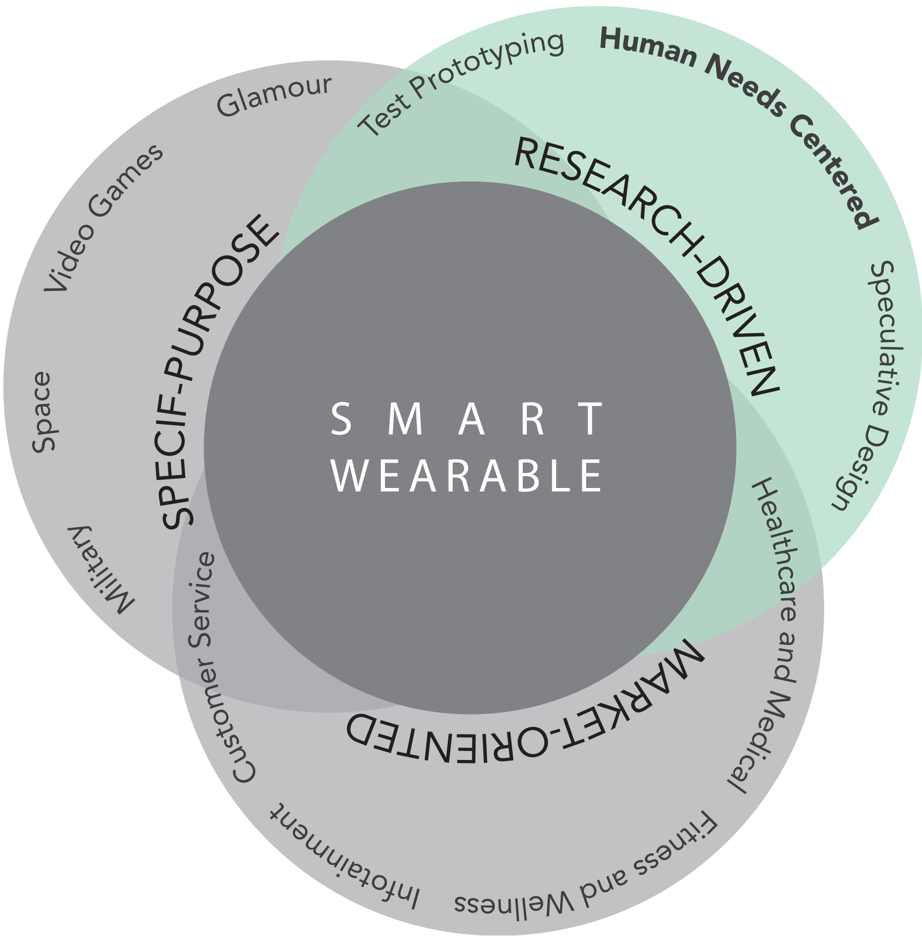


Figure 3. Smart Wearable Research Driven Focus.

2.3 Exploring Biomimicry

The term **"biomimicry"** was first used in 1997 by the natural scientist and author Janine Benyus, who defined it in her book "Biomimicry: Innovation Inspired by Nature" as an emergent science that i**nvestigates natural models and** afterwards **emulates or takes inspiration** from these designs and methods **to solve human problems** (Benyus,1997). Over time, natural selection has allowed organisms to create adaptable materials and structures, in the same way people can conform to their changes in society, environment and interaction taking inspiration from the nature, through the biomimicry science, which incorporates the direct implementation of biological science to engineering, design, chemistry, electronics, and other systems and activities, is a relatively new field (Liu, 2022). The consequences of the rising interest in this new area, which has been recently

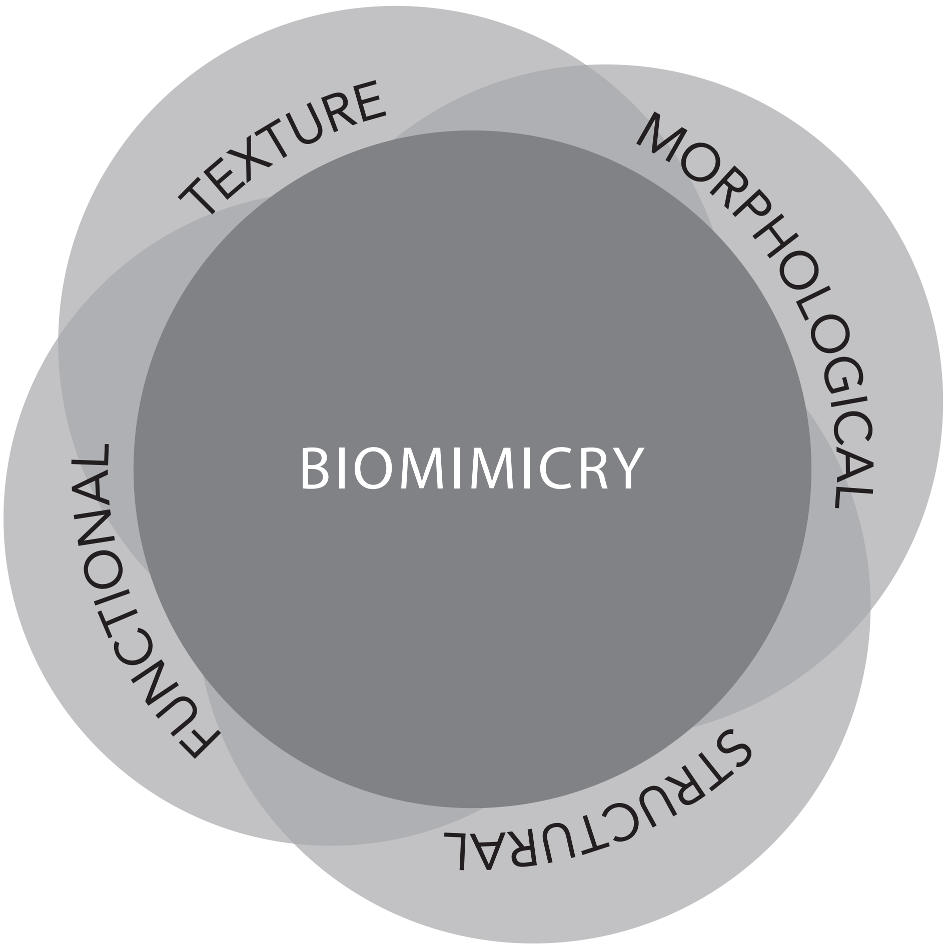
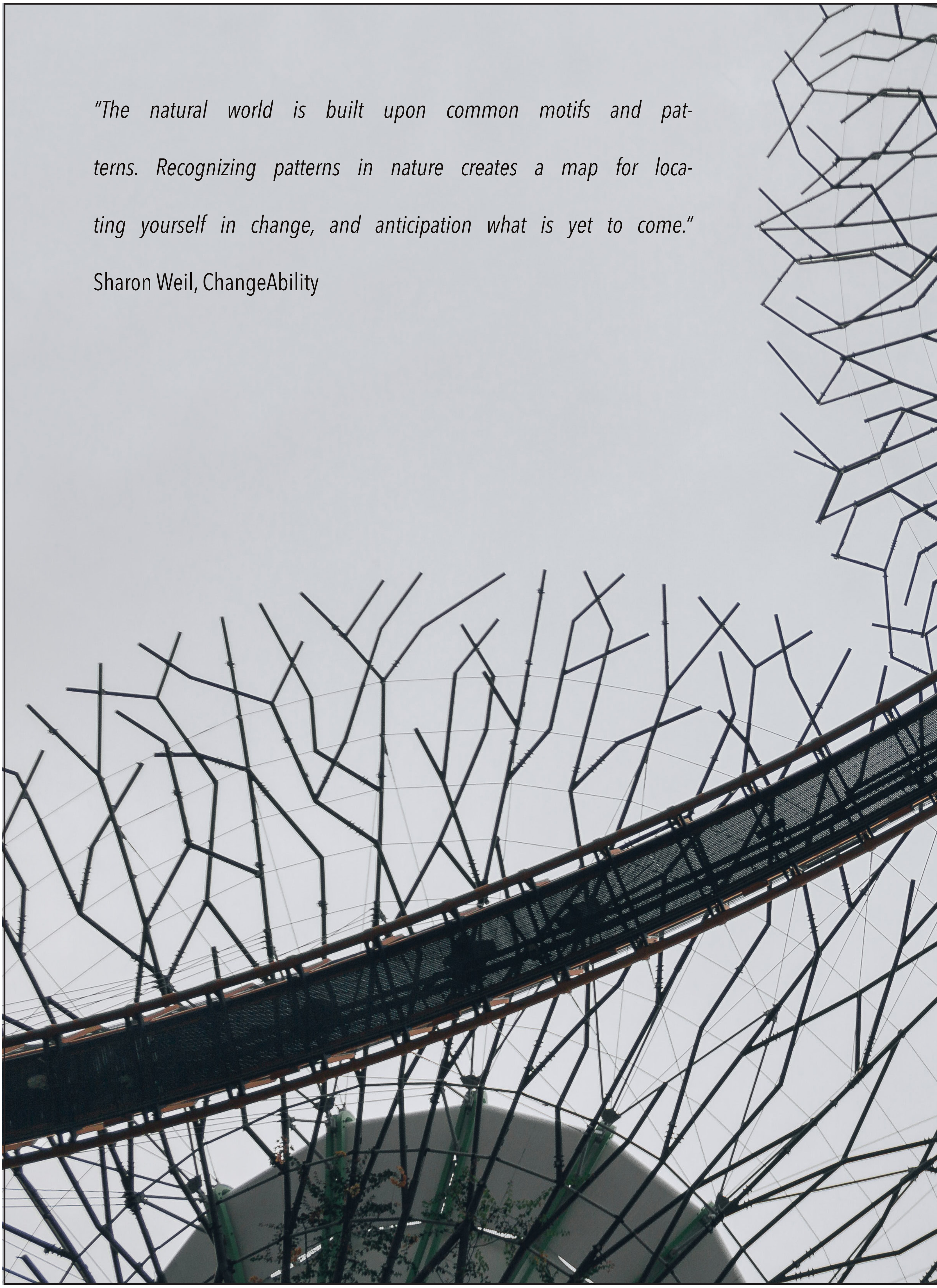


Figure 4. Biomimicry Categories.

introduced into the science application field, have led to a proportionate growth in innovation with the launch of new technologies and products (Lurie-Luke, 2014). Biomimicry is also linked to the expanding requests for alternatives to the environmentally harmful technologies, structures, and methods of the unsustainable contemporary industrial age (Blok and Gremmen, 2016). Moreover, thanks to the interdisciplinarity of this science, the mechanisms of nature are not only applied as sustainable design solutions, but also in the field of architecture, philosophy, construction and so on (Ilieva et al., 2022). To understand the different uses within this macro category, it is necessary to **divide it into four sections**, as shown in Figure 4., that **depend on the natural source of inspiration** and how and in what **field** these will be transformed **for the human being**.

“The natural world is built upon common motifs and patterns. Recognizing patterns in nature creates a map for locating yourself in change, and anticipation what is yet to come.”

Sharon Weil, ChangeAbility



2.3.1 Morphological Biomimicry:

Starting from the aesthetics of nature and living organisms, the morphological design in the field of Biomimicry design is **based on the external and internal forms** that characterize them, it refers therefore to all that purely visual components that are reworked by man to create solutions or original ideas.

Case studies:

CRYSTALLIZATION TOP

Designer / brand	Iris van Herpen	Product description
Years of launch	2010	Iris van herpen crystallization collection main piece, is composed by a woman's shirt made through computer modeling and rapid prototyping. The shapes is formed by a repetition and scale of a single unit, that wraps around the wearer, resting on their shoulders to allow their back to be fully exposed. The final piece takes inspiration from the freezing of the liquid water .
Biomimicry category	Morphological	
Wearable tipology	Specific purpose	

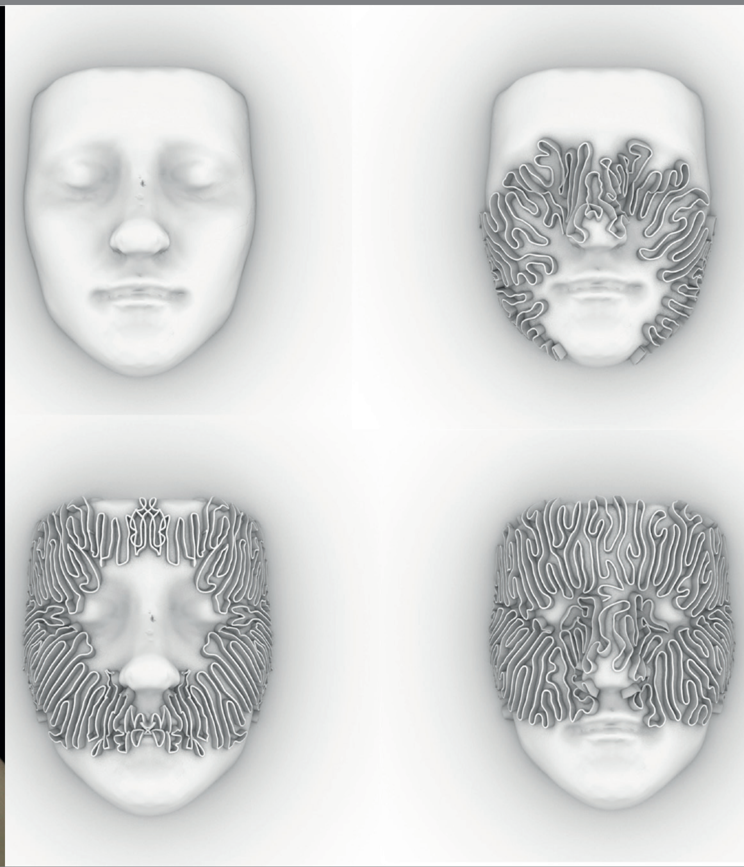
SYNESTHESIA DRESS

Designer / brand	Mariah Alcantar
Years of launch	2018
Biomimicry category	Morphological
Wearable tipology	Specific purpose

Product description

Synesthesia dress inspired by coral external shape. The smart wearable helps deaf people translating the external sounds captured by a sensor, like music, into physical sensations thanks to vibration output.

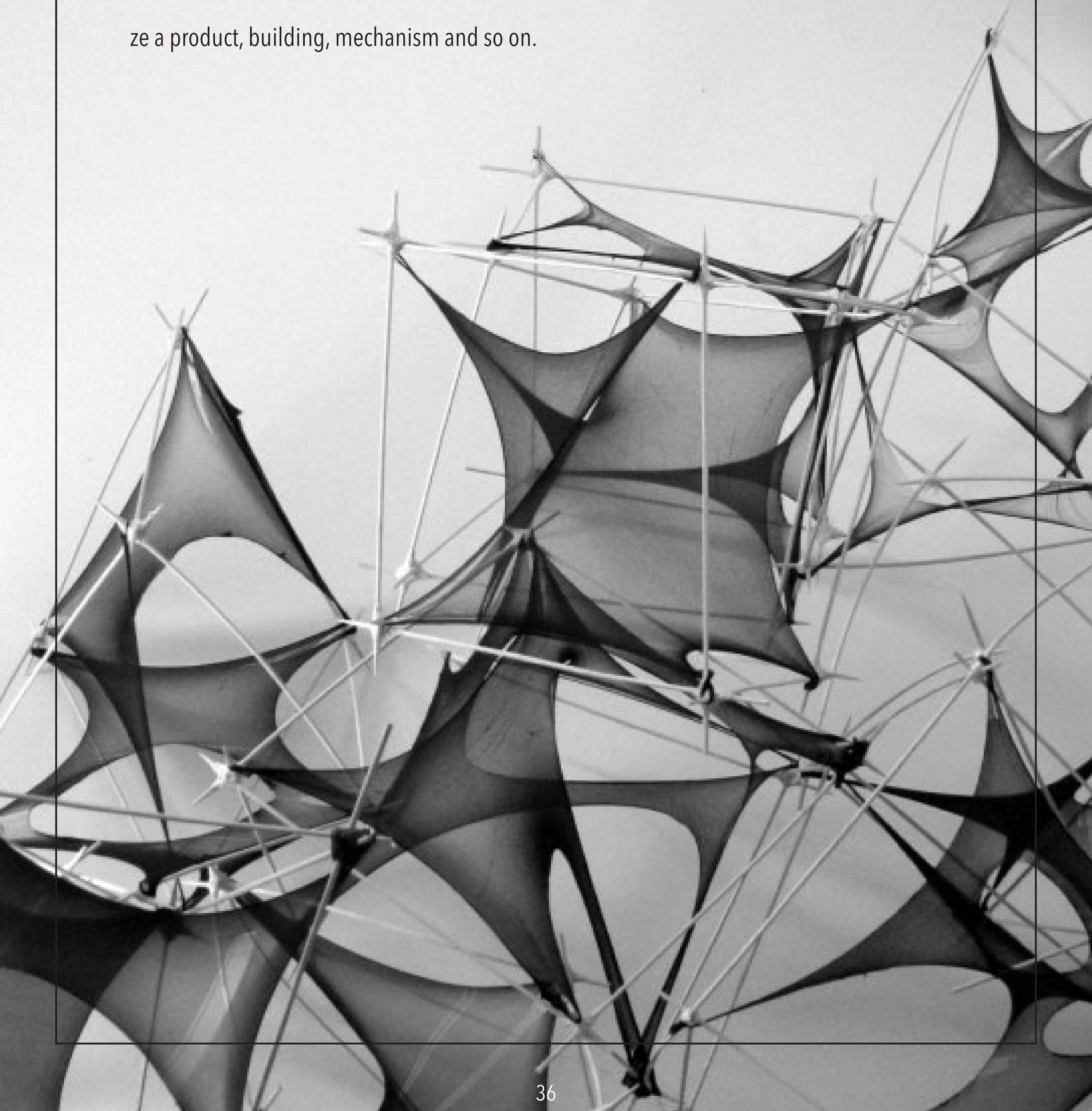
MEANDER



Designer / brand	Kate Reed	Product description
Years of launch	2021	Meander imitate the meandering coral growth. The devices concept is its shape changing with the passage of time, creating different forms as the one simulated by the designer. This wearable belongs to the artist's Beyond Biomimicry collection, which creates a wearable biophilia effect.
Biomimicry category	Morphological	
Wearable tipology	Research driven	

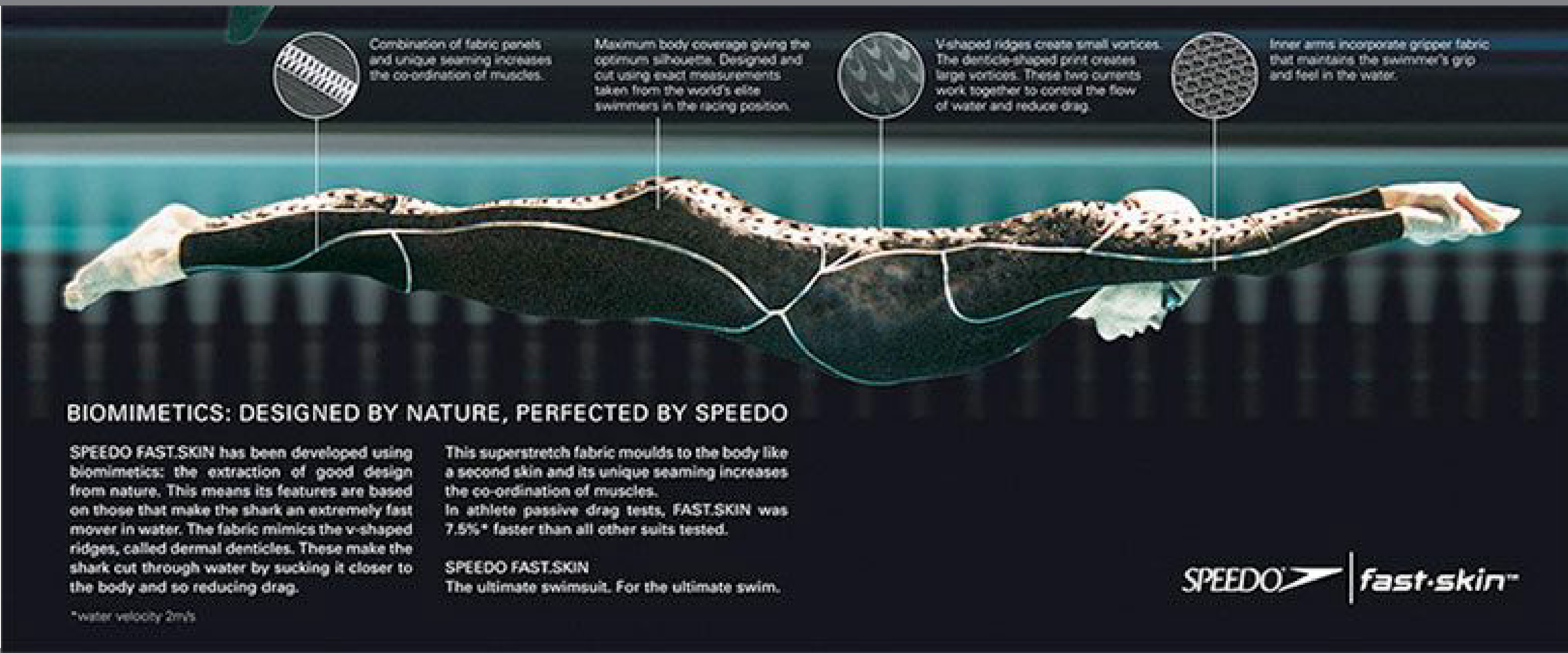
2.3.2 Structural Biomimicry:

Inspiration in this case starts from the existing flora and fauna, depending on the place, the living conditions and the purpose, the constructions created by those organisms have distinct characteristics. Any variance of these factors will then lead to a different structure. The structural biomimicry analyzes the **biological composition** and uses it as a tool to create or optimize a product, building, mechanism and so on.



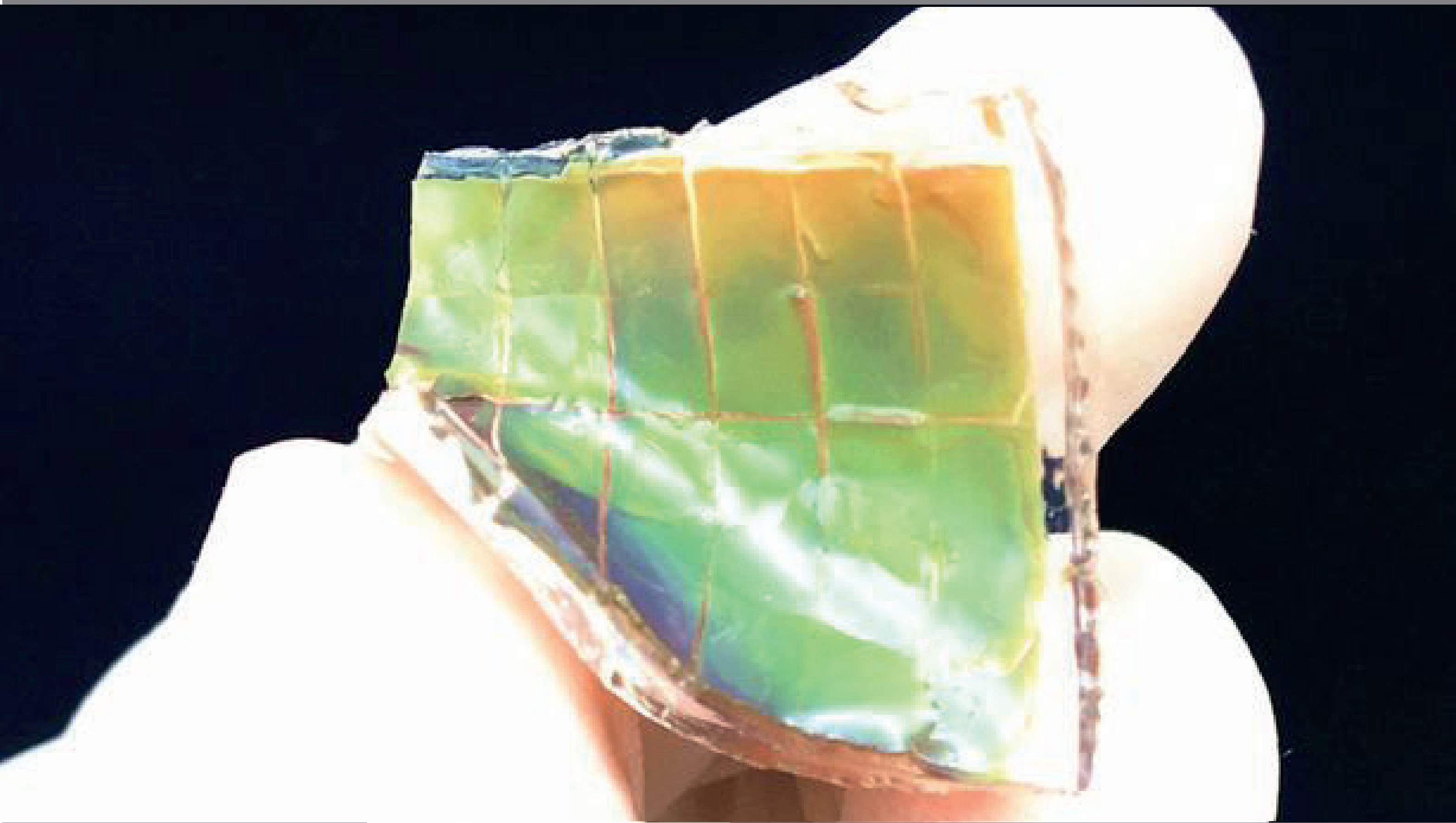
Case studies:

FAST SKIN



Designer / brand	Speedo	Product description
Years of launch	1999	Fast-Skin high-tech swimsuit is inspired by the sharks external structure, which reduce the water resistance. The wearable is composed by small sharp V-shaped folds to separate and push back the water.
Biomimicry category	Structural	
Wearable tipology	Market - oriented	

SMART SKIN



Designer / brand	Emory University of Atlanta scientist
Years of launch	2019
Biomimicry category	Structural
Wearable tipology	Research driven

Product description

The Emory University of Atlanta has achieved a smart and flexible skin that changes color maintaining its original volume, depending on the variation of light and heat. The inspiration comes from the chameleons external layer structure, whose different appearance depends not on the pigments but on the repetitive pattern of photonic crystals particles. In order to reproduce this effect, the crystals were inserted into a hydrogel, a material composed of 90% by water.

MEN'S CASCADA WATERPROOF JACKET

Designer / brand	Paramo
Years of launch	2020
Biomimicry category	Structural
Wearable tipology	Specific purpose

Product description

The Paramo brand uses biomimicry structural inspired materials to achieve greater functionality in their outdoor wearable. The fabric composition is created with the Nikwax's technique, a material that is inspired by animal fur, drawing moisture away from the body to stop perspiration, rain, and humidity.

2.3.3 Functional Biomimicry:

To overcome natural selection, animals and plants had to **adapt** to different environments, changing their **practical functions**, such as the ability to walk, to breathe out of the water, to communicate, actions that were indispensable for their survival. Functional biomimicry is a method to apply the mechanism of biological function to the design process.

Case studies:

MATING COLLAR		

Designer / brand	Kate Reed	Product description
Years of launch	2019	Mating collar is a smart wearable accessory which imitates the animal function of mating. The heart rate sensors in comination with sonar sensors is able to catch when the user is excited, and activate servo motors that will turn on the flutter.
Biomimicry category	Functional	
Wearable tipology	Research driven	

PANGOLINE SCALES

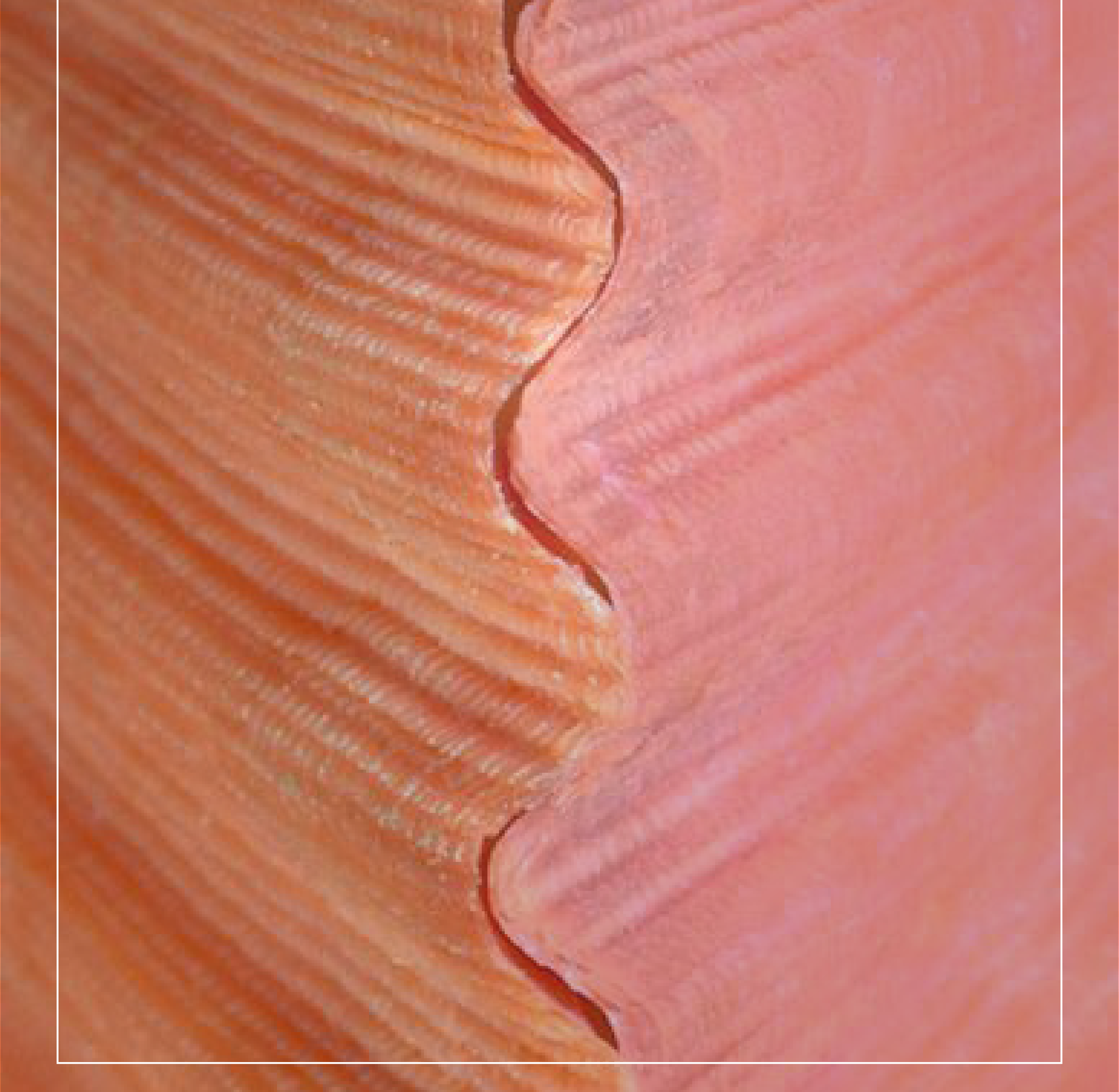
Designer / brand	Anouk Wipprecht	Product description
Years of launch	2020	The Pangolin Scales project is the world's first Brain-Computer Interface able to extract information from the human brain, those are used to control the Pangolin Dress. The 3D printed robotic dress mechanism, thanks to servo motors, moves and lights up according to the brain wave signals. The wearable is inspired by the pangolin keratine scale skin which functionality is to protect the animal from external dangers.
Biomimicry category	Functional	
Wearable tipology	Research driven	

MUSICAL PROSTHETICS

Designer / brand	Kate Reed	Product description
Years of launch	2021	Musical prosthetics are musical instruments attach to the human body in exoskeletal formations, for enhancing non-verbal communication. The wearable is connected to a sensor that sends information to a Teensy microcontroller then, the information goes through Max MSP where it is translated from numbers and data into real-time music and sound.
Biomimicry category	Functional	
Wearable tipology	Research Driven	

2.3.4 Texture Biomimicry:

The **surface properties** of natural items have a role in the product's functionality and in the visual and emotional experience of the exterior texture, which is known as texture biomimicry design. Users can take inspiration from it to **achieve tactile and visual sensations** in addition to experiencing a texture similar to the biological one.



Case studies:

BE-TWEEN

Designer / brand	Pauline Van Dongen	Product description
Years of launch	2015	The shoes of the Be-tween Pauline Van Dongen collection represent the dinamicity of the nature through the external texture. The final product, based on a 3D body scan, is a made-to-measure 3D printed wearable.
Biomimicry category	Texture	
Wearable tipology	Research driven	

SCALED

Designer / brand	Natalie Kerres	Product description
Years of launch	2020	Scaled is a wearable technology that can help athletes to reduce their risk of serious long-term joint injury. Through controlled motion control, the wristbad can be utilized for safety training, rehabilitation, and improving performance. Its texture is designed from the organism scales found in nature.
Biomimicry category	Texture	
Wearable tipology	Specific purpose	

EARTHRISE COLLECTION

Designer / brand	Iris van Herpen	Product description
Years of launch	2021	In this wearable collection the fashion designer takes inspiration from the skydiving and the perception of the body in contact with the air. The texture and colors recreate a unique design of organisms with embrodery techniques, layering fabrics and new fashion technology.
Biomimicry category	Texture	
Wearable tipology	Specific purpose	

After opting for using a method that is more focused on the human-centered need methodology and, consequently, on the design-driven mindset, **this thesis will focus on the functional biomimicry field**. Therefore, analyzing the emerging social needs leads to a design that is not just based on technology or form changes, but that considers the current cultural shifts. To ensure that this action occurs, it is necessary to mimic the interactions that happen in nature, applying their biological mechanism's functionality in the field of smart fashion wearables. The diagram in **Figure 5.** demonstrates this possible correlation.

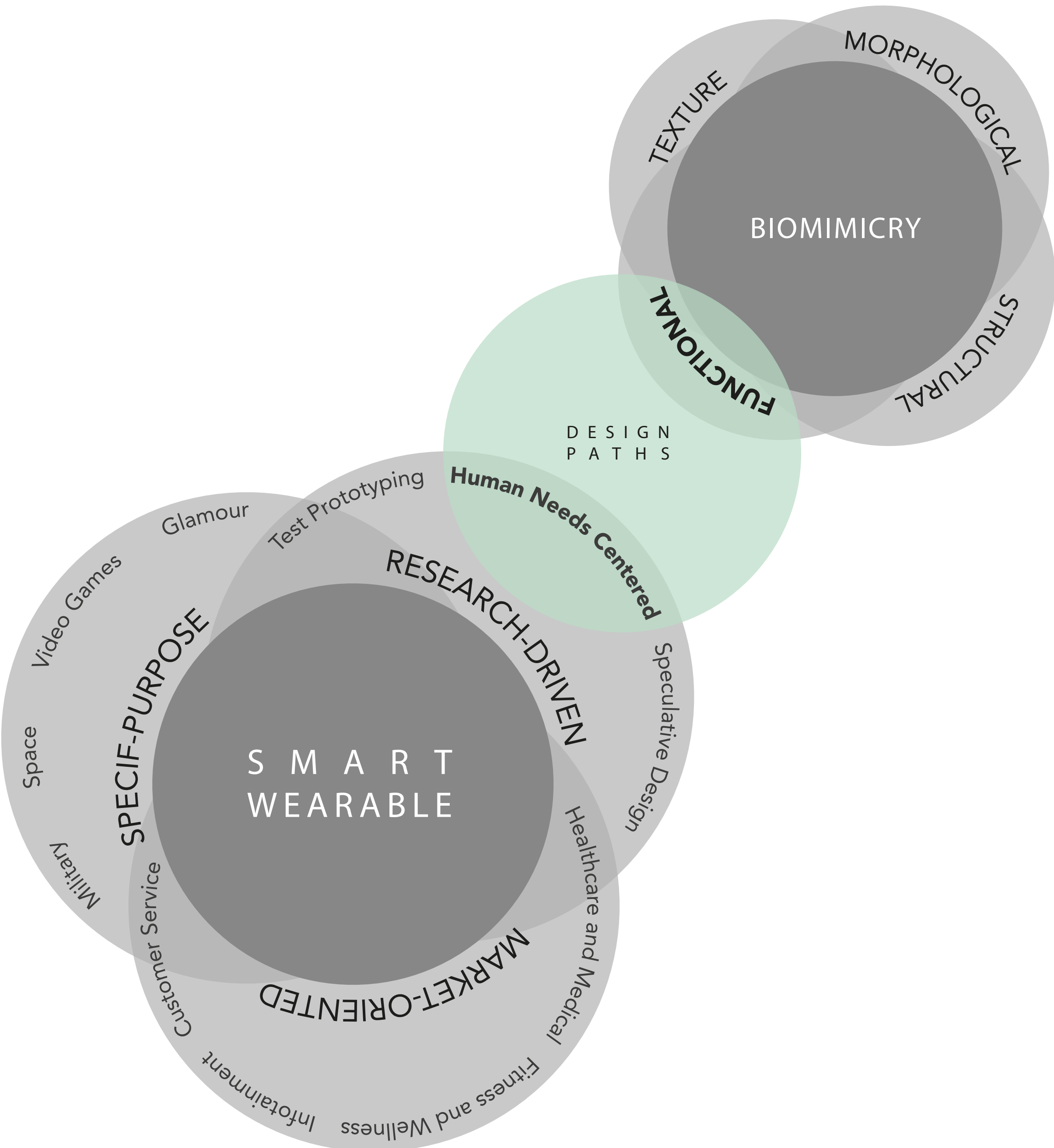


Figure 5. Correlation between Smart Wearable Human Needs Centered and Functional Biomimicry.

2.4 Understanding Well-being

The current c**oncept of well-being**, intended not as a simple absence of disease, but as a **complete positive state of physical, mental and social of human individual** (World Health Organization, 2014), dates back to the philosophy of ethics, where the question was "how to live" in order to pursue happiness and personal satisfaction (Haybron 2008). Often mistakenly incorporated as one

Figure 6. Well-Being Categories. Adapted by Halbreich, 2022

of many health-related sectors, or as one of many branches of psychology, well-being contains broader discourses than purely medical ones (La Placa et al., 2013). The reason why this term is still often used inappropriately lies in its assessment. The analysis of a person's well-being is **based on different subjective aspect**s such as individual, emotional and psychological interpretations (Fern

& Perry, 1995) and other objective ones such as income, housing and work (Diener et al., 2009). To clarify this concept more easily it is necessary to outline its different aspects, which can be grouped into six distinct macro categories visible at Figure 6.: **the physical and emotional health, the daily functions, the financial status, the surrounding social interactions, the community and the subjective components** (Halbreich, 2022).

Physical and mental health: It is based on the balance between all the components of the individual, due to the fact that mind and body should not be distinguished as they affect each other.

Daily functions: All activities carried out daily by the individual, which are divided into the sleeping and waking part, such as working, playing sports, taking care of children, going out with friends and so on. These have a significant impact on the well-being of the person.

Finances: The part relating to income and the possibility of being able to afford the goods necessary for a peaceful life in relation to the well-being of work to obtain them.

Social interactions: Refers to all those relationships defined as an intimate, family, a companion or a close circle of friends. All these elements are part of the quantification to assess a person's well-being.

The community: The general framework of existence is comprised of the material, social, cultural, moral, spiritual conditions and values of the larger community. Every member of society is significantly impacted by the decisions made by governments and local authorities.

Subjective components of well-being: A high degree of well-being is strongly tied to life satisfaction, optimism and hope play a significant part in this. However, these factors are correlated with different personality qualities.

2.4.1 Mental Well-being

Large-scale statistics from the World Health Organization revealed a **sharp rise in the prevalence of psychological diseases in people**, the medium range goes from 15% to 50% of the overall interviewed who have experienced mental illness at a certain point during their lives (Wood and Tarrier, 2010). In response to the increase in mental disease and the destructive consequences it has on both individuals and the global economy during the past ten years, **mental health has emerged as a major issue** (Keyes, 2014). The **well-being** of the psyche is indeed **important for the individual** to coexist with the typical challenges of life and being able to reach one's full potential, to work efficiently, and to give a contribution to the community (World Health Organization, 2014). **However**, mental health has so far been largely **underestimated**, especially **in the context of prevention**. Nowadays there are 400 different types of known mental disorders, including depression, bipolar disorder, and schizophrenia. These are illnesses that interfere with a person's ability to operate psychologically and are defined by changes in attitudes, feelings, and actions (Thieme et al., 2015). For all those reasons it is extremely **important to take care of the mind as well as** people do with their **body**, currently this topic has a low consideration despite its great importance for people emerging needs. **This thesis operates in the field of smart wearable technology, through a research driven oriented approach that aims to prevent and treat mental wellbeing**, as shown in Figure 7. As it will be demonstrated in this paperwork, the exposure to natural stimuli has shown to reduce stress and other several factors that, otherwise, can lead to psyche malaise. Those elements will be the objective from which the design will take inspiration.

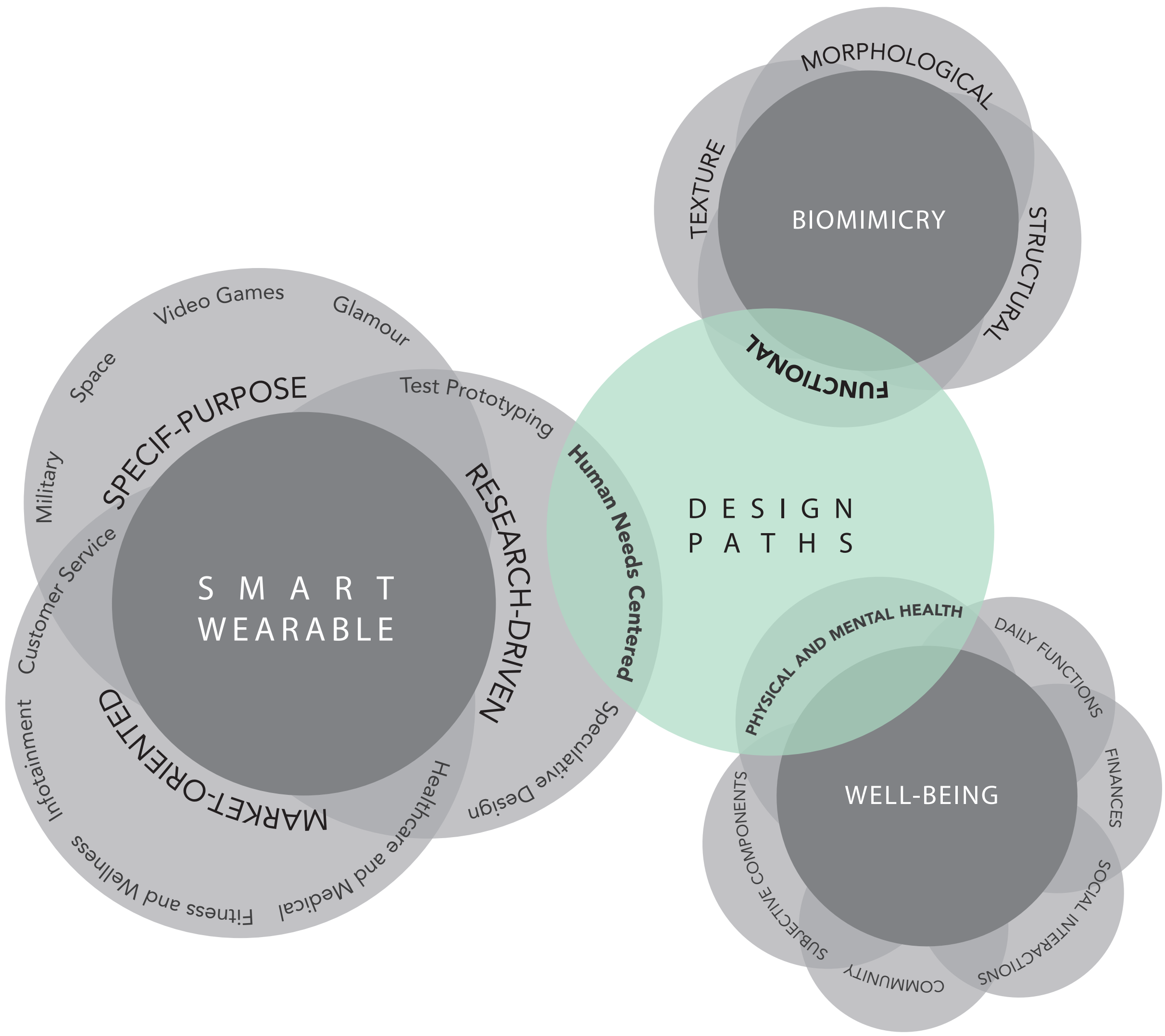


Figure 7. Design Paths.

To resume, the thesis is based on the smart wearable research driven inspired by biomimicry, not on form but on function, to prevent malaise through mental well-being, the main reasons are listed below.

1_ The **field of mental wellbeing** has been so far **taken less into account** than the promotion of health control of the body related parameters for what concerns the development of new wearable technologies.

2_ As will emerge from the subsequent analyses, **natural stimuli serve to reduce work pressure and thus improve** the part of mind-related **well-being** (Rogerson et al., 2020).

3_ These three fields are demonstrated to be **growing trends**, however, they have **not yet been united** to respond to current and future changes in society.

2.5 Chapter Visual Resume

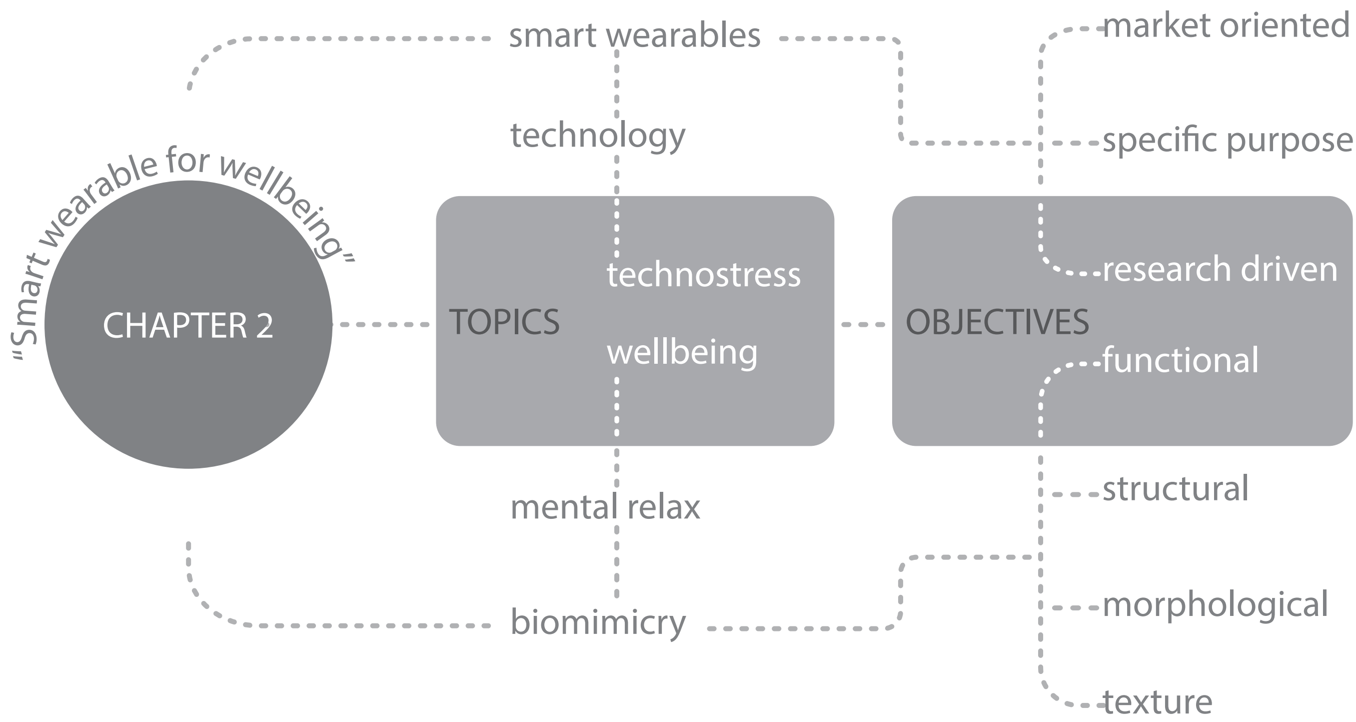


Figure 8. Chapter visual resume.

3. EMERGING NEEDS AND DESIGN PATHS

3. EMERGING NEEDS AND DESIGN PATHS

In order to continue the design process, it is therefore necessary to **analyze the changes in today's society that affect the field of mental well-being**. The results can be the bearers of new significant projects for humans in the field of smart wearable technology and fashion.

3.1 Presenting the Technostress Phenomenon

Over the last decades, a recurrent subject in the field of health psychology has been the effects of new technologies on employees (Tetrick and Quick, 2011). The dispute over the repercussions that these advancements brought from the point of view of human mental health has been ongoing since **1800**, when **Karl Marx introduced the notion of alienation** in the new era of industrialization. The focus on **this theme has grown considerably in recent years**, terminologies such as **technostress, technophobia, cyberphobia, computerphobia, computer anxiety, computer stress, negative computer attitudes, and workplace telepressure**, show how the **problem of the psychological effects of digital technologies** has not decrease over time, but **has grown** and become central focus for many studies (Wang et al., 2008). All these terms refer to how new technologies affect an employee's experience. Although these technologies were introduced to improve workplace life, they may also have unintended consequences, such as intensifying work from different points of view, going in the opposite direction of their original purpose (Chesley, 2014). These side effects are included in the sphere of the so-called **technostress**, which can also be **differentiated into five primary subcategories** as shown in diagram Figure 9. (Tu et al., 2005):

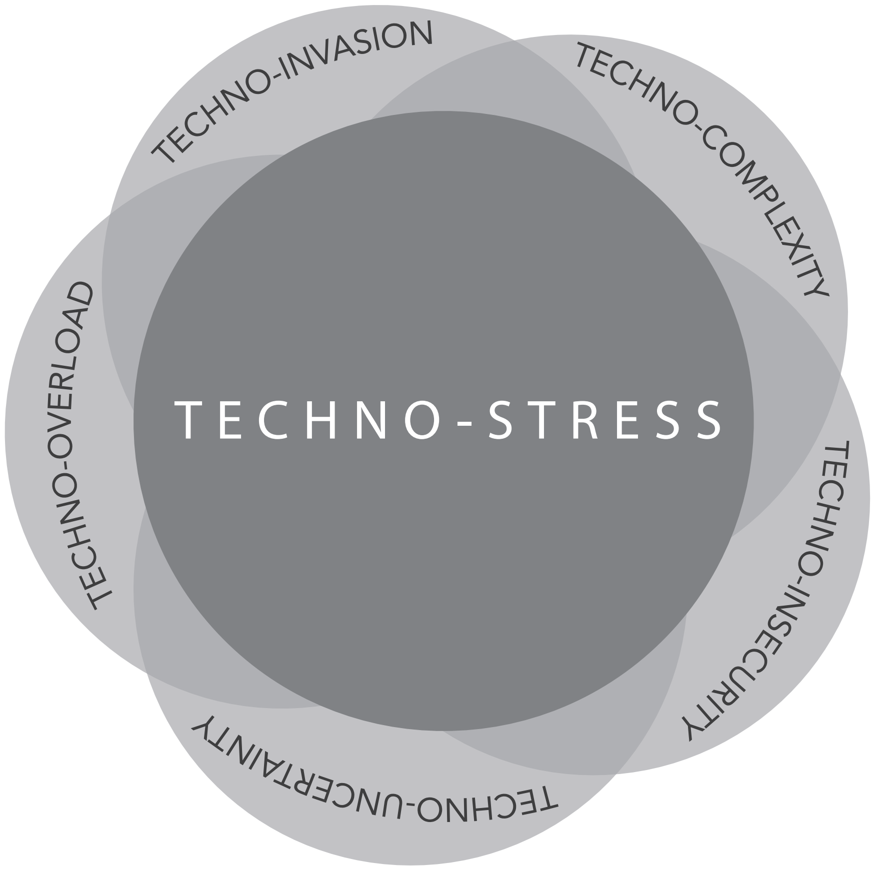


Figure 9. Techno-Stress Categories.

Techno-overload: increased workload, increased productivity, or a shift in working habits brought on by new technologies;

Techno-invasion: technology's intrusion into personal life, people spend less time with their families or on vacation and instead devote that time to learning about new technologies;

Techno-complexity: a lack of aptitude for understanding or coping with the complexity of modern technologies;

Techno-insecurity: employment insecurity brought on by technology (such as the worry of being replaced by workers with more expertise and the ongoing need to upgrade technological capabilities);

Techno-uncertainty: technology's lack of predictability (such as constant changes in computer hardware and software).

Technostress has been shown to have a **harmful influence on workers' mental health**, and as a result, it has been a significant topic of global scientific study since 2003. The graph below (**Figure 10.**) shows how this theme has attracted a growing number of studies in recent years (Bondanini et al., 2020).

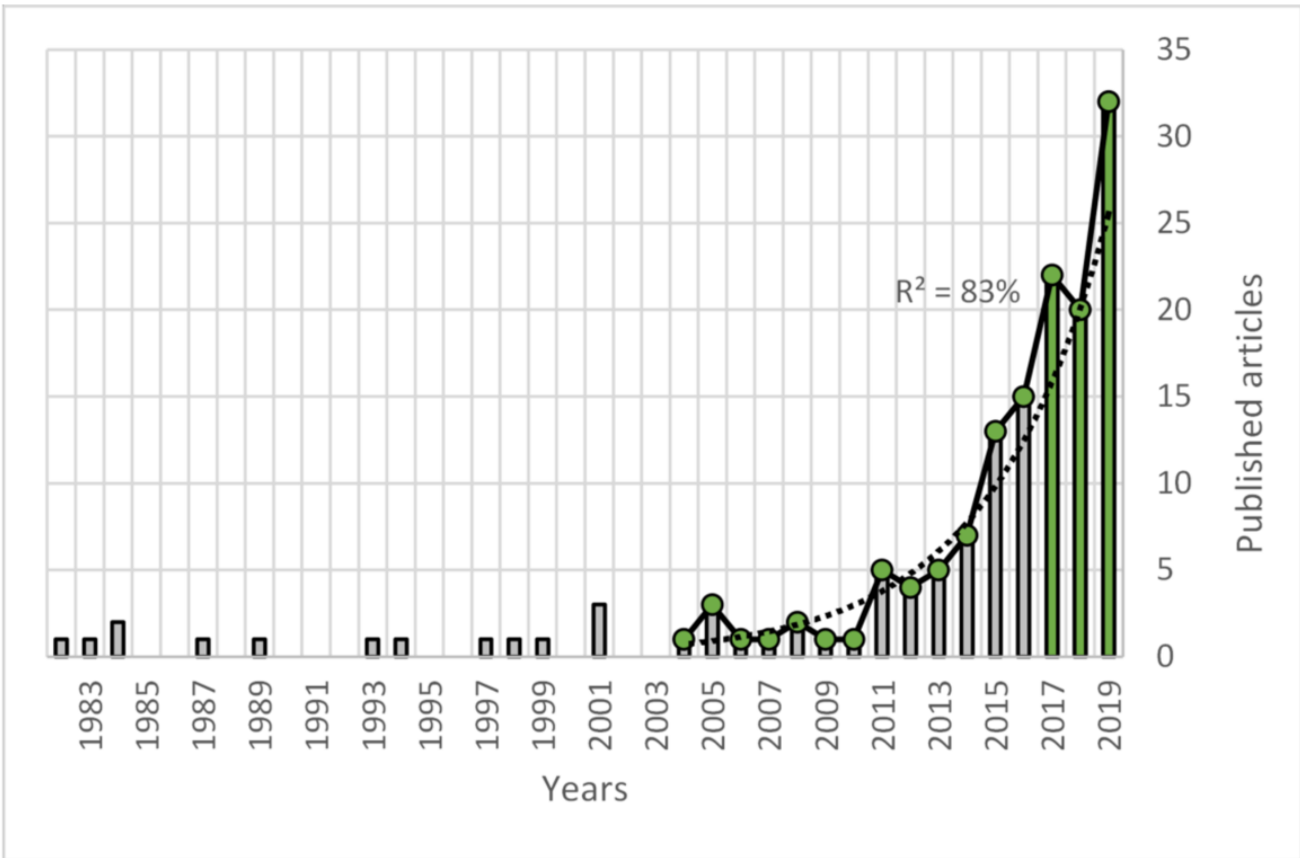


Figure 10. World scientific production growth.

The reason why there has been exponential research in the field of technological stress is linked also to the community awareness increase of mental health promotion importance. In the latest years, thanks to several worldwide campaigns, adult mental health care has shifted from the alienist era of stand-alone psychiatric institutions to join the mainstream of general health care (McGorry et al., 2022). The main intention of these publications is therefore to shed light on a theme existing in our society and to resolve its negative effects on human health, which relate, in particular, to two separate but interconnected experiences that the person can feel during the **interaction with technology**: the struggle to embrace computer technology and the over-identification with it. Both these sensations **can be carriers of extreme stress**, which can contribute to health issues, including migraines, hypertension, and heart illness. Additionally, an anxiety overload can lead to **job burnout**, which includes emotional tiredness and job discontent. The **mental breakdown due to frequent use of computers within the workplace**, which isolates the mind from the surrounding reality, is also accentuated by segregation into internal spaces acting as **physical barriers between people and what is present outside**. These multiple factors affect the human relationship with the external environment caused mostly by the increasingly hectic lifestyle aimed at productivity and driven by today's society, new technologies and the interior environments built by man himself. With the passage of the centuries human beings have been led to consider themselves increasingly as an entity separated from nature, segregating themselves from it by means of internal spaces, but through several studies it is evident that the **survival and mental well-being of the human being are** still inextricably **intertwined and dependent on the natural world** (Schultz, 2002).

"Technology has taken over and there is only one way to stop it: take control back of our own lives. Use it when you want to, not when it wants you to".

Donald A. Norman

3.2 Focusing on Technostress Prevention

The analysis of numerous studies has shown that the **employer must take multiple breaks during the working day**, in order **to maintain the correct performance in the workplace without the risk of a health disorder** (Cropley et al., 2022). In fact, taking rest periods during the job routine has been linked to **reduced fatigue** (Trougakos et al., 2014), **increased work engagement, motivation, and energy** (Demerouti et al., 2012; Fritz, Lam, and Spreitzer, 2011; Kühnel et al., 2017) over the long and short term. The growing dependence on digital technology might lead to stress and other health issues due to the lack of social connection, which is one of the factors that contribute to technostress, and can be avoided through moments of detachment from working life and interaction with other people (Molino et al., 2020). According to main guidelines of the European Health and Safety Regulations of 1992 (Health and outcomes than usual normal breaks concerning a major recovery process, improvement in physical and mental health as well as job performance and creativity (De Bloom et al., 2014).

To resume, one way **to counteract the harmful effects of technostress** and prevent future mental illness **is to be immersed in the natural environment while taking brief but frequent breaks during the working day**. To achieve the maximum possible benefits of this practice and counteract the loss of attention due to portable electronic devices, exposure to relaxation immersed in a natural environment **must occur with a complete detachment of the person from** his/her **tasks**, putting aside the computer and not using the break to talk about work (Jiang et al., 2019). Among the different stimuli that are found in the natural world, those most difficult to reproduce in a closed environment are mainly

Safety Executive, 2013) **the breaks should be taken before the onset of fatigue, not to recover mental balance**, and when performance is at a maximum, before productivity is reduced. Job rest is needed to reduce the on-screen workload, and breaks are more satisfying when short and frequent rather than longer but fewer in number. The time spent not looking at the screen, seem to be more effective in relieving visual fatigue than formal breaks. Where possible, users should also have the freedom to carry out their tasks, as individual control over the nature and pace of work allows for optimal distribution of effort during the daily job routine (Henning et al.,1997). However, despite the growing awareness of the importance of disconnecting the mind and body from work through rest, **many employees find themselves having to give up these moments**. The various reasons were investigated through a study (Phan, 2021) which shows that although the worker may want a break because of the negative experiences (fatigue, negative effects and performance problems) he/she encounters due to high workloads. However, they are discouraged from taking a moment of rest **to pursue a short-term goal** that they would otherwise be afraid of failing to accomplish in time. The article shows not only that the break-taking behaviors of individuals are mainly driven by fatigue, but that there is still a way of thinking about productivity that leads to a **paradoxical consequence of stress and therefore counterproductive**. **Another way to recover from stress is the exposure to natural stimuli that has been shown to promote relaxation, boost wellbeing, and raise work satisfaction (**Korpela et al., 2010), (Bowler et al., 2010). The combination of a relaxation session with an exposure to nature have more favorable two: sunlight and wind, between these the breeze of the outside world in particular, is the one that goes to interact with the majority of our senses. **The wind returns a visual stimulus through the pressure of air on objects, a tactile stimulus through our skin receptors**, even the auditory and olfactory through the rustle and movement of what surrounds us. Often the air is described as something invisible that is not shaped or colored but among all the elements is the one that most dialogues with our body. Furthermore, it has been demonstrated that even well-ventilated interiors cannot equal the t**herapeutic effects of natural outside surroundings** since they do not e**xpose people to** the same levels of **biologically active substances** that are **essential for** our **well-being** (Ross and Mason, 2017).

3.3 Arising Research Aims and Questions

Through the analysis of several studies, there is evidence of the growing awareness in recent years of the importance of mental health, which is in contrast with the increase in the negative effects of technology in the workplace that fall within the "technostress" sphere. Among the different ways to counteract this problem, the use of frequent work-breaks during the daily routine, spend in an outdoor environment rich in natural stimuli and, in particular, exposed to the wind, is a solution, according to the articles mentioned above, valid to prevent future mental breakdown from work. Starting from this initial hypothesis, other factors are added, among which that of self-care. In fact, the study previously analyzed (Phan, 2021) showed that although the awareness of needing a break is present after spending countless time in front of a computer screen, many employees feel overwhelmed by the upcoming responsibilities and deliveries and, while knowing the benefits that a mental break from work would bring, they decide to give up working rest moments creating a paradoxical situation of fatigue and therefore less productivity. **Taking care of ourselves is therefore still today a significant obstacle** despite the awareness of need. In fact, **humans can be more objective and rational towards other people rather than themselves**. This asymmetry between the perception of self and the perception of the other is due to a kind of emotional blindness, a product of the phenomenological position of naive realism (Pronin et al., 2004). **Empathy therefore allows to reason in a more detached and realistic way, but still requires** a state of fact that those who test must understand and r**ecognize the feeling of the other**, since only through the models of perception and action is activated the knowledge of those who witness the phenomenon (Hofelich and Preston, 2012). On one hand, there is a sentimental detachment so that the person does not find at the forefront of the action and can therefore perceive the malaise and needs thanks to a rational perspective, but on the other, for this to happen, there must be an identification and a memory of a similar physical or emotional experience. Based on what previously said, the deduction of how unconsciously people know what they need, but in reality they don't always put it into action, is confirmed. Future transformation requires a transition from a vision that is only focused on technological progress to one that is human-centered. The designer's job is to build on new technological opportunities to create goods and services that ultimately improve people's lives from a human needs-centered perspective (Shneiderman,2022). For this reason, **new innovations in technology can re-educate man to take care of him/herself by means of an empathic approach**.

The amount of information collected up to this point was necessary to outline the main theme of the project from which this thesis arises, that can be considered as a comprehensive summary and solution of the problems that emerged.

The topic is therefore that of technology that must reconnect our body with nature when we should take a work break. The process takes place through a smart wearable that is no longer a wearable surface, but an element that interacts with us and that we must take care of, but that, at the same time, reflects our own needs. This starting theme breaks down into several reflections in the light of previous research:

1_Technology is itself the solution to technostress, it is no longer merely focused on innovation and pure productivity, but on the contrary, to the well-being of man through the use of smart wearable research driven and not market pull.

2_ The reconnection between the human being and his roots, that is the natural environment, takes place in the light of prevention **for** an important and delicate issue, that of **mental well-being.**

3_ The interaction between the body and what is worn is enriched with meaning, through a reproduction of natural stimuli that allow man to "feel" a deep connection with clothing and be tempted to take care of it. Without an interrelation, we are not able to recognize an action in which to identify ourselves and thus create a relationship of empathy and go beyond the perception of an object as such and not as a living being.

4_ The reproduction of biomimicry not in an aesthetic sense, but in the creation of an object that reproduces creating deep interactions between external and internal, nature and man.

This thesis, through the project BIOMIMICRY WEARABLE therefore proposes an experimental approach in the creation of smart wearables to test the effectiveness of this initial hypothesis, the result of a thorough collection of academic studies.

3.4 Thesis Scopes

Once the main theme of using new tech to reconnect the body with nature during the work break is defined, the next step requires a **more in deep definition in all the aspect surrounding the hypothesis**, considering for who the project is needed, how it should interact with the user, the moment in which this happen and, in particular, why it must take place.

Why: the main goal, as previously said, is to reconnect the body with nature through a dynamic relationship between the user and the wearable. In order to **achieve a better quality of users' life**, the technology should change its purpose from a mere innovation one to a human need centered perspective, so that the wearable became no more an object to use, but a real actor, it will have needs as well as the wearer and taking care of it will indirectly lead to taking care of the person itself.

What: the aim of the project is to **reconnect the body with the nature** with the objective to improve a more relaxing environment and to increase the focus and productivity after the work breaks, without side effects on mental health in the short and long term. The possible paths analyzed to make the user feel at ease are mainly two: or to recreate those exterior environments internally or to entice the person to go outside. Due to ethical reasons, reproduce the nature inside couldn't be the answer to the lack of the external world exposure, the solution is then focused on persuade the office worker to go outside. To achieve the core of make people want to go away from the office, is necessary to show to them what they are missing. The role of the smart wearable is then to dialogue with the indoors through the **real-time reproduction of what happens outdoors**, so as to attract the curiosity of the wearer.

Who: the target refers to individuals who want to prevent stress by working indoors in front of the computer screen, because to treat people already suffering from mental problems, exposure to natural stimuli is not enough. The ideal focus is therefore the **workaholic** who cannot detach the mind from work and needs to be re-educated through a process of empathy for what he/she wears.

When: according to the European Regulation on Working Conditions (Cabrita and Cerf, 2019), those who work at the computer for at least 20 hours per week are allowed **15 minutes of break every two hours** of effort in the office. At the end of this two-hour interval the customer should be encouraged to get out and immerse themselves in natural stimuli. Therefore, the project intends to make the user respect his/her psycho-physical needs, keeping in mind these fixed intervals.

Where: the location of reference is the **office due to its sedentary nature**. In fact, working in an indoors environment in front of a screen, usually leads the user to don't move during the day, this condition can increase both the mental and physical diseases of the worker. The wearable aim is to interact with the person through some vibrations and visual stimuli that will stop only when the employer goes outside, those will end in a more effective break without work distractions so that the mind could detach from the pressure of the job and be totally immersed in the nature.

How: the r**eproduction of the external wind** has been chosen between all the different natural stimuli because it affects as many human senses as possible, touch and hearing by the vibration of the air in contact with the person and sight through the movement caused by the pressure of this on the objects. Given this multiplicity of factors across which it manifests itself, the main objective is to reproduce them simultaneously within the office, so as to dialogue with the user and to have more interactions from which to be tempted to exit. The wind tactile and auditory stimulus can be recreated by controlled vibration, while the visual aspect thanks to a shape changing activity of the smart wearable, that will show the mutability of nature through the movement of air.

Final concept: to resume the previous factors, **the project will be a device to reconnect the body to nature through the concept of empathy for the wearable. The person by the manifestation of his dress/accessory that reproduce the visual, tactile and hearing sensation of the wind, can take care of him/herself and of his/her physiological needs, such as those to detach the view and the mind from work every two hours and relax thanks to the outer natural stimuli. The transition between internal and external is due to the activity of the different smart wearables that attract the user's curiosity for what happens in the outside world**.

3.5 Project Paths

In order to recreate interactions of wind with the human body within the office, two main paths were designed to stimulate the user's sight and enacting on haptic perception. To achieve these actions as ergonomic and effective as possible, there is the need to r**ecreate an environment full of outputs from two different smart wearables which are interconnected between each other to achieve a single purpose**. The **one focused on the tactile feeling** must be placed **in contact with the user's skin**, because otherwise the interaction would not be perceived, while as for the **visual stimulus** the wearable must be thought in such a way as to be easily a**ccessible by the human eye**. Taking the office as the basic reference point, that is, the place identified as the starting point to act, and, as the key moment, when the worker is sitting in front of the screen of a computer, several considerations follow. First, starting from vibrations as a touch-sensitive stimulus contact need to take place in significant parts of the body without unnerving the person, through several field tests the forearm part is considered to produce a test prototype. Whereas, for the visible interface, an object placed on the operating bench and that has such a significant surface to attract person sight must be considered, like a computer bag.

3.6 Chapter Visual Resume

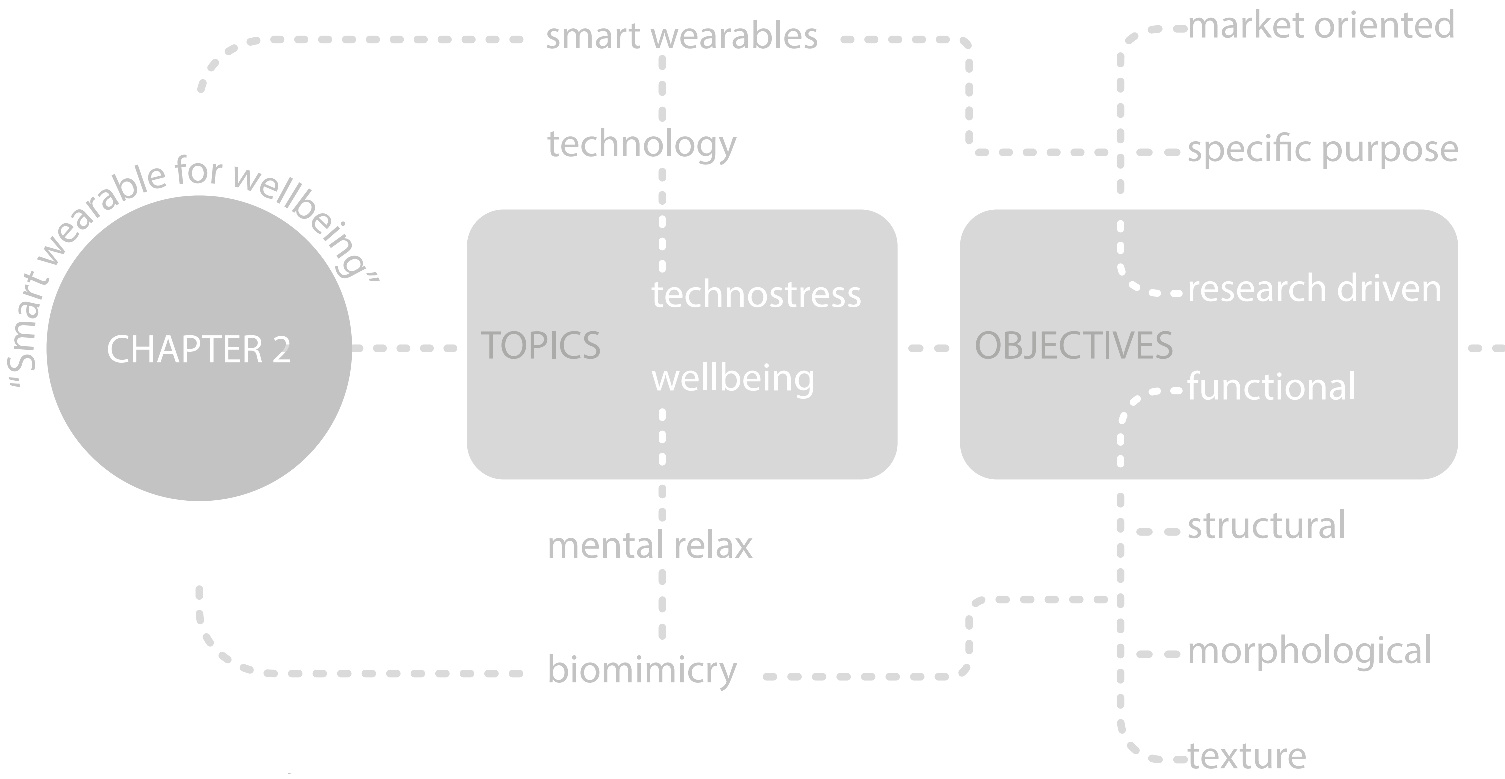
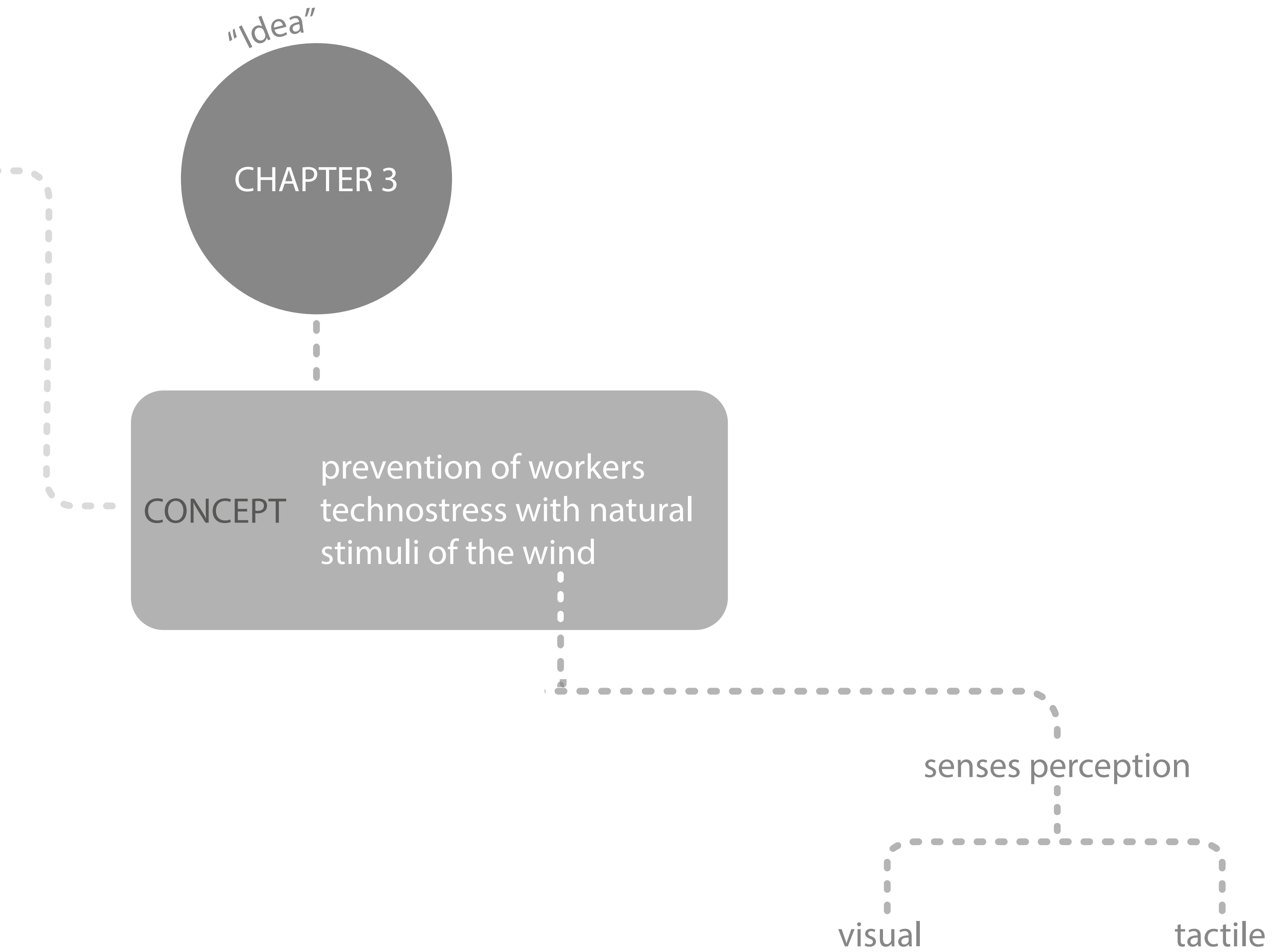


Figure 11. Chapter visual resume.



"Idea"
CHAPTER 3
CONCEPT
prevention of workers technostress with natural stimuli of the wind
senses perception
visual
tactile

4. FIELD RESEARCH

4. FIELD RESEARCH

4.1 Working as Resident to Pauline Van Dongen Studio

The **main part of the project** was **developed inside the Pauline Van Dongen studio**, a Dutch reality established in 2010, specialized in wearable technology. Its collaboration with the FTalliance organization allows the design process to shift from a mere ideological and research part, into a more practical one. The **Ftalliance** is a **residency programme** which weaves universities and companies to co-create fashion-tech future talents. During this period, the experience will result into a transferable model of company and students interactions, from idea conception to product prototype development. The purpose of the Project is to ensure the ongoing innovation in the European Fashion-Tech sector by providing emerging talents with relevant competencies and know-how to enter the job market. The students in this program are trained in those fields together with professionals and companies located in different parts of the world, to create new projects that benefit both the intern, the university and the company itself (Fashion-Tech Residency, n.d.). Indeed, the concept was brought forward in the light of a space surrounded by different collaborators and expert in the field. **The location of the studio** is in **Arnhem, Netherlands**, inside an industrial complex in which other fashion designer, architects, product designer and craft professionals are settled. For this reason, the workflow in this building is constantly in contact with an artistic environment and several common places, that provide machinery as laser cutting, sewing machines, photography rooms and spaces for woodworking. All these elements were crucial for a more inspirational and direct on material trials. In particular, the Biomimicry Smart Wearable was developed mainly in the company **field of smart textile researc**h, followed by the **head of the studio Pauline Van Dongen, a fashion designer and researcher specialised in wearable technology** and founder of the studio. In addiction the project was **supervisioned by other professional as Anna Wetzel and Ellen Britton**, which deal with all the design process, from concept development up to hands-on prototyping. The **company areas of research** shown in **Figure 12.** are mainly three which are design oriented, so based on emergent human needs: **Solar Cells, Haptic Technology and Shape Changing Materials**.

Figure 12. Pauline Van Dongen fields of research.

Pauline Van Dongen Case Studies:

Figure 13. Solar Shirt, Pauline Van Dongen, 2015

An example of the first research field is the Solar Shirt (**Figure 13.**), its innovative and progressive integration of solar cells into textile allow it to incorporate 120 thin film, able to charge a smartphone or any other

USB compatible portable device.

Inside the area of haptic technology there is the clever denim jacket ISSHO (**Figure 14.**), it gives off the impression of receiving a light stroke on the upper back. The external layer responds to personal touches based on the wearer's behavior and acts as inviting the person to be present in an increasingly accelerating world.

Figure 14. ISSHO jacket, Pauline Van Dongen, 2017

Under the shape changing material category is the garment Skinfeel Apparel (**Figure 15.**), which shape is composed by wing flaps placed in different parts of the long jumper's body, in order to achieve an optimal level of areodinamicity.

Figure 15. Skinfeel Apparel, Pauline Van Dongen, 2016

These case studies therefore fall into the three categories of research because they are considered by the studio significant for responding to people's current and future needs. Indeed, the **design method of the brand starts from the research about the human body in relation to its surroundings** that includes the concepts of change, movement, energy and perception, due to the fact that future of fashion lies in its premise to be dynamic. Through the partnerships with different industry, research centers and brands, the firm is able to develop innovative and cutting-edge products that are intersection of fashion, textile and technology.

4.2 Biomimicry Wearable Project and Studio Intersection

Starting from the main theme of the project, that is to reconnect the body with nature through a smart wearable able to reproduce the visual, tactile and hearing sensation of the wind, certain fields of development, within the reality of Pauline Van Dongen, were considered. Analyzing therefore the main areas of the brand interest, **the hypothesis is to recreate the stimuli of the external world breeze through haptic technology, that is the tactile sensation of the body, and the shape changing material, that concern the visual aspect**. In Figure 16.

It's shown the passage from the emergent needs analyzed in the previous chapters, to the concept that intersects with the Dutch reality and finally the main project objectives.

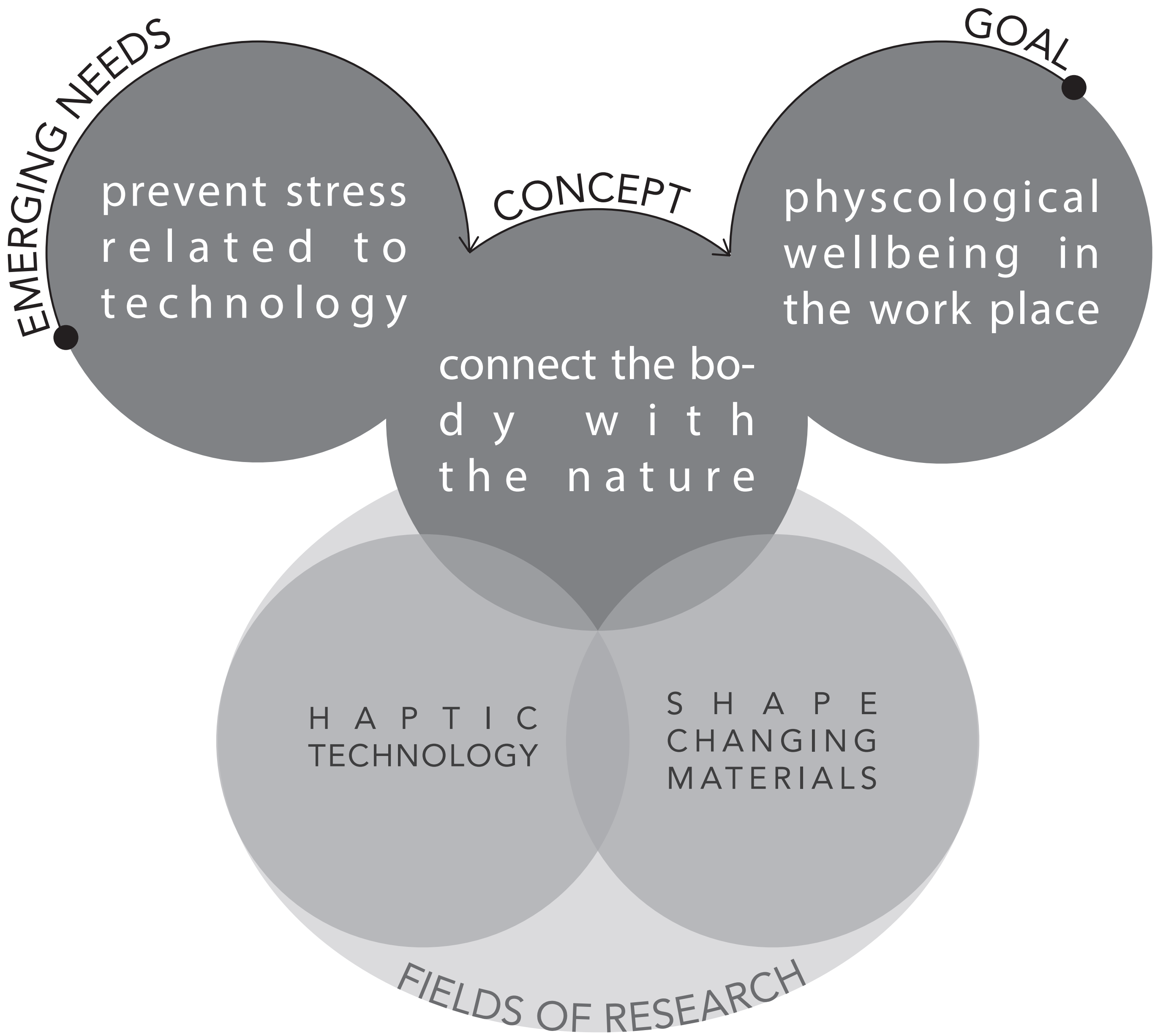


Figure 16. Project passages

4.3 Case Studies Analysis

Once the design paths and the fields for their realization have been determined, several c**ase studies relevant for the design paths**, have been selected for the **future prototype inspiration**. In particular, following two fields of research, the selection cryteria subdivion can be defined on those example related to the visual stimulation and the one more connected with the tactile experience.

4.3.1 Visual Stimulation Case Studies:

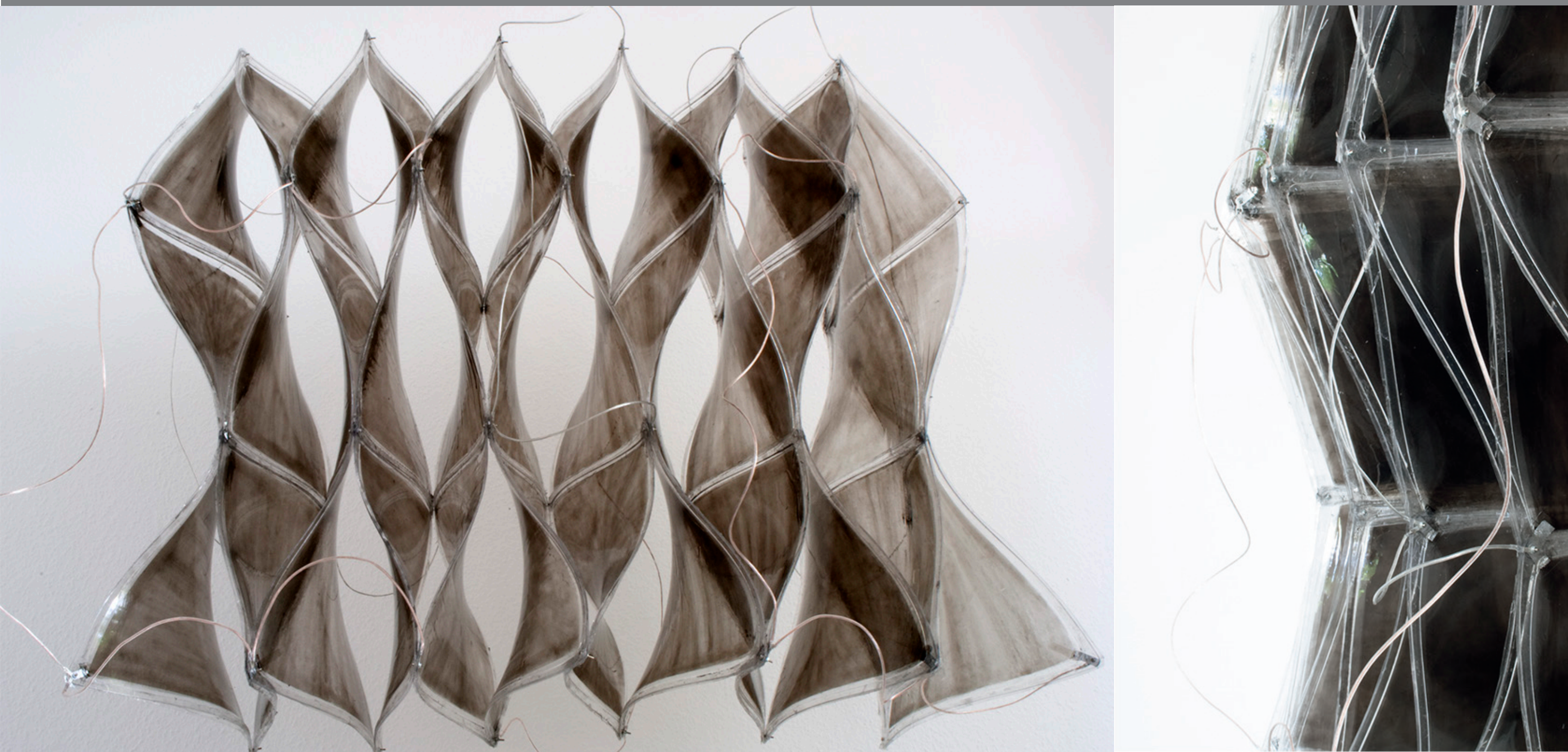
Category	Visual Stimulation	Case study n.	1
RESPONSIVE SURFACE			

Designer / brand	Paula van Brummel	Product description
Years of launch	2015	The Responsive Surfaces project is an interacti- ve surface inspired by the Mimosa Pudica plant texture, it responds to tactile stimulus with visual feedback. The system operates through a capacity sensor that is able to understand when someone is in contact with the smart textile and activate the shape memory alloys, moving horizontally the upper layer.
Biomimicry category	Texture	
Wearable tipology	Research driven	

Strength	Weakness
Great natural visual effect	Very complex, many materials and layers, more waste in the production

Category	Visual Stimulation	Case study n.	2

SHAPESHIFTS



Designer / brand	Manuel Kretzer
Years of launch	2010
Biomimicry category	Texture
Wearable tipology	Research driven

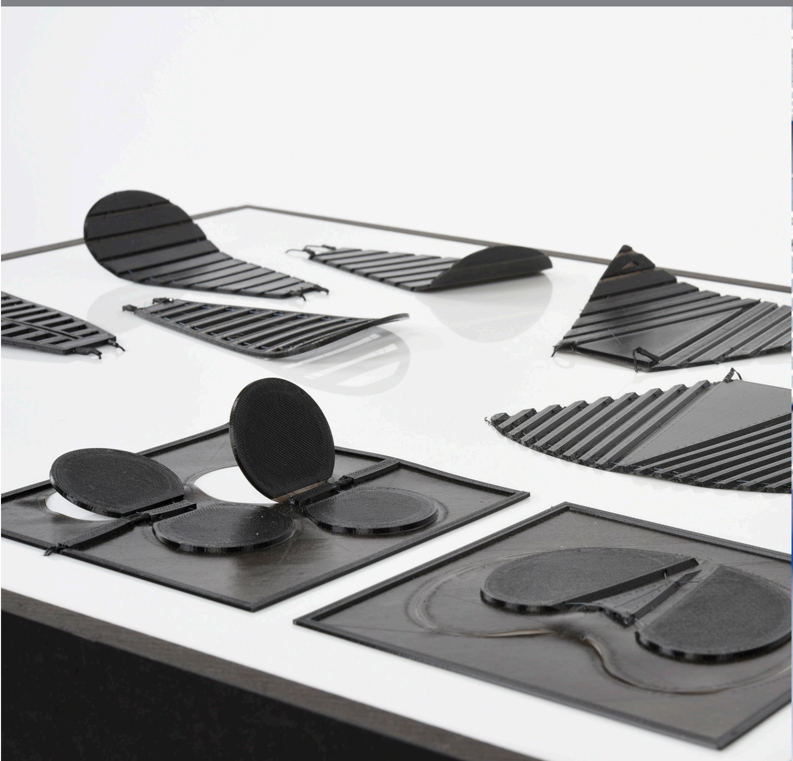
Product description

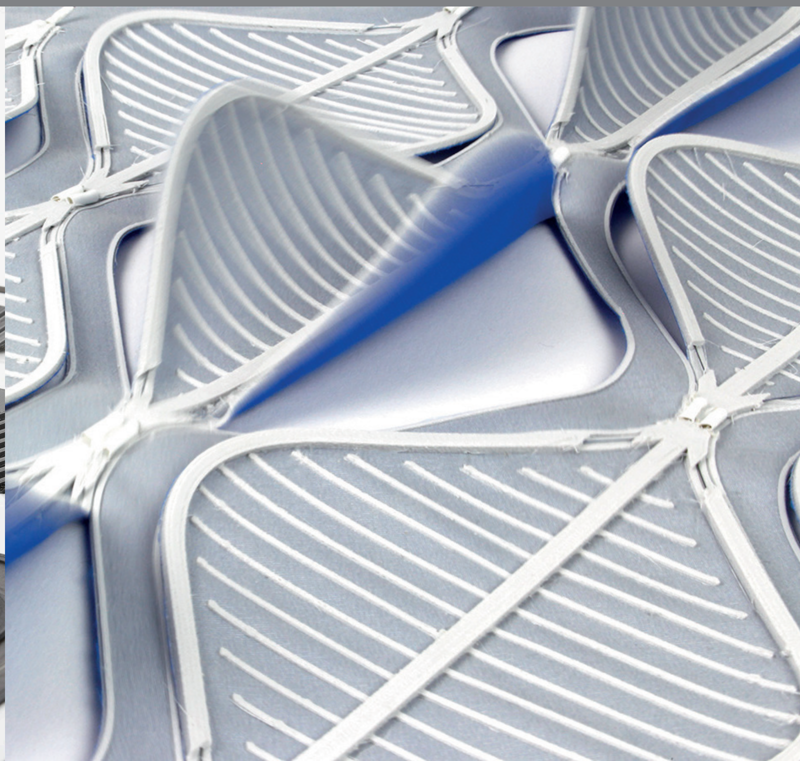
Shapeshifts is based on the use of electro-active polymer (EAP), which allow a ultra-lightweight, flexible material. In addition, this particular composition gives to the final product the ability to change shape without the need for mechanical actuators

Strength	Weakness
The structure allow a very effective movement	Low in natural effect, the final look is more technical

Category	Visual Stimulation	Case study n.	3

EMBEDDED MOVEMENT





Designer / brand	Paula van Brummelen
Years of launch	2019
Biomimicry category	Texture
Wearable tipology	Research driven

Product description

Through embedded shape-changing materials, the surface structures is capable of reacting to changes in their environment with movement. 3D printing and casting processes enable shape memory alloys to be integrated into surfaces.

Strength	Weakness
The structure allow a very effective movement	Low in natural effect, the final look is more technical

Category	Visual Stimulation	Case study n.	4

SHAPE CHANGING BODY

Designer / brand	Pauline Van Dongen
Years of launch	2020
Biomimicry category	Texture
Wearable tipology	Research driven

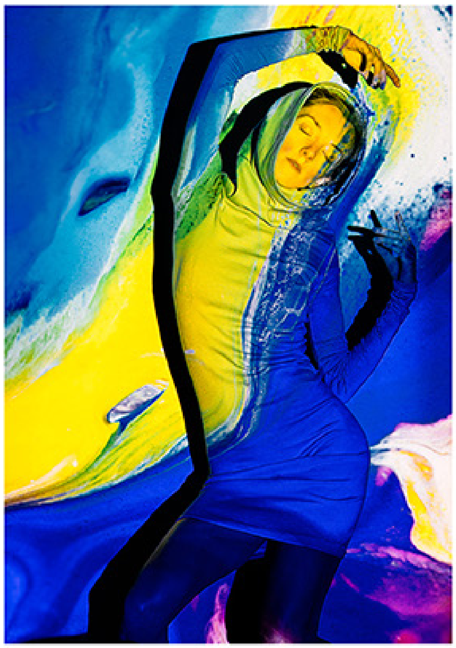
Product description

The body which is composed completly by neoprene, has two intersecting surfaces. the one above with vertical cuts and the second with partially cut shapes, so that they can fit into the cracks of the first layer. Thanks to the body movement, starting from a flat structure,it will be obtained a three-dimensional effect.

Strength	Weakness
Very natural, minimal, and effective design	The shifting of elements is activated only when the body is moving

4.3.2 Tactile Experience Case Studies:

Category	Tactile Experience	Case study n.	1
MAGIC LINING			

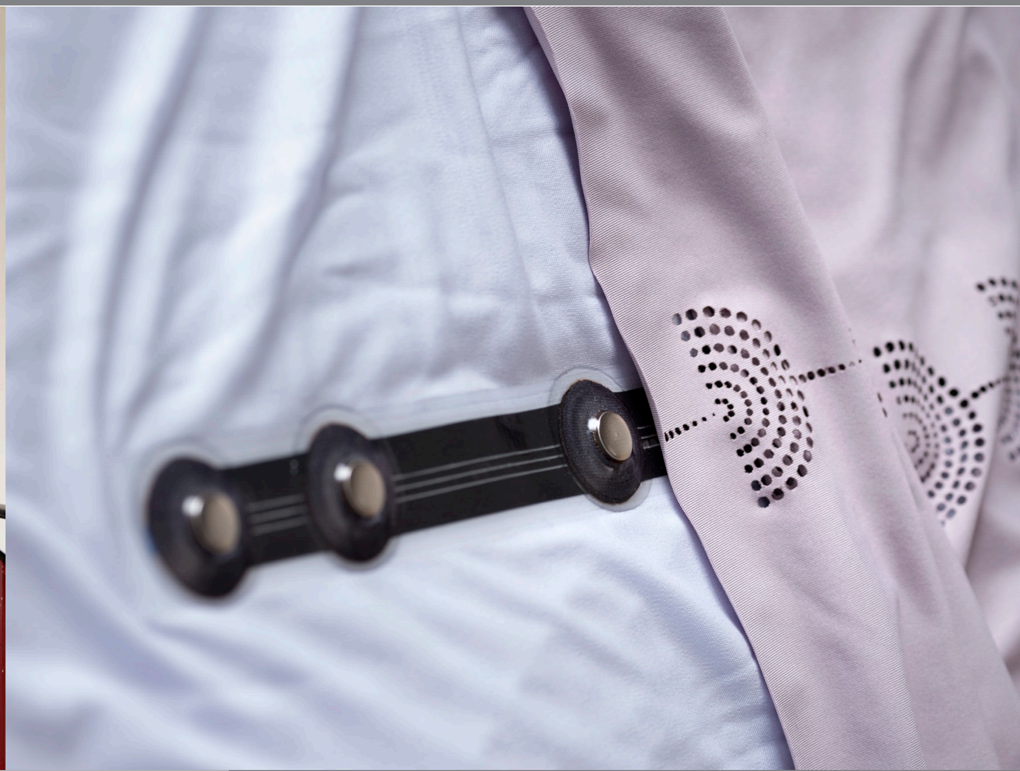


Designer / brand	Kuusk, K., Tajadu- ra-Jiménez, A., Väljamäe, A.	Research description
Years of launch	2020	Magic lining is a smart wearable that combi-nes fashion, design, art and neuroscience. The garment is composed by vibration motors integrated in the textile, those alter the body perceptions and communicate in a tactile way with the user, mimiking different natural stimuli perception such as rock, water and cloud.
Biomimicry category	Functional	
Wearable tipology	Research driven	

Strength	Weakness
Reproducing natural effects all over the body	Big number of electronic components

Category	Tactile Experience	Case study n.	2

MYSA SHIRT



Designer / brand	Pauline Van Dongen
Years of launch	2019
Well-being sphere	Mental health
Wearable tipology	Research driven

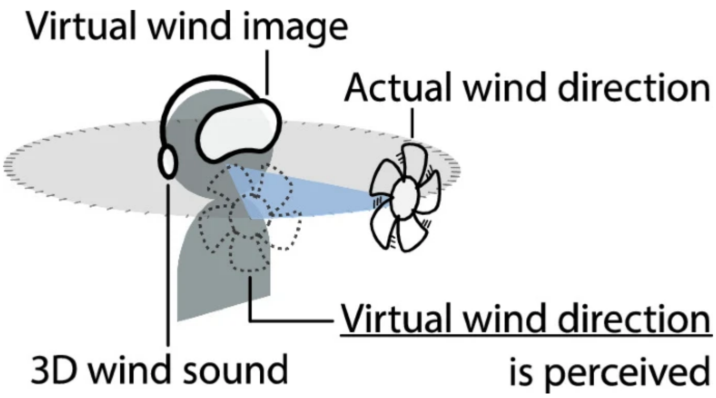
Research description

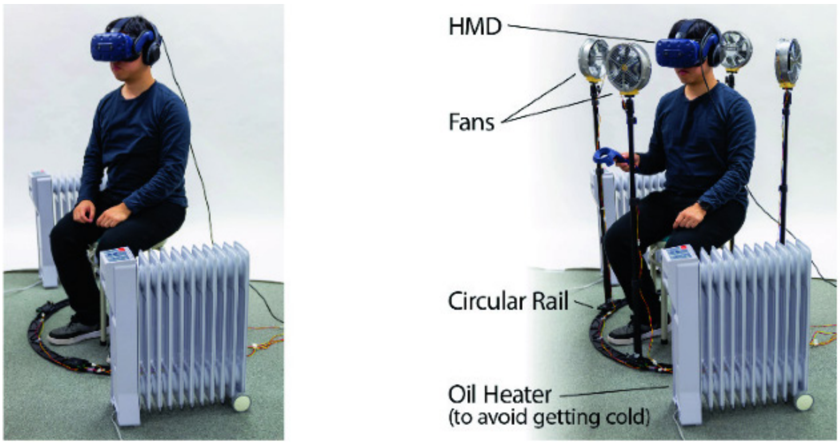
MYSA shirt has been designed to reduce work stress through vibrations, that help the user to perform relaxing breathing exercises. Six vibration LilyPad are positioned along the spine and connected to printed conductive tracks that are bonded to the fabric.

Strength	Weakness
Prevention of work stress and promotion of mental wellbeing	The design is not linked with the nature

Category	Tactile Experience	Case study n.	3

WIND AUDIO-HAPTIC CROSS-MODAL EFFECTS





(a) Before experiment (b) During experiment

Authors	Kenichi Ito, Yuki Ban and Shin'ichi Warisawa	Research description
Years of launch	2020	The research is based on the recreation of wind through the use of different sources. The method used to manipulate the perceived directions of wind by audio-haptic cross-modal effects is the showing of flowing particles virtual images, three-dimensional sounds of wind. The user study has demonstrated that adding visual stimuli effectively improved the result corresponding to certain virtual wind directions.
Biomimicry category	Functional	
Wearable tipology	Research driven	

Strength	Weakness
All the senses are stimulated contemporary, the output recreated is the wind	There is not yet a product, wearable or prototype, only tests on perception

4.3.3 Case Studies Selection

The case studies 1 of visual stimulation category, **Responsive Surfaces project by Paula Brummel, has been selected for the experimental development of the prototype** due to its effective natural movement, very similar to that of the wind blowing on the lawn (**Figure 17.**).

Figure 17. Responsive Surface

The use of these t**wo different surfaces**, wedged together through **vertical cuts** in combination with the use of **shape memory alloy**, will be the starting point for one of the thesis design paths. Whereas, the case studies 1 of tactile experience, **Magic lining, was chosen** due to the interesting components of this sample. In fact, **small piezoelectric motors inside the fabric and conductive thread for the circuit, easily integrable to the fabric**, have been used. Inspirational are also the different parts of the body taken into consideration for tactile feedback, these several points will be the **thesis project starting example** to test the effects of vibrations directly on the skin (**Figure 18.**).

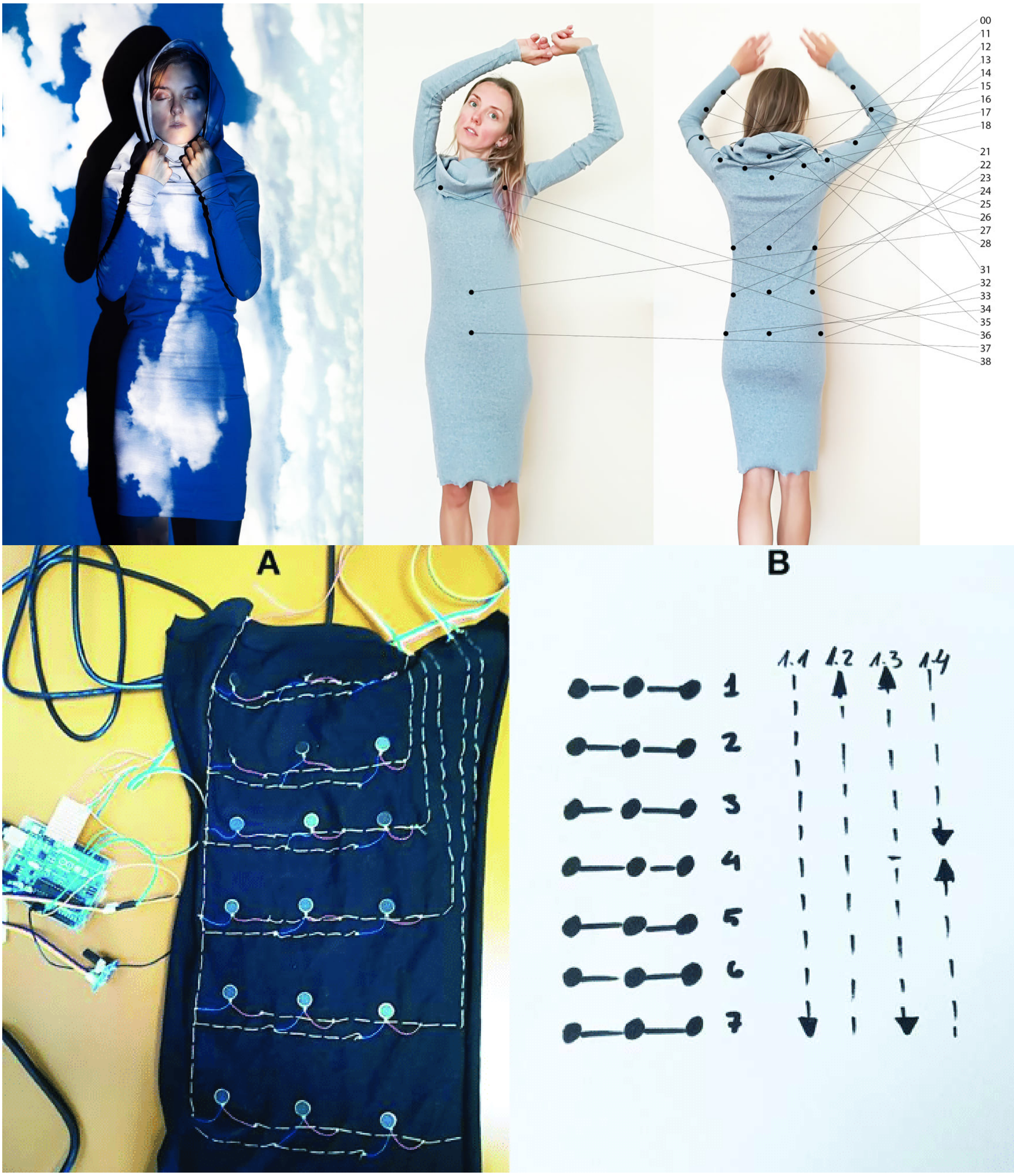


Figure 18. Magic Lining piezoelectric motors

4.4 Iterating Design and Prototyping Activities

Starting from the case studies analyzed previously, small tests were carried out directly on the research field, to hypothesize the shapes that responded optimally to the technology, the project, the human body and the purpose for which they want to be realized. **Rapid tests were carried out directly on the body** using the **Lilypad vibe board**, a small device shown in **Figure 19.**, optimal for its integration into the fabric due to its small size.

Figure 19. LilyPad Vibe Board

As a result of working directly in the studio, it was possible to carry out these tests directly on the people present, having already sufficient material available and collaborating closely with professionals. From the test **outcomes** across different parts of the body (**Figure 20.**), it has been inferred that those where vibration is **most perceived by skin receptors, in a pleasant way, are wrists**. The back and neck have a lower sensitivity of the vibrations, while in the arms this is almost completely absent. In addition, in the hands this stimulus is very strong and annoying, which is why the portion relative to the forearm has been selected as the most suitable to intervene.

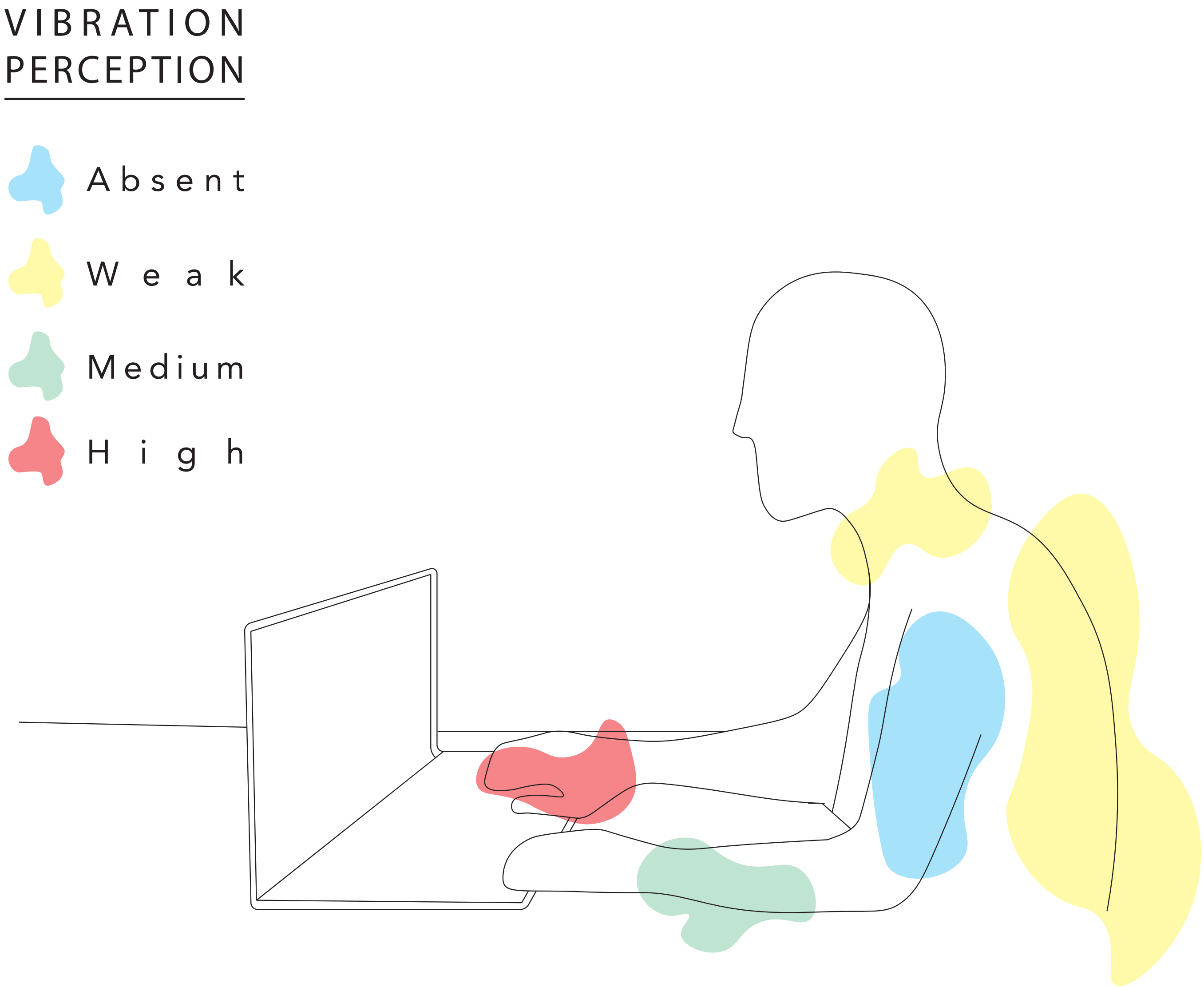


Figure 20. Vibration test outcomes on different parts of the body

For what concern the **visual stimulus**, starting from the target audience, the worker in front of the laptop screen, it is then assumed to insert these elements in a **part visible to the user while performing his duties**, that could be the arms and everything that **can be placed over the workstation, like a computer bag** (Figure 21.).

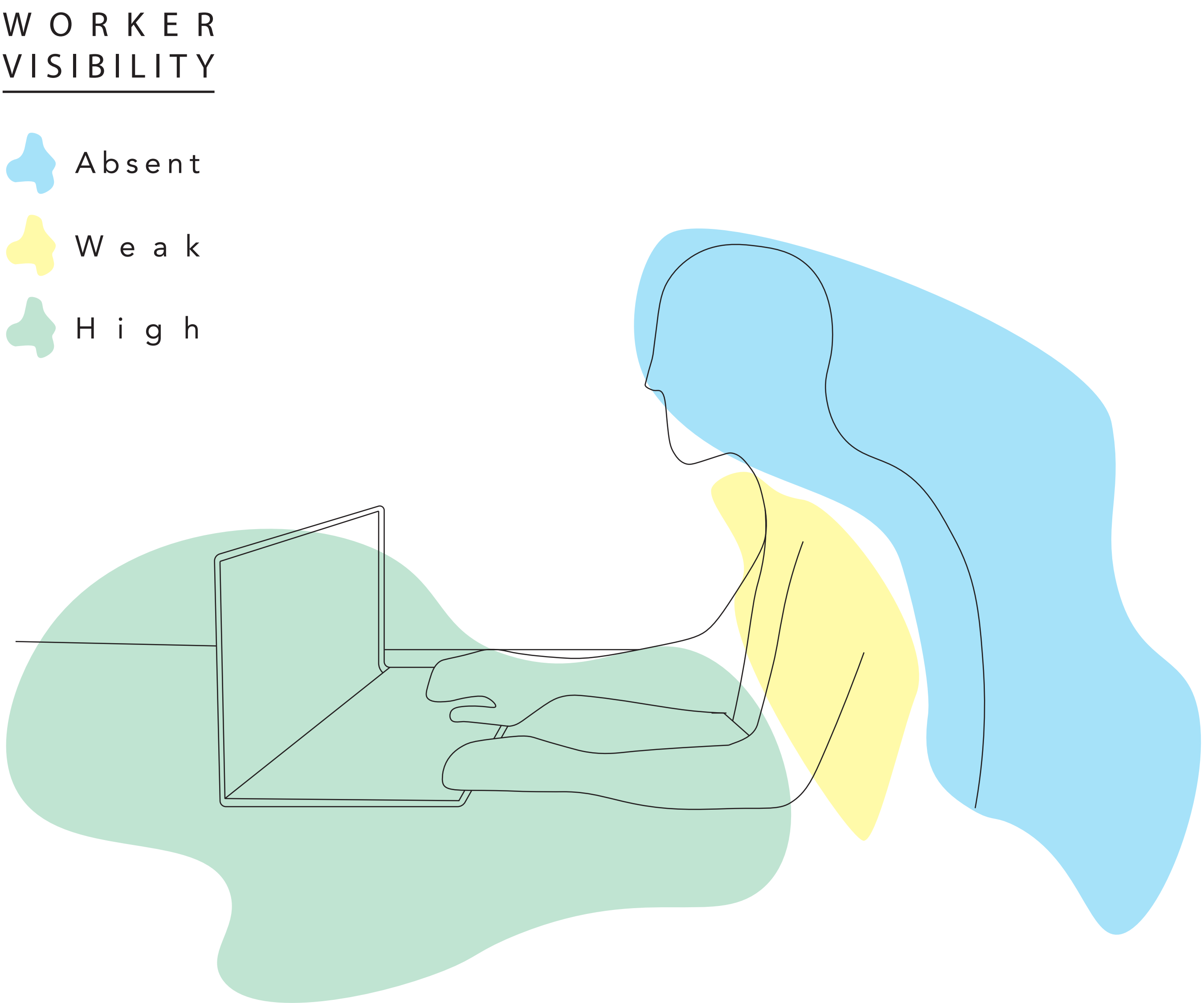


Figure 21. User visibility while working in front of a laptop screen.

However, consequent to the case studies analysis, the **nitinol shape changing alloys**, shown in **Figure 22.**, have been selected for the fabric integration, in order **to reproduce the wind typical movement on the natural elements**. For those materials is then necessary to carry out some considerations. In her years of experience in research in fashion wearable tech, Pauline Van Dongen has repeatedly experimented with shape changing alloys. She declared that to have an optimal functioning those required to be positioned on a flat surface, for this reason the design path will continue with the hypothesis of developing this visual element within a computer bag.

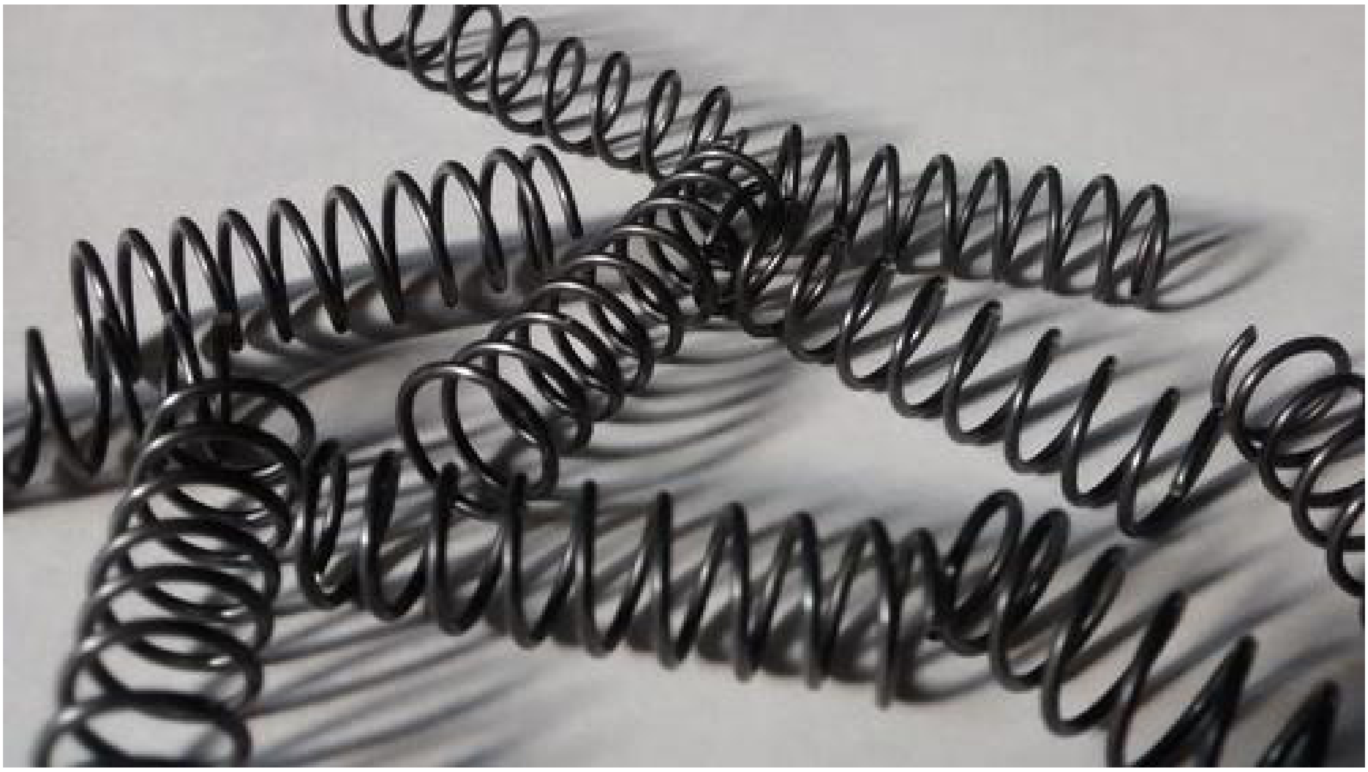


Figure 22. Nitinol wire

After defining the type of devices useful for the return of natural stimuli and their positioning, it was necessary to carry out **market research** (**Figure 23.**) to understand what colors and typical shapes were used by the workers for the elements previously defined, a smart wearable for the wrist and an interactive surface over the laptop sleeve.

Figure 23. Market research source Pinterest

The colors used are mostly different **shades of gray and black**, typically adopted for technical wearables and tha

through technology, is hypothesized the c**ombination of neutral colors such as black**, with **bright texture th**

world, such as pastel **green seams** (Figure 24.).

Figure 24. Color, shapes and materials moodboard

at recall technology and innovation. However, since the desire of the project to **reconnect the body with nature**

hat return the concept of air movement, such as metallic gray, and **small details** that **remember the outside**

The path to express the visual and tactile stimulus through the Lilypad vibe board and nitinol wire embedded in these elements, shapes and colors, starts from an **analysis of the wind characteristics**. In particular, the two quantifying variables through which wind is measured, are its direction in degrees and intensity in km/h.

The direction of the wind: it is the orientation from which the mass of air in motion comes. It is expressed in sexagesimal degrees, starting from 0° (north) and then rotating clockwise passing through 90° (east), 180°(south) and 270° (west), until returning to the north, to 360°. This measure is often identified by the graphic representation (Figure 25.) of the **Wind Rose**.

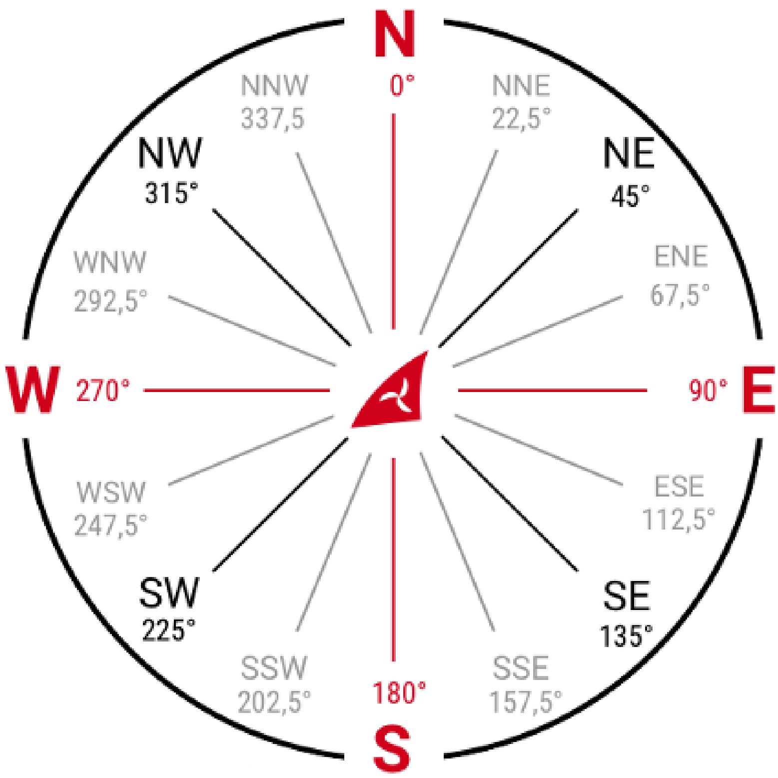


Figure 25. Wind Rose

Extrapolating the wind direction data in real time and transmitting them to the integrated circuit in the smart wearable, is necessary to **divide all the numbers ranging from 0 to 360 degrees into eight different intervals** depicted in Figure 26. To simplify the process, each of these ranges will be matched by a different action of the smart wearable.

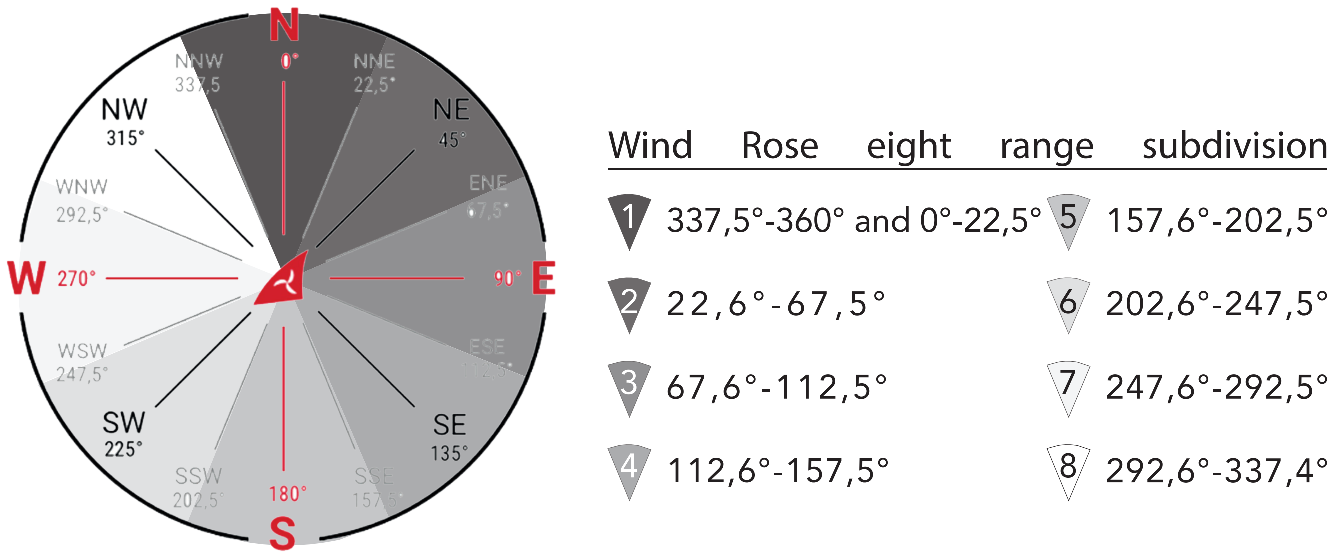


Figure 26. Wind Rose subdivision in eight different ranges

In order **to reflect the main cardinal points** in the interaction between device and person, **four different vibrating motors** will be placed inside the smart wristband and **four nitinol wires** will move the surface of the computer bag (**Figure 27.**).

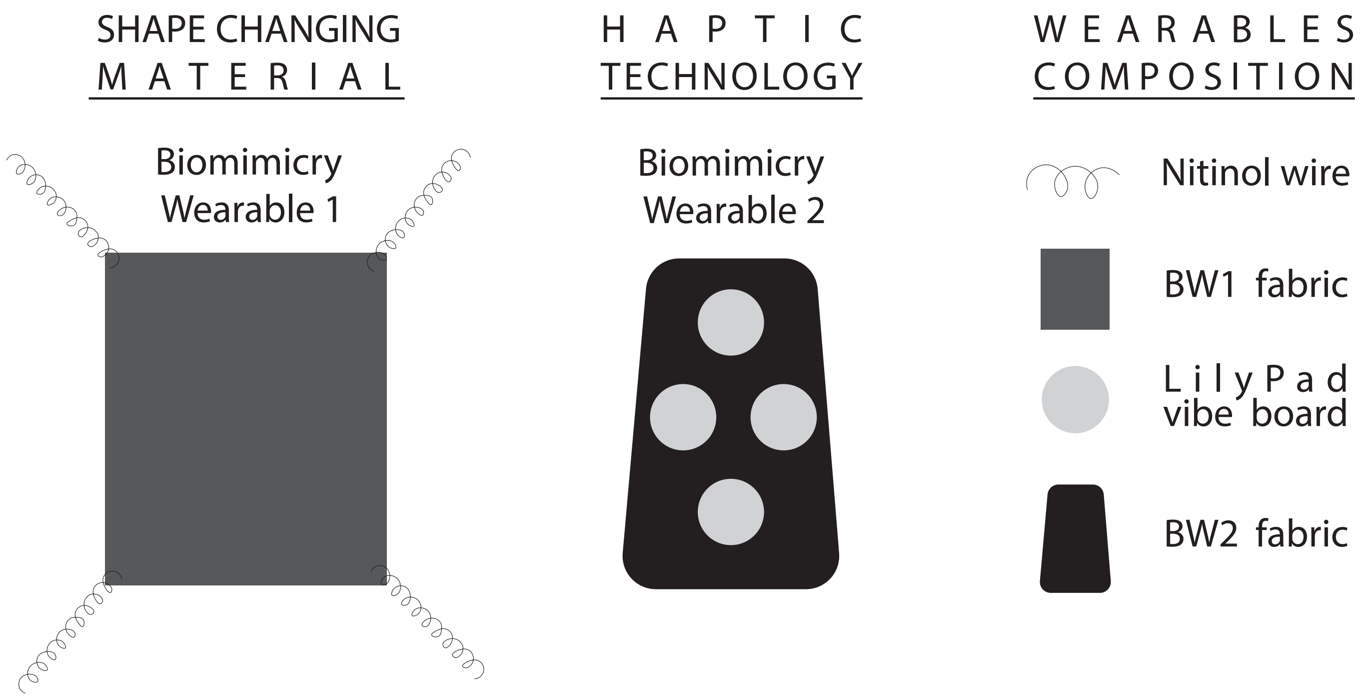


Figure 27. Biomimicry Wearables Composition

These **depending on the wind direction will interact at different intervals** as shown in the diagram in **Figure 28.**

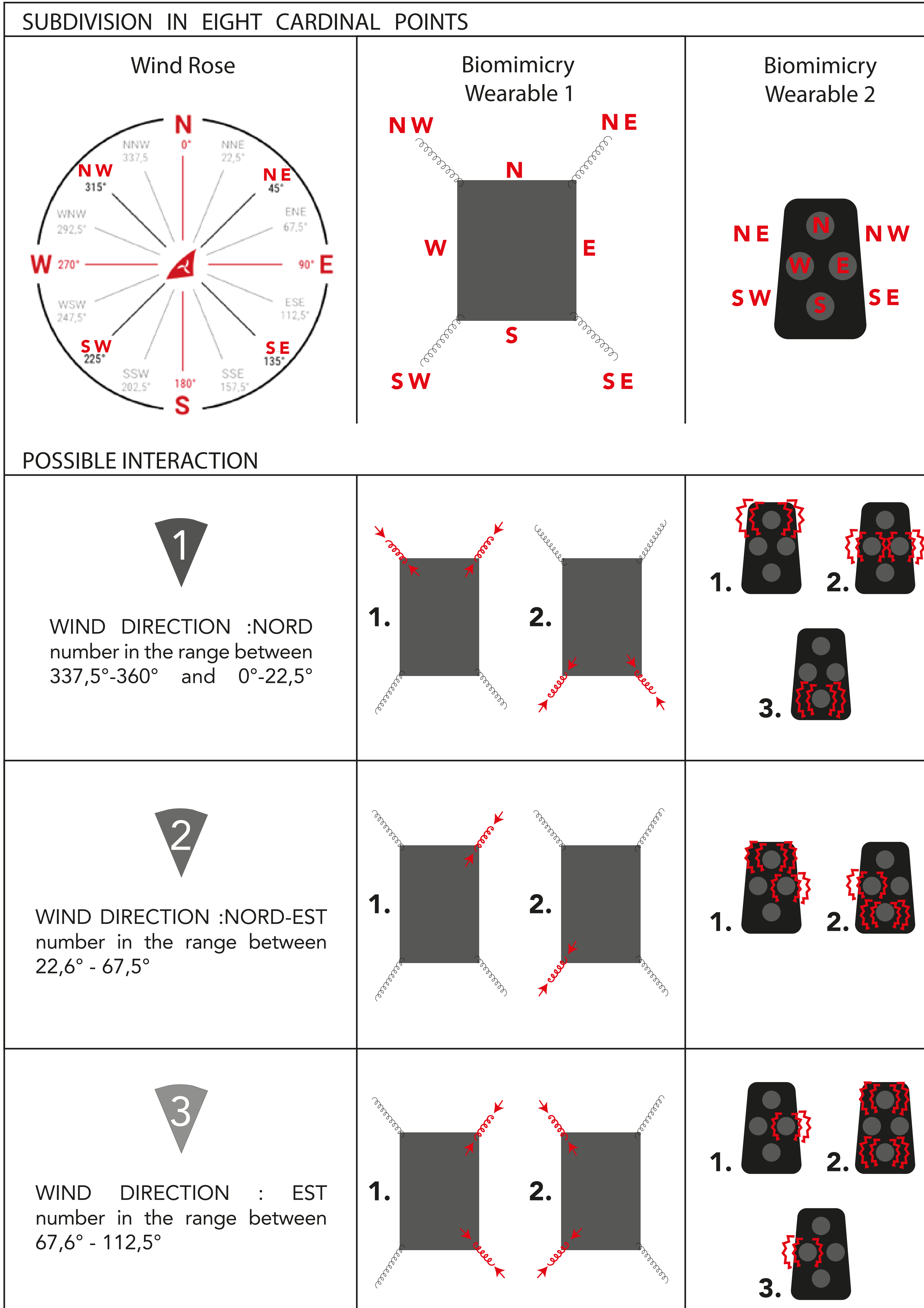
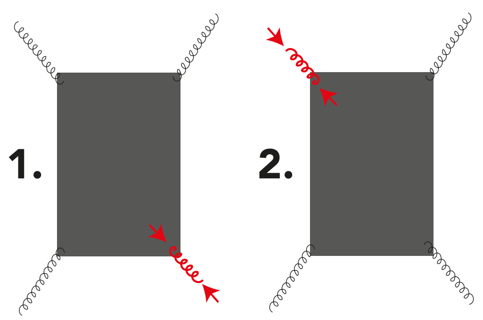
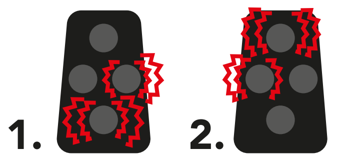
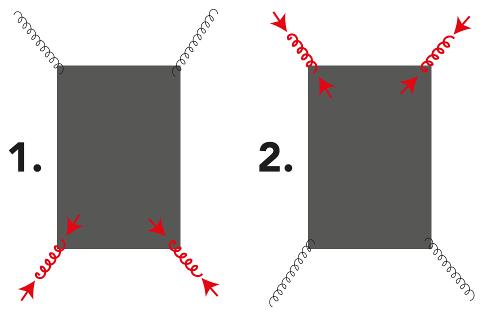
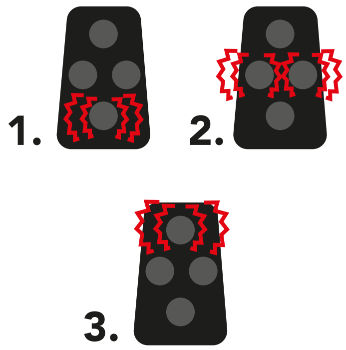
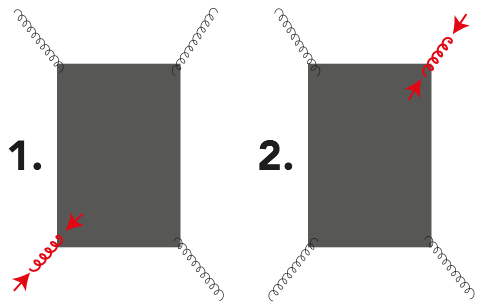
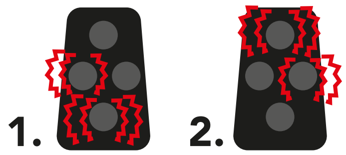
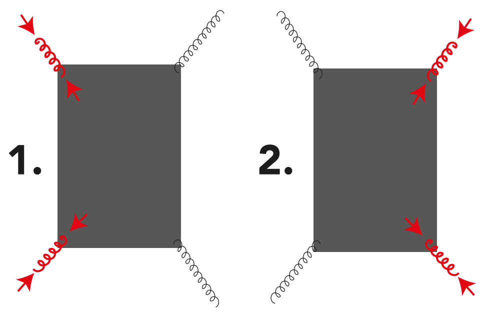
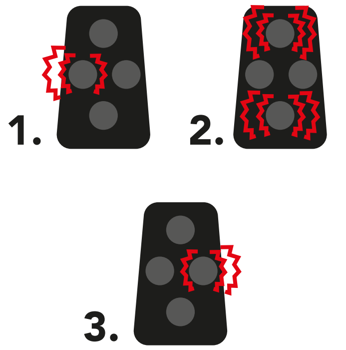
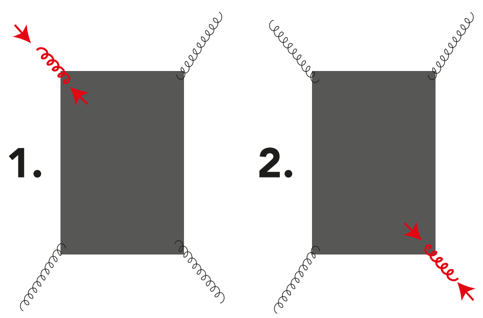
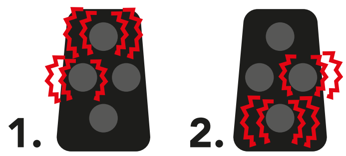


Figure 28. Possible wearable interactions

4 WIND DIRECTION :SOUTH-EST number in the range between 112,6° - 157,5		
5 WIND DIRECTION :SOUTH number in the range between 157,6° - 205,5°		
6 WIND DIRECTION : SOUTH-WEST number in the range between 202,6° - 247,5°		
7 WIND DIRECTION : WEST number in the range between 247,6° - 295,5°		
8 WIND DIRECTION :NORD-WEST number in the range between 292,6° - 337,4°		

The Wind intensity: the wind speed, that correspond to its intensity, is measured in the International System (SI) in meters per second (m/s) or in kilometers per hour (km/h). The conventional **measuring scale** is that of **Beaufort**, Figure 29., in which the values range from 0 to 12 Force Bft, the 0 corresponds to the wind calm, the 12 to the hurricane.

Force (Beaufort scale)	Equivalent speed			Description	Specifications for use at sea
	mph	knots	km/h		
0	0–1	0–1	0–1	Calm	–
1	1–3	1–3	1–5	Light air	Ripples with the appearance of scales are formed, but without foam crests.
2	4–7	4–6	6–11	Light breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance.
3	8–12	7–10	12–19	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered.
4	13–18	11–16	20–28	Moderate breeze	Small waves, becoming larger; fairly frequent white horses.
5	19–24	17–21	29–38	Fresh breeze	Moderate waves, taking a more pronounced, longer form; many white horses are formed. Chance of some spray.
6	25–31	22–27	39–49	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.
7	32–38	28–33	50–61	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.
8	39–46	34–40	62–74	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks.
9	47–54	41–47	75–88	Severe gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over.
10	55–63	48–55	89–102	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. The whole surface of the sea takes on a white appearance. The "tumbling" of the sea becomes more immense and shock-like. Visibility affected.
11	64–72	56–63	103–117	Violent storm	Exceptionally high waves (small and medium-size ships might be, for a time, lost to view behind the waves). The surface is covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are being blown into froth. Visibility affected.
12	73–83	64–71	118–133	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.

Figure 29. Beaufort scale

Once obtained the wind intensity data in real time, is necessary to d**ivide the Beaufort scale into four ranges** instead of twelve, has shown in **Figure 30.** This step will be useful for simplify the process of translating data into smart wearable interaction.

Force (Beaufort scale)	Equivalent speed			Description	Specifications for use at sea	Beaufort Scale four range subdivision
	mph	knots	km/h			
0	0–1	0–1	0–1	Calm	–	1 0-1 km/h
1	1–3	1–3	1–5	Light air	Ripples with the appearance of scales are formed, but without foam crests.	2 1-5 km/h
2	4–7	4–6	6–11	Light breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance.	3 6-11 km/h
3	8–12	7–10	12–19	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered.	4 12-133 km/h
4	13–18	11–16	20–28	Moderate breeze	Small waves, becoming larger; fairly frequent white horses.	
5	19–24	17–21	29–38	Fresh breeze	Moderate waves, taking a more pronounced, longer form; many white horses are formed. Chance of some spray.	
6	25–31	22–27	39–49	Strong breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.	
7	32–38	28–33	50–61	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	
8	39–46	34–40	62–74	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks.	
9	47–54	41–47	75–88	Severe gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over.	
10	55–63	48–55	89–102	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. The whole surface of the sea takes on a white appearance. The "tumbling" of the sea becomes more immense and shock-like. Visibility affected.	
11	64–72	56–63	103–117	Violent storm	Exceptionally high waves (small and medium-size ships might be, for a time, lost to view behind the waves). The surface is covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are being blown into froth. Visibility affected.	
12	73–83	64–71	118–133	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	

Figure 30. Beaufort Scale range subdivision

Each range of intensity will correspond a more or less intense vibration and a contraction of the nitinol, therefore **a faster movement of the surface visual stimulation** (Figure 31.).

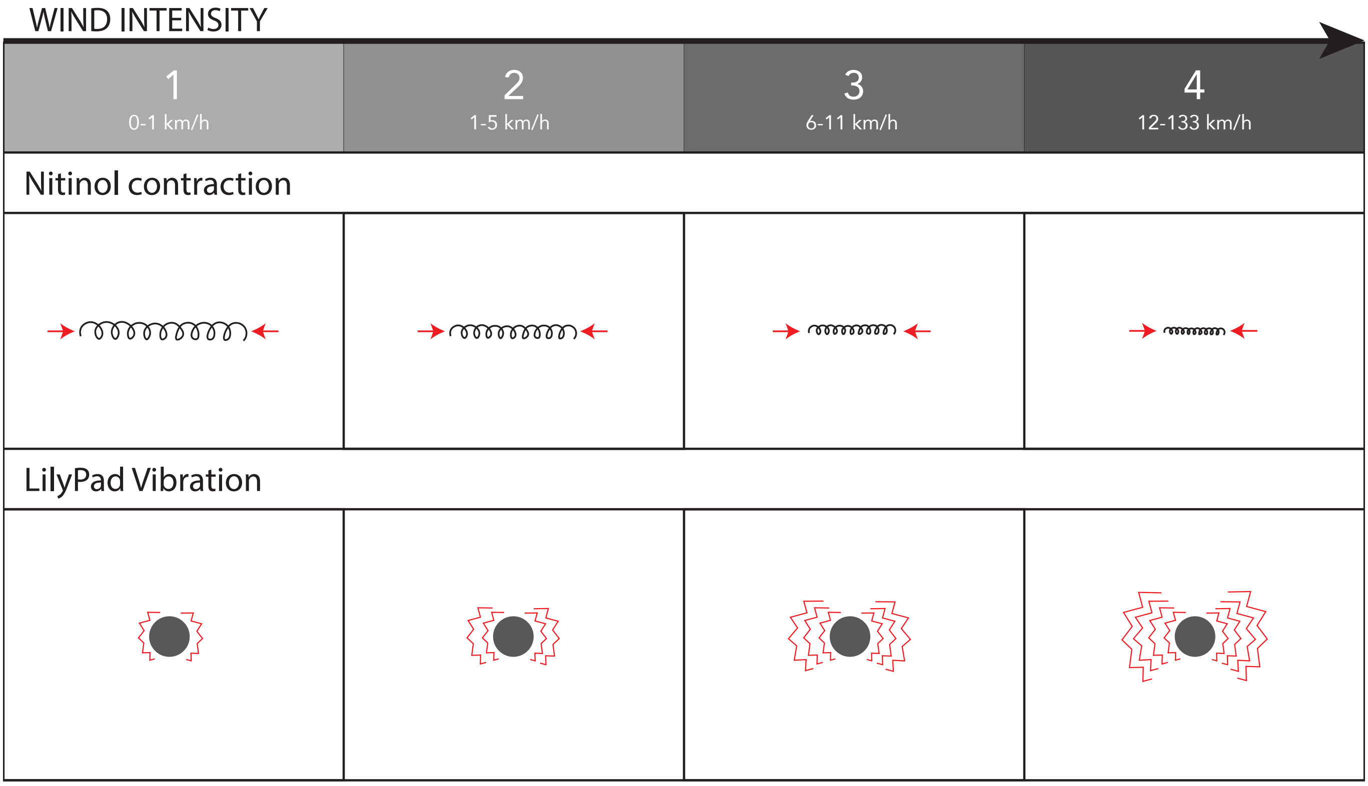


Figure 31. Possible wearable interactions depending on wind intensity

4.5 Input to Output Process

The entire project functionality is based on real-time data concerning wind intensity and direction, these are the **main inputs that will be extrapolated online** and will be analyzed by an Arduino code, uploaded on a board. These data will be **then transformed into outputs** that communicate with the wearer, or **vibrations and contractions** that will involve the movement of the surface texture (**Figure 32.**).

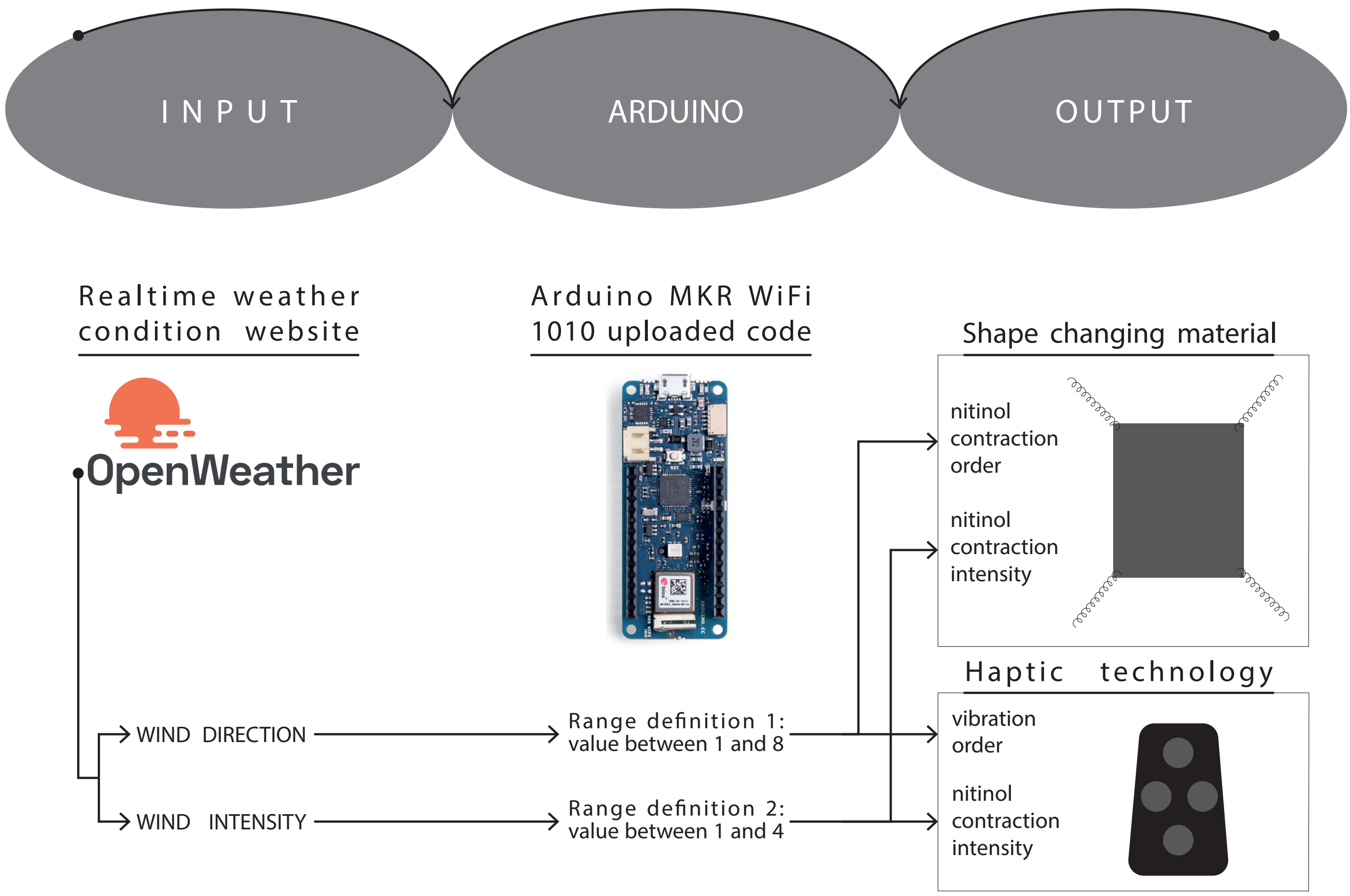


Figure 32. Input to output process

1) Input

In order to **extrapolate the data online in real time of the intensity of the wind and its direction**, a case study has been analyzed (Getting Weather Data, n.d.). It builds a real-time irrigation system through the Arduino board, which takes data from the Opeanweather online platform

(OpenWeatherMap.org, n.d.). The website every second returns a line of code with external climate environment information based on the location. Between those data are present also those useful for the project (**Figure 33.**).

{“cod”:”200”,”message”:0,”cnt”:3,”list”:[{“dt”:1650888000,”main”:{“temp”:281.49,”feels_like”:278.95,”temp_
min”:281.49,”temp_max”:282.82,”pressure”:1012,”sea_level”:1012,”grnd_level”:1011,”humidi-
ty”:89,”temp_kf”:-1.33},”weather”:[{“id”:500,”main”:”Rain”,”description”:”light rain”,”icon”:”10d”}],”cloud-
s”:{“all”:100},”wind”:{“speed”:4.34,”deg”:46,”gust”:5.66},”visibility”:10000,”pop”:0.66,”rain”:{“3h”:0.
56},”sys”:{“pod”:”d”},”dt_txt”:”2022-04-25 12:00:00”},{“dt”:1650898800,”main”:{“temp”:283.44,”fe-
els_like”:282.67,”temp_min”:283.44,”temp_max”:284.75,”pressure”:1012,”sea_level”:1012,”grnd_le-
vel”:1011,”humidity”:82,”temp_kf”:-1.31},”weather”:[{“id”:500,”main”:”Rain”,”description”:”light rain”,”icon”:”-
10d”}],”clouds”:{“all”:100},”wind”:{“speed”:5.03,”deg”:47,”gust”:6.4},”visibility”:10000,”pop”:0.62,”rain”:{“3
h”:0.55},”sys”:{“pod”:”d”},”dt_txt”:”2022-04-25 15:00:00”},{“dt”:1650909600,”main”:{“temp”:282.36,”feels_
like”:280.01,”temp_min”:282.36,”temp_max”:282.36,”pressure”:1013,”sea_level”:1013,”grnd_level”:1012,”hu-
midity”:89,”temp_kf”:0},”weather”:[{“id”:500,”main”:”Rain”,”description”:”light rain”,”icon”:”10d”}],”cloud-
s”:{“all”:100},”wind”:{“speed”:4.37,”deg”:33,”gust”:9.13},”visibility”:10000,”pop”:0.73,”rain”:{“3h”:0.51},”sys”:{“p
od”:”d”},”dt_txt”:”2022-04-25 18:00:00”}],”city”:{“id”:2759660,”name”:”Gemeente Arnhem”,”coord”:

Figure 33. Opeanweather code wind speed and degree

To know the intensity and direction of the wind, the board must connect in real time with internet, for these reason the Arduino MKR 1010 (Arduino MKR WiFi 1010, n.d.) was used. Through the availability of the material within the studio, and the help of professional figures, it was possible to create a code capable of performing the required function.

2) Arduino

In addition to extracting the data, **the code** has been written in such a way as to **transform** them **into higher or lower frequencies, and more or less rapid contractions** in the case of wind intensity. For what concern the direction of air, the final output will have a different vibration or nitinol contraction order.

3) Output

Every two hours from when the user starts working, the circuits inside the **smart wearables** are **activated for fifteen minutes**. The final output is a collection of different interactions, over that time, that want to relate the person to the outside world, inviting him/her to go out and take care of him/herself, in the form of empathy towards the device.

4.6 Chapter Visual Resume

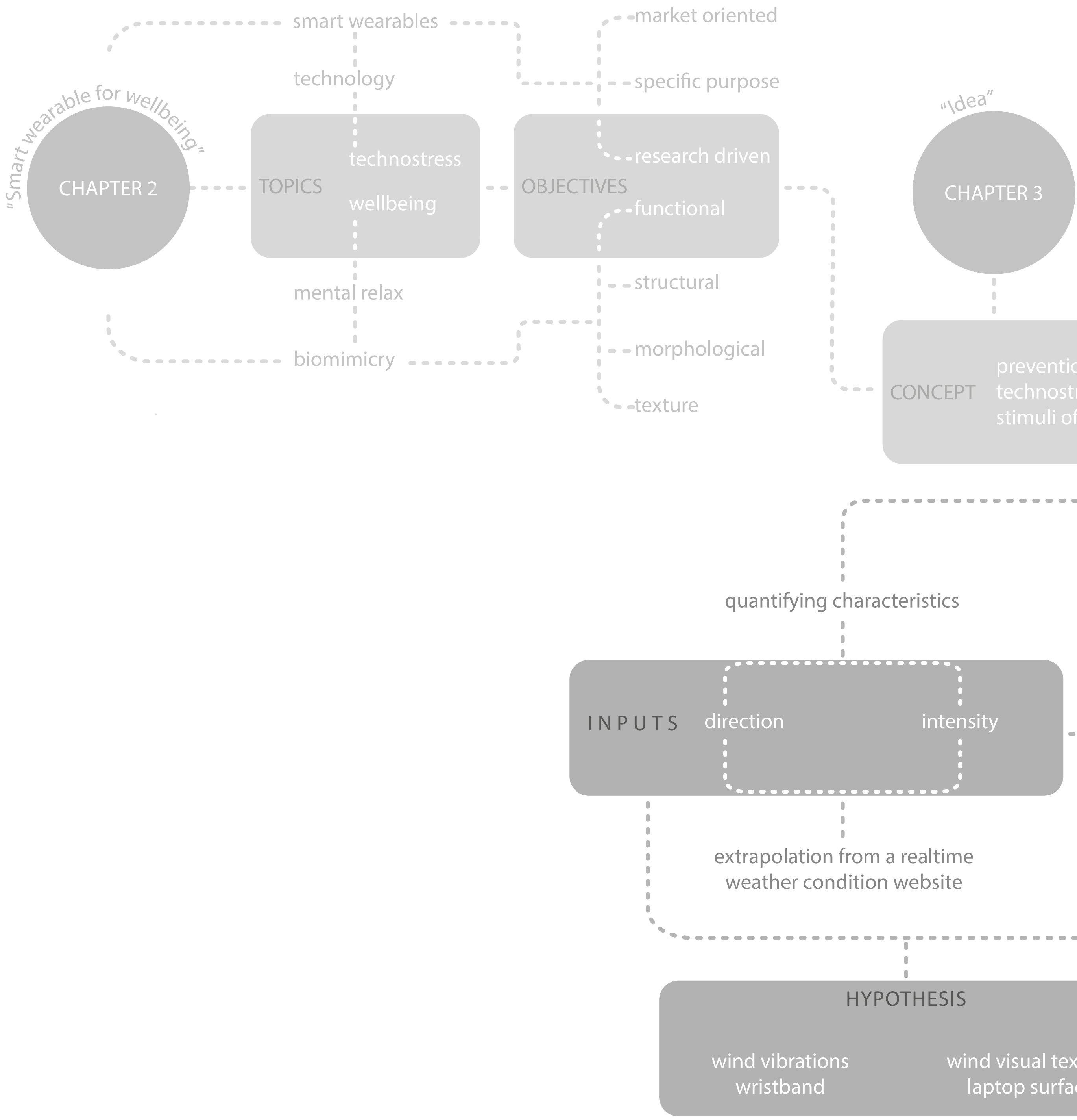
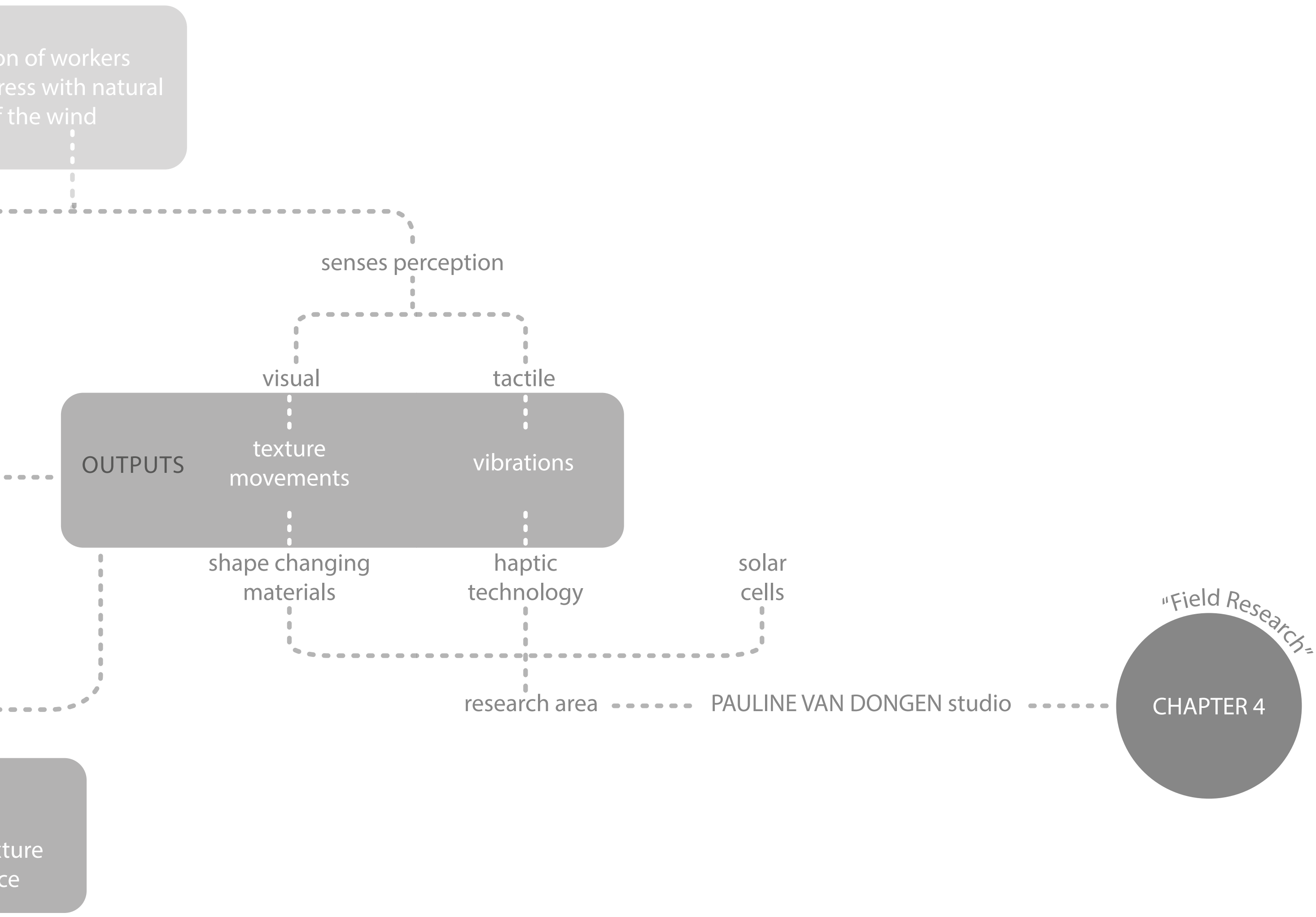


Figure 34. Chapter visual resume.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senses perception
visual
tactile
OUTPUTS
texture
movements
vibrations
shape changing
materials
haptic
technology
solar
cells
research area
PAULINE VAN DONGEN studio
"Field Research"
CHAPTER 4
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5. EXPERIMENTATION AND FINAL PROTOTYPE

5. EXPERIMENTATION AND FINAL PROTOTYPE

Having established the main concept, the tools necessary for the operation, the case studies source of inspiration and all the possible interactions between person and technology embedded in the fabric, **the research thesis passes to an experimental approach**. At this point, the project has been conceptually divided into **two distinct paths**: the **shape changing material** and the **haptic technology**. However, these are interconnected in the final purpose and the development of the various phases, which in the papers are represented at different times, have been carried out simultaneously. Illustrations are used for each process , in order to simplify the overall vision, starting from the hypothesis of the wind visual stimulus structure definition (**Figure 35**).

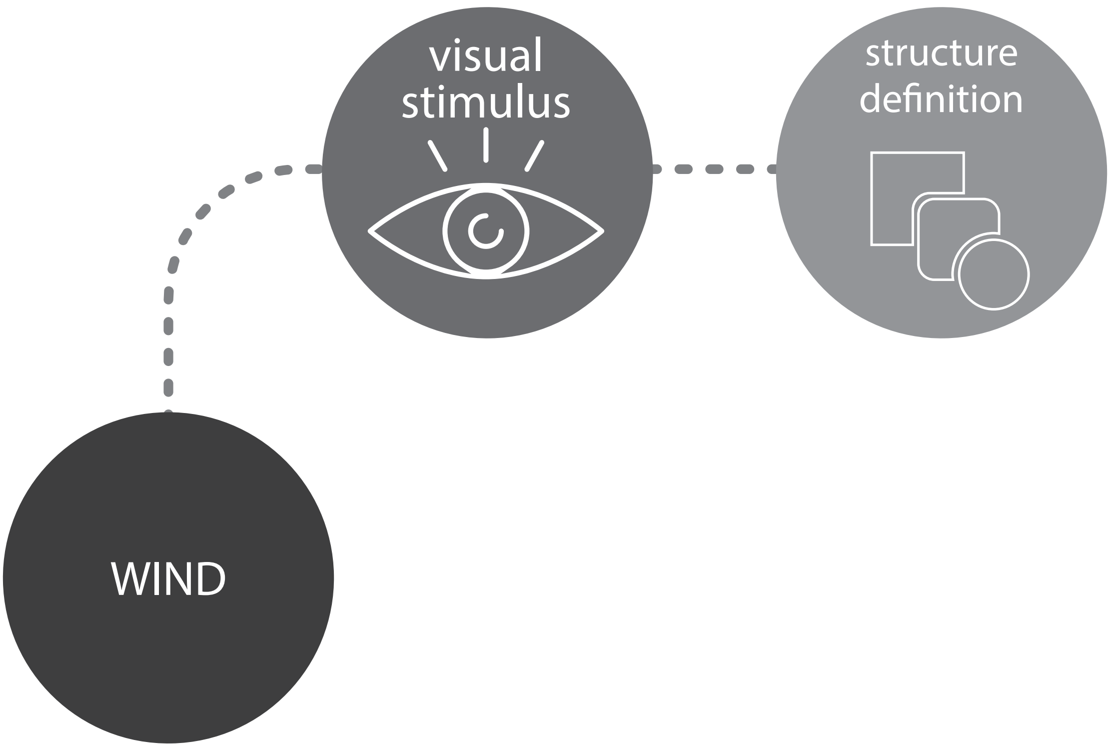


Figure 35. Wind visual stimuls structure definition

5.1 Developing the Shape Changing Material Wearable Accessory

Starting from the design related to the **visual stimulus**, the **experimentation is divided into three main moments, the initial hypotheses, the study of shapes and materials through laser cutting, the construction of the circuit and its integration into the fabric.** Each of these categories required a deep analysis and an approach that was completely based on the evaluation of immediate feedbacks. This methodology was in fact inspired by the studio one's, where the project was carried out. The system oriented to the learning-by-doing process is effective because it locates the designer in the forefront of creating the initial hypothesis. Consequently, it will be more immediate to understand what elements were wrong in the initial theory and, at the same time, new skills and more original paths, otherwise not been considered, are carried on.

5.1.1 Initial Hypothesis

Analyzing in more detail the previously illustrated **case study** (Figure 36.), its various components, which allow its functioning, are outlined.

Figure 36. Responsive Surface of Paula van Brummel

The final product has a **first layer with linear cuts** arranged on a large rectangular surface, whereas t**he one above is divided in smaller planes**. The last element of the structure is the **blade of grass that crosses perpendicularly the two layers** through the holes and remains stable thanks to its shape. Finally, the **movement is given by the contraction of the nitinol horizontal spiral**, which shortens as the current flow and lengthens once the passage of electrons is interrupted. These shape memory alloys, attached to the sides of the small planes, move them in the x axe direction. The contrast between the upper surfaces horizontal shifting and the stationary lower layer, creates a visual stimulator effect like that of the wind blowing on the lawn (**Figure 37.**).

Figure 37. Responsive Surface components

The second example is Pauline Van Dongen's neoprene body, shown in **Figure 38.** This has been specially designed to interact with the movements of the wearer.

Figure 38. Pauline Van Dongen neoprene shape changing body

In this specific case, there are **two intersecting surfaces**, the one above with **vertical cuts** and the second with **partially cut shapes**, so that they can fit into the cracks of the first layer (**Figure 39.**). The incisions on the fabric have been carried out by laser cutting that allows to obtain a high precision, therefore a perfect match of the two fabrics.

In addiction this new technology creates a thre-e-dimensional effect starting from a flat structure, without the use of additional materials.

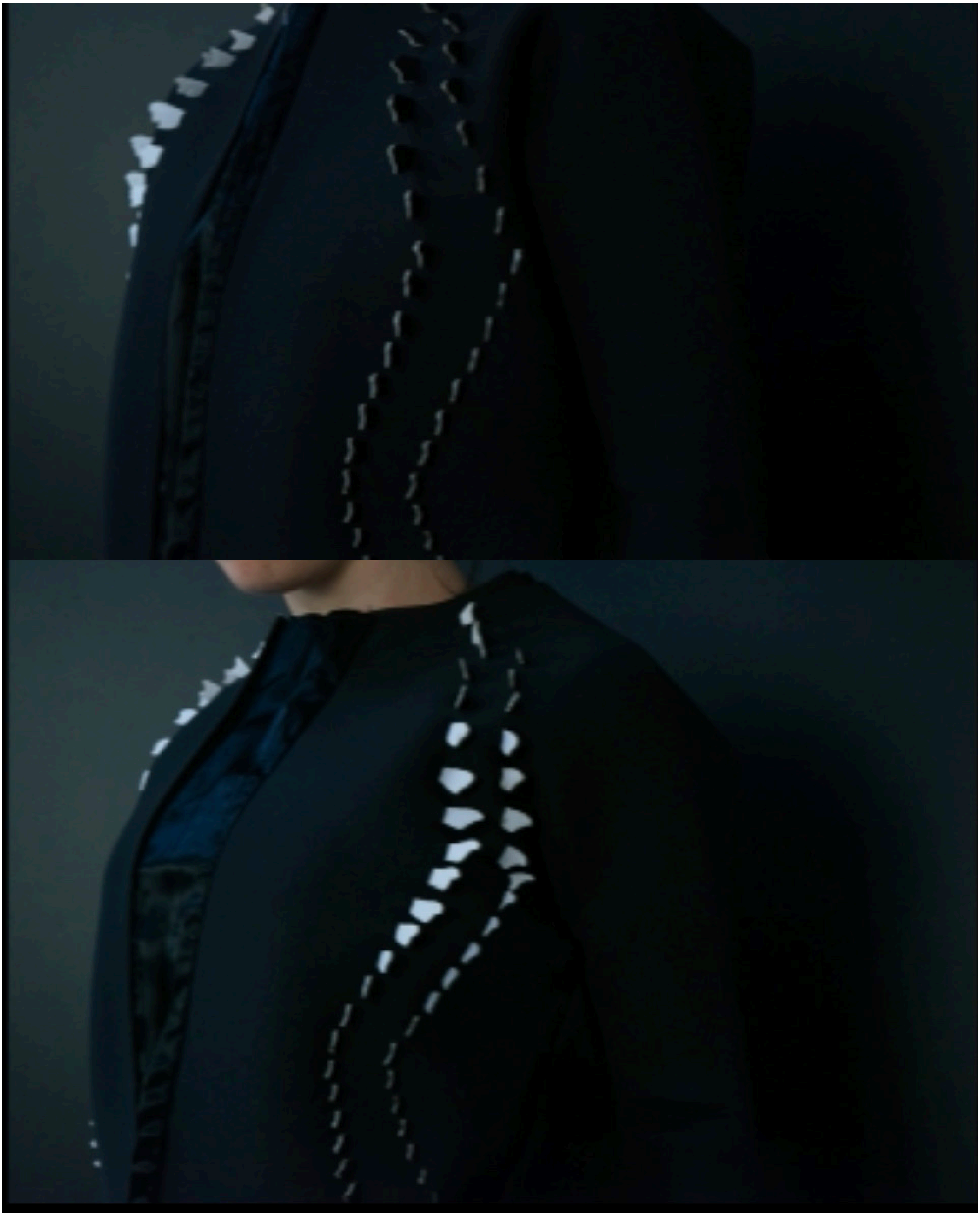


Figure 39. Pauline Van Dongen neoprene body focus.

Establishing the **first case** as **more visual effective** for the final movement, and the **second** as more performing in terms of **simplicity and waste reduction**, **the project combine** the Pauline Van Dongen **structure example together** with the materials used in Paula Brummel design, which is the nitinol wires hooked to the sides of the fabric (**Figure 40.**).

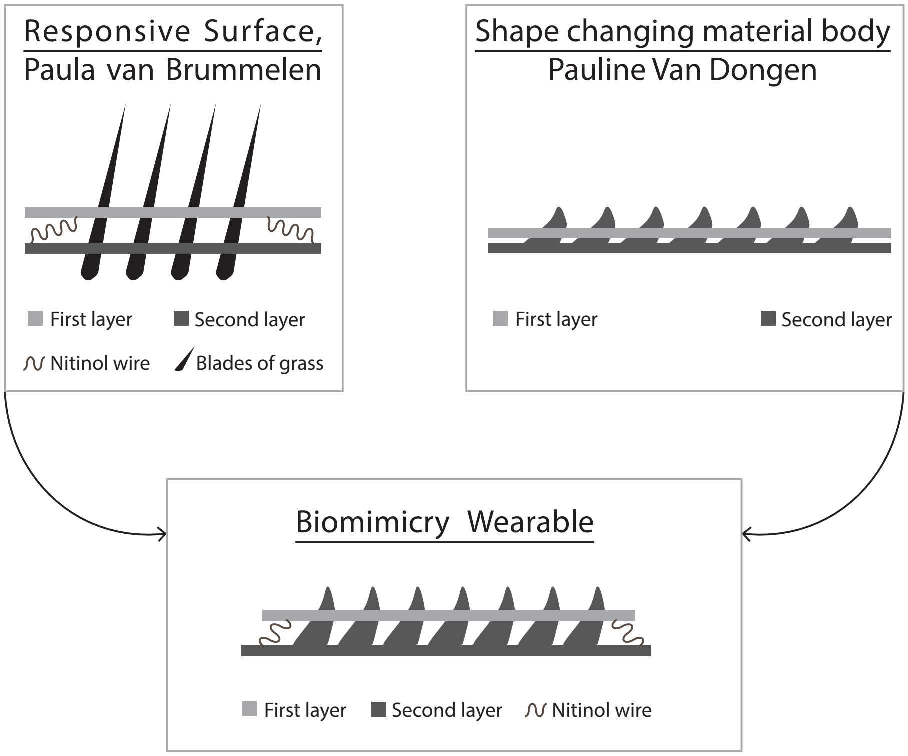


Figure 40. Project hypothesis configuration

5.1.2 Shape and Material Trials

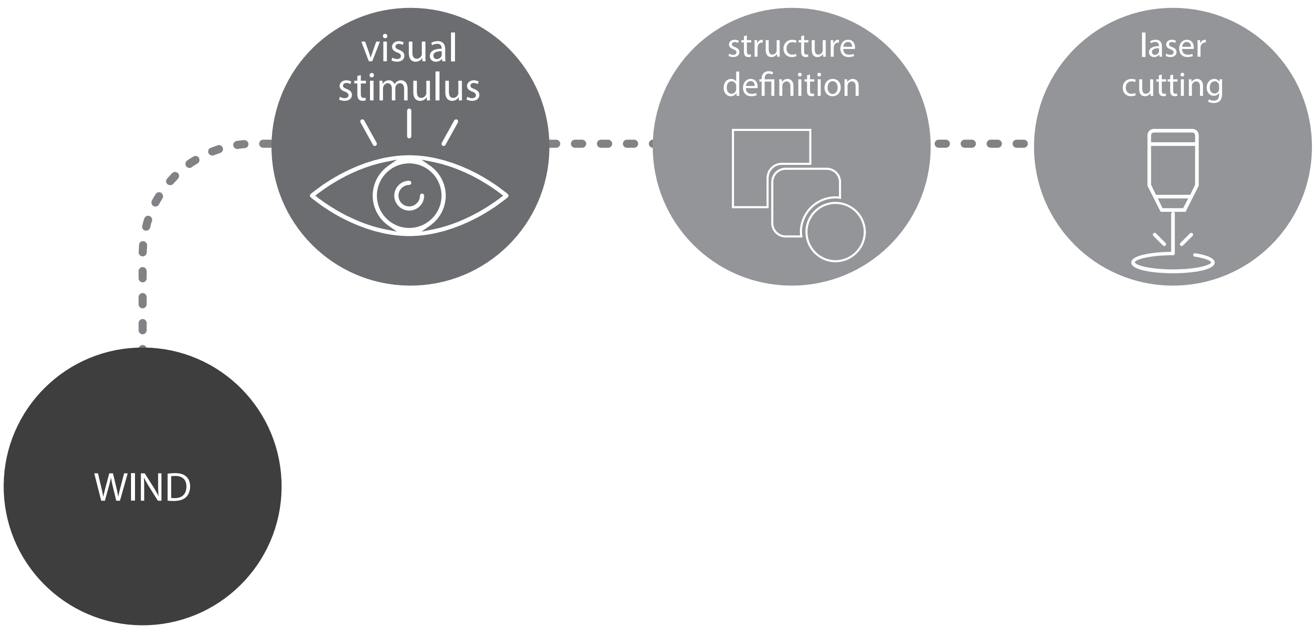


Figure 41. Wind visual stimuls laser cutting tryal

Once the structure has been hypothesized, the **next steps** required are the the **moving shapes verification**, the materials defining and the texture design for the final effect. The internal reality of the studio, unlike the academic one, allows a continuous immediate experimentation on machinery, such as laser cutting. With this type of approach, the designer can act directly by adjusting the intensity and speed of the light beam, until the finding of material right parameters. In addition, another effect of the *Do It Yourself*, is to understand errors and find solutions in a shorter period. **The engraving and cuts on the fabric were created by the laser cut machine, which has required many tests of intensity and speed on various materials**. These data have been collected and catalogued in the diagram in Figure 42. Starting from the **inspirations of the natural world**, the process takes place through the **testing of different shapes and evaluation of performing result**. Therefore, various organic elements are selected as inspiration for the illustrator files creation to be laser cut on neoprene, a fabric highly suitable for this purpose thanks to its elasticity. Through continuous experimentation it was possible to **collect and catalogue the results** obtained **based on three important project factors** (Figure 43.). The first subject considered relevant is **the dynamism**, so the response of the shape during the horizontal movement of the surface. In fact, depending on its conformation, there will be an increase in laser cuts movement more or less evident. The other element of evaluation concerns **the transition from a flat and two-dimensional surface**, to a more articulated and three-dimensional one. As this factor grows, during interaction there will be a structure completely different from its original shape. Finally, **the visual effect**, which must be as close as possible to what happens in nature. The interesting contrast between perfection, due to the precision of laser cutting, and imperfection, that is found in the external environment, is taken into account as a goal to be pursued. For this reason, the files designed have been developed voluntarily difficult to be reproduced by the machine, causing slight burns and smears of the fabric and resulting in elements always different one from another.

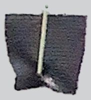
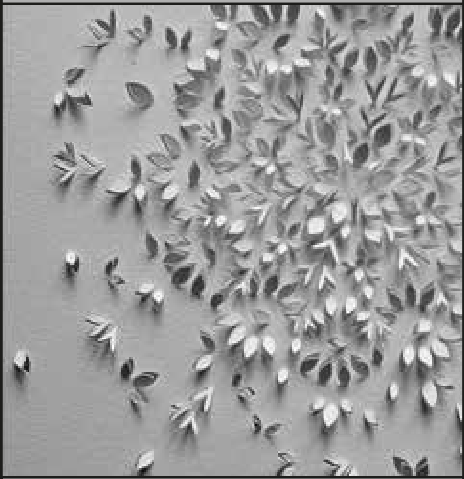
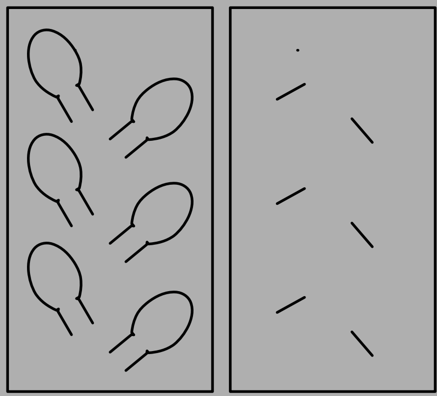
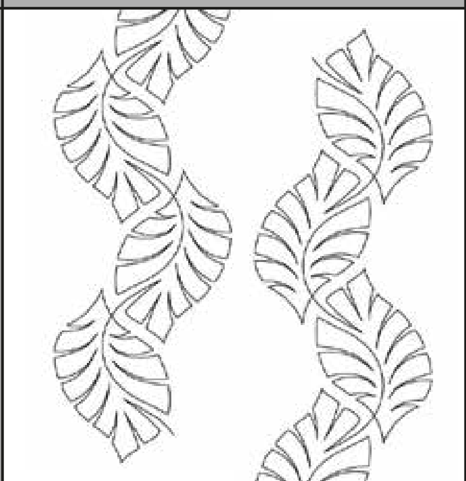
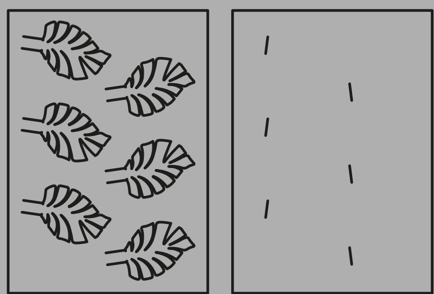
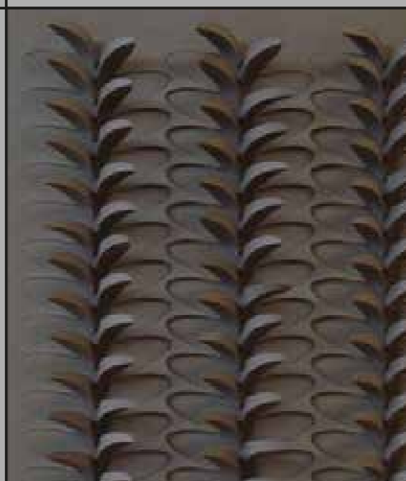
LASER CUT MATERIALS	FEATURES	LASER CUTTING SPEED AND POWER	LASER ENGRAVING SPEED AND POWER	ADDITIONAL NOTES
	black neoprene fabric thickness 2mm	speed: 60 mm/s power: 50 W	speed: 300 mm/s power: 10 W	if pieces are very small edges can be fragile
	black leather fabric thickness 1mm	speed: 40 mm/s power: 50 W	speed: 300 mm/s power: 25 W	Once laser cut has a bad smell and dirty, it needs to be well ironed before
	grey leather fabric thickness 1mm	speed: 40 mm/s power: 50 W	speed: 300 mm/s power: 25 W	Once laser cut has a bad smell and dirty, it needs to be well ironed before
	grey fabric thickness <1mm	speed: 50 mm/s power: 20 W	speed: 300 mm/s power: 10 W	___
	grey shiny jersey fabric thickness <1mm	speed: 60 mm/s power: 20 W	speed: 300 mm/s power: 10 W	To have more melted edges : speed (10mm/s) power (20W)
	black neoprene space fabric thickness 3 mm	speed: 30 mm/s power: 50 W	speed: 300 mm/s power: 15 W	___
	bioadhesive heated for fabrics thickness <1mm	speed: 100 mm/s power: 15 W	___	Cut on the not adhesi-ve side, put a layer of paper between it and the laser-cutting machine bed
	grey synthetic leather thickness 1mm	speed: 50 mm/s power: 40 W	speed: 300 mm/s power: 25 W	___
	black and white neoprene fabric thickness 1,5mm	speed: 60 mm/s power: 50 W	speed: 300 mm/s power: 10 W	___
	cardboard thickness 2mm	speed: 15 mm/s power: 20 W	___	___

Figure 42. Laser cutting on different materials

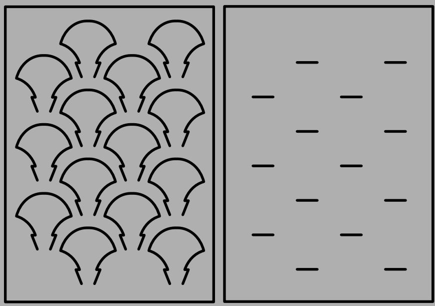
SHAPE N.	INSPIRATION	FILE ILLUSTRATOR
1		
	LASER CUT SHAPE	FEEDBACKS
		Natural visual effect: LOW Passage from 2D to 3D: MEDIUM Dinamicity: HIGH

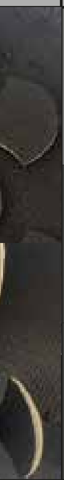
SHAPE N.	INSPIRATION
2	
	LASER CUT SHAPE
	

SHAPE N.	INSPIRATION	FILE ILLUSTRATOR
4		
	LASER CUT SHAPE	FEEDBACKS
		Natural visual effect: MEDIUM Passage from 2D to 3D: HIGH Dinamicity: HIGH

SHAPE N.	INSPIRATION
5	
	LASER CUT SHAPE
	

FILE ILLUSTRATOR





FEEDBACKS

Natural visual effect: LOW

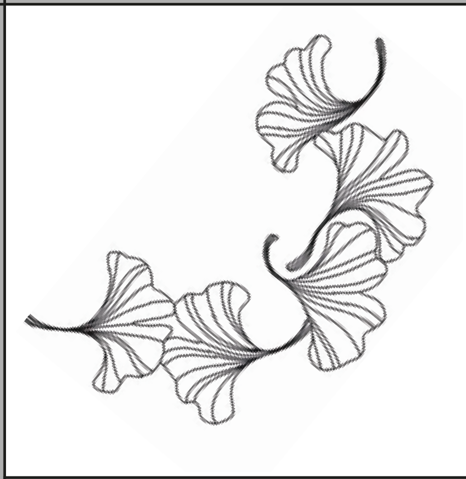
Passage from 2D to 3D: HIGH

Dinamicity: HIGH

SHAPE N.

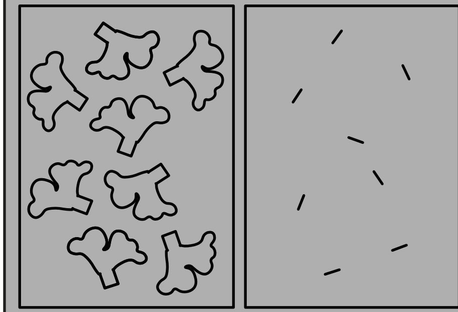
3

INSPIRATION



LASER CUT SHAPE

FILE ILLUSTRATOR

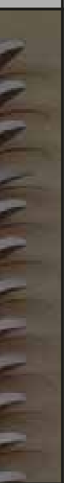


FEEDBACKS

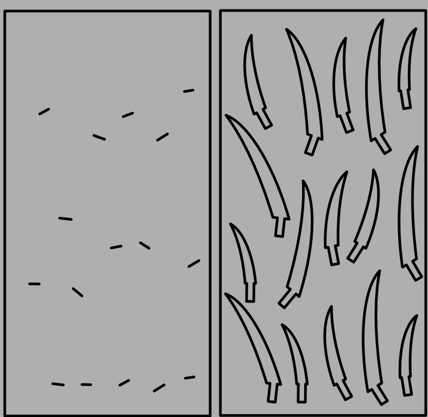
Natural visual effect: MEDIUM

Passage from 2D to 3D: HIGH

Dinamicity: LOW



FILE ILLUSTRATOR



FEEDBACKS

Natural visual effect: HIGH

Passage from 2D to 3D: LOW

Dinamicity: LOW

Figure 43. Three factors catalogation of laser-cutting shapes

Thanks to this three-factor cataloguing, the **shapes that have given the best results have been selected**. (Figure 44.)

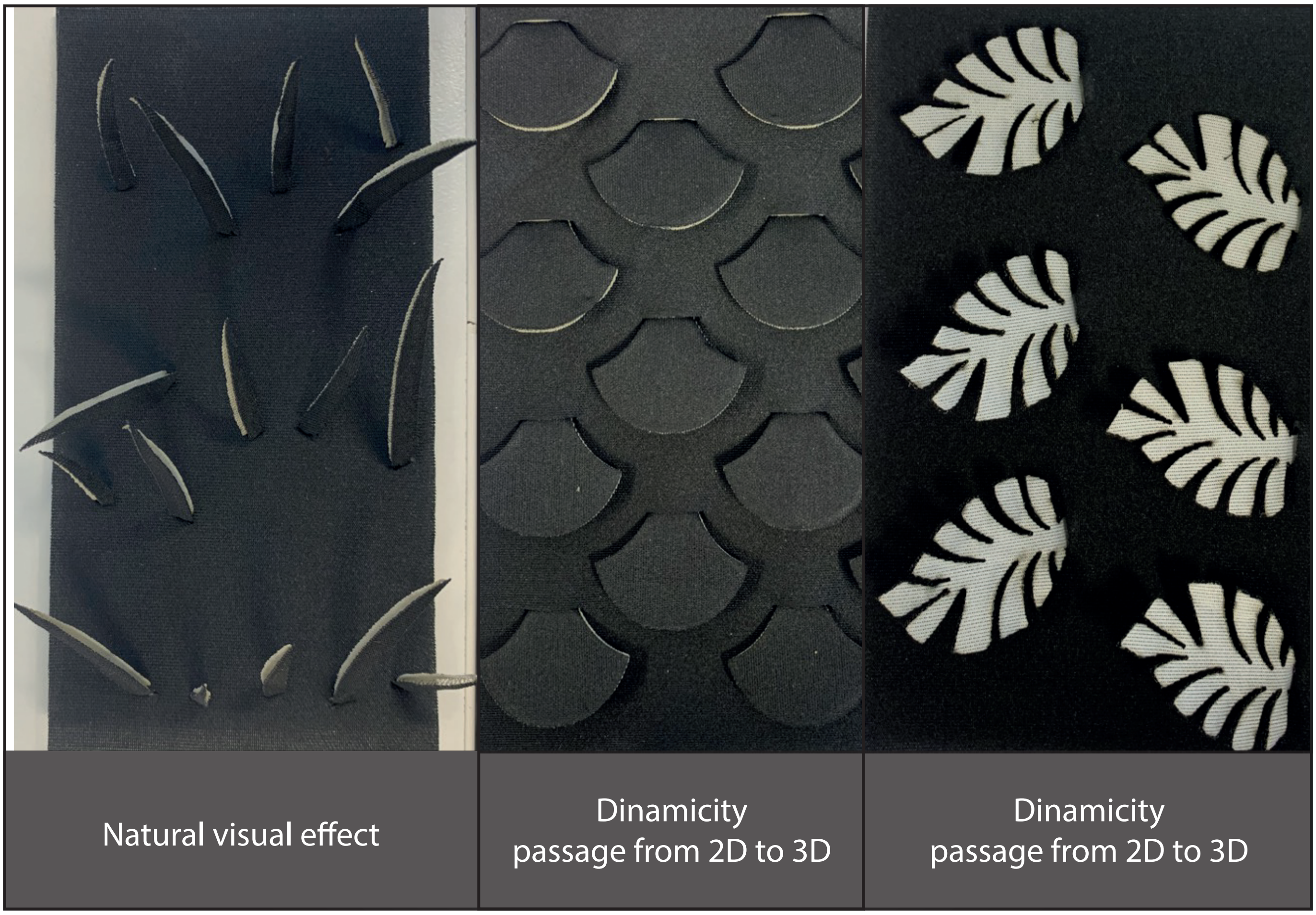


Figure 44. Most performant laser cut shapes

Then, among the three parameters mainly detected, was considered as **the most important** factor for the selection of shapes and materials the one related to the **recreation of the natural effect**. The motivation is linked to the possibility, through the texture design, to improve the other two characteristics. In fact, taking inspiration from the two shapes that were optimal from the point of view of dynamism, and transition from 2D conformation to 3D, the goal is to **improve the design** of grass strands **with the grouping and a section change at the base** of these, starting from a larger structure and coming towards the tip with a fine section (**Figure 45.**)

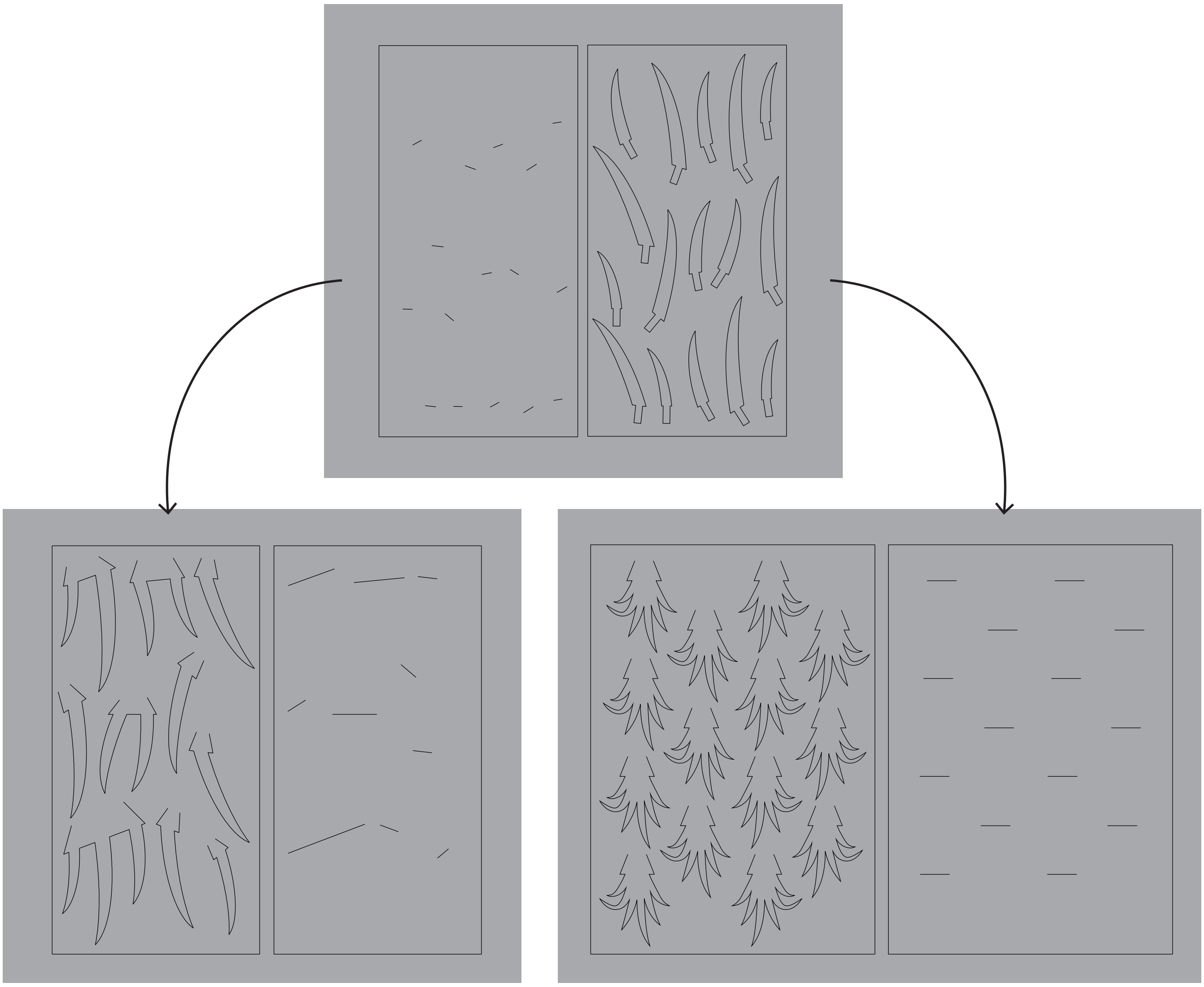


Figure 45. File illustrator improvement

Once two possible file improvements for laser cutting have been redesigned, the next step proceed with the **use of two different materials** considered interesting **for their texture**, a gray skin and a black synthetic leather. Both the results collected on these two fabrics and **new shapes are performing** from the point of view of dynamism and transition from 2D to 3D. Anyway, the **most interesting for the natural effect is the laser cut on black synthetic leather**. Moreover, **this material is preferred** because it is **more ethical than real leather**, but with a **more articulated texture than neoprene** (Figure 46.).

Figure 46. Redesign and material laser cutting trials.

5.1.3 Circuit and SMA Trial:

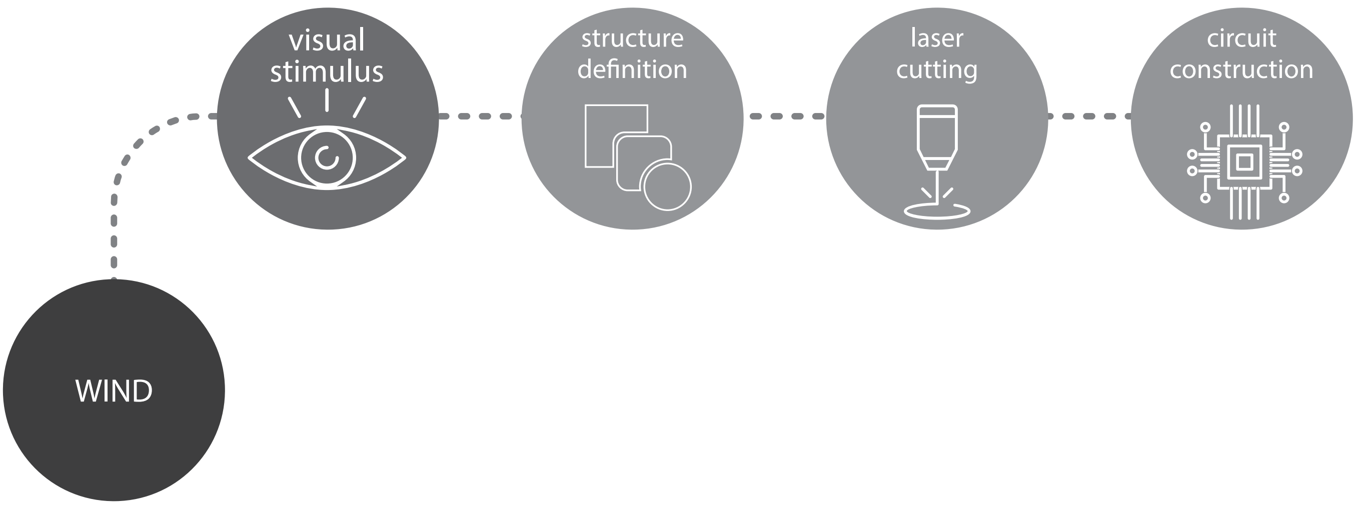


Figure 47. Wind visual stimuls circuit creation

Once the shapes and materials have been established, **the technological components were defined**. The circuit must allow the operation of the four nitinol wires, in such a way that they contract at separate times at the passage of current, according to the intensity and speed of the wind. Through the **analysis of a case study** (Figure 48.) on the official website of Arduino (Flexinol and Arduino, 2018) the diagram necessary for the construction of the circuit has been extracted.

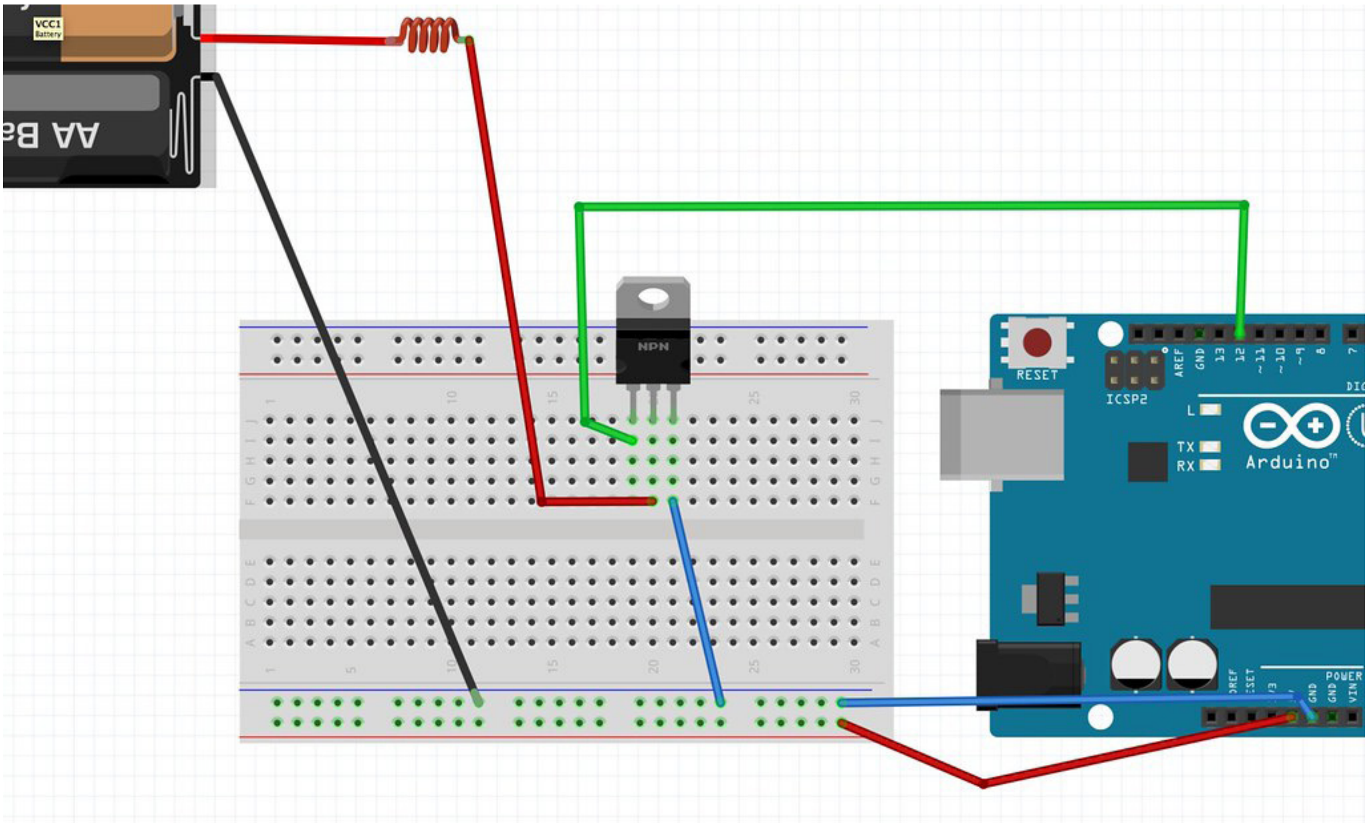


Figure 48. One nitinol wire circuit

The 0.7 mm thick **nitinol wire** is connected on one side to the positive of a 3.7 **Volt LiPo Battery** (EEMB BATTERY Li-ion Battery Specification, 2019) and on the other to the **MOSFET GATE** (Isco N-Channel MOSFET Transistor, n.d.), used to adjust the current passage. The SOURCE of the MOSFET receives the code information from a pin on the **Arduino MKR 1010 board** (Arduino MKR WiFi 1010, n.d.), finally the DRAIN and the negative battery end in the ground of the Arduino board. In the **Figure 49.** the entire circuit is shown including all **four nitinol wires**, each connected to its own MOSFET and battery.

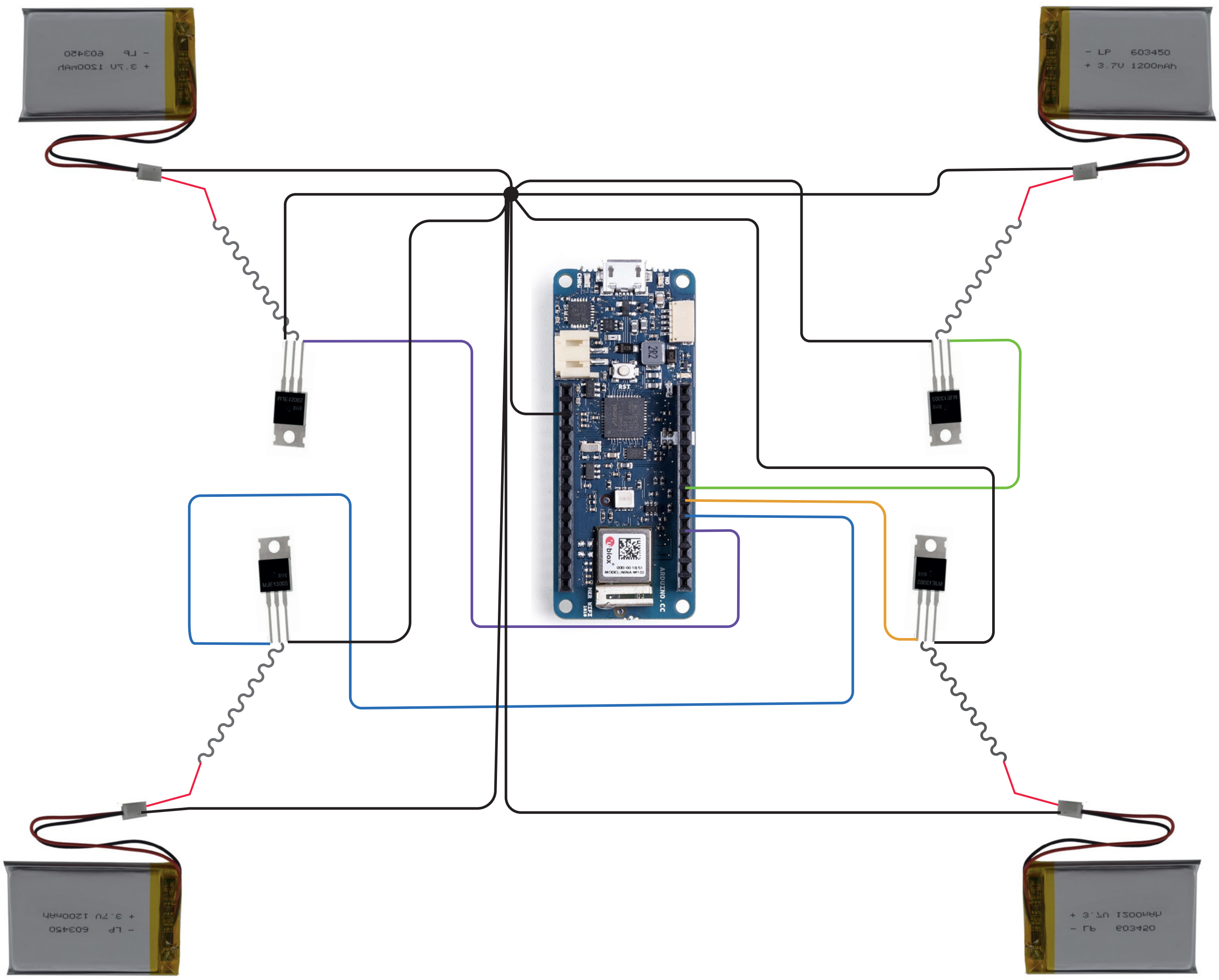


Figure 49. Four nitinol wire circuit

5.1.4 Fabric Implementation

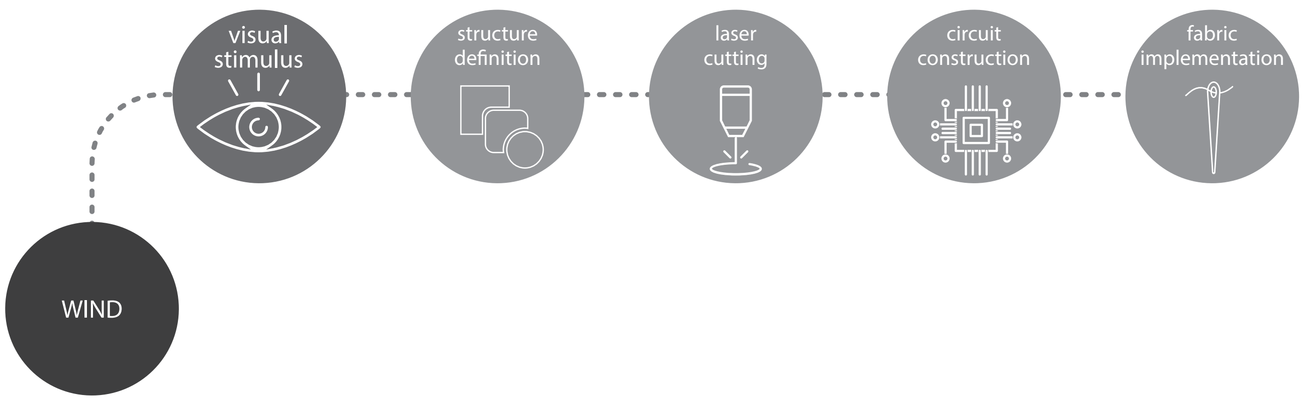


Figure 50. Wind visual stimuls fabric implementation

Collected the necessary information for **the circuit its functionality has been checked**. Later it has been connected to the fabric to evaluate the best way of integration in a **configuration** shown in Figure 51.

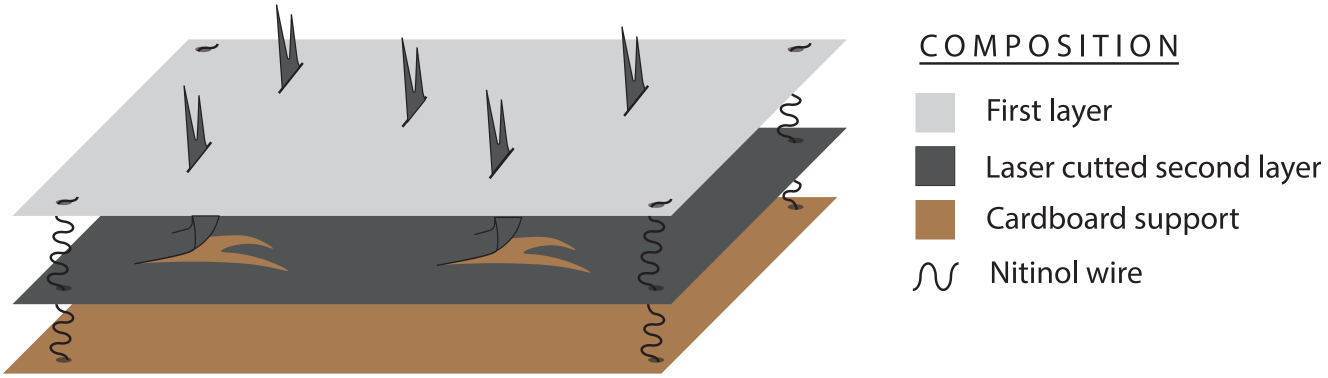


Figure 51. Circuit integration configuration

In this case the test was carried out with the nitinol wires integration charged one at a time through a battery (**Figure 52.**).

Figure 52. Circuit integration first trial result

The resulting interaction is **fluid in the movement**, however, **once** heated the **wire contracts** and the passage of current in the nitinol placed on the other angle, which will lead it to **reduce its size**, is not enough to stretch the previously one. For this reason, the **movement will last only a few seconds before all the threads are contracted** to such an extent that they cannot be shorten anymore and overheat with the risk of fabric burning. In the **second test**, a **different orientation of the nitinol wires and material** were used to check if it could give a more performing result (**Figure 53.**).

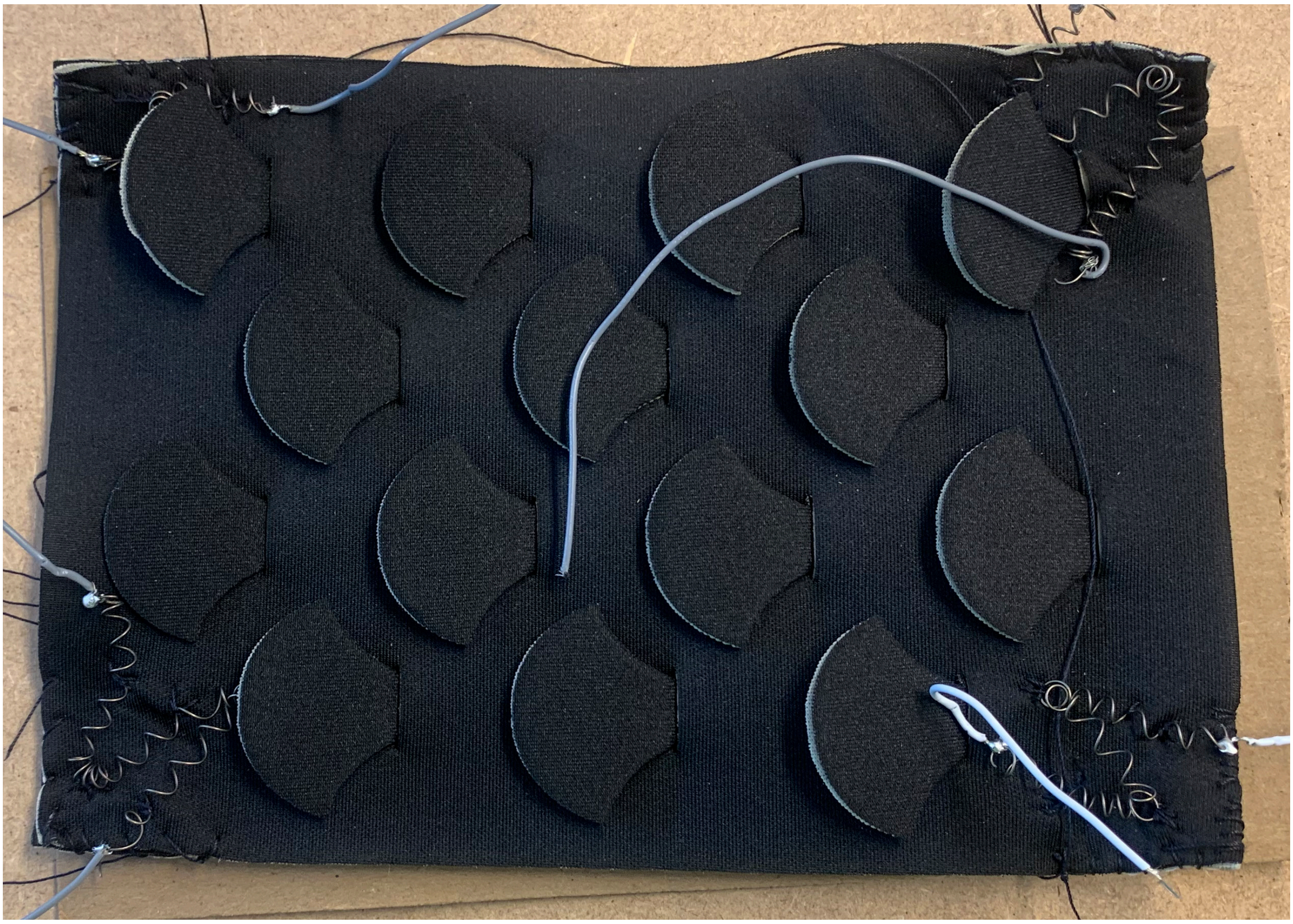


Figure 53. Circuit integration second trial final result

The result of these variants did not lead to **any movement**, consequently it was decided to return to the first trial characteristics and improve the interaction. Through the reality of Pauline Van Dongen's studio, it has been possible, thanks to the network of contacts and collaborations created over the years, to find a solution. It was fundamental for the thesis the **dialogue with Kaspar**

Jansen, a professor of emerging materials at the Faculty of Industrial Design Engineering and researcher in electronic textiles, smart materials, shape morphing materials and electroluminescence. During his years of experience and teaching, he developed numerous projects using shape memory alloy such as nitinol. In particular, for this paperwork **he indicated the case study** at **Figure 54.** built at TUDelft University. The example shows how the introduction of a central element, which connects two wires of nitinol placed at the extremities, can be an answer to extend the spiral shapes once it has been contracted (Shitoot, n.d.).

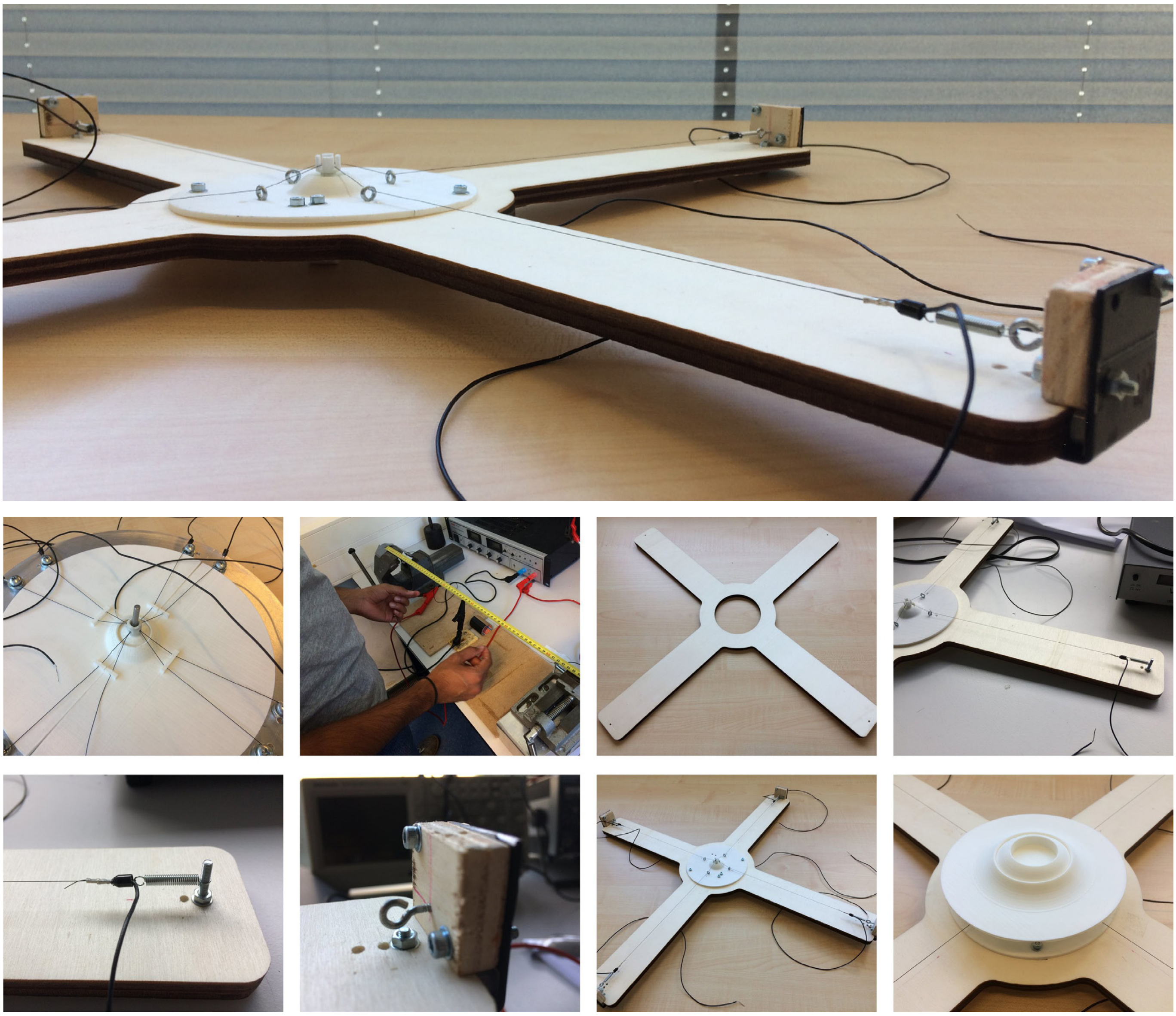


Figure 54. Case study example: Shape morphing application in autonomous cars

The case study **inspired the introduction of two bars inside the prototype** (Figure 55.) that are connected with one end of both wires located at opposite corners of the fabric.

Figure 55. Introduction of two new elements in the structure

Once the desired interaction was obtained, the **illustrator files were prepared** to laser cut the laptop sleeve front surface. At this stage **additional grass strands** were added **to the upper layer**, to increase the feeling of movement given by the fabric shifts (**Figure 56.**).

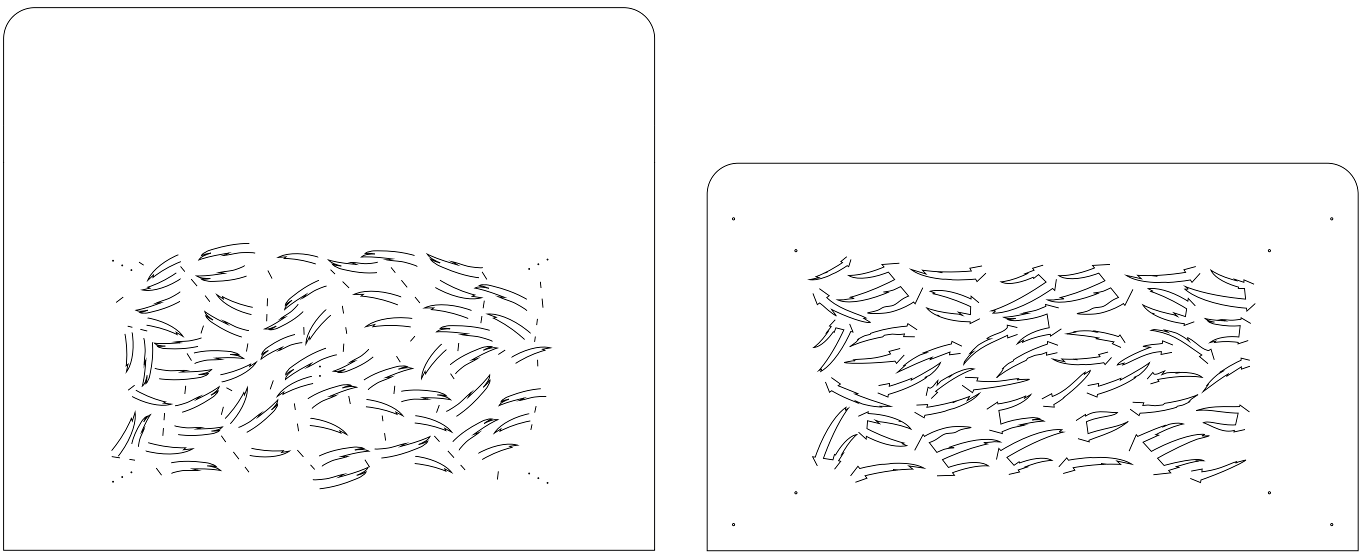


Figure 56. Illustrator files of the laser cutting laptop sleeve surface

Once the entire circuit was integrated into the surface (**Figure 57.**), **its functionality was tested**. The interaction in this case was **weaker** and even **almost absent** compared to previous tests. **The reason** is linked to the need for **very thin nitinol wires** to prevent the overheating fabric, in parallel with the **thickness of the synthetic leather**.

Figure 57. Laptop sleeve surface

Later, a **lighter material was used**, but rigid enough to remain stable during movement and not flex (**Figure 58.**).

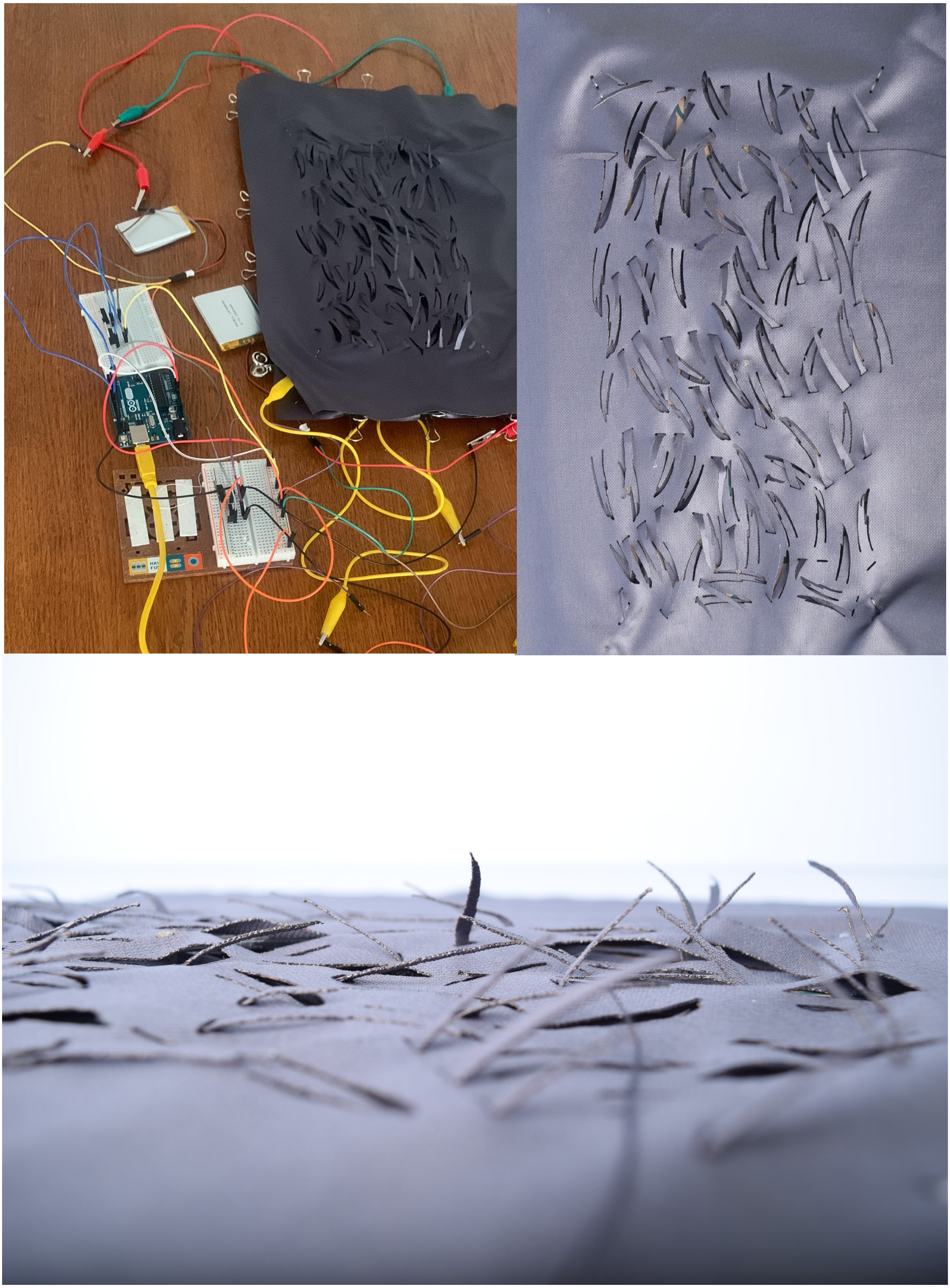


Figure 58. Second tryal of the laptop sleeve surface circuit integration

The **final interaction** obtained was very **interesting** and the new lighter material surface allowed a **greater movement of the grass blades.** In addition, the shiny, almost metallic effect, returned a **visual feedback of greater impact** during the texture waving. Despite numerous attempts and considerations, the s**hape changing material trial was interrupted** at this stage for several **reasons**:

Sustainability: To allow the total operation of the circuit it was necessary to use a battery and a mosfet for each nitinol wire. Since batteries in particular are still very polluting and have a relatively low life service, the project would not have been environmentally sustainable.

Safety: Tests have shown that, despite the low voltages used, the minimum current passage to allow the fabric movement, after one minute can lead wires overheating and risk of fabric and electrical components burning.

Final effect in relation with required energy: Laser cuts gave a greater visual effect of movement when thicker wires were used. However, as the nitinol diameter increases, the energy required to power them grow, leading to the use of bulky batteries and troubles in wearable integration.

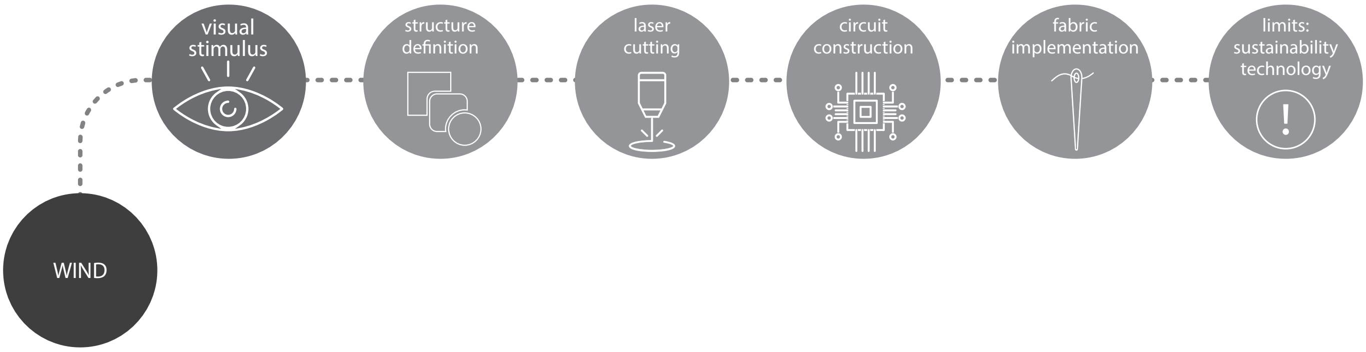


Figure 59. Wind visual stimuls limits

5.2 Developing the Haptic Technology Wearable Accessory

The experimental second part concerns about the **tactile stimulus**. At the same modality of shape changing material trial, it has been divided into an initial hypothesis, resulting from the case studies previously analyzed, to the creation of a circuit, until its test integration through laser cutting and different materials use. Also in this case the process was developed through a learning by doing approach, with feedbacks collection and consequent improvements.

5.2.1 First Hypothesis

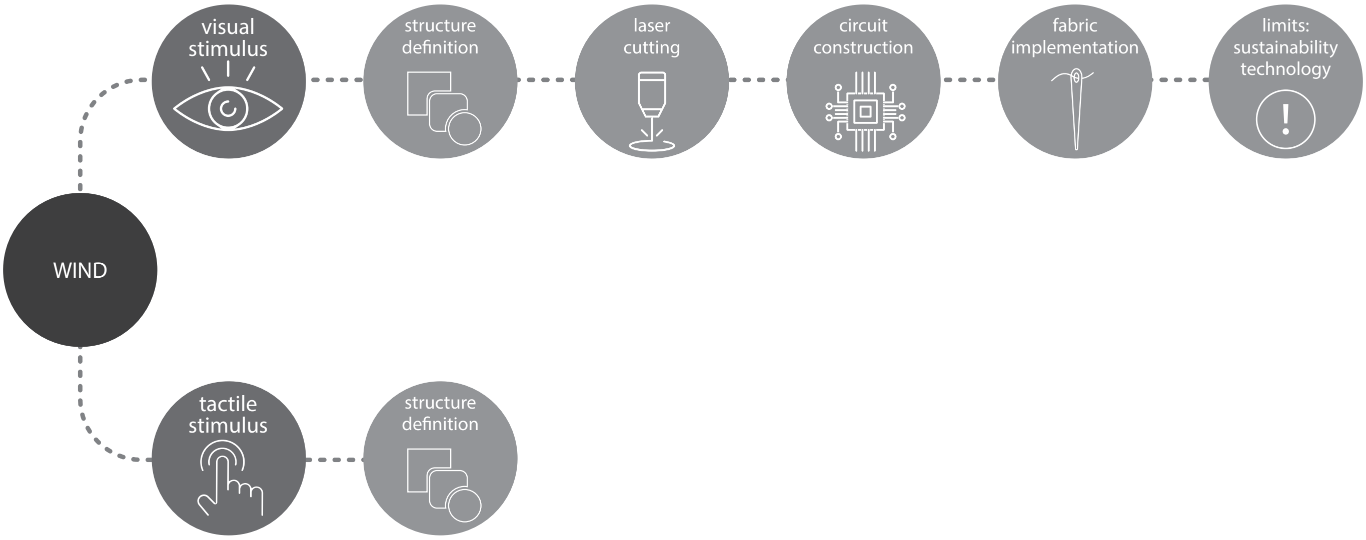


Figure 60. Wind tactile stimuls structure definition

Using the case study previously illustrated (**Figure 61.**) as a point of reference, various approaches to developing smart wearables that include tactile interaction are explored. In this example, the interaction between user and smart wearable aims to return the different stimuli of nature, changing the people's body perception. The tactile stimulus consists of twenty-five **vibrating piezoelectric motors** distributed in an octagonal form, like a spider web (**Figure 62.**). The arrangement has been designed to create an **effect as similar as possible to the passage of a wave**, air and so on.

Figure 61. Magic Lining

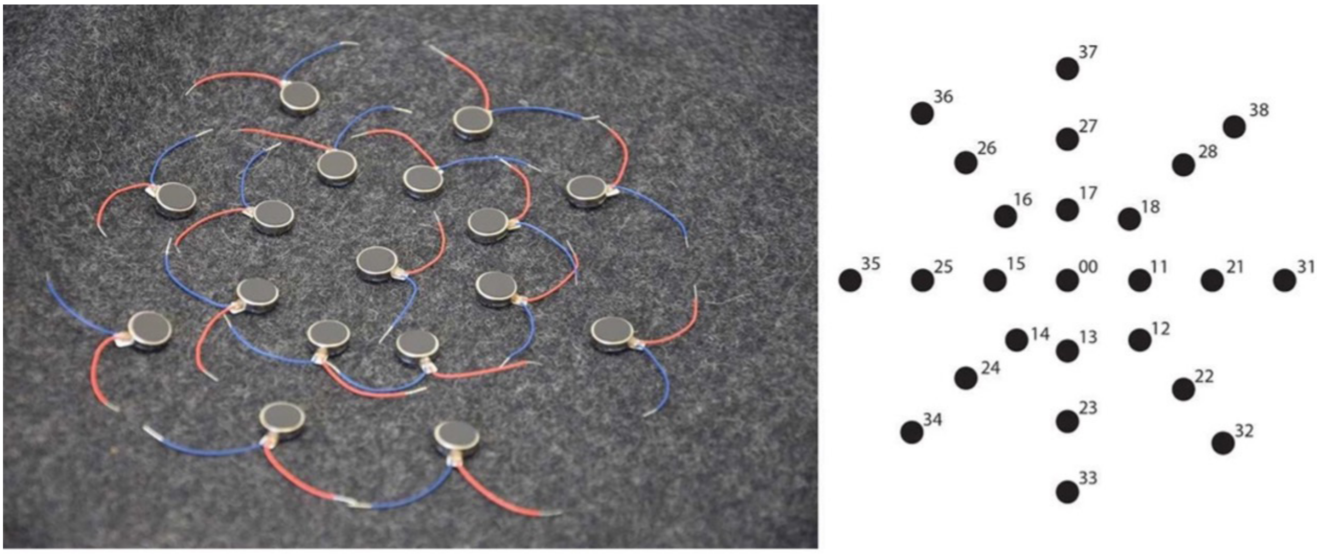


Figure 62. Magic Lining piezoelectric motors disposition

The second case study considered is Pauline Van Dongen's MYSA project, shown in **Figure 63**. The shirt has been designed to **reduce work stress through vibrations**, that help the user to perform relaxing breathing exercises. In this specific example there are six vibration LilyPad shown at **Figure 64.**, positioned along the spine and connected to printed conductive tracks that are bonded to the fabric. The back panel of the garment consists of a second layer, that can be tied around the body to increase the tactile sensation.

Figure 63. MYSA shirt, Pauline Van Dongen

Figure 64. MYSA shirt LilyPad focus, Pauline Van Dongen

Starting from the assumption of r**ecreating a smart wearable that returns the tactile sensations of the wind**, the first case is established as more effective for the **motors radial arrangement**. Whereas, the second is classified as more innovative for the **integration of Lilypads** through a greater stability technique. Consequently, the Biomimicry Wearable project will be composed by a network of vibrating motors located in circle, as in the Magic Lining project, and integrated in order to be near the skin, as in the MYSA shirt.

5.2.2 Circuit Trial

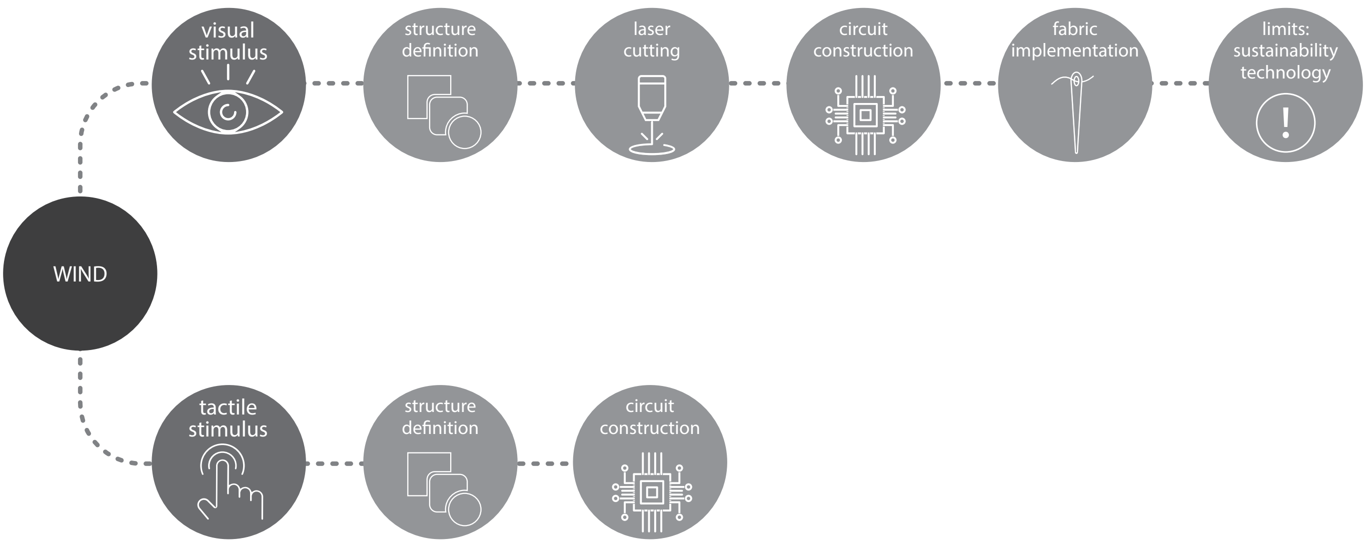


Figure 65. Wind tactile stimuls circuit construction

The next step, once the sources of inspiration have been established, is to **create a circuit** that will allow the vibrations to be transmitted to the wearer's body. In the **Figure 66.** there is the case study of inspiration (Vibration Motor With Arduino, 2020) from which the project circuit diagram is extracted.

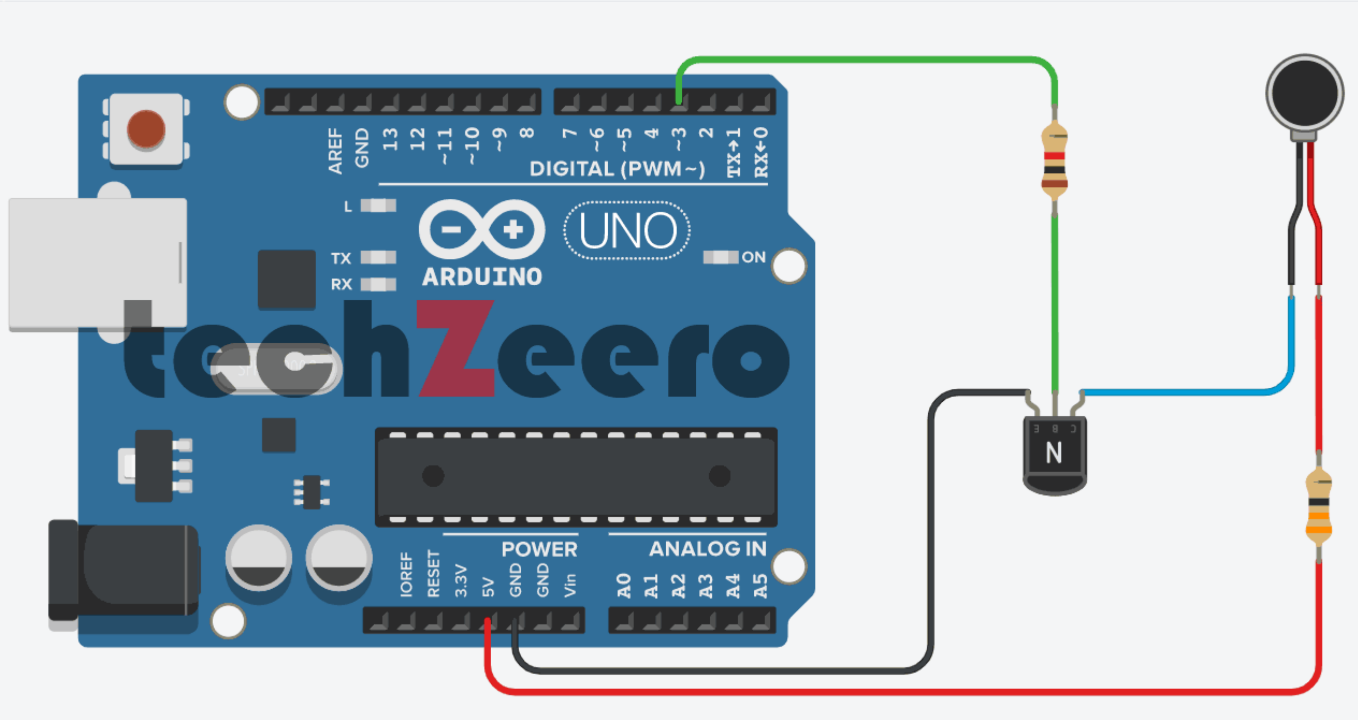


Figure 66. One vibration motor circuit

The positive **vibration motor** wire (10mm Shaftless Vibration Motor 3.4mm Button Type, n.d.) is connected to the 5V of the **Arduino board** (Arduino MKR WiFi 1010, n.d.), while the negative pole is connected to the collector of the **NPN purpose transistor** (General Transistors, n.d.), that regulates the power on and off. Finally, the emitter of the transistor reaches the ground of Arduino (**Figure 67.**).

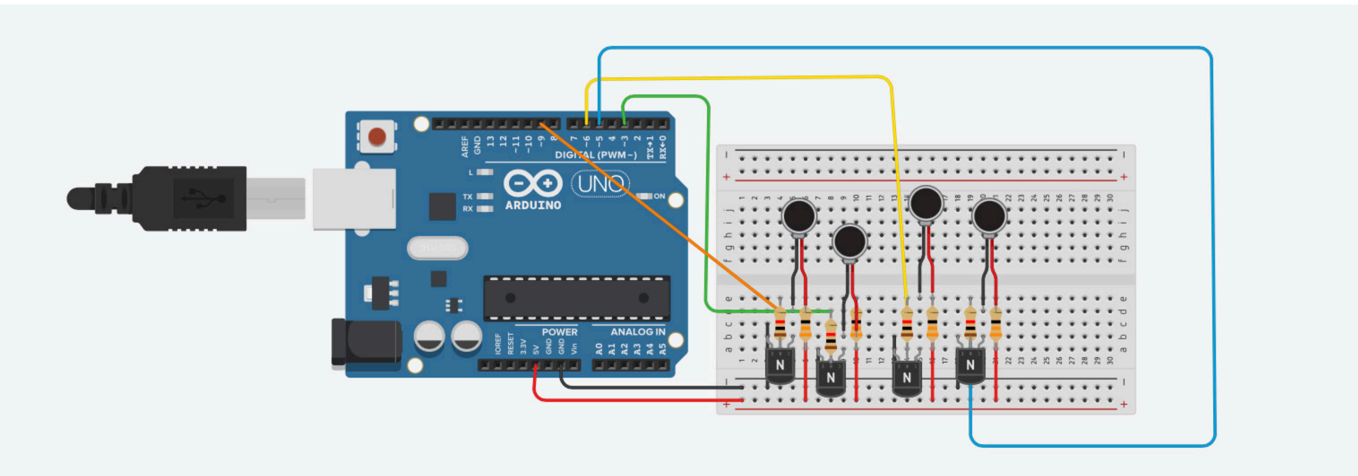


Figure 67. Four vibration motors circuit

Having collected the necessary information for the **circuit, it has been tested** (Figure 68.) to verify its functionality. Consequently, the **drawing of the whole circuit** on the smart wearable is shown at **Figure 69**.

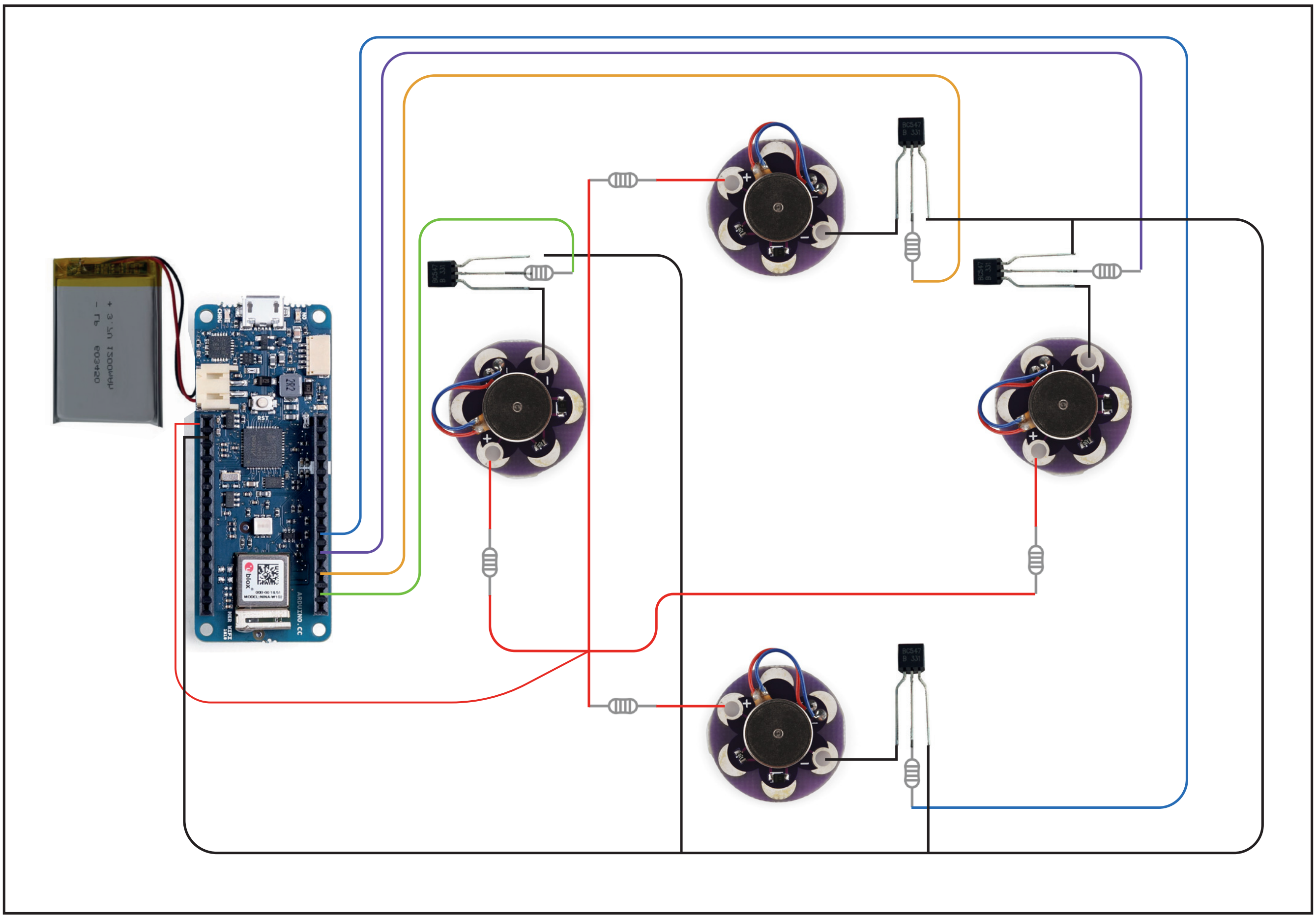


Figure 68. Circuit test

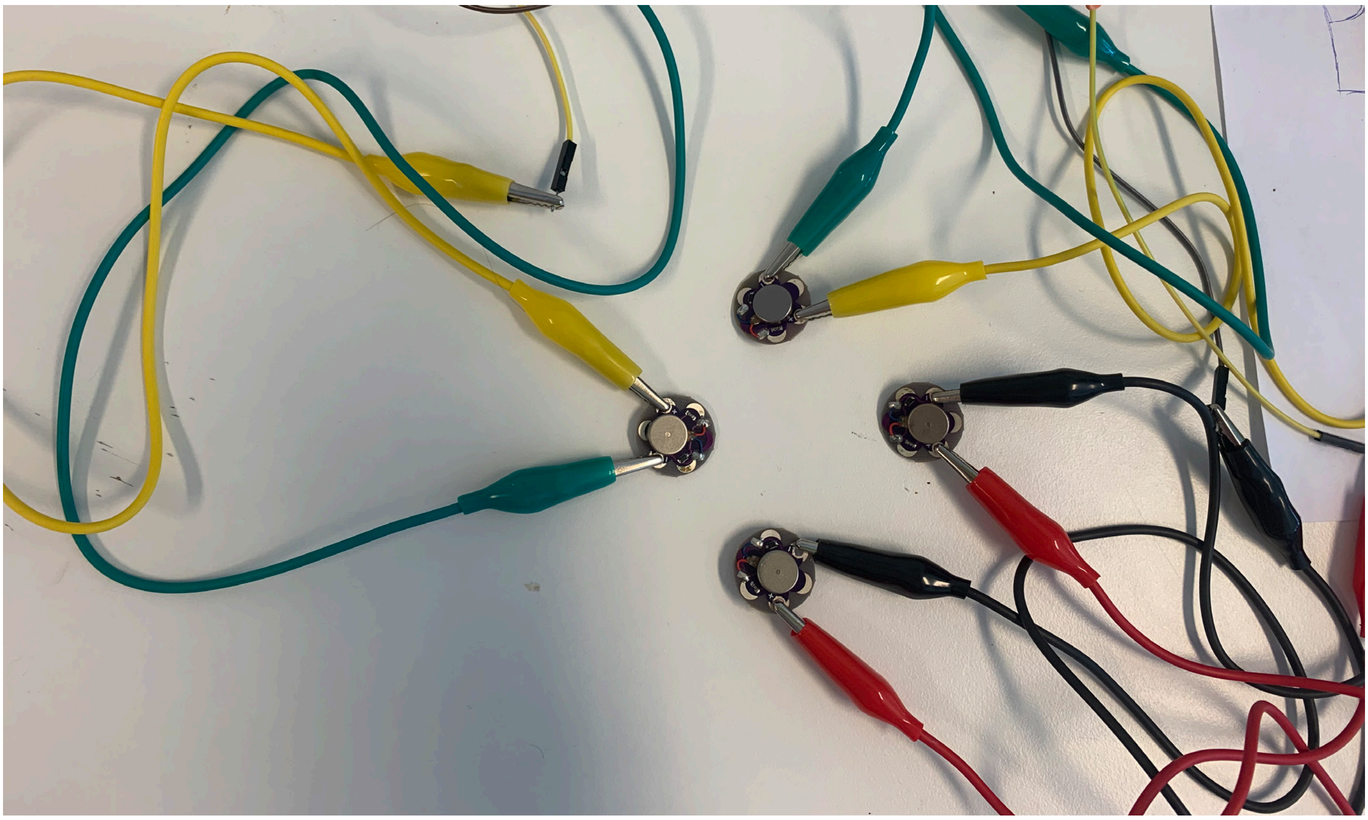


Figure 69. Wind tactile stimulus circuit schematic

5.2.3 Shape and Circuit Integration Trials

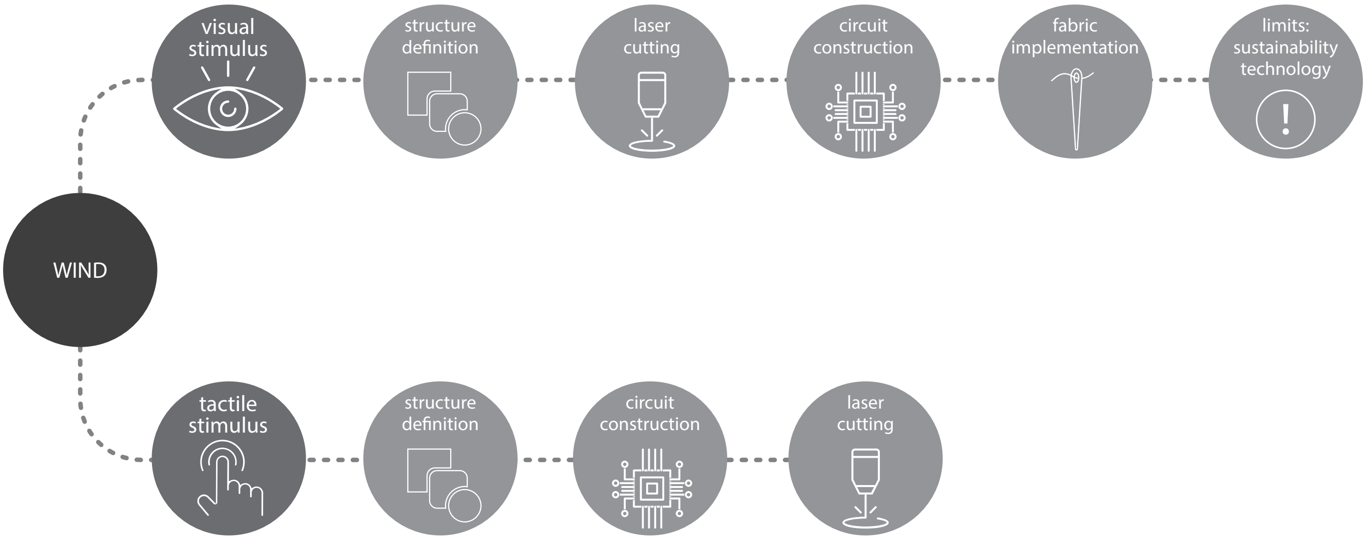


Figure 70. Wind tactile stimuls laser cutting

A soft and light material pleasant to the touch and laser cut in two rectangles was used to **integrate the circuit into the fabric**. In the first one four circles were **engraved to fit the LilyPad base**, whereas in the other, four smaller circles were laser cut, to cover the electronic components. Finally, through the **conductive sewing thread** the different parts of the circuit were connected (Figure 71.).

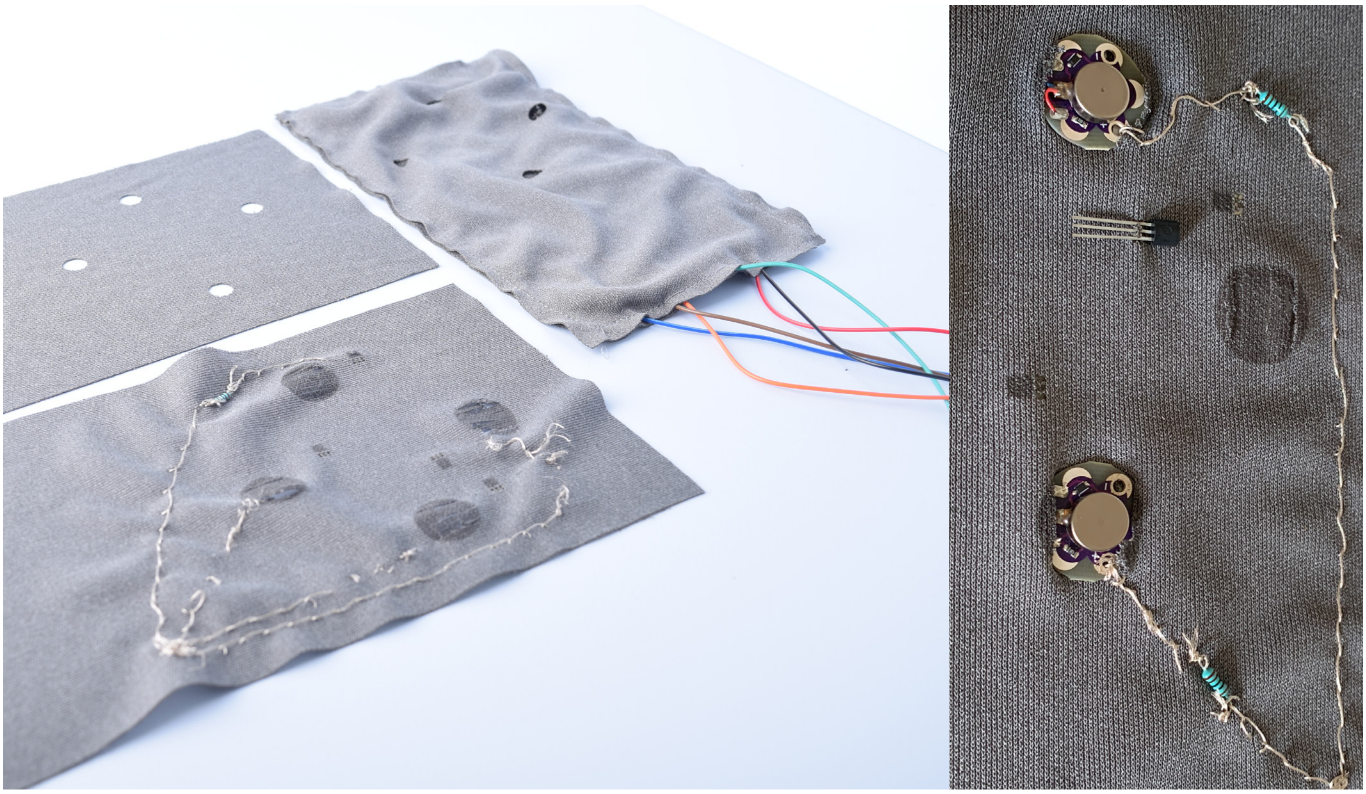


Figure 71. Shape and material first trial

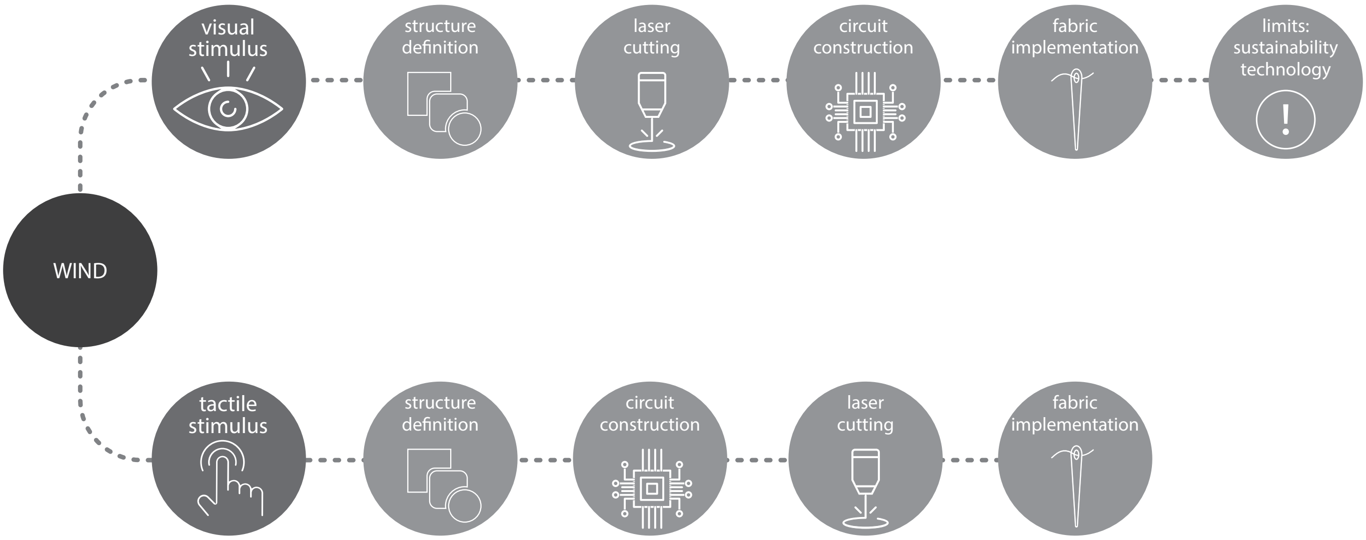


Figure 72. Wind tactile stimuls fabric implementation

The results obtained, following a functionality test, have been very **performing for the tactile stimulus**, but **weak for the elements joints**. In fact, the four small boards were not stable inside the fabric and did not allow an optimal skin contact. Moreover, the conductive thread integrated in a very thin fabric risks to enter in contact with the wearer. **The next experiment** took place with a **neoprene space fabric**, a material with large pores on one side, and a compact composition on the other, allowing the thread to slide easily inside without hand stitching operations. Thanks to its properties, it was also possible to engrave only one side, and, at the same time cut a small central hole (**Figure 73.**).

Figure 73. Shape and material second trial

Through this configuration **the board is stable**, however, to make it safer, **a second material has been added**. The shiny grey jersey is first glued to the neoprene, **through a heated adhesive sheet, and then stitched in zigzag** to create a visual detachment from the technical materials. Finally, the Lilypad has been inserted and its functioning and interlocking verified (**Figure 74.**)

Figure 74. Shape and material third trial steps.

Once the materials and all the steps necessary for the elements integration have been defined, **matching colors and shapes tryals** have been carried out for the final prototype (**Figure 75.**).

Figure 75. Shape and colors combinations

5.3 Final Prototype

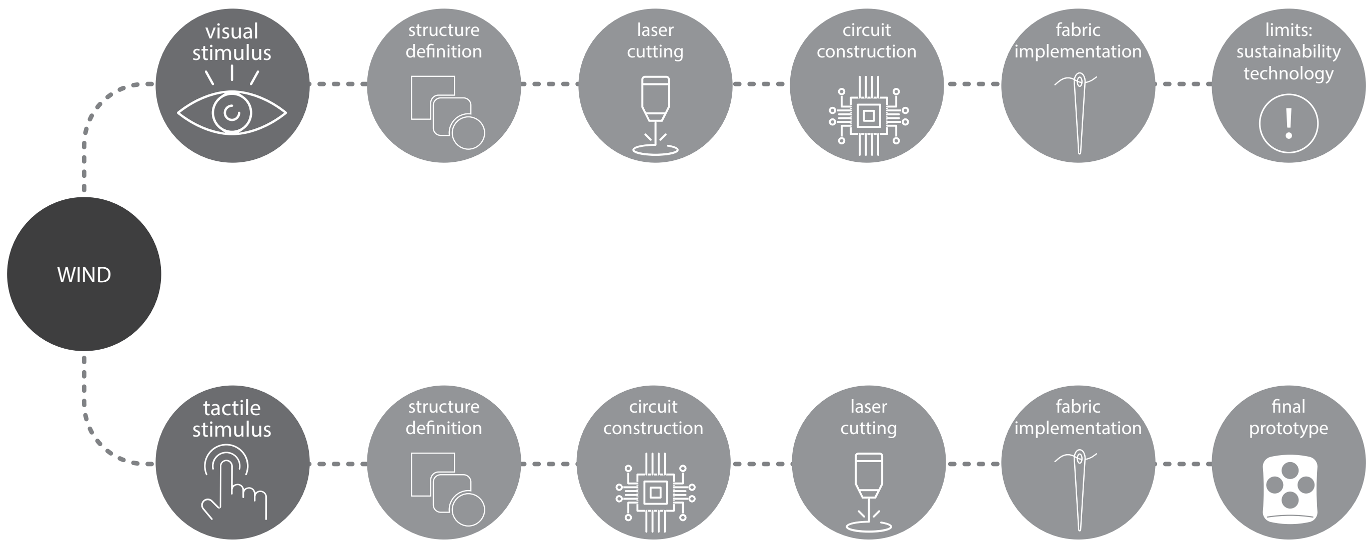


Figure 76. Wind tactile stimuls final prototype

The first phase of the prototype creations required the **Illustrator shapes design** for the laser cutting. As shown in the images below, the Biomimicry Wearable is composed of two main elements: the **neoprene space fabric**, which has been laser cut along the black lines and engraved in the blue circles (Figure 77.) and the **jersey grey shiny fabric** (Figure 78.), which has been divided in four organic shapes representing the main cardinal points and the wind puffs.

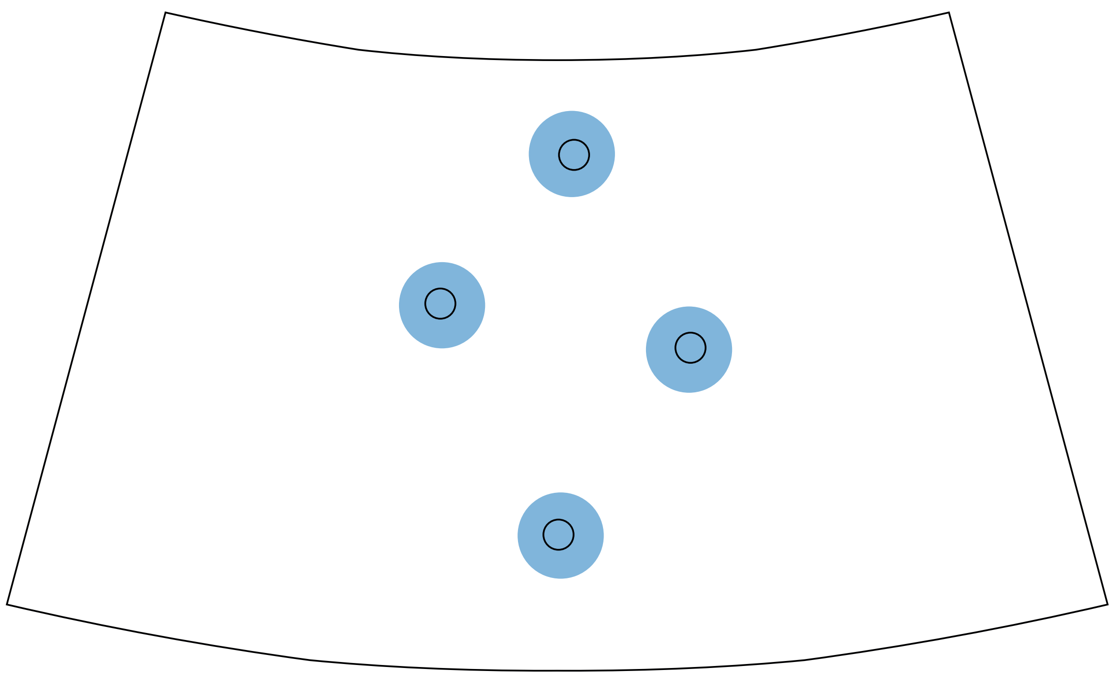


Figure 77. Illustrator file for neoprene space fabric

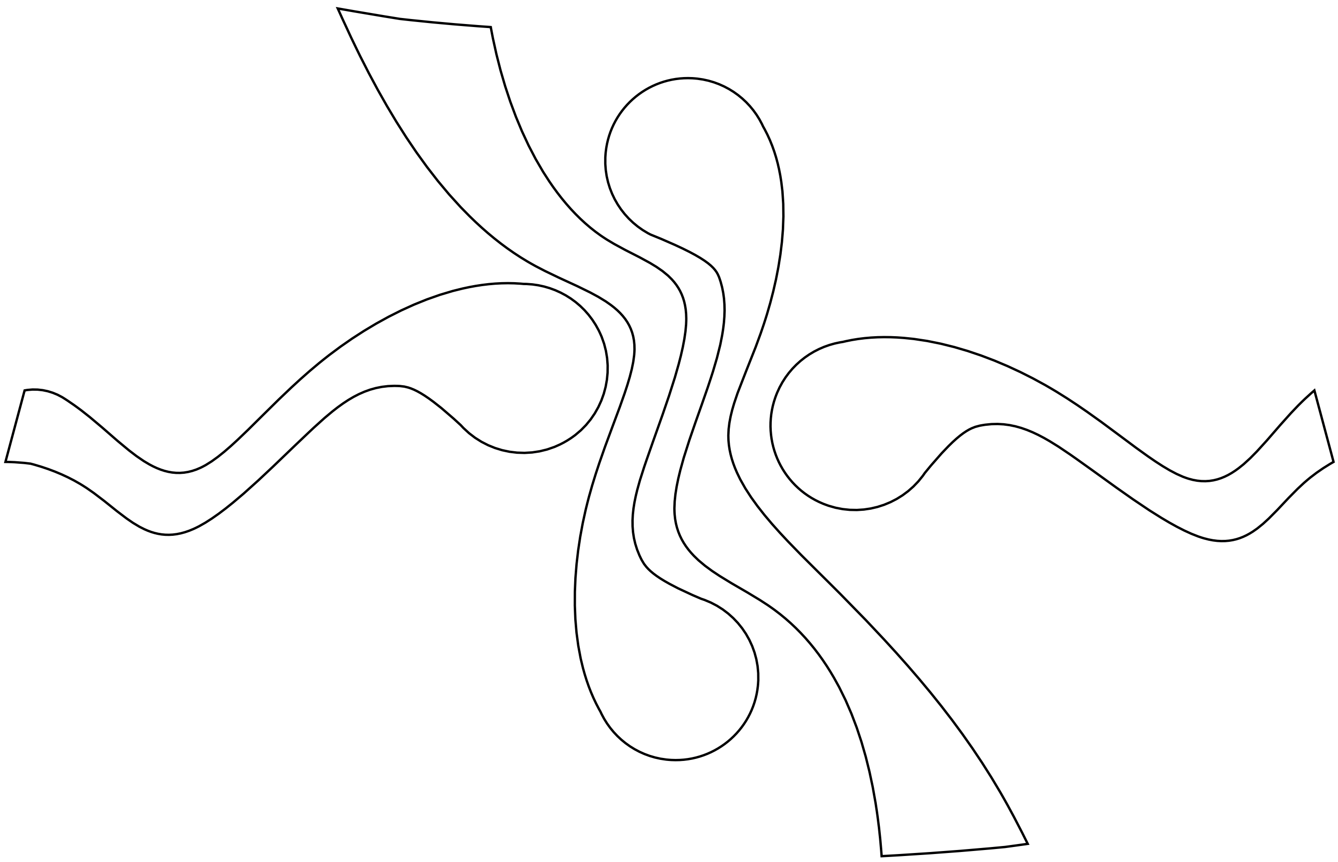


Figure 78. Illustrator file for jersey shiny fabric

As shown in **Figure 79.** the **next steps** concern the **union of the two fabrics by adhesive strips**, laser cut and then heated. The shiny material was then **secured with pastel green zigzag seams**.

For what concern the **circuit integration**, through a **conductive sewing threads** and a soldering station, it was integrated in the back of the wristband, which was then **covered in the edges and on the above layer** with specific fabrics, in order to prevent user arm injury from the current voltage. At the end a **zip was added** to have a more comfortable and adaptable wearable (**Figure 80.**).

In the following images (**Figures 81., 82., 83.**) the **final prototype** is shown open on a plane, with the closed zip and during its hypothetical use: while the person works in front of a laptop screen.

Figure 79. Neoprene and Jersey union steps

Figure 80. Circuit integration and final details steps.

Figure 81. Biomimicry Wearable open zip

Figure 82. Biomimicry Wearable closed zip

Figure 83. Biomimicry Wearable use

STORYBOARD

re-extrapolation

4 becoming aware of the outside world

feeling the real-time effect of the wind on his/her skin the user get interested on what is happening outside the office

1 extrapolation of wind datas

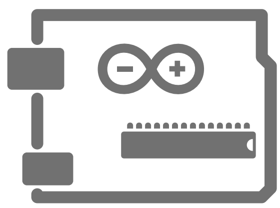
local wind datas are extrapolated in real time from the OpenWeather website

OpenWeather

wind speed

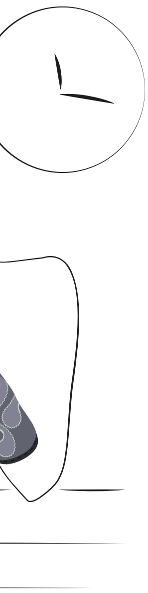
wind degree

2 conversion throught arduino



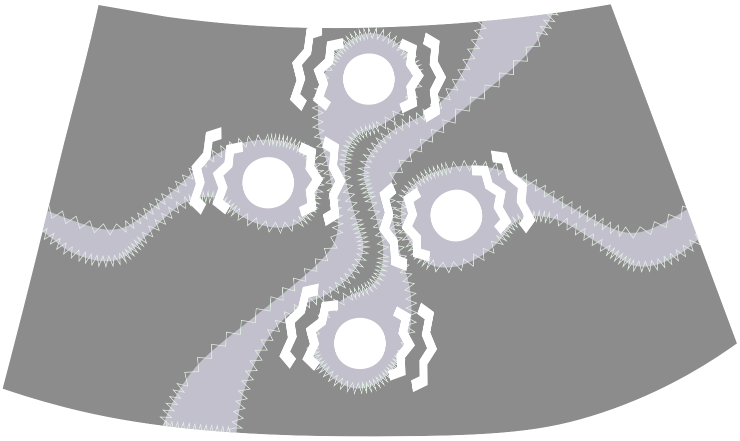
vibration fre

vibration



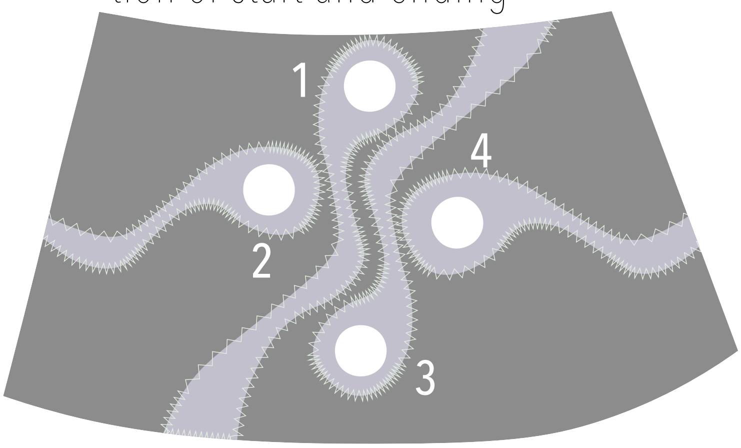
3.2 vibration frequency

depending from the wind intensity the vibrations will be with an higher or lower frequency



3.1 vibration direction

depending from the wind direction the vibrations will have a different position of start and ending



5.4 Chapter Visual Resume

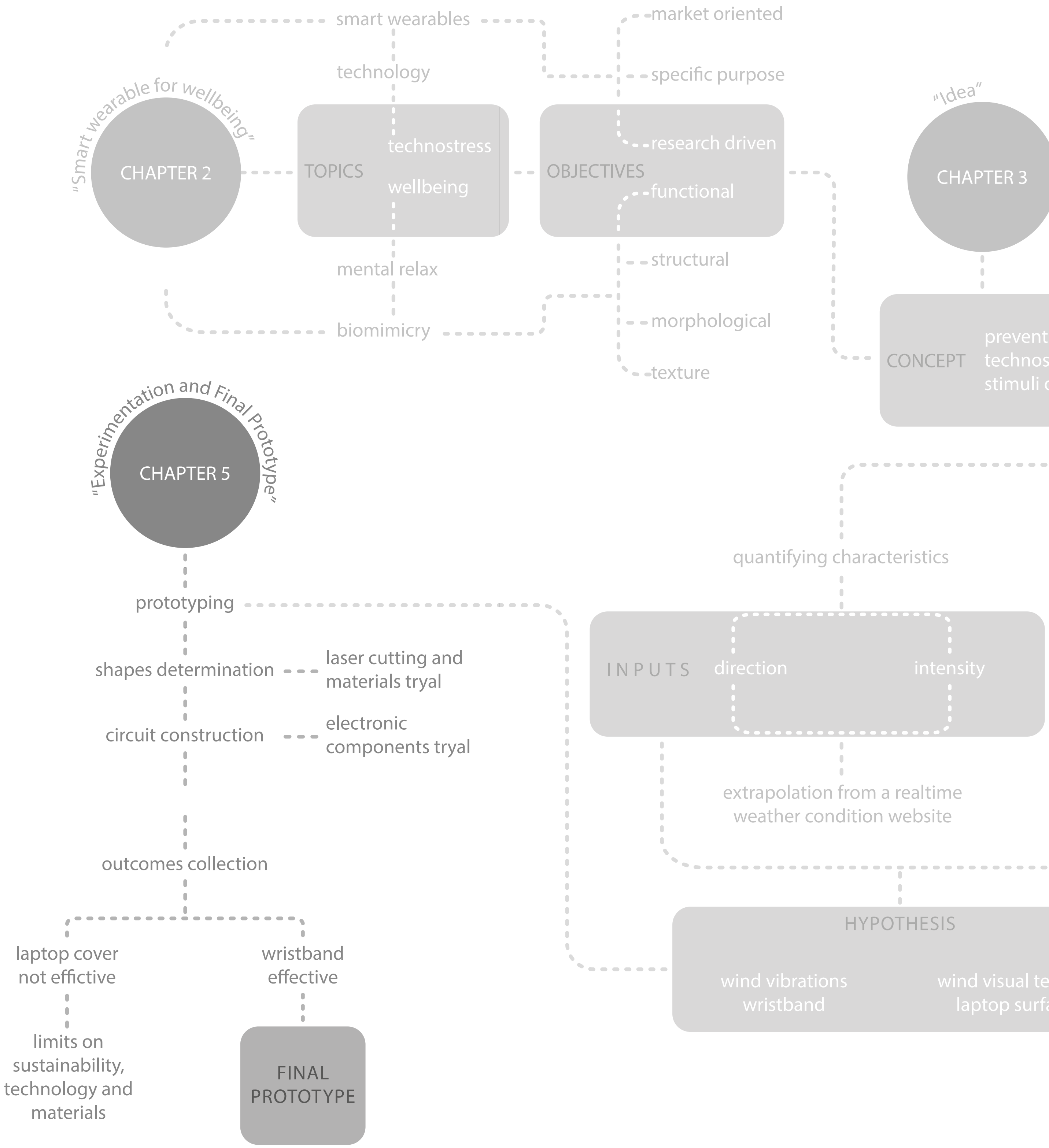
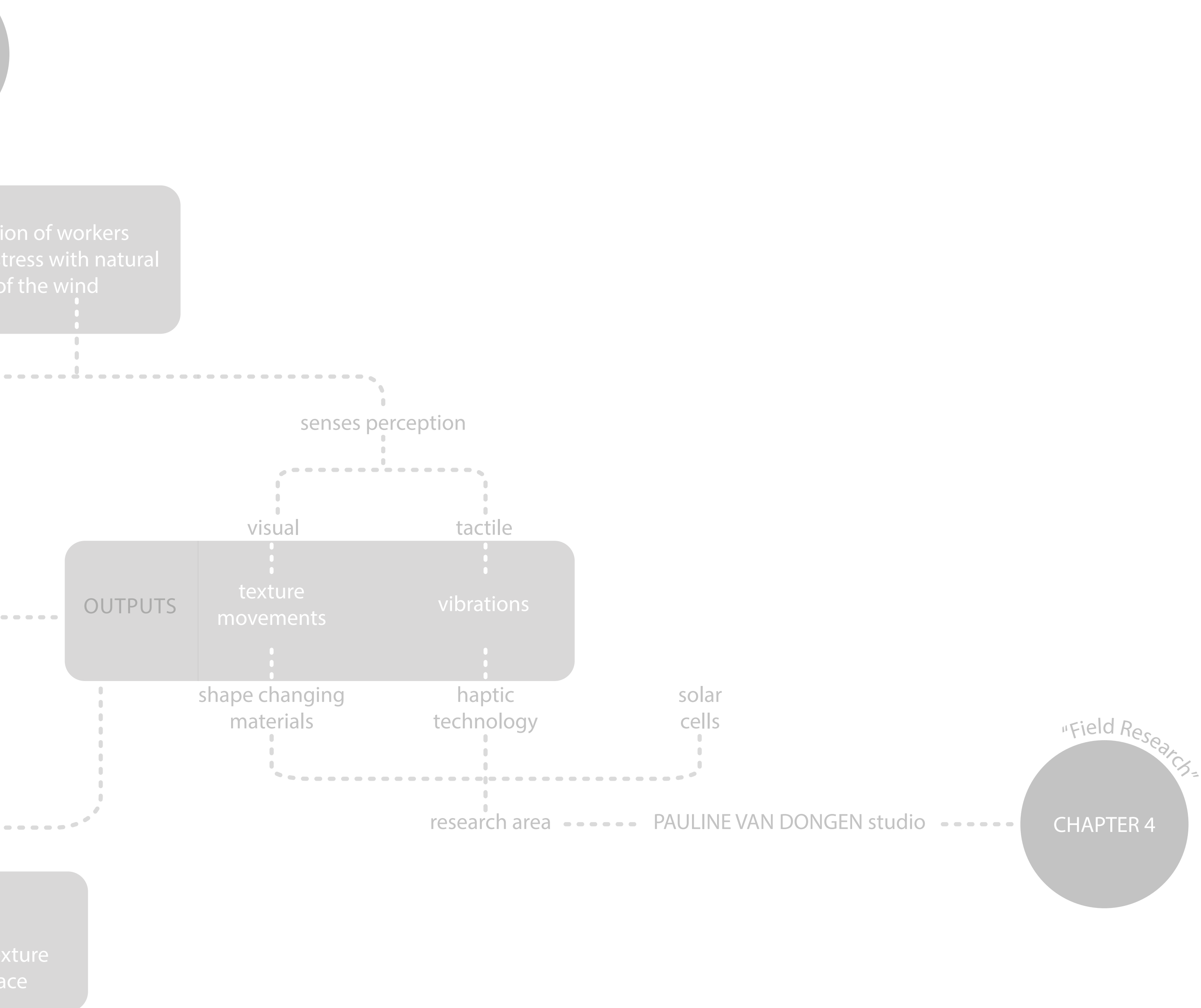


Figure 84. Chapter visual resume.



ion of workers
tress with natural
of the wind
senses perception
visual
tactile
OUTPUTS
texture
movements
vibrations
shape changing
materials
haptic
technology
solar
cells
research area
PAULINE VAN DONGEN studio
"Field Research"
CHAPTER 4
xture
ace

6. USERS' ACCEPTANCE AND FEEDBACK TESTS

6. USERS' ACCEPTANCE AND FEEDBACK TESTS

The Biomimicry Wearable project **underwent an evaluation through a survey system** to **collect user opinions and feedbacks**. In order to reach useful answer, the test was carried out by different people with the development of several activities in various location. The last step consists in a survey and its in-depth questions sections compilation, attached at the end of the thesis, from which general guidelines for the improvement of the prototype were extracted.

6.1 Research Hypothesis and Objectives

The starting hypothesis is a smart wearable that is connected in real time with the external wind and that transmits to the worker, during the periods when he/she should take a break, vibrations similar to the air stimulus. The wind breeze recreation, being absent in the office, should encourage the users to go outside and immerse themselves in nature. After 15 minutes, the wearable biomimicry stops vibrating and the worker returns to his normal activities. The work breaks in parallel with the activity of the device will lead to numerous benefits, in the short term since the employee will work better immediately after the device manifestation, and in the long term for his mental health status at the place where most of the daily time is spent. The objective of the test is to **assess the validity** of this hypothesis, with simulations carried out in real life, during the routine of several people who every day must interact with computers during their work, leisure or study. The thesis **main self-critical questions** which will be investigated in this part have been classified in three main aspect:

Haptic technology: everything that concerns the vibrations. The perception of the vibrating motors, the reactions that people will have the first time they feel the interaction on the skin, the intensity that makes them perceive as a relaxing movement, the interconnection with the wind, the effect that would entice the worker to interrupt the job activities for go outside.

Well-being: the focus of this paper work, particularly mental well-being in the workplace. As pointed out by the previous research, feeling psychically at ease is a current need of people, due to changes in society and the world of work; however, it is not yet recognized as a priority. Therefore, a goal of this thesis phase revolves around the device and its effects of relaxation connected with the productivity increasing, the well-being perceived at the end of the working day and the change of mood depending on the breaks activity carried out.

Design and ergonomics: Intrinsic to the design of a wearable object is its careful project, which must have as its main element the user center experience. The wearable Biomimicry will be evaluated by the target audience in terms of ergonomics; therefore, of comfort and ease of use. In addition, the aesthetic and how people associate certain colours and materials with certain concepts is also fundamental.

6.2 Target Group of Reference:

The tests will be performed on six different people chosen for different age, lifestyle, daily routine, interests and relation with new tech. They had in common that are **used to interact with technology in their work/study**.

1) Carlo, 21 years old, studies design and he is always informed about new technologies as they are his passion, he does some work as a free-lancer in his spare time, so between study, design and work is constantly in front of the computer. Even in his spare time, he prefers watching TV series, scrolling through Instagram or watching live on Twitch. With the money he managed to put aside he bought the apple watch and a wristband that monitors his heart parameters when he runs. (The test will be held inside his university)

2) Carlotta, 25 years old, works inside a biomedical laboratory for the analysis of food, in her working routine she almost always uses excel to catalog the data collected from the analysis, if she is not in front of a computer it is because she is extracting samples to be evaluated. She loves his work very much and therefore does not perceive the stress of the hours spent in the laboratory. (The test will be carried out inside his laboratory analysis)

3) Chiara, 28 years old, has recently finished her studies in biomedical engineering, she is looking for work and spends almost every day in front of LinkedIn and other platforms for the research. She would like to work in the field of three-dimensional modelling of prostheses as she is passionate of these new opportunities emerging. However, she suffers for spending a lot of time in front of a computer to look for work, this brings her a lot of stress. (The test will be done in the library, where she usually goes for applications)

4) Giuliano, 33 years old, works in the field of accounting, from Covid-19 has passed to smart working most of the week, his work is very stressful because since he started working from home he

perceives a kind of distortion of time, as if there is no a real detachment from his job, unlike when he worked in the office. He would prefer to return to the presence routine so that he can leave the office and return home to disconnect the view from the computer screen, as his eyes almost always burn at the end of the day. However, he considered himself a workaholic as he cannot relax when he has important deadlines. (The test will be carried out in his home studio)

5) Gabriella, 45 years old, works in a warehouse and deals with orders and customer service, the workplace is very chaotic and she often finds herself in difficulty because she has to carry out several activities simultaneously: manage orders electronically, answer calls and catalog the products that arrive. The work stress accumulated in her days is very high, so she claims to impose 10-minute breaks to relax. She has a good relationship with technology in her spare time but at work sometimes she finds herself a little anxious to follow the new technological innovations that are introduced. However, she states that with the time and the right instruction these allow her to work quickly. (The test will be carried out inside the warehouse)

6) Enrico, 61 years old, nature lover, with his 3 partners has founded a landscaping design studio. With time he claims to have switched to completely different approaches, once the customer use to came in presence and the works were partially designed on paper and then carried out directly on the construction site. Whereas nowadays the commissions take place online and the study has expanded to include a whole series of people who deal only with computer design to give an almost definitive vision to the customer before the work. Having a bad relationship with technology but a great dowry in social relations, he mostly deals with the management of the green and

construction site, however he finds himself some days having to answer all the e-mails that customers send to the office. (The test will be carried out in his landscaping studio).

6.3 The Methodology:

The test will be **carried out over a whole day**, all respondents will be asked to wear the device when they start working/studying. Every two hours the vibrations will be activated connected with the external wind. Those will last 15 minutes and will be more or less intense depending on the climatic conditions. In addition, the vibrations given by the four piezoelectric motors, that indicate the four cardinal points, depending on the direction of the breeze, will be activated at different intervals. The person will be asked to keep the phone active and will be given the **following instructions thought text** in order to guarantee a more dynamic test and introduce the different information gradually. Infact, the experience will be divided into 5 sections. In the first part of the interaction the user known only that the time passed since the work start is two hours, in the second one is asked to take a break for relx, then it has been provided the connection between the device and the real time wind stimulus. In the end, knowing that previous information, the user should take a relaxing break of 15 minutes inside a natural environment near is working/studying place.

6.4 The Results

The results were obtained by the participants' answers to a questionnaire. It was divided into **five different parts**, each investigating a different theme, the **first four** concerned with the **user interaction**, **the last are general answers on the design, comfort and aesthetics** of the smart wearable. At the beginning of the test the user wears the device being only aware that this will be activated after two hours. The analysis shows that **85% of the audience continued to work after this period of time, and all of them were performing a task that required the use of a bright screen**. As shown in the paper mentioned above, the absence of a fifteen minute break for every 2 hours of computer work could be a source of physical and mental distress. Despite this, **people prefer to ignore their well-being and pursue their goal**. Several studies mentioned previously demonstrate that this attitude involves a paradoxical counter-productivity. In fact, 75% of them confirmed that they felt nervousness or tiredness in the following hours, while the 15% which took a break declared to feel more relaxed and active after. (**Figure 85.**).

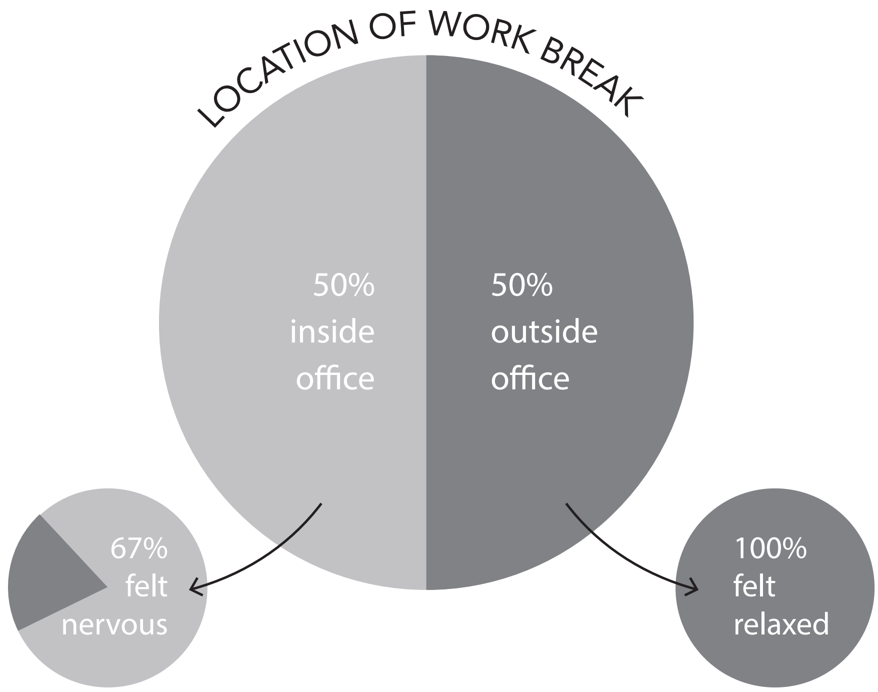


Figure 85. Audience activity after two working hours

The **general impressions** of this first interaction with the smart wearable were cataloged for the most part under the adjectives of **surprising** or **relaxing** (50% of respondents) **weird**, **interesting** or **annoying** (33%) **pleasant** (16%) (Figure 86.).

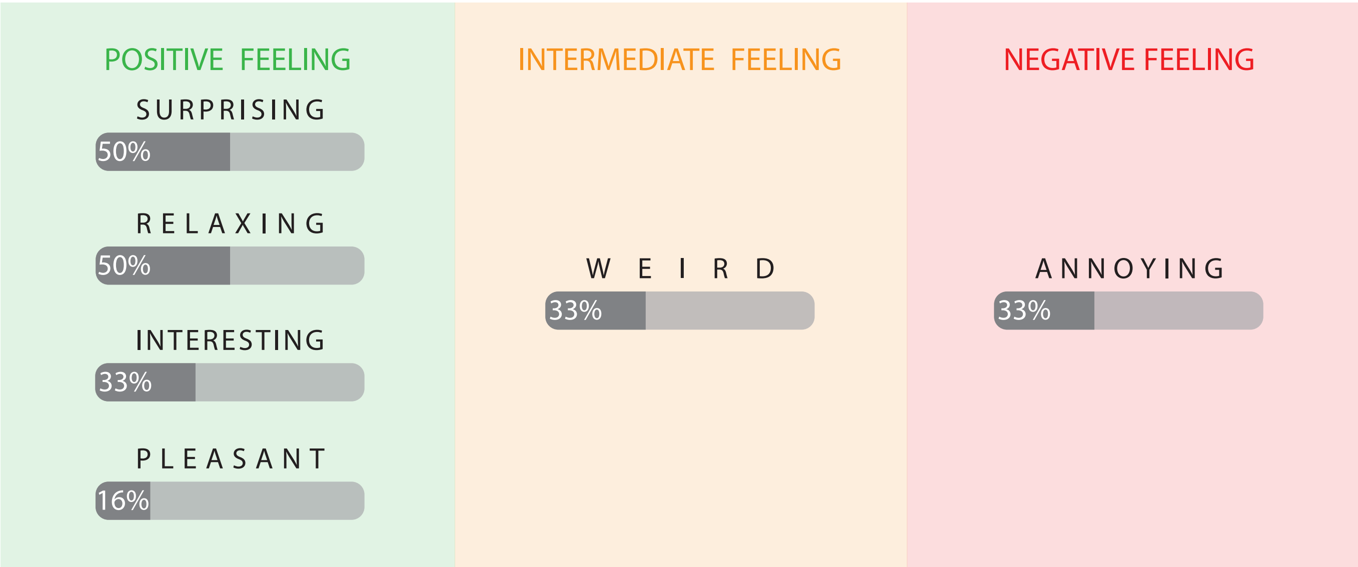


Figure 86. Interaction first general impression

The people who categorized the vibration as annoying belonged to 85% of those who did not take a break during the activation of the smart wearable, while those who found it pleasant benefited from a momentary break from work. As a result, it can be deduced that the **job rest brings greater benefits**, both in terms of **mental relaxation and productivity**. The device is perceived positively when it is used in conjunction with this.

In the second phase of the test the request to take a work break is added. In this section the investigation concern the kind of the activities performed by the people during these fifteen minutes. **50% of the audience took a break outdoors and felt more relaxed**. By contrast, **most of those which spent the time inside** (67%) developed **agitation or nervousness** later (Figure 87.).

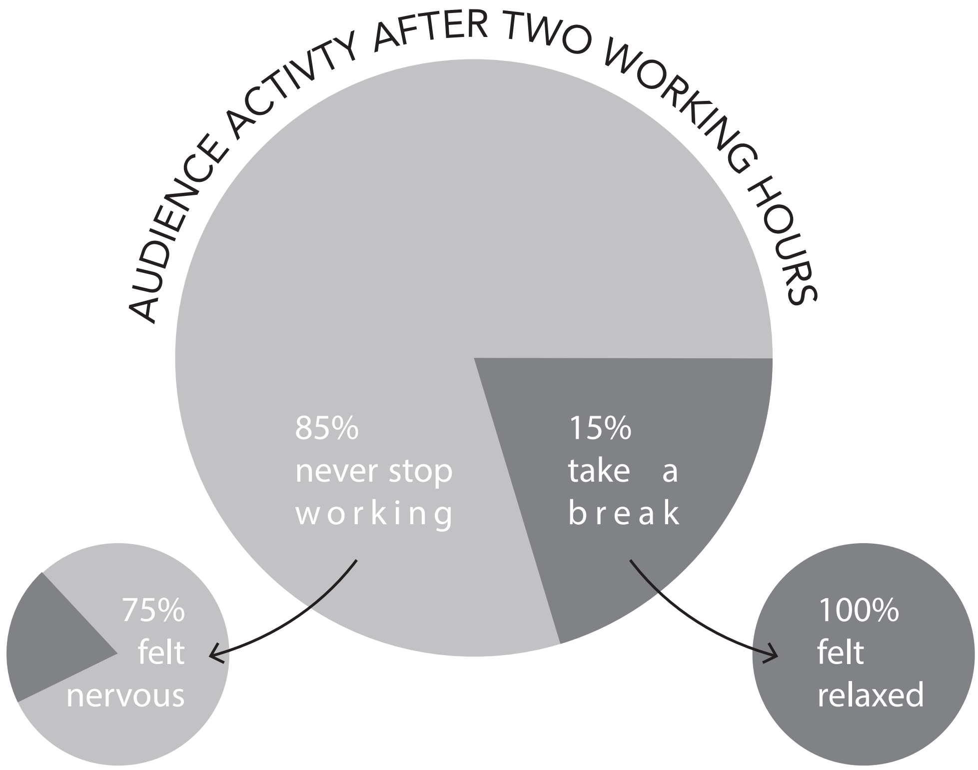


Figure 87. Location and benefits of the work break

The deduction that follows is the **importance of how people spend time during their break more than the rest itself**. Outdoor breaks are in fact significantly more effective. In the next step, the audience has been informed about the device's real-time wind connection. All the interviews took a break outside, everyone felt more relaxed. These percentages demonstrate what was already stated: the effectiveness of the outdoor break. In addition, the knowledge of a recreation of the wind stimulus through something that is worn, entices people to get out of an indoor place. After that, people were asked to go outside, possibly surrounded by natural elements and away from noise pollution to perform a relaxing activity. **The immersion of the audience in an environment rich in natural stimuli changes the perception of vibrations** compared to the first one. In fact, the adjectives used to describe this tactile stimulus are **interesting** (67%) **relaxing, pleasant and aware** (50%) (**Figure 88.**).

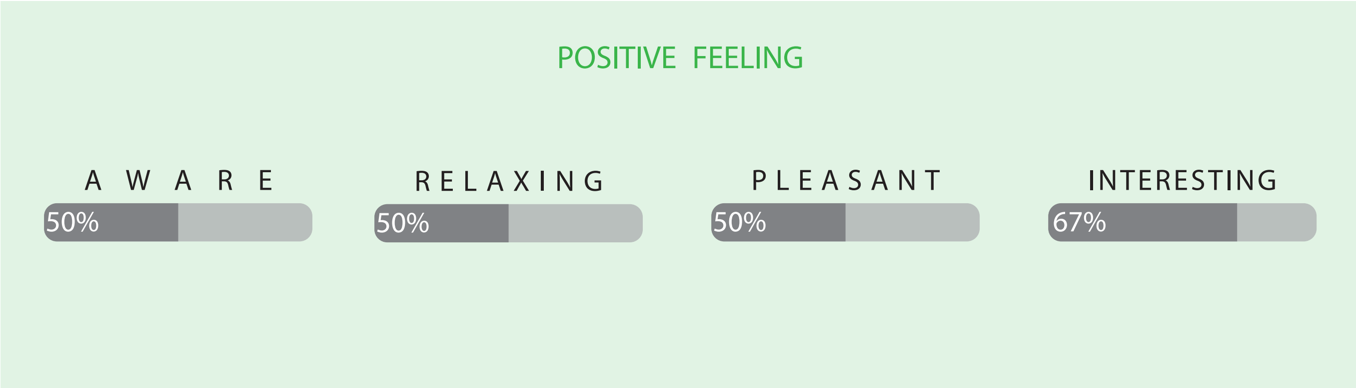


Figure 88. Interaction final impression

In addition, the entire audience found this pause more effective than the others. The general considerations on design, comfort and aesthetics, data are collected in **Figure 89.** concerning **efficacy in wind reproduction**. The recreation of this natural stimulus was **perceived only by the 33%** similar to reality, the rest perceived it as a sliding or otherwise, without being aware of the concept, would not reconnect the vibration to a natural element.

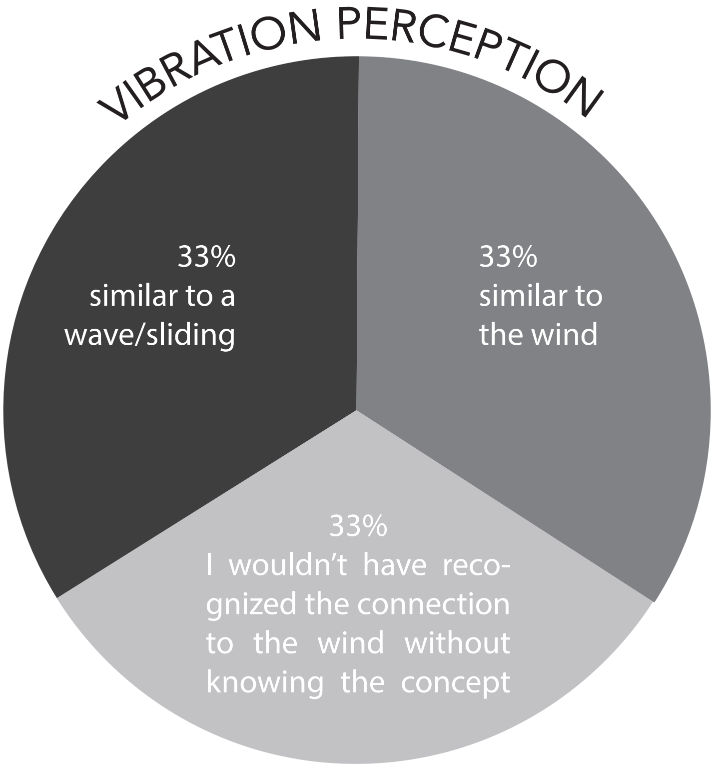


Figure 89. Feeling of wind reproduction percentage

As for the **intensity adjustment**, the survey results show that perception is **very subjective**, exactly the same amount of people stated that they would prefer a more intense, less intense or the same as the simulation strength of vibration. The motivation might be **related to the width of the wrist of each of the respondents**, some later claimed to feel the wearable tight or too wide. For an improvement in future developments is consider the possibility of tightening the device according to the needs of each. The aspect concerning the effectiveness of **vibration motor positioning**, saw the **majority of the audience propose the back** as the most suitable part to obtain a relaxing experience (**Figure 90.**).

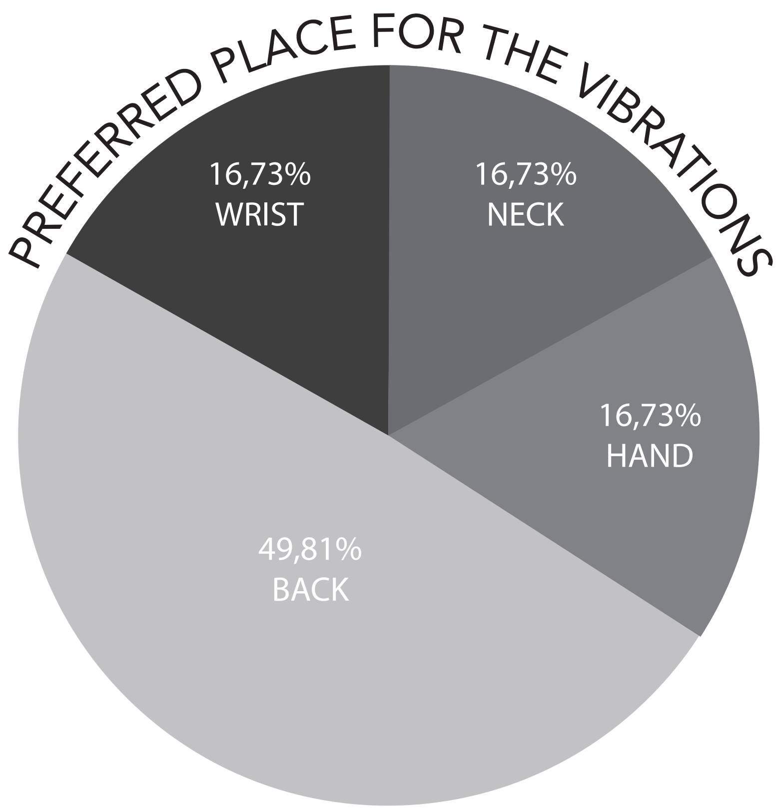


Figure 90. Vibration location improvement percentage.

The proposals of **colors that recall the wind were collected** at Figure 91., these are kept in consideration for future color variations.

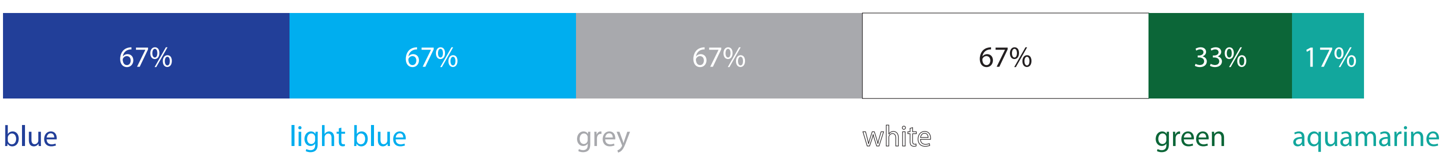


Figure 91. Wind color perception

Finally, some of the general considerations on aesthetics, comfort and general interaction that have been considered the most interesting, useful and inspiring for future improvements are mentioned anonymously below.

"I felt it comfortable but there was an external wire a bit annoying and also the activation was not immediate."

"I believe that the vibration could be lighter and faster in order to recreate better the wind sensation"

"The wristband was too large for me."

"Maybe the vibrations can be more effective and relaxing on the upper back, I feel a lot of pain in that area after my workday"

"I felt the interconnection between the wind and the device partially, I believe that a larger area is needed to increase the tactile experience."

"I would remove the zip; it was very annoying and also create a thinner layer of fabric."

"When I went out, I felt the connection because I saw all the leaves and grass of the park moving while I was walking."

All these sentences have been extrapolated from different subjects and represent mostly criticism or lateral considerations compared to the thesis hypothesis. Thanks for these thoughts it is possible for the designer to **observe different points of view** and to understand in an objective, but also **original way the possible solutions and improvements for the future**.

6.5 Chapter Visual Resume

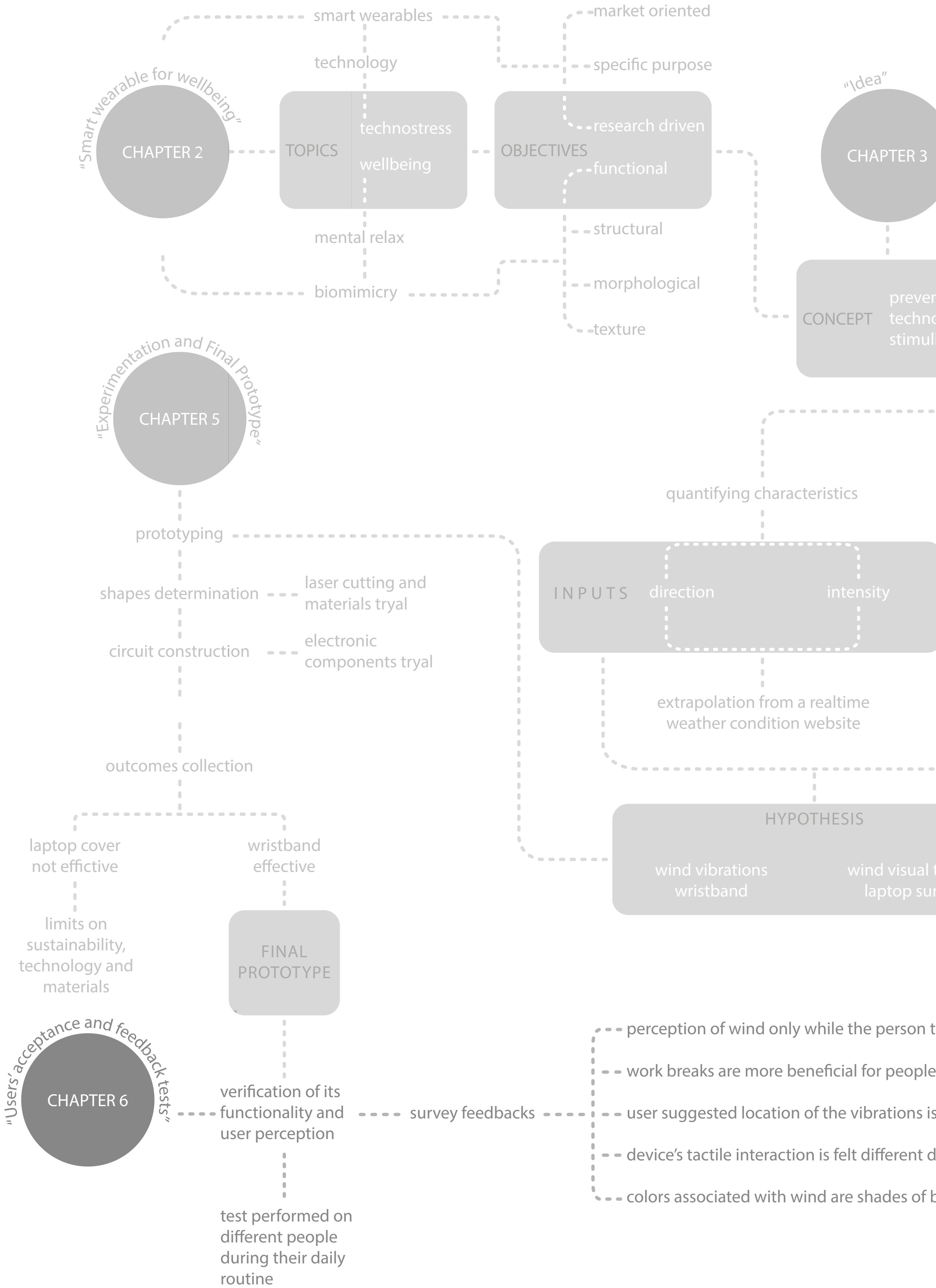
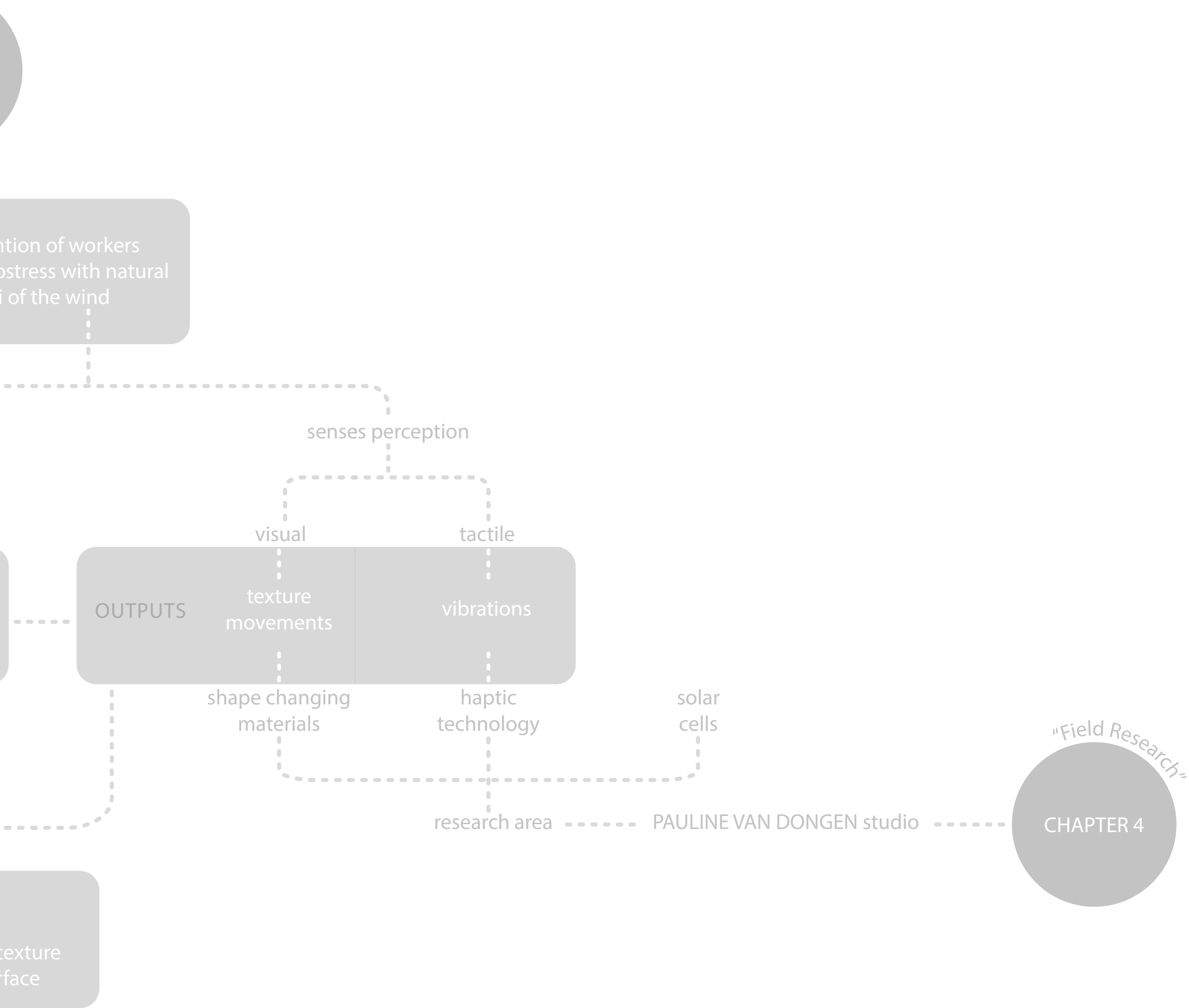


Figure 92. Chapter Visual Resume



akes a break outdoor

's productivity and relaxation

the upper back

epending on the person wrist size

blue, grey, white and green

7. RESULTS AND DISCUSSION

7. RESULTS AND DISCUSSION

7.1 Results Achieved

The project of this thesis emerged from the **residential experience in the Pauline Van Dongen studio**, where it was possible to develop **new theoretical and practical skills and approaches**. The opportunity of growing a starting **idea** in an **environment rich in stimuli**, professional figures, **inspirations**, **materials and machinery** available, lead to several advantages in the design and generation of a product. First of all, **the practicality** given by having the **necessary items** close and without **any limitation** on experimentation, cunducts the designer to immerse its own in the hypothesis. Open the chance of run several tests with materials, develop techniques shown by experts from different fields, therefore multidisciplinary, and act primarily on machinery such as laser cutting, sewing machine and welding circuit station, inevitably leads to **autonomy** caused by the ***learning by doing process***. Once ideas collide with the reality of the facts, the touching and seeing activity allows to **experience directly what has been hypothesized**, with a consequential practical **awareness** of the theory. From the point of view of the personal baggage acquisition, the knowledge due to the shaping of a project and the sharing transmitted by individual people, allow to take a step back and **re-evaluate the original premises of the project**. This transition from theory to practice can proceed, as in all design activity, to infinity, as a **product, fashion item or system** can always be improved. The next step is therefore **prototyping and testing on people**, the entity for which a object is developed. The **feedbacks received** make it possible to understand the veracity of the idea, and then be increased and **become part of the development process** (Figure 93.). In conclusion, i**mmersion in a multidisciplinary environment and open**

to experimentation allows to manually have **a match with assumptions to** create a more fluid and **connected to reality process**, instead of a purely ideological design, it is from the imperfections of concreteness that new knowledge can arise and push the limits of creativity.

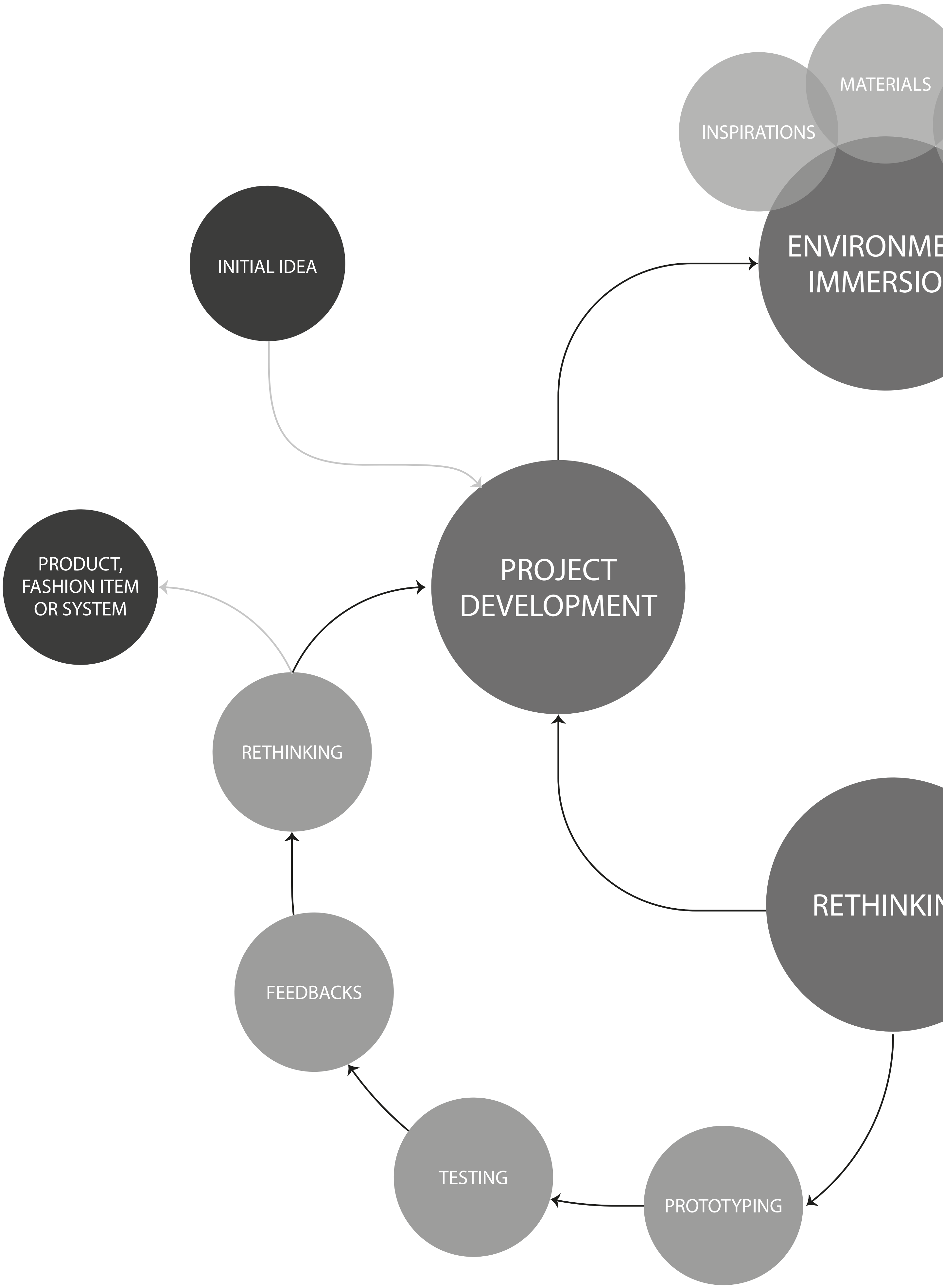
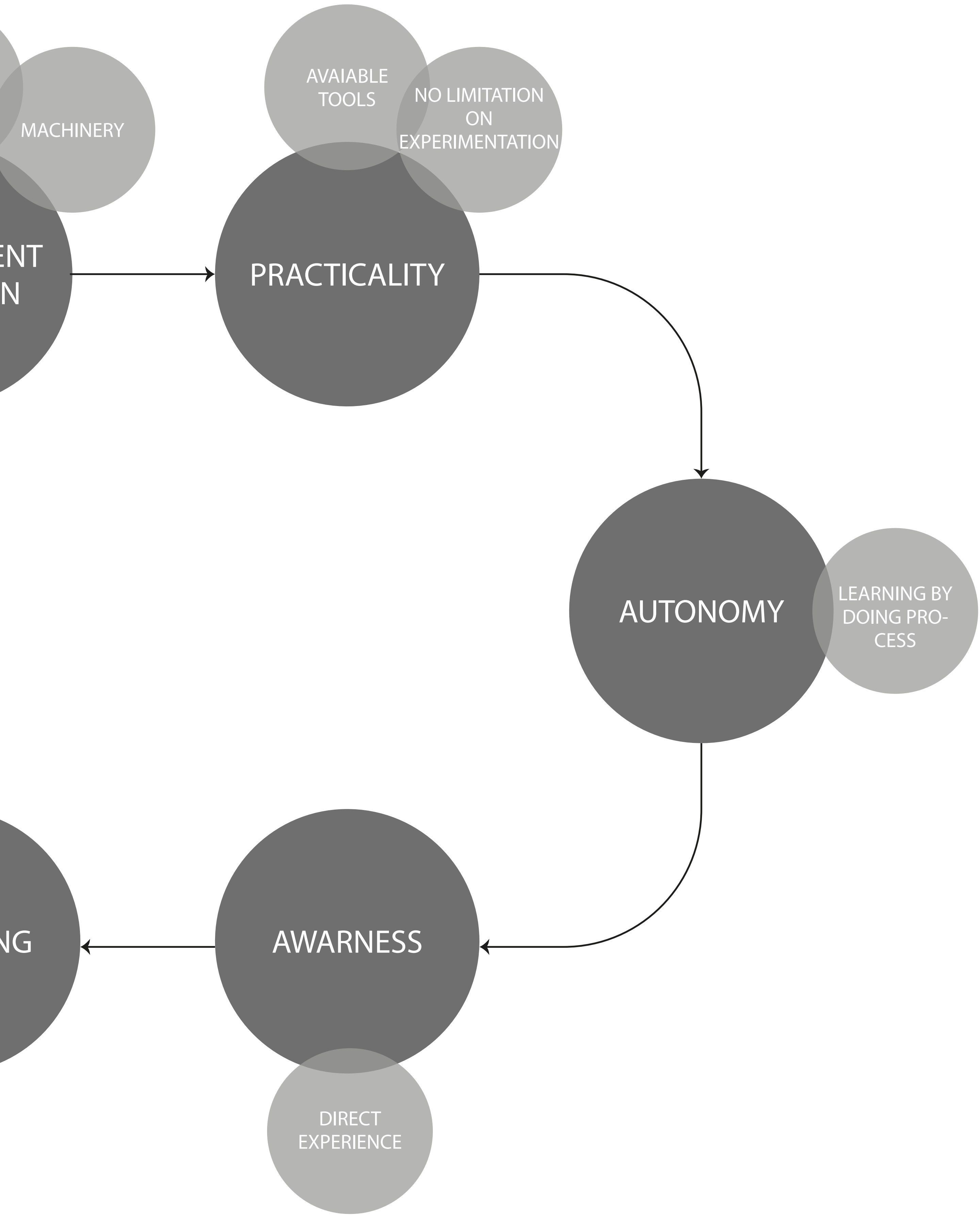


Figure 93. Developing an Idea with an experimental approach


ENT
N
MACHINERY
AVAIABLE TOOLS
NO LIMITATION ON EXPERIMENTATION
PRACTICALITY
AUTONOMY
LEARNING BY DOING PRO-CESS
AWARNESS
NG
DIRECT EXPERIENCE

7.2 The Ethical Topic Relevance

The acquisition of smart wearables is growing considerably in recent years, as demonstrated by all the new products on the market, in particular smart watches and smart wristbands. In the encounter between demand and offer, arises **the role of the designer**, the one who must see the future emerging needs and who is now required to **consider sustainability as a fundamental** point in the discipline. To ensure it, **three key factors** illustrated in Figure 94. must be considered: **society, economy and environment** (Mota et al., 2015).

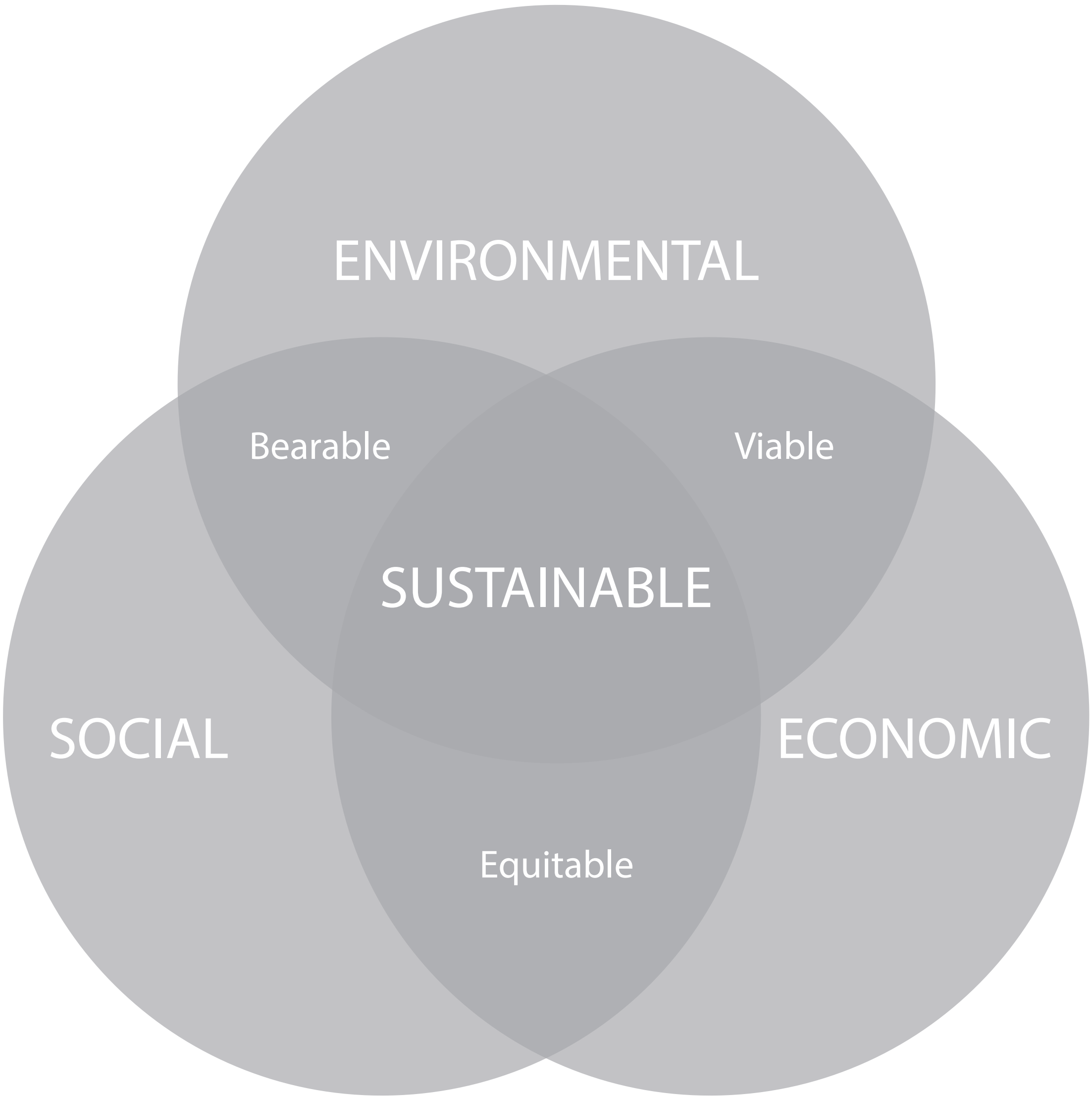


Figure 94. Three pillars of sustainability

Indeed, in parallel with the increase of devices that allow to reach certain work ambitions, or monitor various parameters, **the research part must focus in a social direction**. The social dimension of sustainability, according to the Global Reporting Initiative (GRI), "concerns the impacts the organization has on the social systems within which it operates". For this reason, **the thesis highlights the importance of physical and mental well-being**, as an objective that people should pursue, but often set aside for companies work. Infact, the questionnaire showed that **all participants suffered at least once of technostress**, and that, **they are aware of the prevention mode** through the care of themselves and the dedication of time to relax the mind and body. **However,** while people are conscious of this, they **still fail considering their mental care less important than productivity in the workplace**. This is demonstrated by data collected by user centered research, which states that half of respondents continued to work, even though they knew to had spent two hours doing their jobs. However, the lack of these intervals brings out all the negative sides of techno-stress, leading to job bornouts. Through the results obtained from the test is evident how informing the person of wearing a device connected in real time with the outside world, led all users to take a break, and of these the totality claimed to have been more productive and relaxed afterwards. From here emerges how the **human being to reach a working state of mental well-being**, in the short and long term, **needs something that entice them towards these goals**, transforming the wearable interaction in an interesting and effective action to distract and grab the person attention. However, despite the fact that **Smart Wearable Biomimicry performed well** during the user's detachment from the duties, its concept of **reconnecting the person with the outside wor-**

ld for mental rest, is **not sufficiently effective** without an explanation and information given to the user. In addition, **its vibrations refer to different inputs from the environmental wind**, but **could dialogue with the user** in order to make him/her perform different activities , depending on the intensity and placement of the vibromotors. In fact, in addition to the possibility of enticing the worker going out in the open air for a break, the wearable could communicate other practices for mental well-being. For example **whenever it is necessary to drink water, talk about a non-working topic with a colleague or stand up from the chair to walk for a few minutes** (Figure 95.)**.** All these activities, analyzed from the literature present in chapter 3, help in part **to relax the mind and reduce daily stress**, since the whole purpose of this thesis project is based on a more oriented vision to social sustainability, in view of **a future based on human needs, and no longer on mere labor efficiency.**

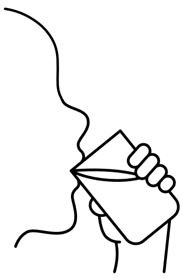
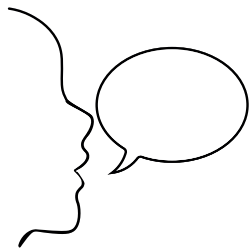
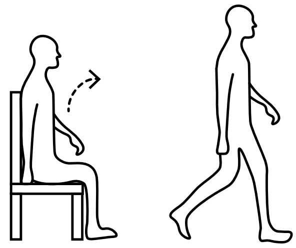
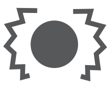
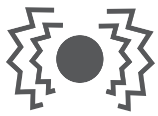
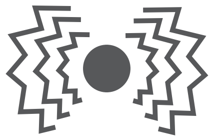
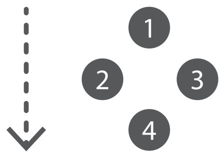
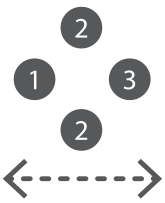
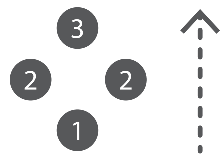
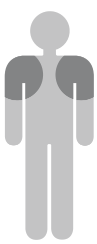
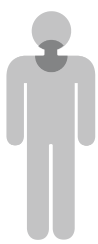
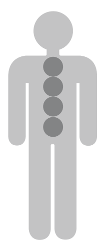
Action to achieve		
DRINK WATER 	TALK ABOUT A NON-WORKING TOPIC WITH A COLLEAGUE 	STAND UP FROM THE CHAIR TO WALK FOR A FEW MINUTES 
Vibrations intensity		
LOW 	MEDIUM 	HIGH 
Vibrations order		
		
Vibrations time range		
fast and with long intervals between one vibration and another, it should remind the rain drops	fast and without intervals between one vibration and another, it should remind the fast and continuous movement of neck rotation	slow and continuous, it should remind the body relaxation upwards
Vibrations position		
shoulder to encourage raising the arm 	neck to turn the head towards those around 	along the spine to extend the back upwards 

Figure 95. Additional possible comunication of Biomimicry Smart Wearable

7.3 Environmental Impact Concerns

Another **fundamental element to take into account in every single aspect of a project**, from its creation, to the production processes, up to the end of life of a product, is its **impact on the environment**. Through the phase of design and experimentation, what are today's possibilities and limitations have been determined.

7.3.1 Product Life Cycle

The designer act in the field of research driven, because is always guided by a careful analysis of people and the surrounding environment, in contrast to the market pull sphere. This modality of creation is indeed detached and in contrast with the fast fashion sphere, based on the production of garments used for a small period of time responding exclusively to the moment demands. The **smart wearables**, having nowadays as base a more complex design, composed of different elements and therefore generally more expensive, **must respond to the needs related to the long term** and, consequently, their **life cycle before the disposal is longer**. In addition, the ability to integrate elements that communicate with the user, increases the connection between the person and the wearable, which is no longer seen as a simple coating or aesthetic element, but will be established a **sentimental bond** that will further **expand its period of use**.

7.3.2 Material Recycling

Biomimicry Smart Wearable was developed inside the Pauline Van Dongen Studio, the whole experimentation and final prototype **was created starting from the brand previous project scraps**. The application of second-hand resources that can be reused, reassign a new value to items that had exhausted the previous one, reduces the waste used in the fashion industry. Moreover, thanks to new technologies such as **laser cutting**,

it is possible to design garments that **avoid the use of unnecessary fabric**, with a **pattern** previously analyzed to **satisfy the final user and** at the same time **reduces waste** as shown in **Figure 96.**.

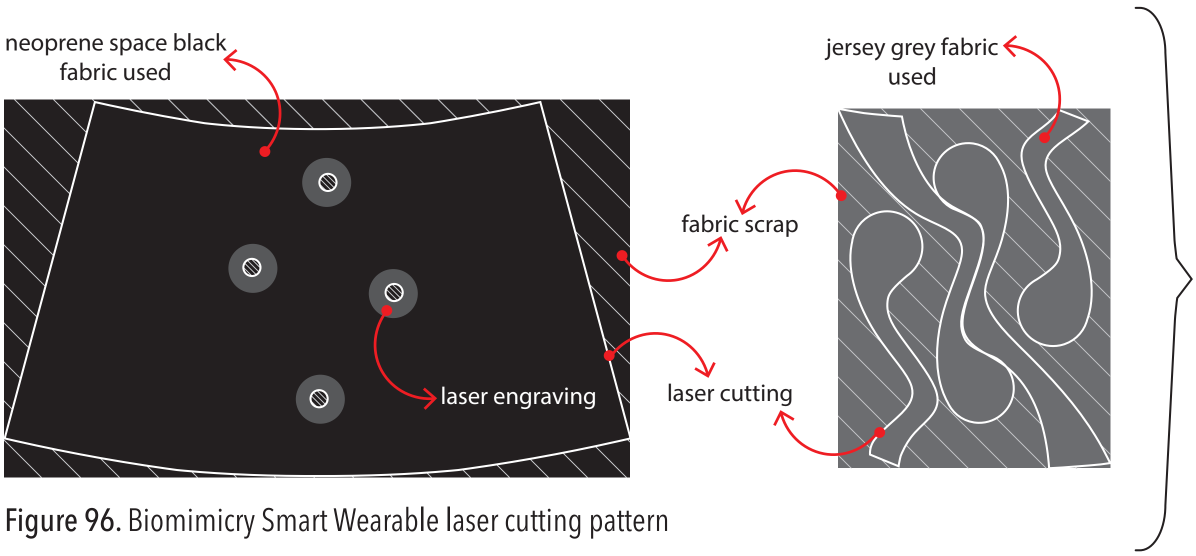


Figure 96. Biomimicry Smart Wearable laser cutting pattern

In conclusion to make the project even more sustainable, **a future development of a pattern**, that allows to **reduce the leftover fabric** and at the same time meet the ergonomics required. In addition, the use of the same kind of fabric allow an easier washability and disassembly(**Figure 97**).

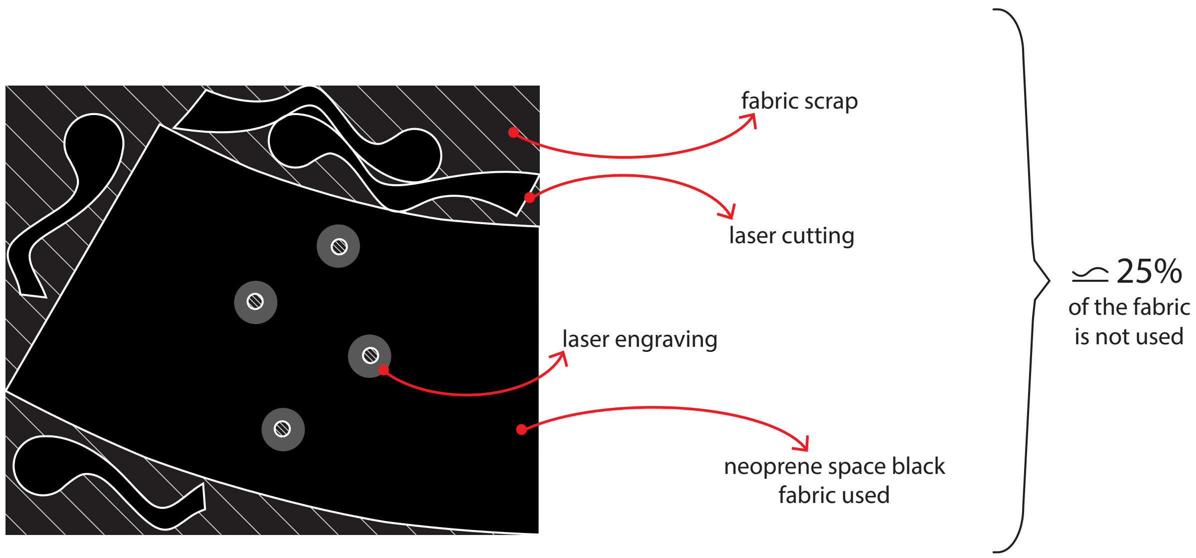


Figure 97. Biomimicry Smart Wearable laser cutting pattern improvement

7.3.3 Wearable Dissasembly and Washability

Another important element for the environmental sustainability of a garment is the **ability to disassemble its different materials**, in order to **facilitate its disposal at the end of life**. However, if the integration of electronic elements increases the sentimental and functional value of a fashion item, the union with the fabric represents a significant difficulty from the disassemblying point of view. The **use of piezoelectric motors** that are interspersed in their vibration times and intensity through information collected from the outside world, **requires the integration of a circuit within the structure**. At the same time it is necessary to have the vibrations close to the skin of the wearer, in order to make possible their frequencies perception, for this reason the motors have been integrated into the wearable through soft circuit and use of sewing conductive thread. This **union between fabric and electronic components makes it difficult the final wearable washability**, as these cannot come into contact with water without the risk of being damaged and impair their operation. Solutions such as separation of components through insulating coatings, as in the example of Pauline Van Dongen (**Figure 98.**) would lead instead to a major difficult in the product disassembly.

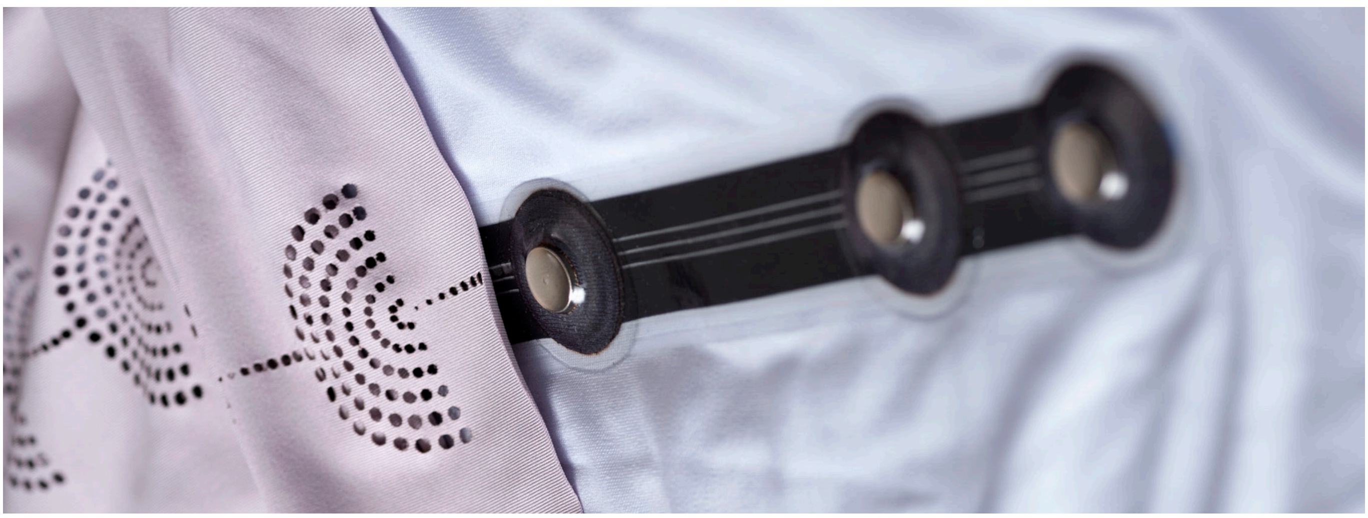


Figure 98. Pauline Van Dongen MYSA shirt detail.

A possible path for the future could be the study and **design of interlocking mechanisms** such as to **allow the removal and introduction of the circuit** and an easy separation of different materials (**Figure 99.**).

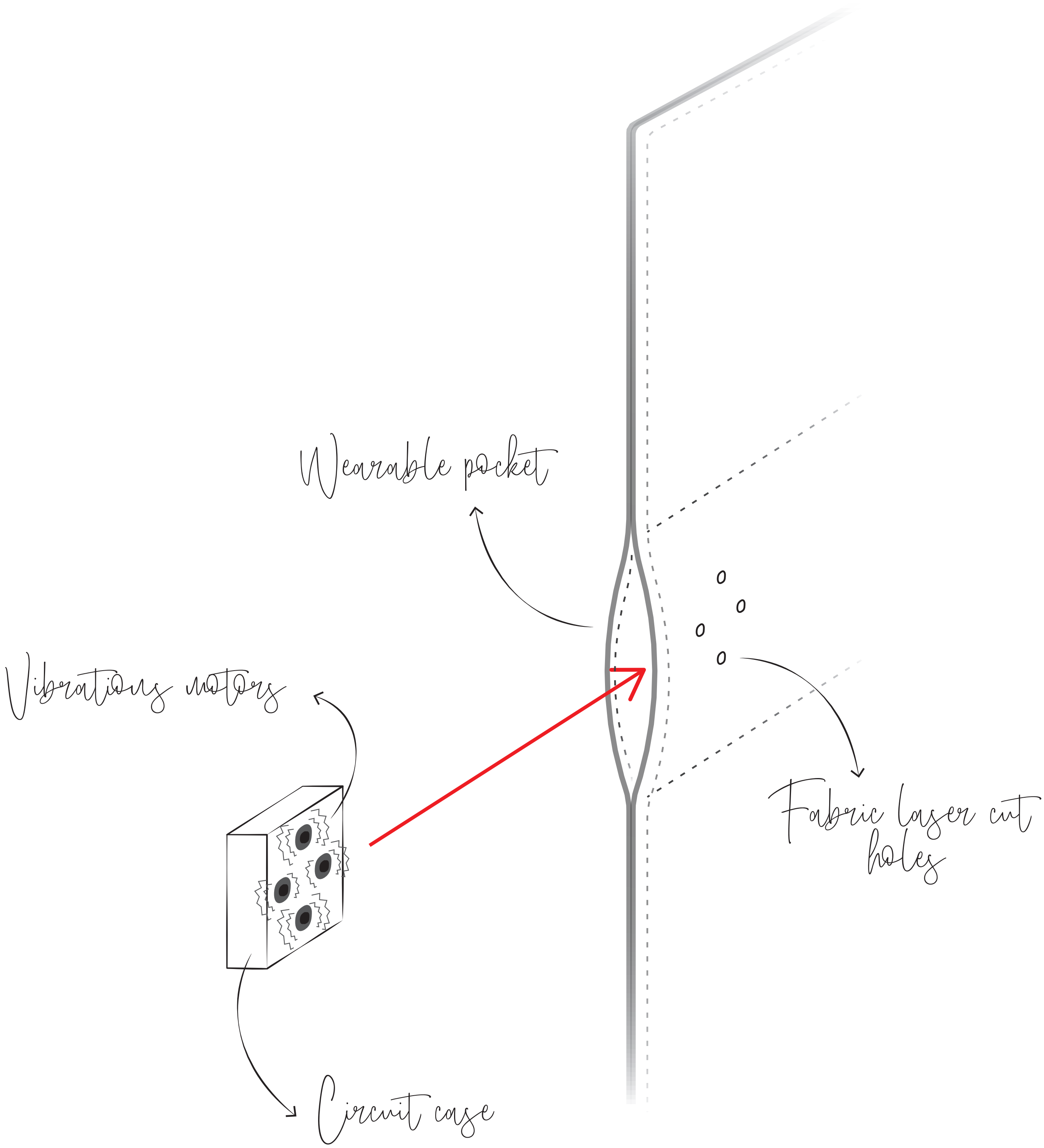


Figure 99. Biomimicry Smart Wearable materials separation improvement

7.4 Reflection on Aesthetic and Functional Implementation

In this step of the thesis it is important to collect the main relevant points of the user-centred research. It is stated through the input of the survey results, that work breaks are useful to feel more relaxed and active in the workplace. In particular, those carried outside the office return more benefits. The smart wearable interaction is perceived as more relaxing, pleasant and interesting when occurring in these conditions. Moreover, **the interconnection with the wind is better recognized when the wearer is located in an external environment**, **the reason** is linked, as shown by the survey outcomes, to **the combination between visual moving elements and wind sounds while the vibrations arise**. Consequently, the future project paths can be rethought with the aim of r**e-including the part of shape changing material research**, initially rejected for several motivations regarding the materials and technology limitations, **in addition to an auditorial experience**. As explained above, the nitinol wires require the use of a single battery for each wire to ensure their efficiency. These, to be integrated in the smart wearable, must be small in size. Nowadays the ones that encounter these parameters have a very limited power and duration, causing a continuous substitution. Despite this, looking at the innovations of the last centuries, the batteries have gone from low efficiency big surfaces, to reduced elements more performing, for this reason in a forward-looking perspective, it will be possible to recreate a **moving fabric** that, together with the effect of vibrations, will encourage the user to leave his office to meet the natural stimulus of the wind. To isolate the **nitinol threads** avoiding their overheating and contact with flammable tissues or people's skin, they could be **insulated through a protective layer** as in the example of Paula Van Brummelen (**Figure 100.**).

Figure 100. Paula Van Brummelen Embedded Movement detail

In addition, the project could **include the auditory stimulus of the natural element of wind**, which through its pressure on the elements interacts with the sense related to the human ear. This **combination of vibration perception, visual stimulation and auditory contact** between the user and what is worn, seen and felt, could allow to **create an immersive environment** through different outputs that will lead the person back to the external wind, curious about what's outside the office walls. Moreover, through the survey results, **the displacement of vibrations from the wrists to a part in contact with the back,** is evaluated to make the effect **more relaxing**. Following these reflections, the interaction between natural stimuli and the human body can occour through the **re-imagination of the interior space and what the user wears and interacts with** (**Figure 101.**).

Figure 101. Immersive and sensory stimulation through Biomimicry Smart Wearable

7.5 Chapter Visual Resume

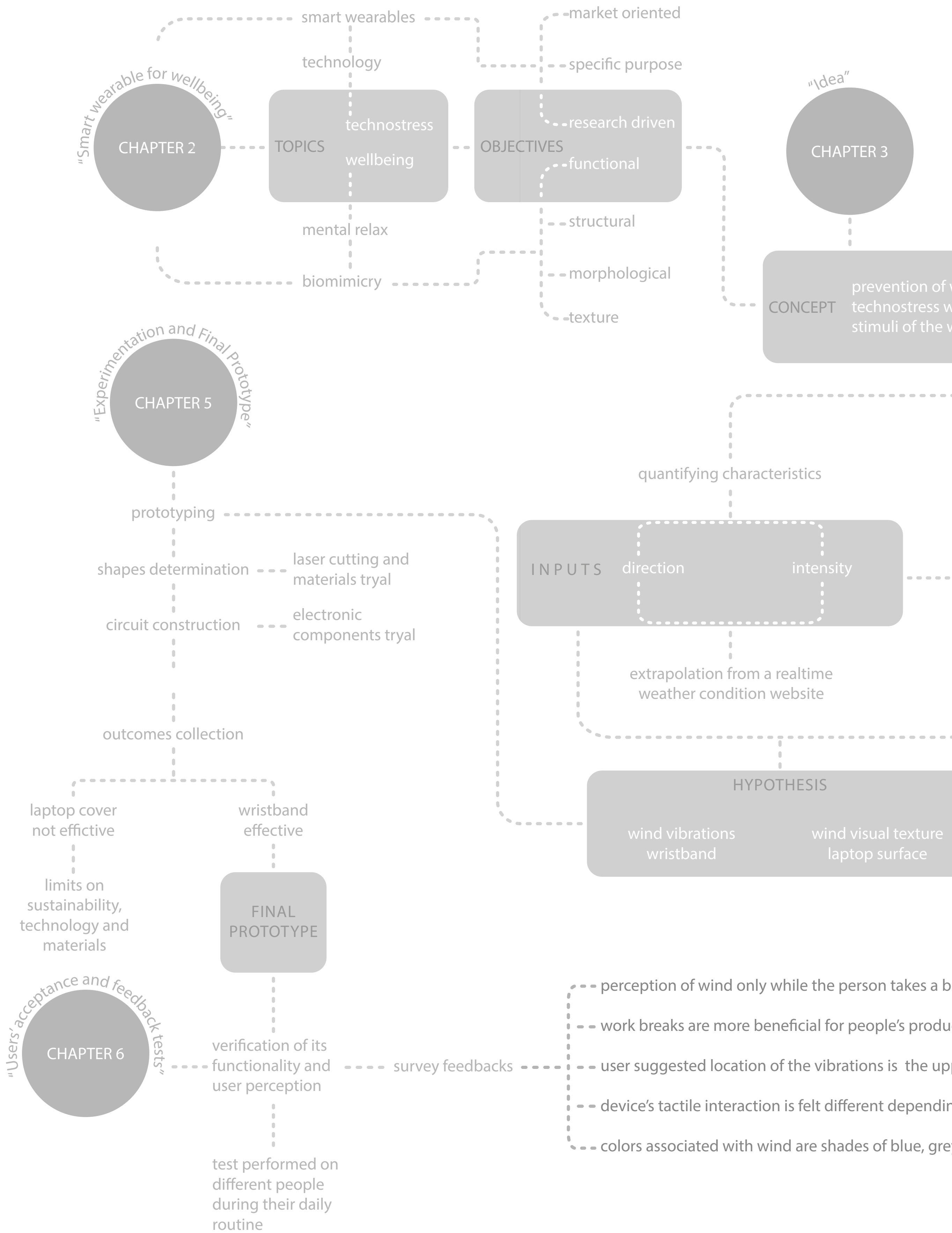
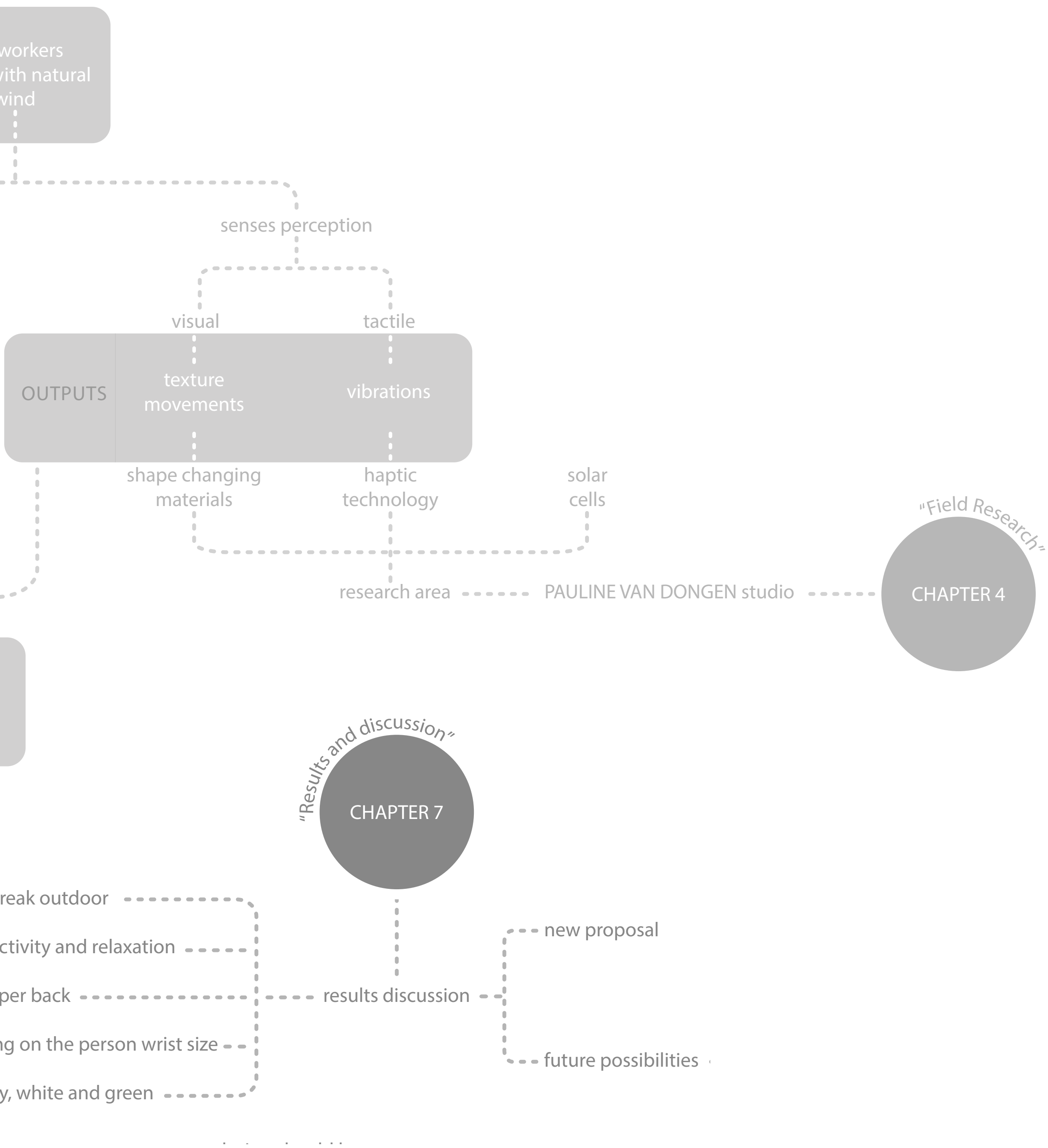


Figure 102. Chapter Visual Resume



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8. CONCLUSIONS

8. CONCLUSION OF BIOMIMICRY WEARABLE PROJECT

8.1 Project Conclusion

The technostress in workplaces is increasing in the last years due to the introduction of new technologies within the daily routine of employees. The role of the designer is to notice these emerging social problems that lead to different opportunities and new ways of design.

Through the literature in **chapter 2: *"Smart Wearable for Wellbeing"***, it has been seen that in the field of new technologies in addition to all electronic components intended to increase productivity in the workplace, there is a category less explored but focused on human needs and assumptions that are placed in the process of speculative design, or the **research driven**. The **union of this category with that of biomimicry**, the imitation through artificial creations of natural processes, especially functional, can give rise to **smart wearables focused on human well-being.**

In particular, the n**atural stimulus has been proven to relax the mind and prevent stress**. In fact, in the next **chapter 3: *"Idea"***, the human well-being and especially the mental well-being of workers have been examined, leading to the conclusion that frequent pauses from computer tasks and reconnection with the natural world, bring benefits in this field. The idea therefore r**eproduces the stimulus of the wind, an intangible external element, to entice people to reconnect with the outside world, through tactile and visual interactions of the smart wearable.**

In **chapter 4: *"Field Research"*** the intersection between the objectives of the project and the research areas of Pauline Van Dongen's studio, where the experimentation took part, was underlined, bringing to light the research fields of **haptic technology for tactile sensations and shape changing material for visual stimuli**. The analysis of case studies and the most visible and perceptible areas of the body, has led to define the possible modes of wind reproduction through two smart wearables, one with four vibrating motors positioned on the wrists and a surface whose laser cuts are moved by the contraction of four nitinol wires. Later, the **two quantifying characteristics of the wind**, namely **the intensity and the direction**, were translated into different interactions of the electronic devices. Indeed, the data extrapolated from a real time weather condition website, will pass through a circuit, integrated inside the devices, and **converted**, thanks to the Arduino software, **into vibrations and texture movements. Depending on the intensity the tactile feedback will be more or less intense and the movement faster or slower. Whereas, the direction adjusts their activation order.**

The shapes, materials and electronic integration tests described in **chapter 5**: ***"Experimentation and Final Prototype"***, require the use of **laser cutting machine, circuit construction and fabric implementation**. The initial hypothesis of the **visual feedbacks** has been rejected due to s**ustainability, technology and materials limits**. Whereas, for what concerns the **vibrational smart wearable**, it was created a wristband final **prototype**. The Biomimicry wearable is composed by a layer of black neoprene space fabric laser cutted to introduce four LiLyPad Vibe boards, secured by a second material, grey jersey, laser cut and joined over the first through the use of heat-adhesive paper and zigzag seams green pastel.

Having obtained a prototype, the **verification of its functionality and user perception**, has been checked through the **chapter 6**: ***"Users' acceptance and feedback tests"***. The test was performed on different people that had in common the laptop application during their daily routine, the device was worn for eight hours while the user had received several information and tasks. **The survey objective** was to **collect the effect of biomimicry wearable on well-being** and the general considerations on design and ergonomics. **The results** showed how the prototype **perception of wind** and **relaxing outcome,** happen only while the person takes a **break outdoor**, which seems to **bring a more beneficial effect on people's productivity and relaxation in the workplace**. In addition, the user suggested location of the vibrations is mainly the upper back, while for the ergonomic design, the device's tactile interaction is felt different depending on the wrist size of the interviewed. For what concerns the aesthetic, the colors which unconsciously remind the wind are shades of blue, grey, white and green.

All those survey inputs were examined and transformed into new possible redesign in **chapter 7**: ***"Results and discussion"***. The users feedback were developed as a **new proposal**, taking into account also the **future possibilities**, the **social relevance of wellbeing** and the **sustainability impacts**, linked to the product disassemblability and maintenance. **Through a tactile, visual and auditory stimulation, the user can feel more tempted to stop his activities and more easily recognize the connection with the wind in the external environment.**

8.2 Future Approaches

In the light of these considerations, precise themes and modalities have been identified to be improved in the future. **A series of guidelines summarize these concepts** for **further developments of the Biomimicry Wearable project**.

Perception: the sensation of a stimulus that reconnects the body with the outside world, through feedback similar to those of the wind, can take place through the recreation of tactile, visual and auditory outputs. The interaction of different smart wearables, allows to reimagine a continuous dialogue between the internal and external space, acting with the user at different levels and creating various sensorial experiences.

Ergonomics: the possibility of amplifying the contact between the skin and the vibrations, can be created through a smart wearables easily adaptable to the body of the person and the sensitivity of his/her skin receptors.

Social sustainability: the analysis and testing of different levels of stimuli interaction received by the smart wearable, could lead to a final product that communicates a series of messages to the person in order to take better care of his/her mental health.

Environmental sustainability: through the construction of patterns based on zero waste production, and component isolation through interlocking tests, to facilitate the washing and disassembly of the product, it will be possible to reduce the environmental impact of Biomimicry Smart Wearable project.

User centered research: all hypotheses must be tested both downstream and at the end of the experimentation process, in order to receive immediate feedback from the beginning and be able to exclude some design paths, favouring others. One of these theories that can be tested before production is the placement of vibrations on the back, to verify the relaxing benefits.

Learning by doing process: in the light of a continuation of this thesis work, it is recommended to proceed through several small steps of physical verification of ideas, to create a greater awareness on the most efficient production processes, materials and technologies.

Aesthetics: finally, improvements in this field could be carried out through studies of the unconscious part of the brain, developing shapes and colors that institively the human being associates with the wind concept able to act not only in the area of functional biomimicry, but also widen the design paths in the spheres of structural, textural and morphological biomimicry.

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9. REFERENCES

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10. APPENDIX

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10.1 Biomimicry Wearable test experience

The test was carried out on six people, of different age, profession and use of technology. The common element of the audience is to interact in their routine frequently with the laptop. The user centered research, was carried out in order to verify the primitive assumption that the prototype could reconnect the person with the outside world and entice the worker to take breaks from his duties. For this reason, each interviewee was asked to wear the Biomimicry Wearable during a whole day. In these eight hours, a series of messages pre programmed at very precise times, were sent to the user. In the message interaction, certain tasks were assigned and various reflections proposed, these contents are collected below.

Message 1) h. 9.00 a.m.

Hello, I would kindly ask you to wear the device you were given to start the test. As soon as you feel stimuli from the device you should take a picture of the activity you are doing while wearing it. Also, as soon as you feel the interaction you will know that it's been two hours from now, this will last 15 minutes. Thanks for your participation!

Interaction 1) h. 11.00-11.15 a.m.

The first vibration, the user at the moment only knows that it's been 2 hours from 9.00 a.m., does not know what kind of stimulus to expect from the smart wearable and what is the concept inherent in the project.

Message 2) h 11.15 a.m.

At this moment the interaction has stopped, I ask you please to note what you did from when it started, knowing that it's been two hours since you begin to work and the device has manifested for 15 minutes. Generally, after two hours of work the person has the right to take a 15 minute break to relax. At the next vibration I ask you to take some time for yourself and do an activity that relaxes you, until you feel the device interrupt its interaction.

Interaction 2) h 1.15 - 1.30 p.m.

The second vibration, the user at this time knows that it has been 2 hours from 11. 45 a.m. and that he must take a break to relax by performing an activity of his pleasure.

Message 3) h 1.30 p.m.

At this moment the stimulus has stopped, please note what you decided to do in 15 minutes following the request to carry out a relaxing activity. The stimuli that are sent by the device are vibrations connected in real time with the outside world. At the next vibration I ask you to turn back a relaxing activity for yourself and think about the feeling the vibrations give you.

Interaction 3) h 3.30 – 3.45 p.m.

The third vibration, the user now knows that it's been 2 hours from 1.30 p.m. and that he must take a break to relax performing an activity of his pleasure in parallel with the feeling perception that the device transmits

Message 4) h 3.45 p.m.

At this moment the interaction has stopped, I ask you please to note what you decided to do in 15 minutes following the request to do a relaxing activity and what kind of sensations the vibrations have transmitted to you. The smart wearable you wear is in real-time connected to the external wind, the vibrations go in different directions and intensities depending on the movement of the air. I ask you to the next vibration to come out from your work station, possibly in a green environment or anyway far from noise pollution, and try to relax in the open air with the knowledge that your device is connected in real time to it.

Interaction 4) h 5.45 – 6.00 p.m.

The fourth vibration, the user at this time should come out into the open air aware that the device is connected in real time with the outside wind and relax.

Message 5) h 6.00 p.m.

At this moment the stimulus stopped, I ask you please to take a picture of the place where you went and to note the general sensations of this last work break. The test is over, Thank you so much for your time.

10.2 Survey Questionaries: User-Centered Research

After the experience a series of questions were proposed through a questionnaire that is attached in its different sections.

10.2.1 Survey Introduction

Thank you for your participation,

below you will see the reflection questionnaire on your experience. It will be divided into 5 sections. There are 4 parts related to every moment of the day when you have perceived vibrations and one concerning your feelings in general on the device. I kindly ask you to fill it out by thinking deeply about the kind of experience you had.

The results of the questionnaire will be used to feed the development of the prototype. They will be anonimized, aggregated and clusterized. In case you would like to have any other information about the project, please write me at: cecilia.saffirio@mail.polimi.it

10.2.2 Survey Section1:

Tactile experience h 11:00 a.m.

This section refers to the first vibration you experience.

1) When there was the first vibration what activity were you doing?

2) Can you please describe the activity you were doing: if it was related to the use of an electronic device,

how long it was performed?

3) If it has not already been uploaded through the chat please insert the photo of the activity you were doing

4) Knowing that it had been two hours since you stopped working, did you decide to stop your activities or did you continue?

5) If you interrupted your work what did you do? For how long?

6) How did you work after? Were you tired or active? Relaxed or nervous?

7) What was the first feeling you had about vibrations? (e.g., did they give you pleasure or annoyed?)

8) At this time of day how much have you realized that the vibrations were connected in real time with the external wind?

10.2.3 Survey Section 2:

Tactile experience h 1:15 p.m.

This section refers to the second vibration you experience.

9) In this second interaction with the device you were asked to do a relaxing activity, was it possible?

10) If yes, what have you done?

11) If no, for what reason?

12) How did you perceived the vibration at this moment compared to the previous one?

13) How did you work after? Were you tired or active? Relaxed or nervous?

14) At this time of day did you realize that the vibrations were connected in real time with the external

wind?

10.2.4 Survey Section 3:

Tactile experience h 3:30 p.m.

This section refers to the third vibration you experience.

15) In this third interaction with the device you were asked to do a relaxing activity for you, was it possible?

16) If yes, what have you done?

17) If no, for what reason?

18) How did you perceived the vibration at this moment compared to the previous ones?

19) How did you work after? Were you tired or active? Relaxed or nervous?

20) At this time of day did you realize that the vibrations were connected in real time with the external wind?

10.2.5 Survey Section 4:

Tactile experience h 5:45 p.m.

This section refers to the fourth vibration you experience.

21) In this last interaction with the device you were asked to go outside, possibly in a green environment, for 15 minutes and relax, was it possible?

22) If yes and you have not already upload the picture of where you go in the chat, please upload it here

23) If not, for what reason?

24) How did you perceived the vibration at this moment compared to the previous one? Knowing that the device was connected in real time with the wind did you feel this interconnection? How did it make you feel?

25) How did you work after? Were you tired or active? Relaxed or nervous?

26) In your opinion, was this work break more or less effective than the others? Why?

10.2.6 Survey Section 5:

Part 5: General considerations

27) How much and how do you think the vibrations return the effect of the wind?

28) How much and how do you think they're relaxing?

29) How much and how did they entice you to go outside?

30) How do you think the vibrations intensity can be improved?

31) Do you think that on another part of the body they can give a better, more relaxing effect and that you are more tempted to stop what you were doing? If yes where? and why there?

32) Have you ever suffered of technostress while you were working/studying?

33) Do you believe that many short breaks could prevent technostress?

34) Listed at least 3 colours that reminds you the wind

35) What are your general impressions regarding the smart wearable design? Is there anything you

would improve for comfort or aesthetic appearance?

35) Other considerations