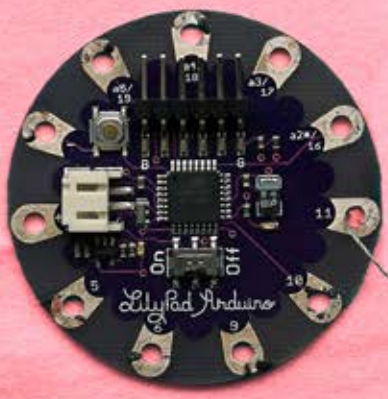
Sacha Franken
Graduation Report
2016 - 2017

SECOND-SKIN: AN ON THE JOB RECOVERY EXPERIENCE

THE RESEARCH AND DEVELOPMENT OF A MEANINGFUL INTERACTION USING TOUCH SENSITIVE FIBERS IN TEXTILES



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Preface

My graduation project was about following my passion for smart textiles. As a Design for Interaction student I put the user in the middle of the design process. Maybe that is partly where my passion for smart textiles comes from; there are not many product-designs a human being uses so close and so long to its body. As humans we create an identity, a statement and carry out our believes through fashion. Unfortunately the fashion industry has been making textiles seem worthless. Adding functionality to a garment, thát perspective on textiles will hopefully change. Smart garments not only create value but can also elicit meaningful experiences.

Working on this project has taught me how valuable it is to work together with people from different backgrounds. Getting inspired by the stories of ***Marina Toeters*** *and her perspective on smart textile design, being passionate and eager to learn more about smart fashion design because of* ***Linda Plaude****, understanding limits and possibilities of smart design from* ***Kaspar Jansen****, staying critical with every step from* ***Sadiq van Overbeek****, being able to get in touch with the user on a deeper level from* ***Marieke Sonneveld****, getting to know electronic components and their magic from* ***Hans Franken****, understanding how to tackle the design process from* ***Erik Jepma****, plotting the perfect Arduino brain with the experience of* ***Michiel van Overbeek****, wanting to do more for our planet due to the stories of* ***Peter van Akkeren****, understanding the value of relaxation from* ***Cathrien van Dam*** *and finally being able to communicate the value of my design through the eyes of* ***Beyond Awakening Collective*** *and* ***Emma Notenboom****.*

A big thank you to everyone that has contributed to this amazing and final experience as a student.

Executive summary

For us human beings in the West, clothing has become a disposable product that provides us with protection from the environment and displays our sense of style. But, the future of clothing is about to change with the rise of smart textiles.

This report provides a research and evaluation of a smart garment designed with capacitive fibers as an input. With use of the material driven design method, a material selection is made at the start of the design process. The best result from the material research is using silk as an electrical insulator and stainless steel as an electrical conductor.

As silk forms the basis of the garment design, its properties and qualities were used as guidelines to find a suitable context. Silk as a smart garment has high potential to be used in an office environment.

During the analysis and observation of the office context a group of female employees (aged 25 to 35) with a need for recovery was found that could be solved with smart garment design. Looking into possible solutions for the recovery problem, the relaxation response presented itself as a solution for on-the-job recovery.

Using body and mind relaxation techniques derived from the relaxation response a choice of electronics was made that could imitate bodily activities. These are a vibration motor that resembles a heartbeat at rest, a DC motor that mimics the movement of the body while breathing and LEDs that provide a breathing exercise for wearers to engage in.

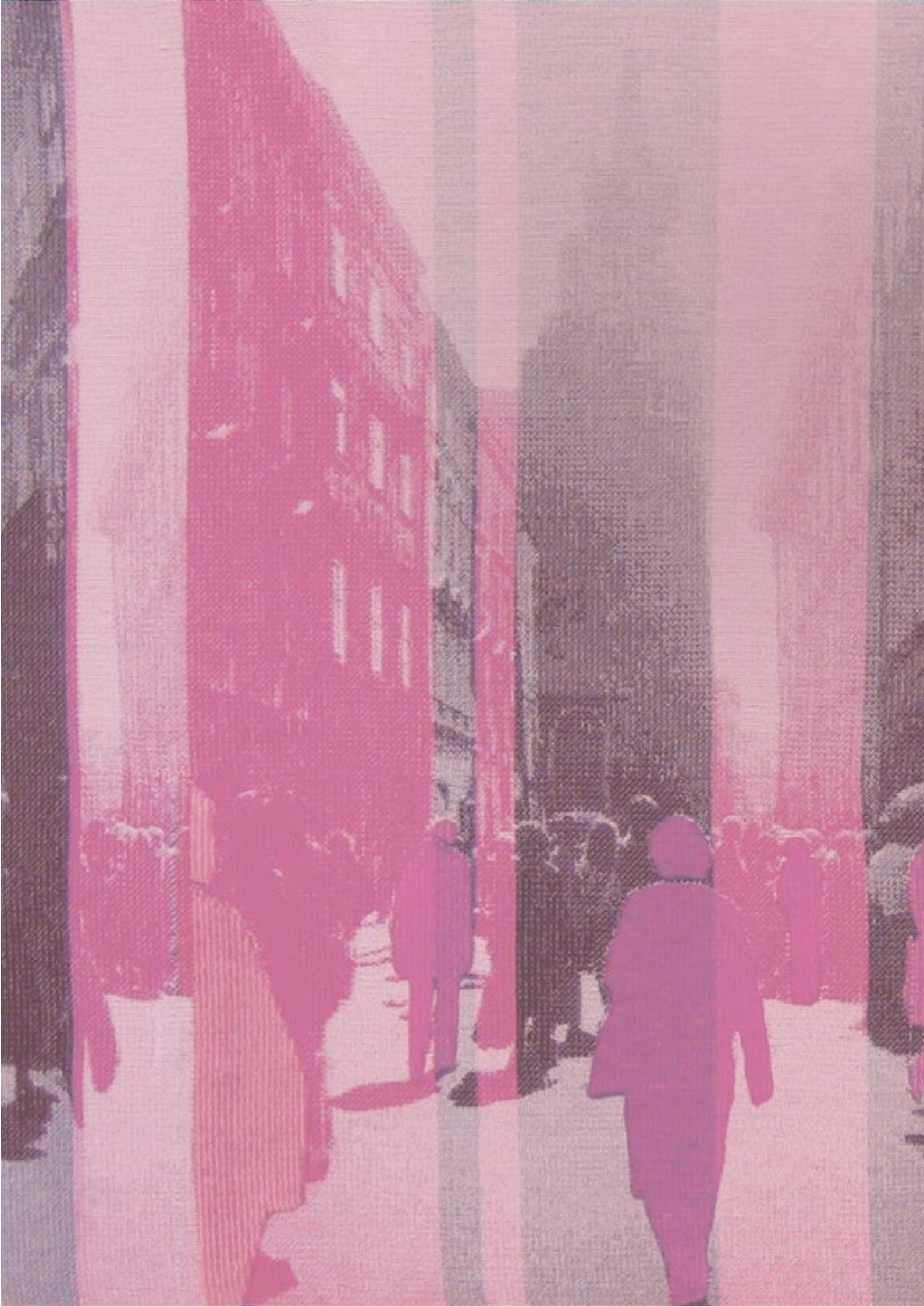
A blouse was chosen as a garment design which aesthetic features are inspired from fashion trends of this year's autumn/winter runway shows.

This report concludes that the design of the smart blouse was found successful. It provides the wearer with a psychological detachment from work for a few minutes and enables the wearer to have control over when and how the relaxation process is happening. Next to that it is an intimate experience that can be initiated within an office space without distracting others.

This report concludes that the design of the smart blouse was found successful. It provides the female office employees aged 25 to 35 with a psychological detachment from work for a few minutes and enables the wearer to have control over when and how the relaxation process is happening. Next to that, with the right adjustments, the smart blouse can become an intimate experience that can be initiated within an office space without distracting others.

Recommendations

- Longer term research is needed to optimize the benefits of on-the-job recovery using the smart blouse.
- Improve the motion of the DC motor.
- Reduce the sound of the DC motor by looking for more advanced models.
- Change the visibility of the LEDs.
- Change the code of the breathing sequence so it responds better to the touch behavior of the wearer.
- Improve the size of the front, back and cuff panels of the pattern.



THE MOST PROFOUND TECHNOLOGIES ARE THOSE THAT DISAPPEAR. THEY WEAVE THEMSELVES INTO THE FABRIC OF EVERYDAY LIFE UNTIL THEY ARE INDISTINGUISHABLE FROM IT

– MARK WEISER –

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smart textiles

ANALYSIS

capacitive fibers
touch
dressing the body
material research
context exploration
target group exploration
relaxation and recovery
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Design Process

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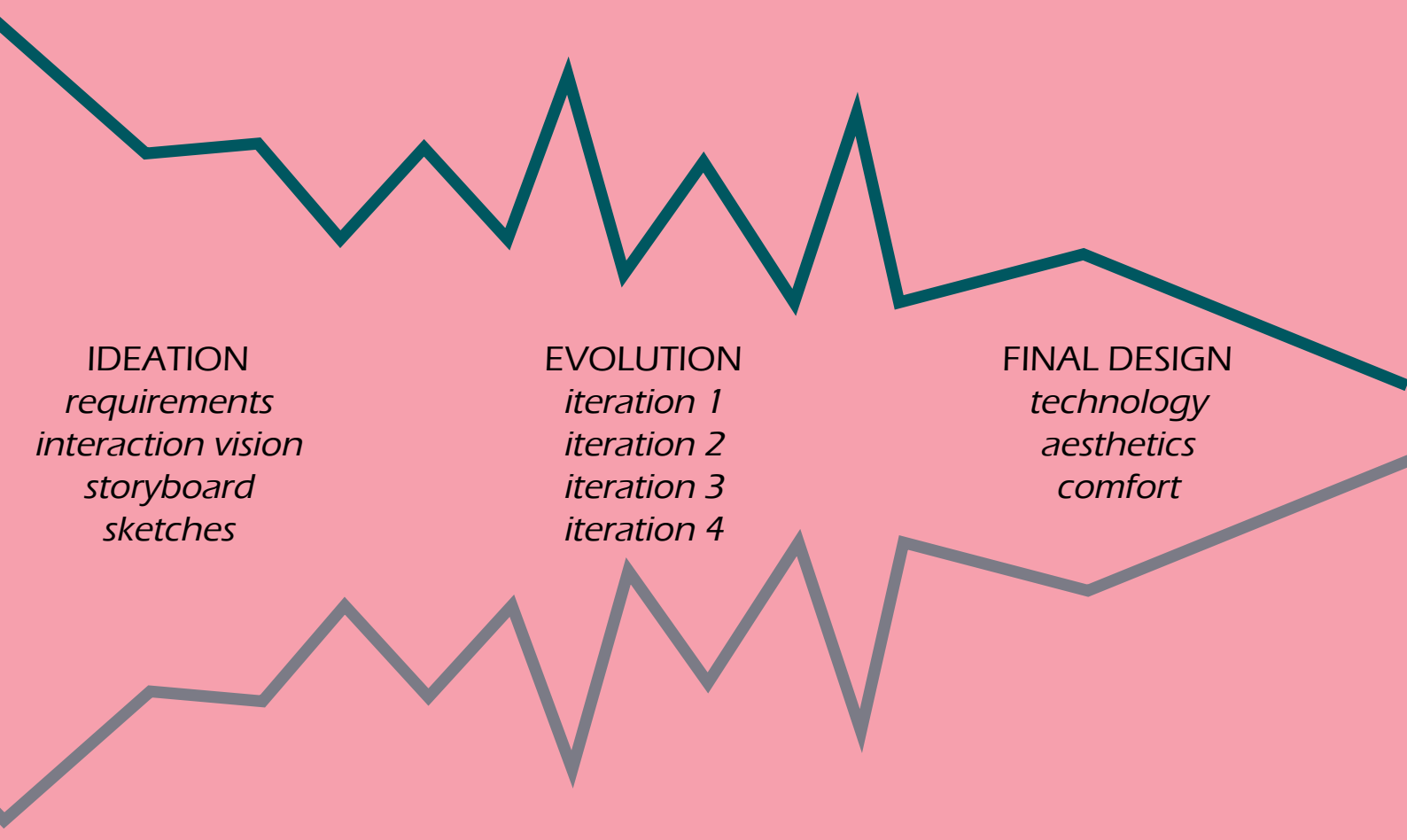

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FINAL DESIGN
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INTRO

Giving clothing a brain could be a description to explain what a smart textile is. In this chapter a short introduction is given what smart textiles exactly are and how they have changed over the past twenty-five years.

ONE
Smart Textiles

Smart textiles are defined as a new garment feature which can provide interactive reactions by sensing signals, processing information and actuating the responses (Textile Institute (2001), Schwartz, M. (2002)). Other terminologies for smart textiles are smart clothing, smart wearables, e- and i-textiles, smart apparel and smart garments. Some common examples of smart wearables can be found in figure 1 - 3.

According to its behavior a smart textile can be classified into three categories (Tao, 2001; Stoppa et al., 2014):

- Passive smart textiles; only able to sense the environment/user, based on sensors;
- Active smart textiles; reactive sensing to stimuli from the environment, integrating an actuator function and a sensing device;
- Very smart textiles; able to sense, react and adapt their behavior to the given circumstances.

figure 1. Moov chair by Nathalie Teugels - *Piezoelectric elements* in the shell generate an electric charge in response to applied mechanical stress like pressure or vibration.

figure 2. Bird and Beetle dress by Theunseen - *chromogenic ink* is applied on the leather which changes color in response to electrical, optical or thermal stimuli.

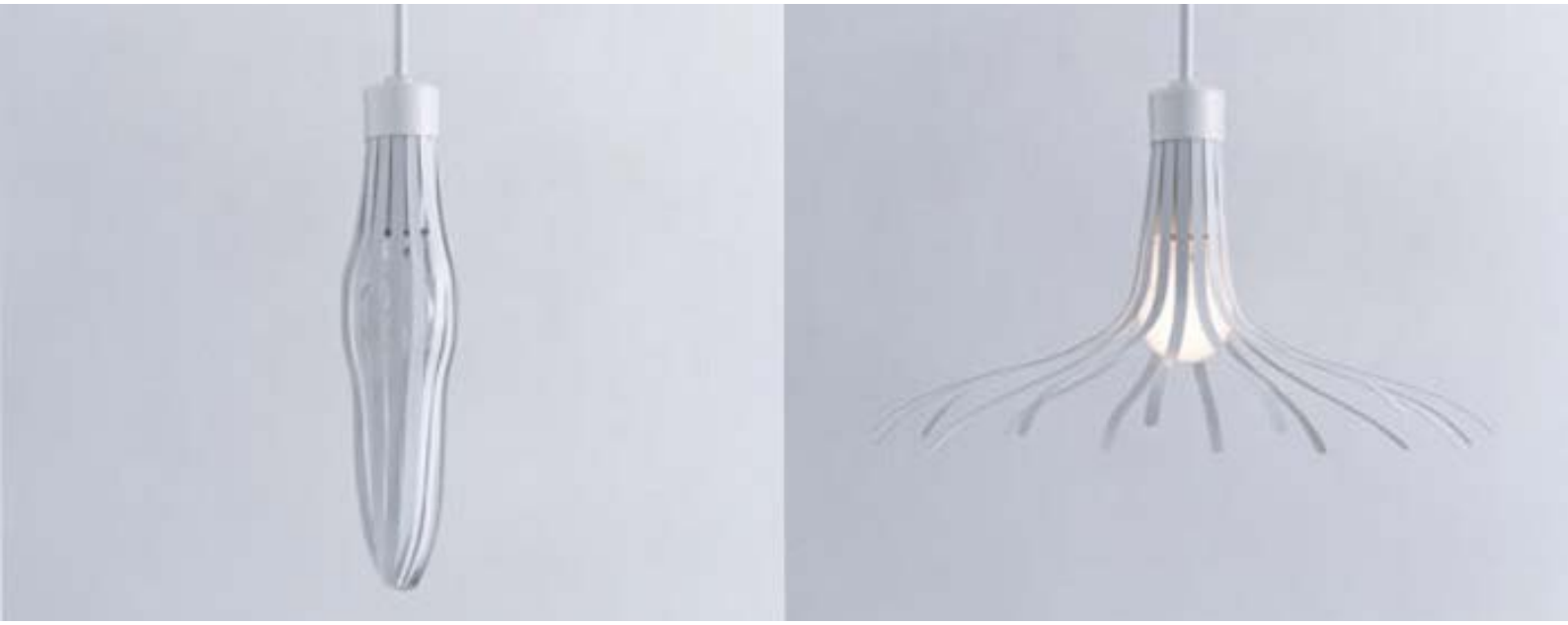


figure 3. The Hanabi Lamp by Oki Sato - The heat of the bulb makes this *shape-memory alloy* lamp "bloom" whenever the light is turned on.

2 THE EVOLUTION OF SMART TEXTILES

The start of smart textiles began in the 1993 when MIT students started researching smart textiles for military purposes. Since then the amount of research done on smart textiles as presented in papers found on Google Scholar and IEEE has been increasing rapidly (see figure 4).

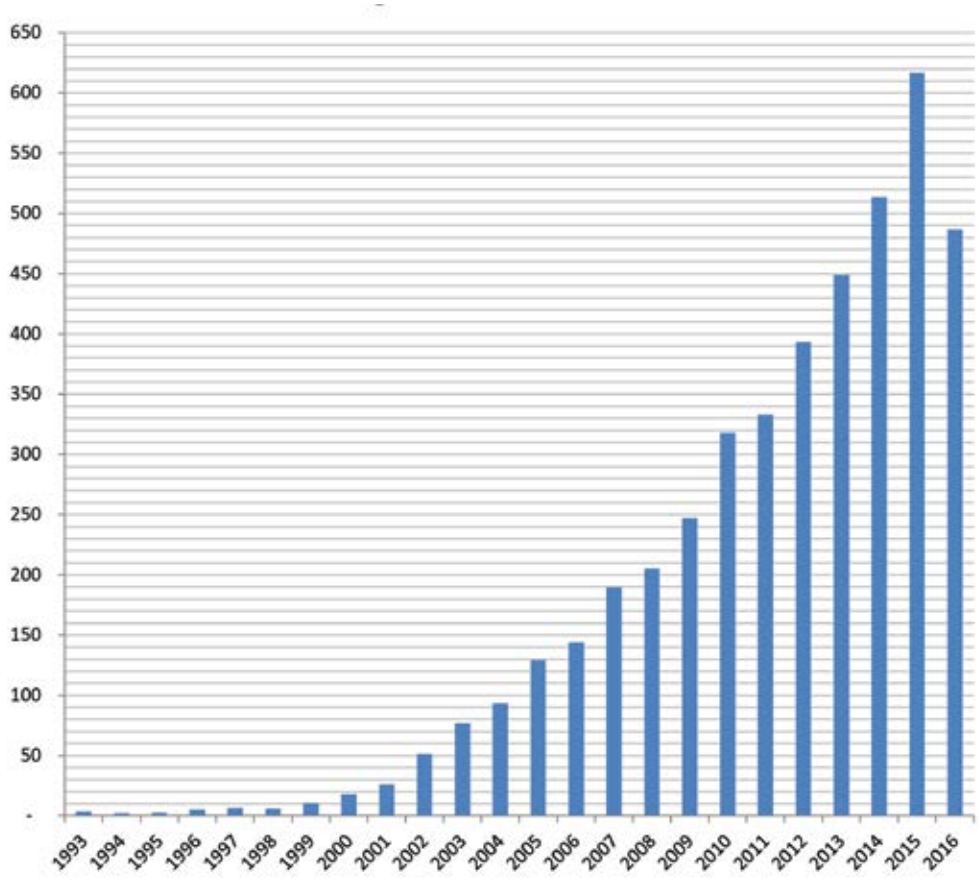


figure 4. Average amount of papers published on smart textiles per year

Suh et al present five stages of smart clothing:

Stage 1 - 1990s to 1997

The concept of using clothing as a means of a wearable computer has been initiated. Researchers are focused on technical innovations and textiles function as a passive platform.

Stage 2 - 1998 to 2001

The fashion industry and technology industry start to co-create. This leads to the collaboration of Levi's and Phillips who create the first commercial about electronic wearables in 1999. Technology is still under development.

Stage 3 - 2002 to 2005

The industry of smart textiles hits the market. The user's needs are put more into focus. Technology improvements create higher levels of comfort and fashion/aesthetics become a bigger part of the garment's design.

Stage 4 - 2006 to 2010

Technological innovations lead to interplay between the user and the environment. Electronics are improved which creates smart garments that work on solar/kinetic energy.

Stage 5 – 2011 to present

Technical innovations are done to create smart textiles with electronic parts that are flexible, organic, lightweight, low-cost and low power.

Companies are investing in manufacturing lines for woven electronic textiles to produce smart garments on a larger scale. Also, large-area distributed sensing tasks are a field that is being explored by researchers (Belli, 2009; Messervey, 2009). The main challenge is to create a fabrication process that is durable, reliable and at the same time scalable and industrializable (Kirstein, 2013).

The Do-It-Yourself movement has picked up smart textiles and started experimenting with them. This leads towards usage in design, art and performance. Artists make publicly aware that smart textiles can be aesthetic and not just technical (Buechley, 2008; Katterfeldt, 2009).

Also more focus is put on global energy issues around the world. Textiles have the potential to act as energy suppliers. Several researchers are looking into smart textiles as a means to provide energy inside the fabric, but also for external devices (Beeby, 2006; Lee, 2009; Bedeloglu., 2010, Riaz, 2011; Wang, 2008; Hu, 2010, Vatansever, 2011).

Smart textiles are thus becoming more efficient, user friendly, lower in cost, lower in power and environmental friendly. Right now the major applications of smart textiles can be categorized into protection and safety/military (30.4 %), medical/healthcare (6.1 %), communication/transport (14.4 %), fashion/entertainment (11.4 %), sports/fitness (15.4 %) and home/architecture/other (22.3 %) (Ariyatum, 2003; Smirhers Apex, 2011;). The highest growth is expected in consumer entertainment, medical status monitoring and military applications.

Still, some smart textiles designers like Marina Toeters are wondering if smart textiles are just a hype or if they will become a common good for all sorts of users in the near future. The only answer to that question she and other scientists (Suh et al, 2010; Berglin, 2013; Gaddis, 2014; Park and Jayaraman, 2003; Stoppa and Chiolerio, 2014; Seymour, 2008; Kirstein, 2013) give is that designers and researchers should start to collaborate and create smart garments more often to show the value of them to the public.

As more human beings seek connectivity and interactivity with their surroundings, clothing does have the potential to become a system that is able to sense its environment in a different way (Park & Jayaraman, 2003). This innovation asks for a re-evaluation of the function of textiles and electronics as well as human needs in order to transform a passive textile towards an interactive one.

This report focuses on one specific area of smart textiles, namely capacitive textiles. Capacitive textiles are active smart textiles. Their input comes from touch sensitive fibers and causes a reaction in a garment which can be programmed.

ANALYSIS

During the analysis phase an evaluation was done on the function of textiles and capacitive electronic systems.

By applying the material driven design method as an evaluation method of the materials, a better understanding about the possibilities of smart textiles was gained. This created new design possibilities and presented a suitable context of use.

Looking into the context, the user needs were derived and a solution through smart material usage was given. This has ultimately led to the vision of an on the job recovery experience.

figure 5. Ping by Electricfoxy - 2011

figure 6. figure 6. MIDI Controller Jacket by Machina - 2013

figure 7. Project Jacquard by Google and Levi's - 2015

TWO
Wearable Capacitive Fibers

1 INTRODUCTION

Textiles surround and protect people almost every minute of the day. They are natural to be close to and to touch. Therefore, adding capacitive fibers into textiles seems to be a logical fit.

Capacitive textiles form the combination of touch sensitivity and smart textiles. Whenever the user touches the conductive fibers or textiles, the garment responds in different ways which outputs can be coded. Some interactions are playful and experimental, others are quite clear.

Examples of touch sensitive garments created in the past are Ping designed by Electrifoxy, the Midi Controller Jacket by Machina, Project Jacquard by Google and Levi's, Jacket Antics by Barbara Layne, Heartbeat Hoodie by Diana Eng, Flare by Stijn Ossenvoort, Interactive Pillow by The Interactive Institute, Bubelle by Philips and Tactile Dialogues by Martijn ten Bohmer (see pictures 5 - 13).

Ping - figure 5
Ping is a garment designed in 2011 that connects to your Facebook account wirelessly and from anywhere. It allows you to stay connected to your friends and groups of friends simply by performing natural gestures that are built into the mechanics of the garments we wear.

The MIDI controller jacket - figure 6
The MIDI controller jacket is a fashionable and professional quality musical instrument. It allows a musician to create music through body movements and body sensors. It includes: an accelerometer, a gyroscope, two push buttons and one piezoelectric sensor. Users can raise their arms to raise the volume and tempo of the music and tap their chest to make sound.

Project Jacquard - figure 7
Project Jacquard makes it possible to weave touch and gesture interactivity into any textile using standard, industrial looms. Google integrated Jacquard technology into the Levi's Commuter Trucker Jacket designed specifically for urban bike commuters. Jacquard allows wearers to control their mobile experience and connect to a variety of services, such as music or maps, directly from the jacket. This is especially useful when it might be difficult to use the smart phone, like when you are riding on your bike in a busy street.

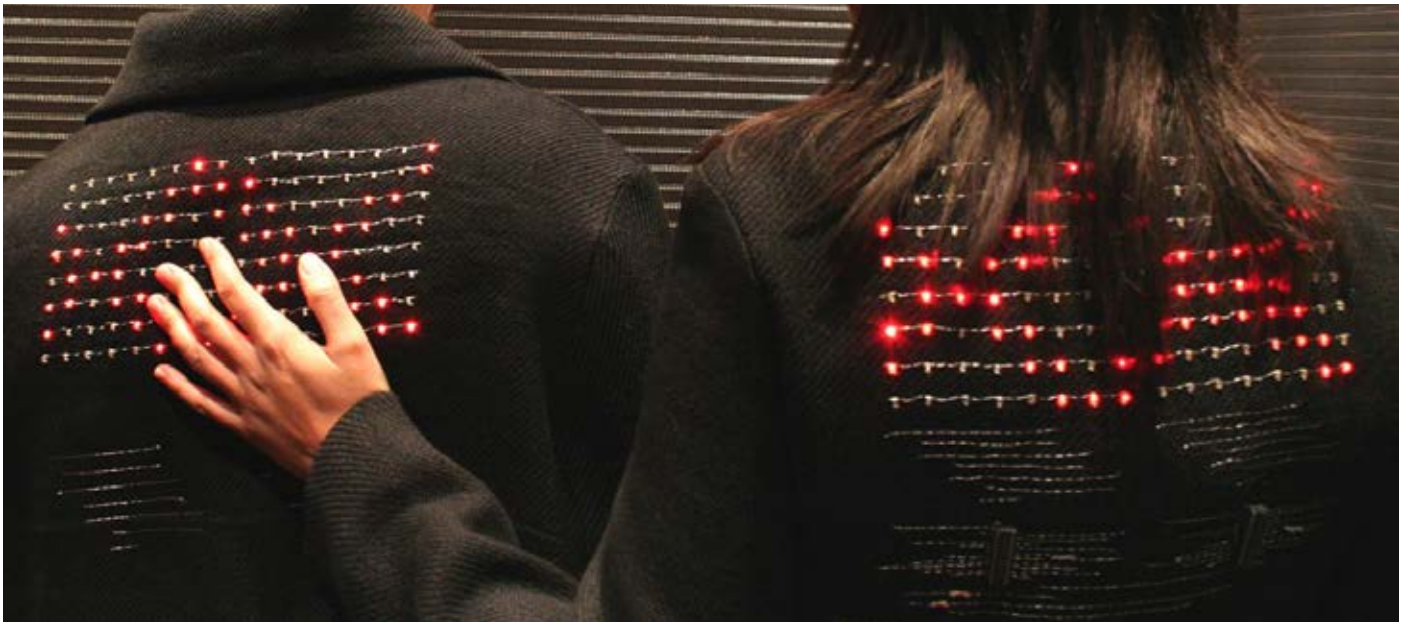


figure 8. Jacket Antics by Barbara Layne, Studio subTela - 2007

figure 9. The HugShirt by CuteCirquit - 2002

figure 10. Flare by Stijn Ossenvoort, SOS Design Studio - 2007

Jacket Antics - figure 8
Jacket Antics (2007) features unique texts and designs scrolling through the LED array on the backs of two garments. When the wearers hold hands, the LED arrays presents a third, synchronous message that scrolls from one to the other, presenting a new pattern of communication. When the wearers release hands the message reverts back to the individual themes. The garments are constructed of handwoven cloth, made from traditional black linen yarns woven alongside light emitting diodes, microcontrollers and sensors.

The capacity for interactivity in the animated cloth displays extend the narrative qualities of cloth and provide new possibilities for dynamic social interaction.

The HugShirt - figure 9
The HugShirt (2002) allows users to feel hugs from over a distance. Embedded in the shirt are sensors that feel the strength, duration, and location of the touch, the skin warmth and the heartbeat rate of the sender. The receiver feels the location and warmth of the touch through her garment with use of actuators. It is rechargeable and washable.

The Hugshirt was invented in 2002 and has won several awards since.

Flare - figure 10
The Flare dress (2007) gives a more comprehensive awareness of the users surroundings by perceiving wind. The dress has two fabric layers. The outside layer is covered with 15 'Dandelions'. Each flower consists of 32 LEDs that light up in a sequence that simulates dandelion seedlings being blown away.

Only the flowers that face the wind become active. The windier it gets the more responsive the dress becomes.

figure 11. Interactive Pillow by The Interactive Institute, Sweden– (2001 – 2002, 2004)

figure 12. Bubelle – Blush Dress by The Skin Probe Project of Philips, Eindhoven - 2006

figure 13. Tactile Dialogues by Martijn ten Bohmer - 2013

Interactive Pillows - figure 11
Responding to the need for more subtle forms of communication to complement existing IT devices, the Interactive Pillows project (2001 – 2002, 2004) explores interactive pillows as a means of enhancing long-distance communications. Through natural interaction with a pillow in one location, dynamic textile patterns are activated in a pillow located elsewhere. Expanding the vocabulary for remote communications through tangible and aesthetic interaction, the pillows offer a new repertoire of expressive possibilities that consider emotional, social and aesthetic values

Bubelle - figure 12
The Bubelle – the 'Blushing Dress' – (2006) behaves differently depending on who is wearing it, and therefore exhibits completely nonlinear behavior. A delicate 'bubble' surrounds it, that responds to skin contact by illuminating various patterns.

Tactile Dialogues - figure 13
Tactile Dialogues (2013) is a smart textile service which consists of a textile object in the form of a pillow with integrated vibration elements that react to touch. The goal of the textile object is to enable a dialogue by triggering physical communication patterns between a person with severe dementia and a family member, spouse, or other caregiver, by a joint interaction with the product.

These projects show intimate and social experiences which are situated almost directly on the body. Capacitive garments are thus about textile design, touch sensitivity and technology working together almost directly on the human body.

THREE
Dressing the Body

1 TEXTILES AND CULTURE

To understand how smart textiles work so close to the body we have to take a step back to look at how textiles alone have been working with the body and what it means to get dressed.

In every culture dressing the body is done be it with clothing, paint, tattoos, cosmetics or embellishments. The type of dress differs. In Western societies, clothing is the most visible form of consumption and works as a display of a wearer's identity in human social life. This individual expression has not always been the case.

In pre-industrial Western societies clothing was a means to show your origin and social status. Every village and region had their own type of costume of the period (Crane, 2012).

This meaning of clothes changed when the Industrial Revolution took place and clothing gradually lost their economic importance. People got access to inexpensive clothes which allowed them to create a meaningful identity instead of imitating styles that were originally sold to the rich (Giddens, 1991). This so-called hyper-segmentation has led to a variety of lifestyles that each had their own niche (Vidich, 1995; Holt, 1997). These groups may define our occupation, religion, interests or social standing.

Fashion is a means for people to (re)define themselves and their social identities by continually giving new meanings to clothing. It's a mixture of materials and styles that have a different meaning for different social groups. This way, clothing can be used to signal the interests and the groups to which people wish to belong or to differentiate themselves from other people (Berger, Heath, 2008), see figure 14.

Dress is thus both an intimate experience of the body and a public presentation of it. It is so closely related to the self that the dress, the body and the individual are perceived as one (Entwistle, 2015). This caused for a growth of healthy lifestyles and changed the way we look at our bodies. We are no longer satisfied to see our bodies as finished, but actively try to change its shape, weight and contours (Featherstone, 1991).

Fashion can create satisfaction by helping to design the user's envisioned body. It takes into account the limbs, erogenous zones and body orifices, but also limits or adds existing forms to them. It is an interface between creation and social communication (Loschek, 2009).

Since the 1990s the economic value of fashion has been practically zero and is seen as a disposable commodity (Sinclair, 2014). The quick changes of seasons and styles in fashion make fashion-conscious people eager to throw away their purchases far before the end of their useful life. Next to that, employees in third world countries still suffer from bad working conditions (The Guardian, 21 may 2016).

Choosing a fabric that is fair trade and ecological can help steer the fashion industry towards a more conscious industry. Ecology and fair-trade is an easy accessible path to take within the clothing industry if you do a little research (see figure 15). Therefore, it will be included in the final design.

figure 14. City Girls - London 2008 by Exactitude

figure 15. Examples of ecological and fair-trade labels for textiles

figure 16. Humanæ is a "work in progress" by the Brazilian Angélica Dass, who intends to deploy a chromatic range of the different human skin colors.

2 COMFORT

Designing a garment means thus creating a garment that contributes to an intimate experience, but also creates a dependable and almost perfect representation of the self. The garment should thus feel comfortable personally as socially.

The human skin is the best type of fabric when looking at human physiology (Selker, 2000). It has its own size and color (figure 16) and provides the human body with four different types of comfort (Smith, 1986; Fan, 2009a; Watkins, 2011; Slater, 1986):

1. Thermal comfort;
2. Sensorial comfort;
3. Body movement comfort; and
4. Psychological comfort.

Thermal comfort

Thermal comfort is the state of mind which expresses satisfaction with the thermal environment (Choudhury, 2011). According to Goldman (2005), there are six key factors involved in thermal comfort. They are air temperature, air movement, humidity, mean radiant temperature, body heat production and type of clothing. Thus the fabric should not only insulate the human body to keep it's bodily temperature steady, but it should also be air permeable in order to let the body cool down without feeling wet. The energy requirement of an average man is 2,500 Calories per day, and one calorie is 4184J. Therefore he emits about 10.5MJ/day or about 120W. An average woman requires 2,000 Calories per day, so she emits about 97W.

Concerning the thermal insulation of a garment, Fan (2009a) put together design factors that might help the design. Some are good to keep in mind:

- The greater the amount of the body covered, the better the insulation.
- An air space between the body and the garment generally has a beneficial effect on thermal insulation.
- Layering of fabrics in the garment improves thermal insulation.
- Body movement can reduce thermal insulation, by 10–15%.

Sensorial comfort

Sensorial comfort is the sensory response of nerve endings to external stimuli (Choudhury et al, 2011). The brain answers to those stimuli by controlling the suitable response, for instance by shivering the blood flow, sweating rate or heat production are adjusted.

Li (1998) found that 26 sensory descriptors could be classified into four clusters as shown below:

- Tactile sensations – prickly, rough, raggy, scratchy, itchy, picky, sticky.
- Moisture sensations – clammy, damp, wet, sticky, sultry, non-absorbent, clingy.
- Body fit (pressure) sensations – snug, loose, lightweight, heavy, soft, stiff, tickling.
- Thermal sensations – cold, chilly, cool, warm, hot.

It should be taken into account that women and men differ in the sensing experience and thus in sensorial comfort. In a study performed by Kweon (2004) women responded more sensitively to thickness, flexibility and tactile sensation whereas men responded more sensitively to sensation of stiffness.

Exploring materials with others can thus give a good insight what types of materials are preferred and what sensations can be experienced interacting with the material.


NTONE 65-5 C
PANTONE 75-9 C
PANTONE 75-8 C
PANTONE 89-6 C
PANTONE 320-2 C
PANTONE 71-7 C
PANTONE 69-
NTONE 91-9 C
PANTONE 97-7 C
PANTONE 66-3 C
PANTONE 58-6 C
PANTONE 98-7 C
PANTONE 39-8 C
PANTONE 73-
NTONE 98-9 C
PANTONE 62-9 C
PANTONE 58-5 C
PANTONE 54-7 C
PANTONE 51-5 C
PANTONE 316-5 C
PANTONE 78-
NTONE 72-4 C
PANTONE 59-5 C
PANTONE 322-7 C
PANTONE 92-9 C
PANTONE 63-5 C
PANTONE 62-5 C
PANTONE 72-
NTONE 54-7 C
PANTONE 90-8 C
PANTONE 50-8 C
PANTONE 57-8 C
PANTONE 68-4 C
PANTONE 74-8 C
PANTONE 91-
NTONE 64-6 C
PANTONE 69-3 C
PANTONE 99-7 C
PANTONE 70-8 C
PANTONE 320-3 C
PANTONE 97-9 C
PANTONE 76-
NTONE 59-4 C
PANTONE 86-9 C
PANTONE 59-7 C
PANTONE 70-6 C
PANTONE 65-5 C
PANTONE 92-6 C
PANTONE 63-
NTONE 98-9 C
PANTONE 80-6 C
PANTONE 58-8 C
PANTONE 63-6 C
PANTONE 78-5 C
PANTONE 57-6 C
PANTONE 58-
NTONE 75-8 C
PANTONE 322-1 C
PANTONE 50-6 C
PANTONE 74-7 C
PANTONE 99-9 C
PANTONE 77-9 C
PANTONE 51-

figure 17. Warmth, Touch, Movement and Love.

Body movement comfort

The level of comfort in clothing related to movement is predicated by the structure of the fabric, the fit of the garment and the design of the garment (Ashdown, 2011). The human skin is a very flexible fabric which elongates and recovers for different activities and varies in flexibility for different parts of the body. The structure of a garment can also recover and elongate depending on the type of fiber and the type of weave that is used to make the fabric. Knitted fabrics, due to their interlooping yarns, usually possess a minimum of 15% elongation, but can sometimes also be rigid (Fan et al, 2009). Depending on the activity, the type of fabric is chosen. A dancer for instance, needs a fabric that moves along with the body, whereas a business woman needs a fabric that makes her body able to move within the fabric (Ashdown, 2011).

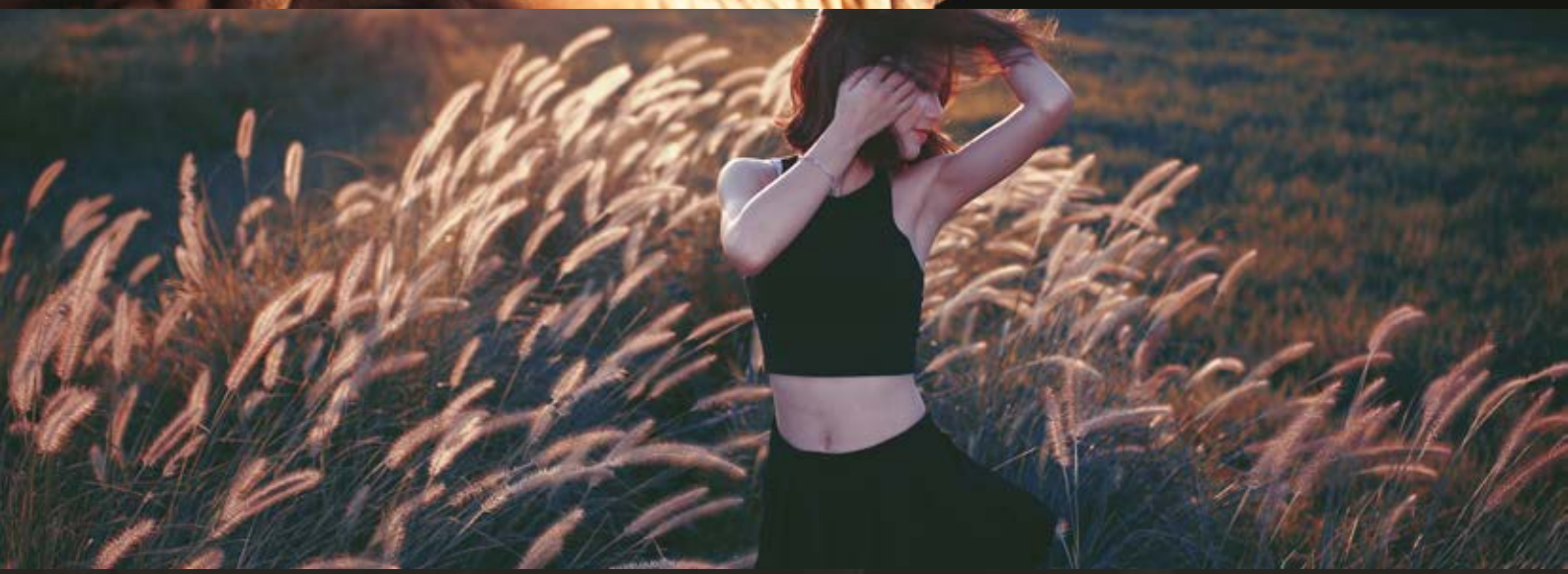
The fit of the garment is related to pressure comfort. To achieve the right fit, an appropriate amount of skin pressure is necessary. Okabe and Yamana (1991) found in their study on skin pressure points that softer bodies felt less pain, particularly at the side of the waist. That could be interesting places for adding specific electronics. Next to that, Dunne et al. (2005) suggests shoulder, upper back, and abdomen as places on the body that could be used for placing electronics since there is less body movement happening here.

The design of the garment can also help to improve the body movement comfort. This can be done by using a specific type of cut in the design, by designing loose flowing clothes, by creating areas where a garment separates itself, by creating open areas or by using pleats or elastic inserts that stretch out as the wearer moves (Ashdown, 2011).

Psychological comfort

Psychological comfort may be defined as a pleasant state of psychological harmony between a human being, the function of the garment, the body and the environment (Slater, 1986). It is the feeling of comfortable and good with the garment the user is wearing. Fan (2009b) describes this as a feeling whenever the user wears something that is in accordance with one's view of one's economic, social and functional status. It is thus a garment that fits the user's personal and social identity.

Concluding these four types of comfort it can be stated that the fabric and garment of choice should be thermally insulating as well as breathable, should fit the user's tactile expectations, should enable the user to move in certain ways one's expecting and fit the personal and social identity of the user.




love

figure 18. Tools to create and expressions of fashion

3 FASHION DESIGN

Garments can thus elicit sensory experiences by having their unique look, feel, touch, smell and even sound. Next to that, garments can elicit emotional experiences as can be seen in the exploration of silk's identity. Finally, some garments can even have cognitive experiences, when referring for instance to symbols. All these experiences fall under the name aesthetics. Or, as O'Neal (1998) defines aesthetics, it is the study of human reaction to the non-instrumental qualities of an object.

According Regan (1998), clothing products are characterized 80% by aesthetics and 20% function, whereas other products are 80% function and 20% aesthetics. These percentages will probably change when designing smart textiles since it will shift from a fashion industry driven approach towards a more technological driven approach. Though, some opportunities to find meaningful directions for smart textile development might be overlooked with only technology-driven approaches (Kuusk, 2013). In addition, design and aesthetics can affect a user's perception, belief system and even task ability (Csikszentmihalyi, 1990). This means that aesthetics should be of bigger importance when wanting to design a meaningful garment.

Important influencers of clothing appearance, comfort and feelings of identity are silhouette, proportion, color, fabrics, trimmings, embellishments, prints and styling (Yu, 2011).

Silhouette
Silhouette is the basic outline of a garment on the body. Every time period has its own popular silhouettes. The 1920s for instance has its signature dropped waist and the 1980s were known for its big shoulder parts. Thus a silhouette places an emphasis on a specific part of the body be it the bust, the waist the hips or on a mixture of body parts.

Proportion
Well balanced proportion in a garment is done by choosing where to place the emphasis on the body. This can be done by adding dark colors or vertical stripes to make things slimmer, or using bold horizontal stripes to make things wider. Next to that, colors, patterns and variations in length can help to change the perception of the human body.

Color
Color has to work in harmony with the silhouette and the proportions of the garment. Some colors are never out of fashion. Those colors are black, white, grey, brown and more neutral colors. The rest of the colors are introduced each season by Pantone, a color matching system which previews future color trends.

Research on the effects of psychological sensation of colors on humans suggests that cool hues and dark shades make people calm while warm hues and light shades make people more active (Davis, 1996).

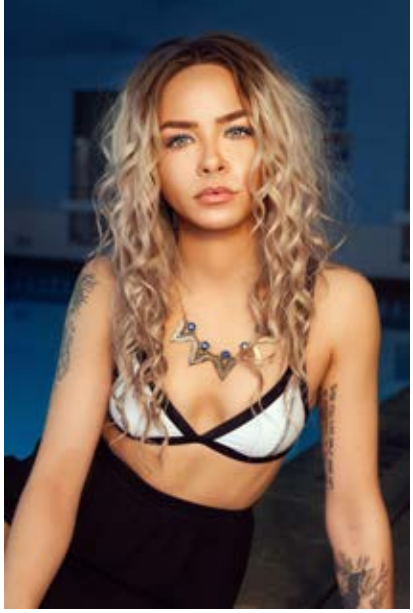
Fabrics and trimmings
Fabrics work on different sensations; touch, sight, sound and smell. All of them influence the experience people have with the garments made with them. Fabrics have to work with the envisioned silhouette and function since every fabric has its own drape, look and feel. Understanding the material characteristics helps to understand what type of garments are possible to create with a certain material (Gaimster, 2015).

Trimmings should also be in harmony with choice of silhouette and proportions, but also with the choice of fabric. Very heavy buttons or zippers on a light fabric do not pair well.

Prints
Prints and motifs can attract a specific target group or emphasizes a certain expression the designer is looking for. For instance a romantic look can be emphasized by a floral print.

Embellishments
Embellishments can be decorative stitches, seams, pleats or quilts. Most of them can be done by machines, but some techniques require labor by hand which can add a considerable number to the price.

Styling
Styling is done on the model itself by doing her hair and make-up and by adding jewelry, a handbag and shoes which help create a look that displays the garment even better. Stylists are mostly hired and make the designers vision come to life.



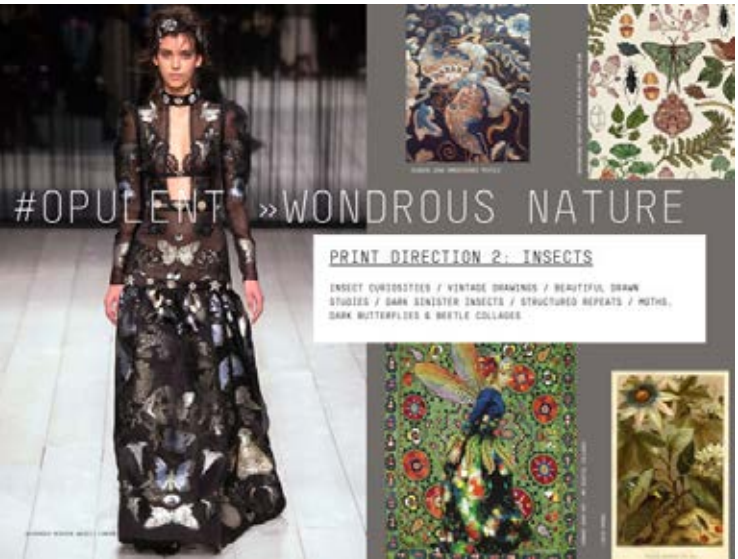

#OPULENT »WONDROUS NATURE
PRINT DIRECTION 2: INSECTS
INSECT CURIOSITIES / VINTAGE DRAWINGS / BEAUTIFUL DRAWN STUDIES / DARK SINISTER INSECTS / STRUCTURED REPEATS / MOTHS, DARK BUTTERFLIES & BEETLE COLLAGES

figure 19. Interaction between user and garment in different environments

FOUR
Touching Capacitive Fibers

1 HUMAN TOUCH

Capacitive fibers are touch sensitive fibers that are sewn into textiles. Looking at touch and the human body you see that touch has been an important part of human interaction and communication. Human touch knows different types of interaction. One is directed to the body itself, another to the body's direct surroundings and yet another towards other bodies as a means of communication.

All of us have experienced that touching the body itself varies when being on public display than being in a private situation. Being in public, the type of audience also influences the way we touch ourselves. Some touches are just not appropriate at work while being perfectly fine when being with friends. If we look at how we touch our clothing at work we want the interaction to be familiar, non-disruptive and non-distractive (Dryer, 1999).

Tactile interactions within the environment help the body to understand its surroundings better. It helps the body to understand where it is in space and time, and on the physical attributes of certain objects. This tactile sensation helps us to make use of tools such as a car or a pencil. It is part of our evolution as a species. Combining touch with other senses like vision creates an even better understanding about the environment and the objects in it (Haans, A & IJsselsteijn, W, 2006).

Touching others as a means of communication also knows different forms. It is a very intimate communication which can evoke feelings of trust, support, tenderness, intimacy and persuasion. All these types can be communicated through affective touches, which communicates somebody's emotional state or empathy, or through controlled touches, which is used to change somebody's behavior. The same goes here as for personal touches; some touches are just not appropriate with colleagues while being perfectly fine when being with friends.

When people interact with machines, they tend to treat them in a social manner as well. Making a smart garment allows us to be social and intimate with our bodies at the same time.

Adding a function to a certain type of touch may strengthen the experience or create a new dialogue between people. This can be done by using capacitive fibers as an input. Understanding the technology will help to successfully implement functional features in a garment design.













2 TECHNOLOGY

So far, capacitive sensing is probably the most promising technique for the textile-based sensors, as it does not depend on the applied mechanical force (including bends and stretching) and also enables multi- touch and gesture recognition functionality (Gorgutsa, 2012).

Capacitive fibers work with use of electrical conductivity. Electrical conductivity functions because of electrical current. Electrical current brings charges in motion through an object. In a garment these are transported by electrons. To create an electrical current there must be a flow of charge through an object along a potential difference that corresponds to an electrical voltage. Without a potential difference, no current will flow. In metallic wires the movement is of a negative charge carrier within an electrical field and therefor will flow from the negative towards the positive pole.

The electrical current that flows through an object is dependent on the material it is made of. The object's resistance towards the flow of current through it plays a role here. The resistance R can be defined by dividing a potential difference V with the current I. This is explained in Ohm's law;

$$R = \frac{V}{I}$$

The resistance R is expressed in Ohm (Ω). Though, the materials ability to oppose or conduct the flow of electrical current should also be definable regardless of its dimension or shape. The potential difference V should then be regarded as an electrical field E at a point in a resistive material. It should also not be focused on the current I through the resistor, but on current density J at the point in question. Thus instead of the resistance R of an object, it should be referred to resistivity ρ of the material:

$$\rho = \frac{E}{J}$$

Often the conductivity σ of a material is used. This is simply calculated by using the equation:

$$\sigma = \frac{\rho}{1}$$

If you know the resistivity of a material, you can now calculate the resistance of a length of a wire if the current density is uniform throughout the wire:

$$\rho = R\frac{A}{L}$$

Though, it should be noted that resistance can be linear or non-linear. Since yarns are composed of several individual fibers, they are far from homogeneous. The most reliable approach is to relate the electrical resistance of a fiber or yarn to its length L:

$$R_y = \frac{R}{L}$$

3 CAPACITIVE SCREENS

With smart textiles the change in motion comes from the fact that the human body is an electric conductor and can make a change in flow of the electrical current.

The most simple comparison can be made with the capacitive phone screens. They work with anything that holds an electric charge, which includes human skin as well. The screens are produced with use of copper- or indium-tin-oxide which stores current in an electro-static grid with fibers each smaller than a human hair. There are electrodes placed at the corners of each of the squares that form the grid. The electrodes place a low voltage on the conductive layer which creates a uniform electro-static field. Whenever a human finger tip crosses the screen, a slight amount of current is drawn, creating a voltage drop. Theoretically, the amount of current that is drifts through the four electrodes should be proportional to the distance fro the touch point of the four corners. The controller precisely calculates the proportion of the current passed through the four electrodes and figures out where the finger was situated on the screen.

The sensing electrodes measure the charge distribution in the grid that is injected by the transmit electrodes. This distribution is a result of high frequent logic pulses driven in burst mode (figure 20). To optimize the signal-to-noise ratio, the detection electronics attenuate random noise from the environment like the ac power network, motors, lamps, etc. When a finger touches the panel, the field coupling is reduced and touch is detected.

The same principle works for capacitive fibers in textiles. The capacitive fibers hold the electric current and the textile functions like a passive layer; the capacitive fibers form the conducting part of the system and the textile forms the insulating part of the system. Different materials hold different types of conductivity.

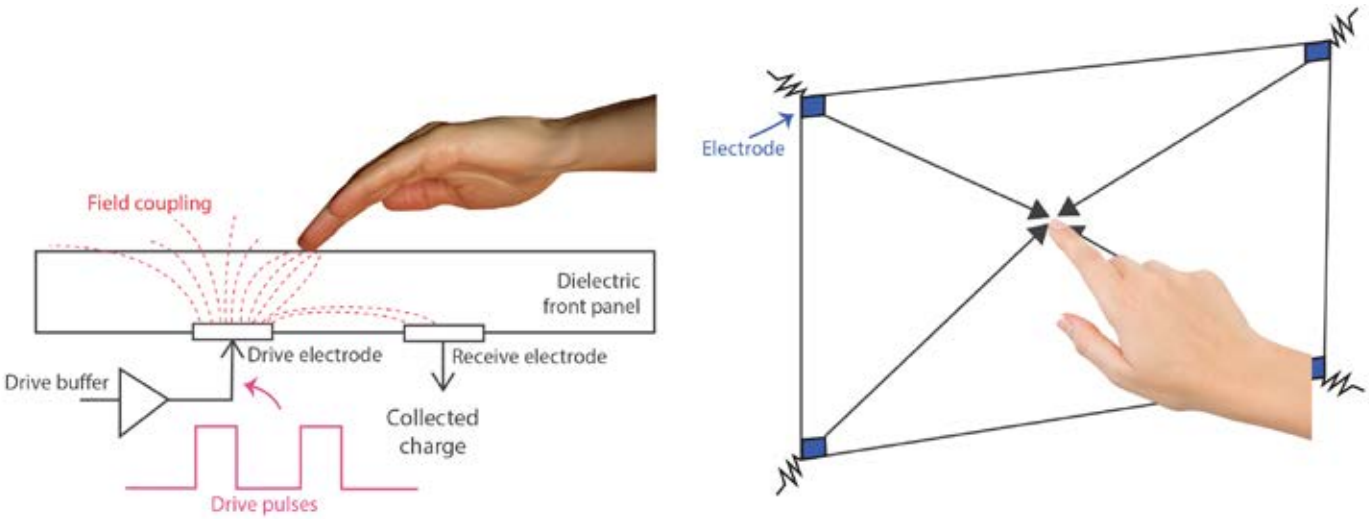


figure 20. Capacitive Screen Schematics derived from Embedded.com.

3 CONDUCTIVITY IN MATERIALS

Materials can be classified in three groups in terms of conductivity: conductors, semiconductors and insulators. A conductor is a material that allows an electrical current to pass easily. Semi-conductors have electrical properties that can conduct electricity under some conditions but not under others. There is a growing interest in using semi-conductors in smart textiles, but the application of them is still in a research phase. Therefore, they will not be investigated further in this project. Insulators oppose electrical current due to their high resistivity. Most conventional textiles, like wool and cotton are insulators.

3.1 Conductors

Metals are materials that are typically hard, shiny, strong and have a good electrical and thermal conductivity. The atoms are structured in a crystal structure which leaves electrons floating free around the atoms. This provides the ability of metals to easily transmit heat or electricity.

In smart textiles there are a few types of conductors used as capacitive fibers. They are stainless steel, silver coated nylon and copper nets. Every type of material has different thicknesses. The thickness of the thread affects the easiness to sew with it and the resistance of the thread; a four-ply thread will be more conductive than a two-ply one.

The material properties of the conducting fibers can be found in appendix B. An overview of some commonly used conductive fibers is presented in figure 21.

3.2 Insulators

The insulating materials form the base of smart textiles and are almost always applied directly on the body. Almost all natural fibers are insulators. In the area of natural fiber materials, a distinction can be made between fibers originating from plants (i.e. cotton) and fibers originating from animals (i.e. wool). Then there are insulating fibers made by man. These are regenerated fibers (i.e. rayon) and synthetic polymers (i.e. polyester). Examples of insulating fibers can be found in figure 22.

For touch sensitive textiles it is important to look at the material properties of the insulating fibers. Depending on the field of use some textile might be better suited than others. In general the most interesting properties are tensile strength dry, tensile strength wet, wear resistance, flexibility, density, modulus of elasticity, transition temperature, absorption level, lye resistance, acid resistance, chloride resistance, UV resistance and mold resistance. Next to that availability and price are also important factors in making clothing. The types of insulating materials can be found in appendix B.

Name	Stainless thin conductive thread	Stainless medium conductive thread	Stainless thick conductive thread	117/17 two ply conductive thread	60 g conductive thread
Source	Adafruit	Adafruit	SparkFun	SparkFun	SparkFun
Part Number	640	641	DEV-10120	DEV-08544	DEV-11791
Ply Number	2	3	4	2	-
Resistance (Ω/ft)	16	10	4	300	28
Material	316L Stainless Steel	316L Stainless Steel	Stainless Steel	Silver-plated Nylon	Spun Stainless Steel
Notes	Stiff	Stiff		Likely to oxidize	Hairy
Look and Feel					

figure 21. Comparing Conductive Thread (Kate Hartman, 2014)

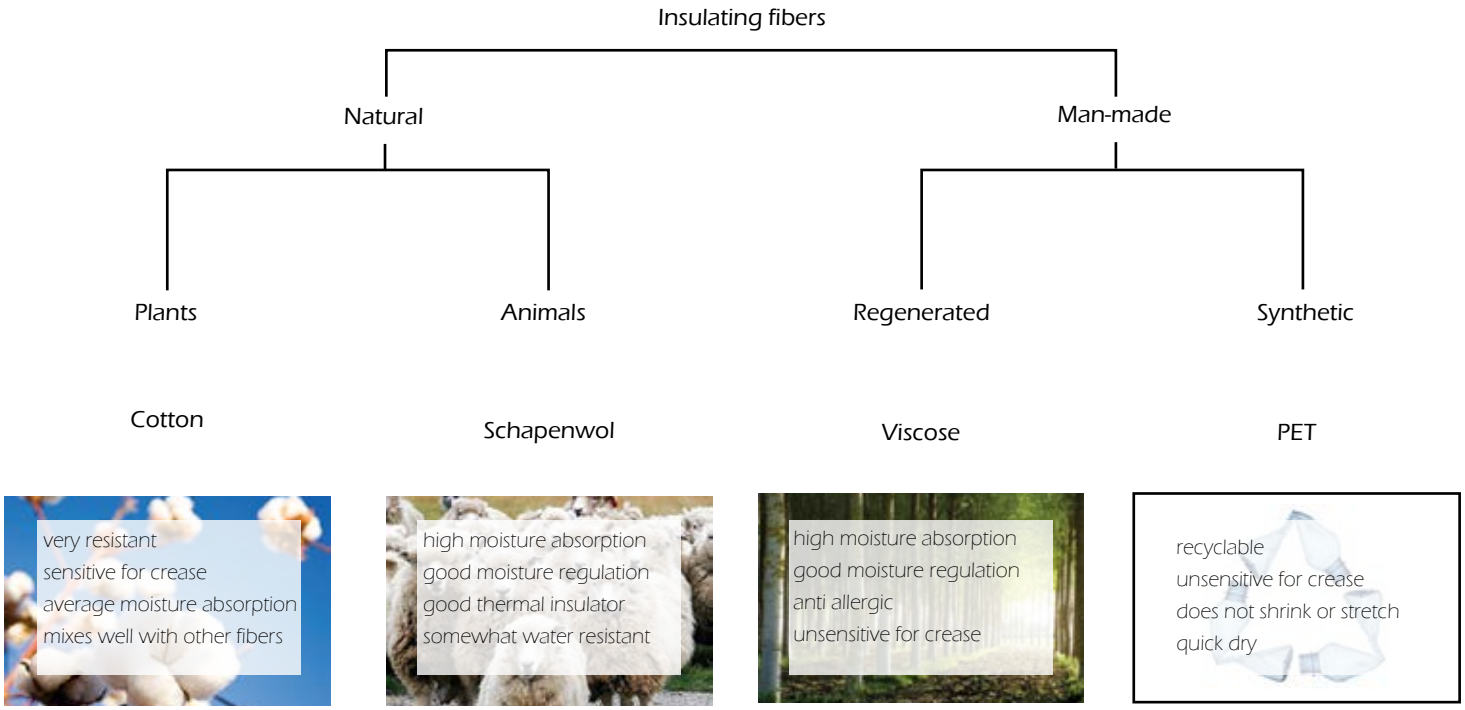


figure 22. A few examples of insulating fibers

FIVE
Exploring the Material

1 INTRODUCTION

To understand which insulator-conductor material combination creates a functional and comfortable garment a material study is needed. The before mentioned conductors and insulators will be combined and researched.

The research will start with a material test and will finish with a user test. During the material test stainless steel and silver conductive fibers will be fold into several insulating materials. The materials that were tested are cotton, wool, hemp, linen, silk, denim, viscose, polyester, nylon, polyurethane/polyester mix and cotton/viscose mix.

The testing will be done in two different contexts; one will be inside at a room temperature of 20 degrees Celsius and the other one will be outside at a temperature of 0 degrees Celsius to understand how the material responds to its surroundings (see figure 23, 24 and 25). Next to that, the materials will first be put on a wooden surface and then put directly on skin to understand if the responsiveness of the conductive thread will differ.

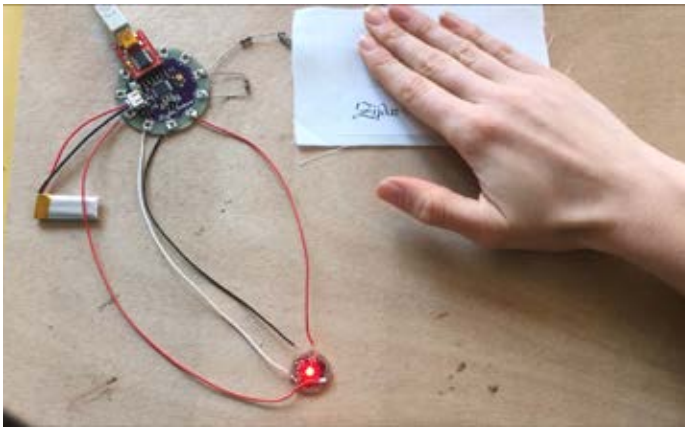


figure 23. Example of the test done on a wooden surface at room temperature.

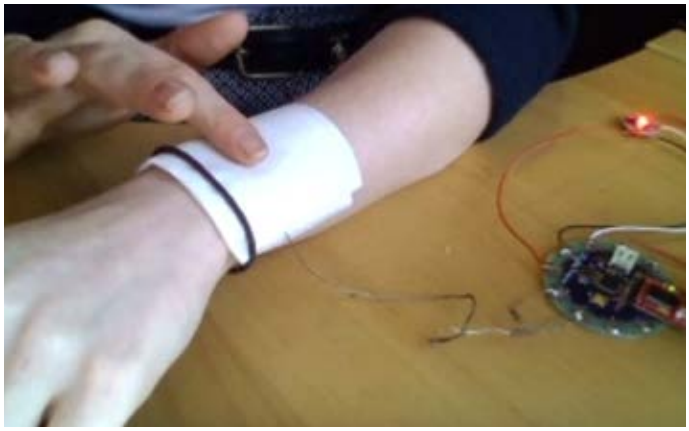


figure 24. Example of the test done on the skin at room temperature.

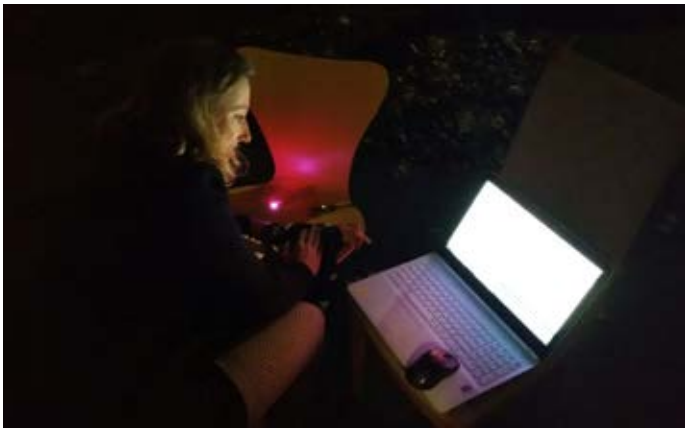


figure 25. Example of the test done on the skin at 0 °C.

2 MATERIAL TEST SET-UP

The set-up of the test is as follows (see figure 26). An Arduino Lilypad micro-controller is connected to a capacitive sensor as an input and an RGB LED as an output.

The capacitive sensor can sense the electrical capacitance of the human body via a conductive thread. The capacitive sensor method toggles a micro-controller send pin to a new state and then waits for the receive pin to change to the same state as the send pin. A variable is incremented inside a while loop to time the receive pin's state change. The method then reports the variable's value, which is in arbitrary units.

The physical setup includes a 10 Mega ohm resistor between the send pin and the receive pin. Then a 10Kohm resistor is attached to the receive pin as well to make sure no damage can be done to the Lilypad board.

When the send pin changes state, it will eventually change the state of the receive pin. The delay between the send pin changing and the receive pin changing is determined by an RC time constant, defined by R x C, where R is the value of the resistor and C is the capacitance at the receive pin plus any other capacitance (e.g. human body interaction) present at the receive pin.

The RGB LED is used to visualize the interaction between the human body and the conductive fiber. When there is no interaction, the RGB LED will show a green light, when there is a delicate touch the RGB LED will show blue light and when there is an active touch the RGB LED will show red light.

All outcome has been filmed and put into an excel sheet for comparison. The results show only the most promising material combination. The total research can be found in Appendix C.

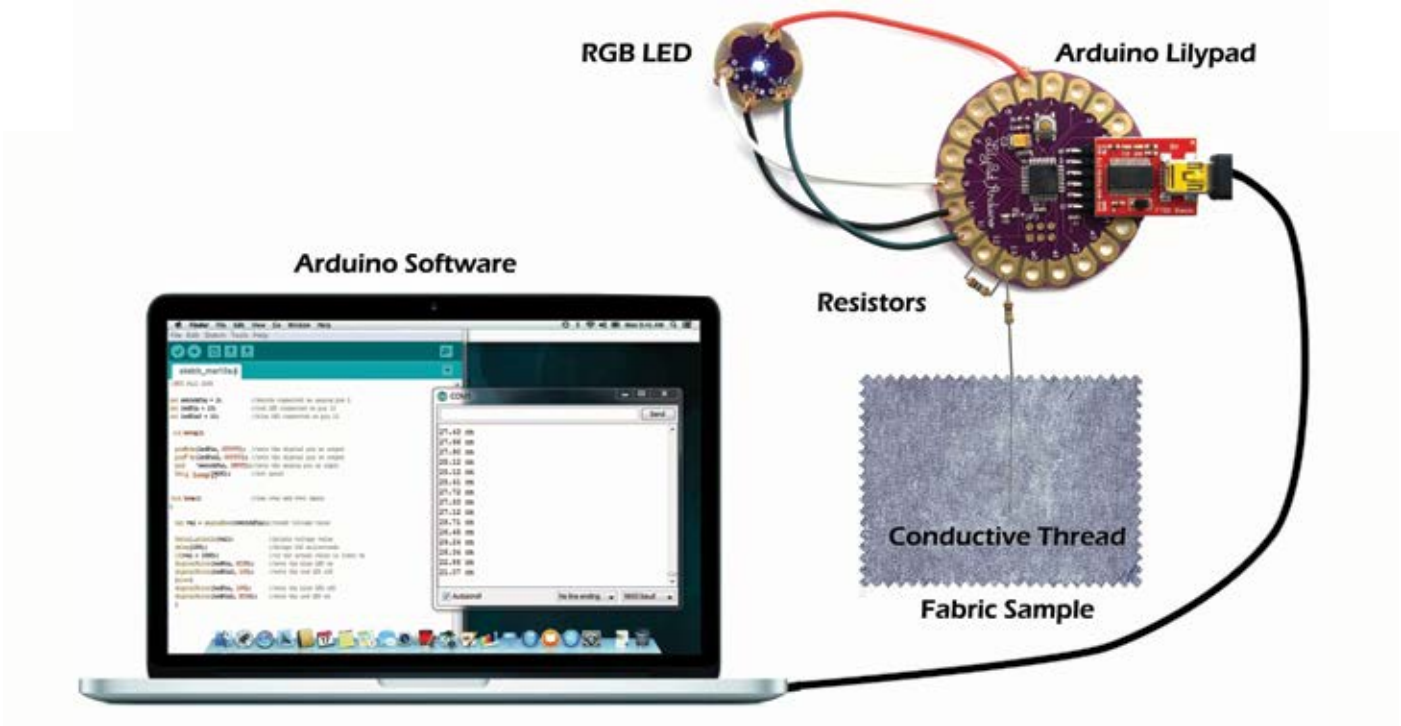


figure 26. General Study Set-up

3 MATERIAL TEST RESULTS

SILK

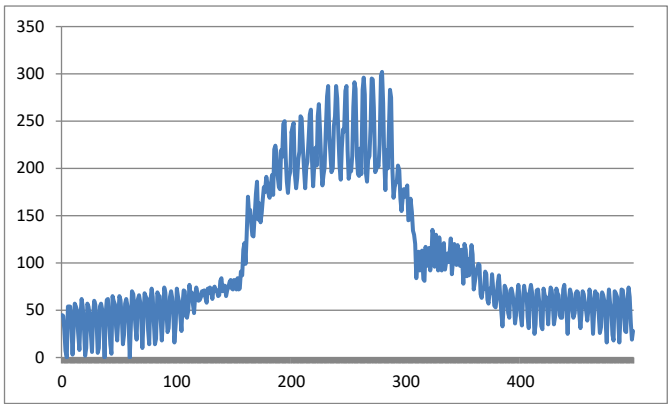


figure 27. Result silk with stainless steel on a wooden surface at 20 °C room temperature.

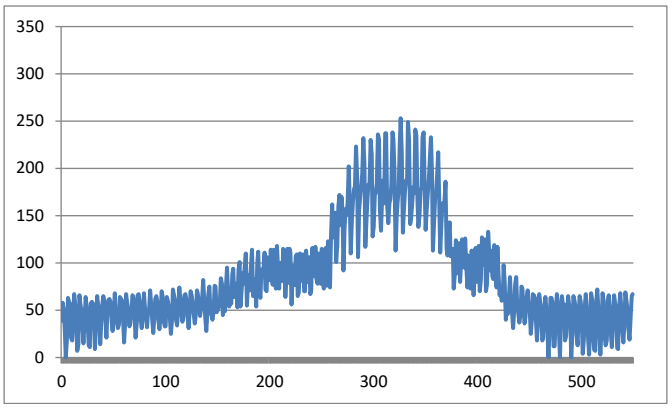


figure 30. Result silk with silver coated nylon on a wooden surface at 20 °C room temperature.

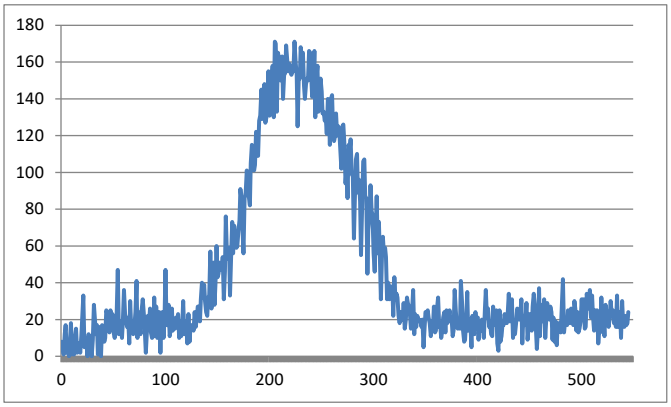


figure 29. Result silk with stainless steel on the skin at 20 °C room temperature.

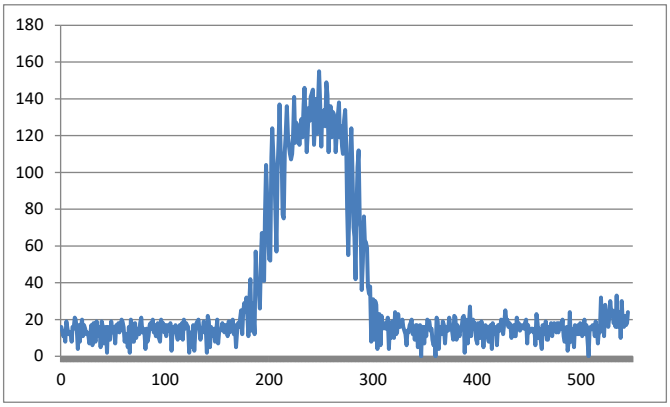


figure 32. Result silk with silver coated nylon on the skin at 20 °C room temperature.

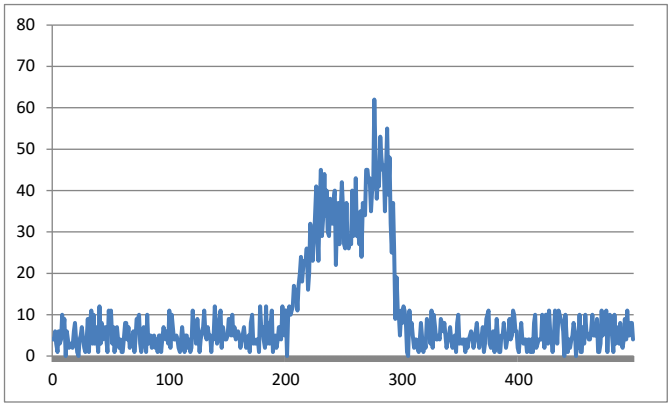


figure 28. Result silk with stainless steel on a wooden surface at 0 °C.

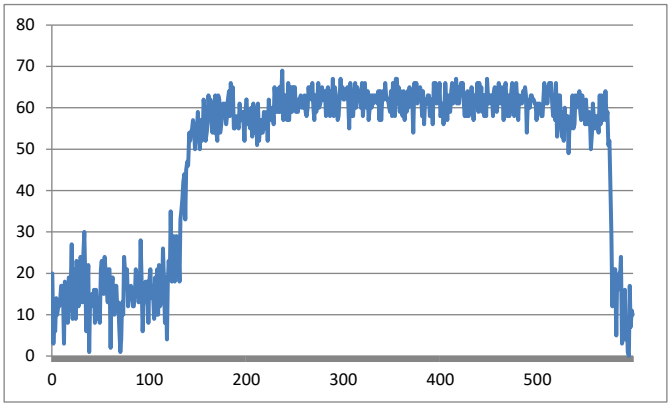


figure 31. Result silk with stainless steel on the skin at 0 °C.

DENIM

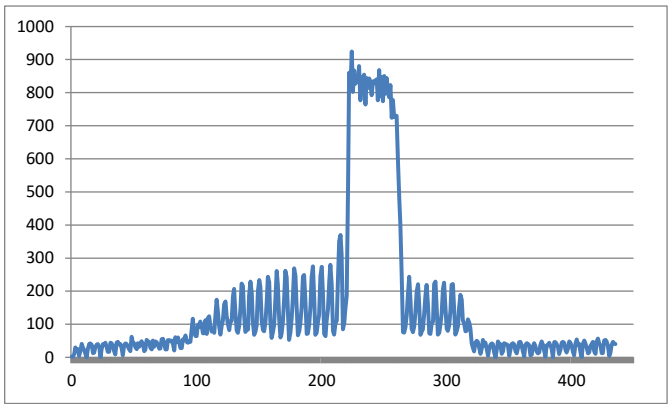


figure 33. Result denim with stainless steel on a wooden surface at 20 °C room temperature.

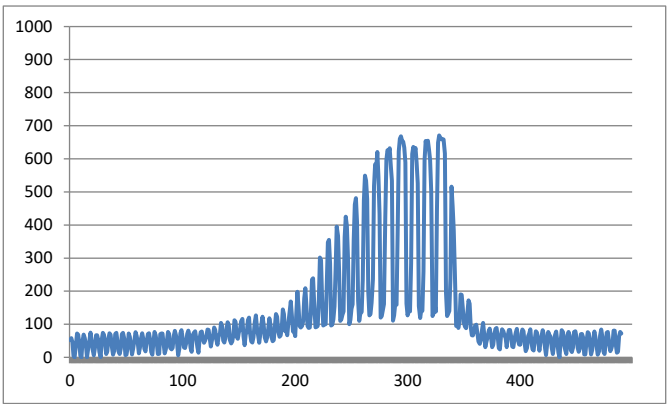


figure 35. Result denim with silver coated nylon on a wooden surface at 20 °C room temperature.

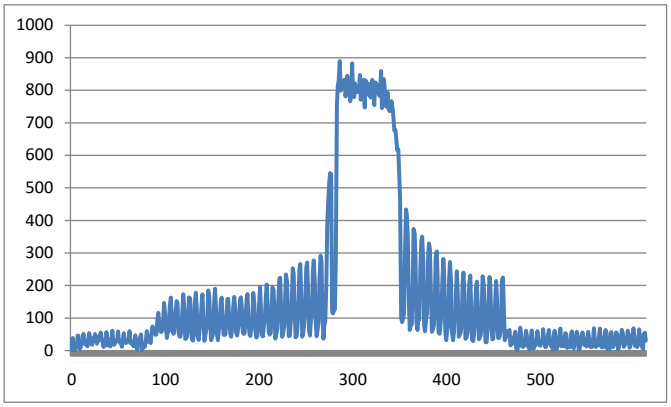


figure 34. Result denim with stainless steel on the skin at 20 °C room temperature.

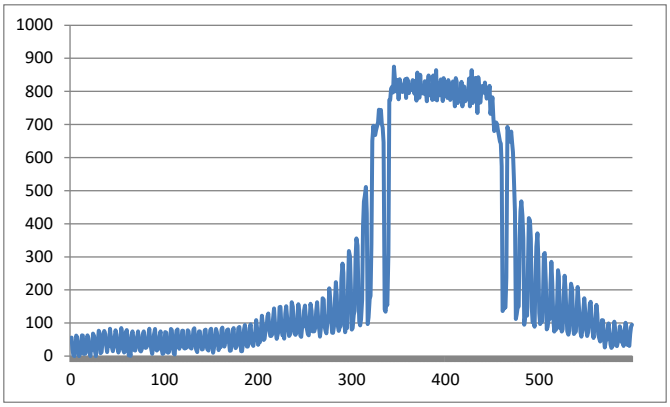


figure 36. Result denim with silver coated nylon on the skin at 20 °C room temperature.

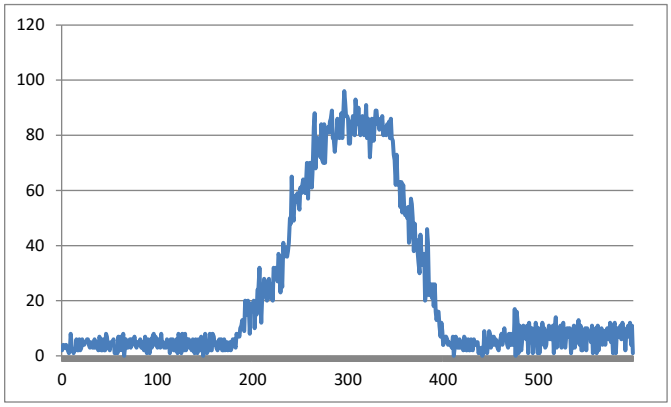


figure 37. Result denim with stainless steel on a wooden surface at 0 °C.

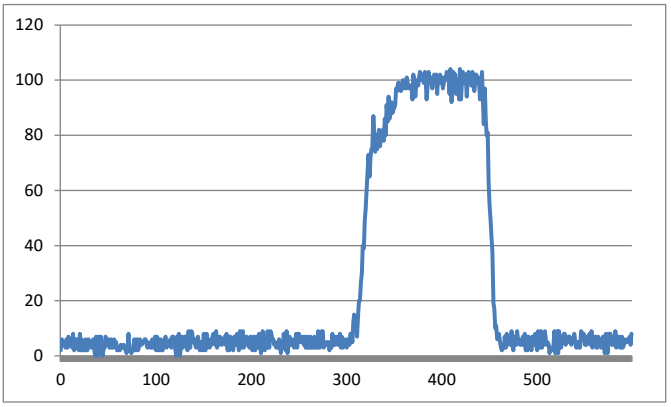


figure 38. Result denim with stainless steel on the skin at 0 °C.

VISCOSE

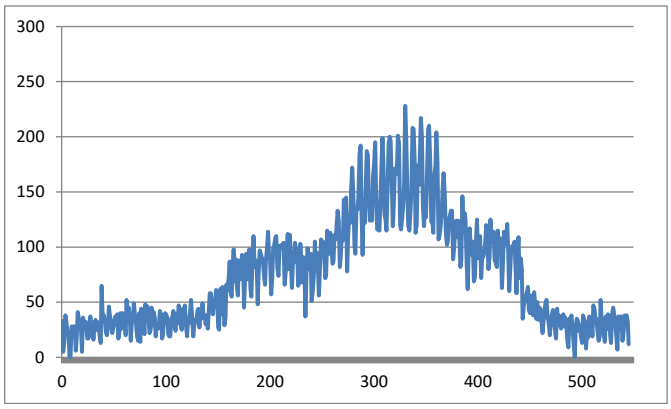


figure 39. Result viscose with stainless steel on a wooden surface at 20 ˚C room temperature.

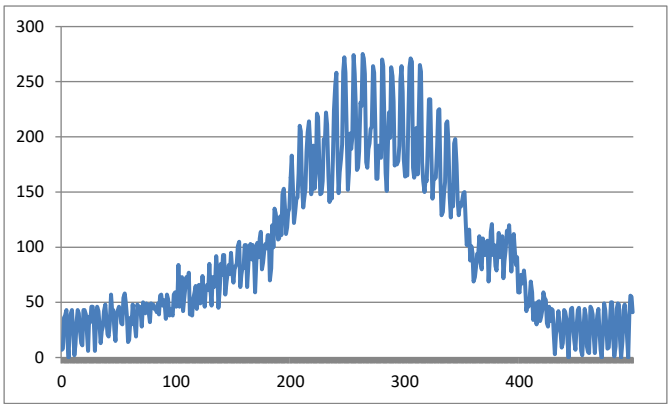


figure 41. Result viscose with silver coated nylon on a wooden surface at 20 ˚C room temperature.

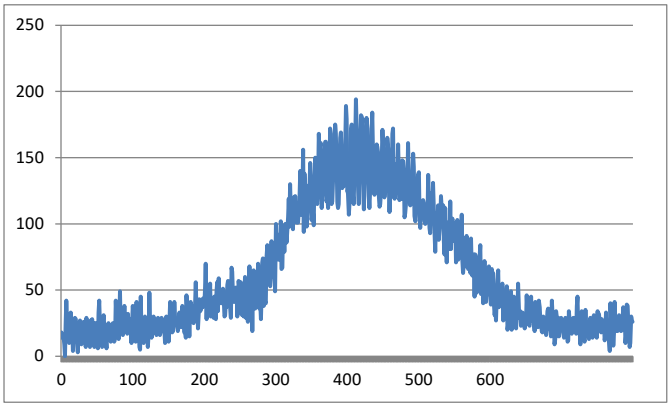


figure 40. Result viscose with stainless steel on the skin at 20 ˚C room temperature.

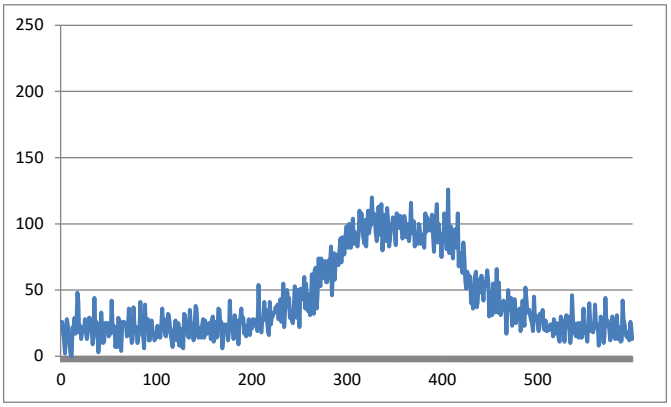


figure 42. Result viscose with silver coated nylon on the skin at 20 ˚C room temperature.

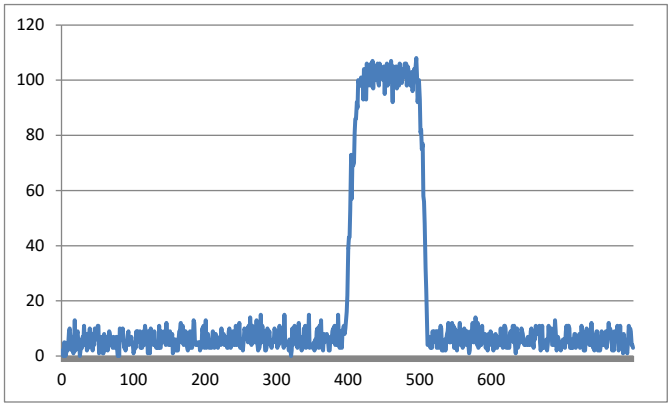


figure 43. Result viscose with stainless steel on a wooden surface at 0 ˚C.

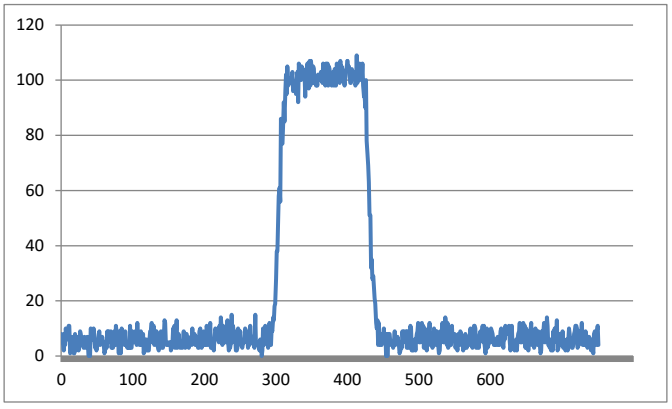


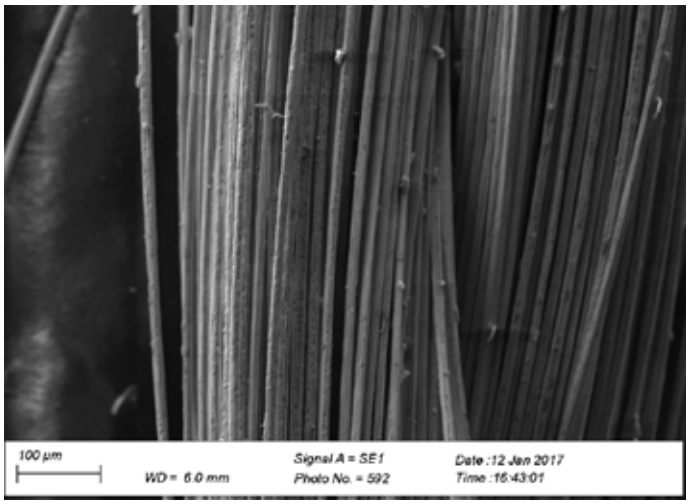
figure 44. Result viscose with stainless steel on the skin at 0 ˚C.

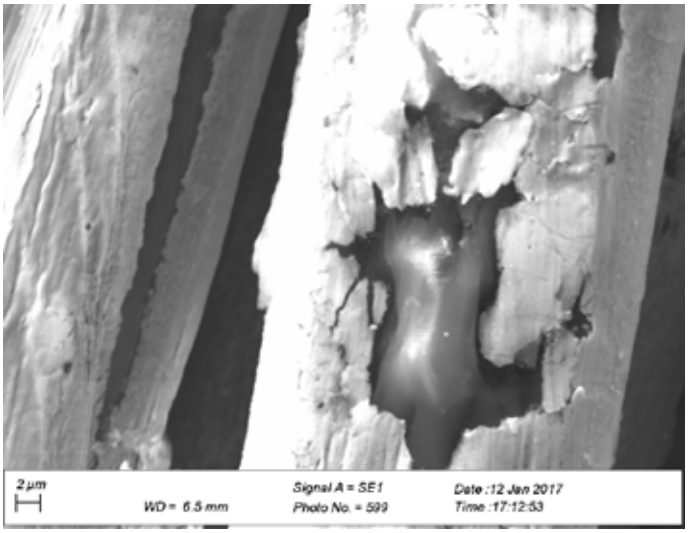
4 MATERIAL TEST CONCLUSION

Many natural fibers seem to have a good interaction when mixed with a conductive fiber. The waves don't show a lot of noise, except for wool. Most of the synthetic fibers show a larger amount of noise, only polyester shows promising results. Though, it sometimes did have some errors while testing. Lastly, mixed materials have bad results and show a lot of noise.

Most promising insulating materials are silk, denim and viscose in combination with stainless steel. The thickness of the steel and silk is still to be determined.

Stainless steel and silver coated nylon showed similar graphs though stainless steel performed a little bit better in every fabric. To understand why the used fibers were put into a scanning electron microscope (SEM) to look at the fibers on a nanolevel (see figure 45 and 46). The surface of silver coated nylon shows a lot of cracks in the silver layer which may effect the efficiency especially over time and after washed the fabric. The stainless steel fiber is a solid one, which efficiency is not affected by time or water usage.





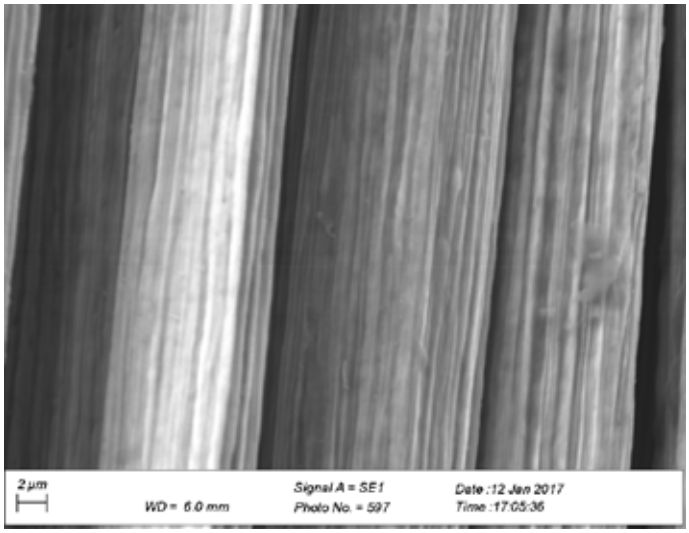


figure 45. Silver coated nylon fiber under a scanning electron microscope (SEM) at 100 and at 2 µm

figure 46. Stainless Steel fiber under a scanning electron microscope (SEM) at 100 and at 2 µm

5 MATERIAL USER TEST

To conclude the material research, a practical study is organized where the Material driven design methodology (*Karana, 2015*) will be used; a step-by-step approach where new materials will get a better design perspective. The main questions towards new materials are 'What is the material, what can the material do and what can you make with use of this material? These questions will be answered with use of the toolkit provided by Serena Camere in co-creation sessions with multidisciplinary groups.

Group 1; DfI students with affinity towards fashion, experienced with touch and out of the box thinking.

Group 2; students from different backgrounds; Industrial Design Engineering, Physics and Electrical/Aerospace Engineering. They have an advanced understanding about electric circuits and experience with wearable technology.

Group 3; experts from the fields of Textile Design, Electrical Engineering and Fashion.

Goal
The outcome of this phase is to understand the meaning of the material; what are its limits and possibilities, what are its properties, what emotions does it evoke and how is it interpreted?

Approach
The students will start by exploring the materials. Provided are two samples (30x50 cm) of a very cheap silk, a standard denim and viscose with a print. They are of different qualities and look in order to test a broader range of textile properties. Two samples of every material are put on the table. One without any smart materials and the other one with stainless steel wire, the Lilypad and an RGB LED. The users are asked to evaluate the materials with use of the toolkit (see figure 47). Every level will go deeper into the evaluation. The levels are as follows:

a. PERFORMANCE; The participants are asked to freely explore the material. Then, they are asked to describe what the material makes them do.

b. SENSORIAL; The participants are asked to explore the material with her/his senses and rate it with the sensorial scale provided.

c. EMOTIONAL; The participants are asked to describe which emotions the material elicits to them.

d. INTERPRETIVE; The participants are asked to choose 3 adjectives from the set provided and place them on the template. Then they are asked to select 2 pictures for each word, to explain what they associate with that word.

e. Finally, the participants make a selection:
- Which material is the most pleasant?
- Which material is the most disturbing?
- Which material is the most unique?

The toolkit is a means to observe and discuss the materials one by one. The discussion is the most interesting part of the research, since the users then have evaluated every level which provided them with enough insights on the properties of the material to give a meaningful final verdict. The statement cards of the user test can be found in appendix D.

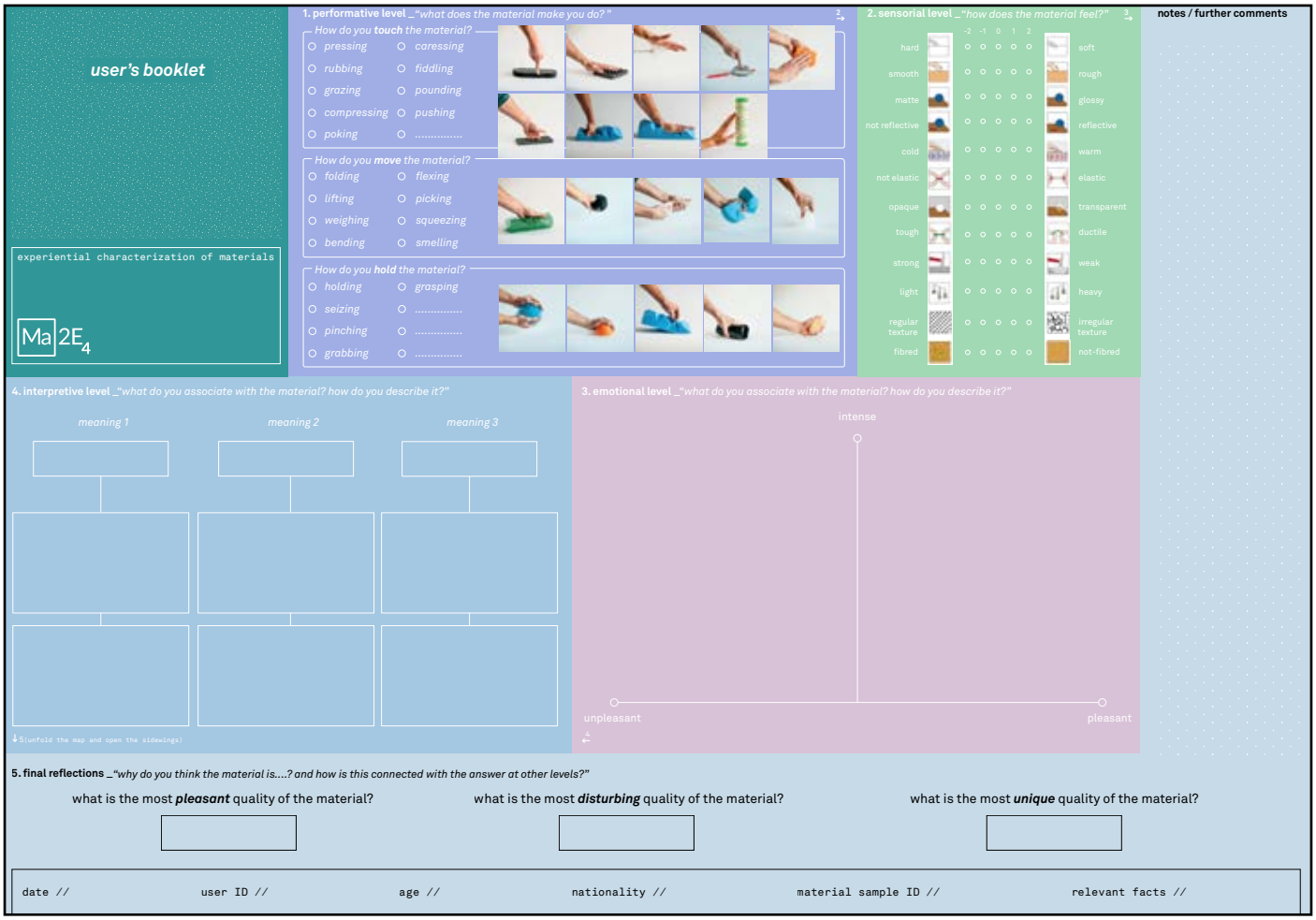


figure 47. the material user test's user's booklet

6 MATERIAL USER TEST RESULTS

Insights group 1
The interaction was not clear in all of the samples, though adding clear use-cues might help to understand the interaction better. Not being able to understand the interaction and the function raises frustration. The sort of interaction is dependent on the body placement and on the type of material that is used. Also, all of the materials were associated with previous experiences and feelings.

Dark colors resemble masculinity; light colors and print resemble femininity. Viscose and silk are therefore experienced as feminine and denim as masculine.

The look and feel of denim is considered of high quality, whereas silk is considered very low quality. The smell of viscose and denim is though experienced as unpleasant.

Patterns are very personal and need to be in line with the type of interaction input and output. An unexpected shape and unexpected interaction can enlarge the level of curiosity.

The color, smell and weave structure can help to raise the level of experienced quality.

Denim and viscose are materials that have a multipurpose.

The feel of viscose and silk is experienced as nice and denim feels natural. The flow of silk was found very amusing.

figure 48. Usertest group 1

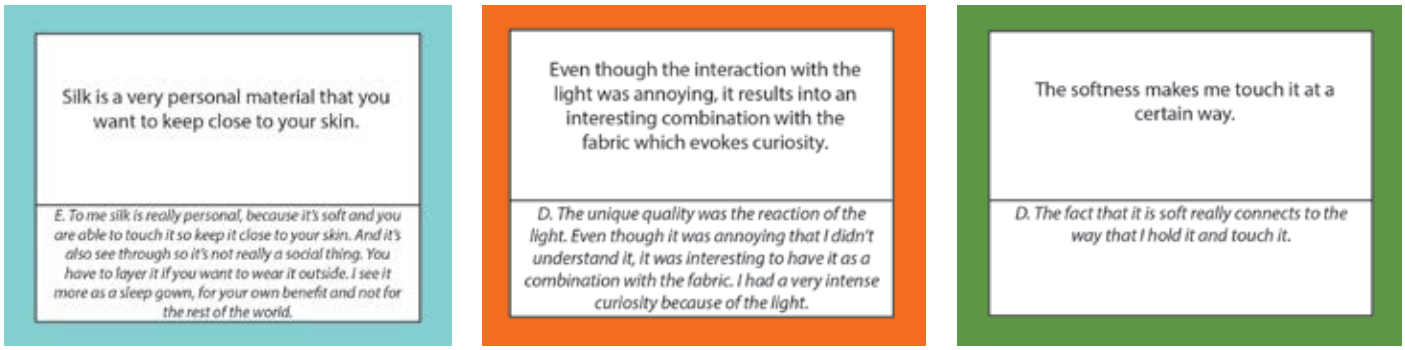


figure 49. Examples of the statementcards of group 1

Insights group 2

Group 2 explored two materials; denim and silk. In both materials the interaction was not clear and therefore unpleasant. Though, the interaction with denim was a subtle interaction instead of flashy one in the silk. The flashy light works well in the silk. Therefore the interaction with the light is considered personal in denim and social in silk due.

The group had fewer associations with the silk material and therefore they find it inviting to touch because of its mystery and seductiveness. The silk material was found to look more like a product than a piece of clothing. The denim is considered as part of clothing.

figure 50. Usertest group 2

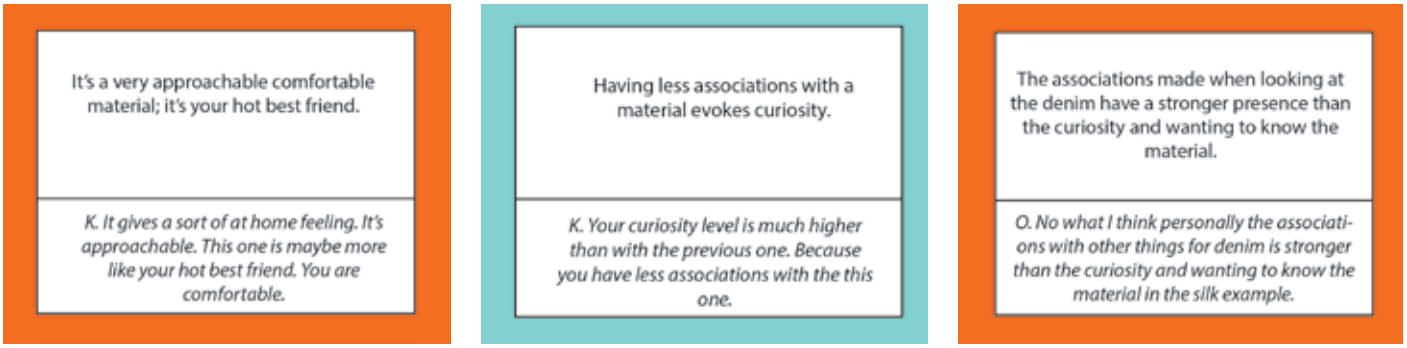


figure 51. Examples of the statementcards of group 1

Insights group 3

Exploring the material is depended on the type of material; denim was weighed, viscose and silk were fiddled with and looked through.

Both denim and silk are very unlikeable materials. The materials are considered cheap and of low quality. Touching and exploring these materials is different than they expected. Especially silk was hard to connect emotions to and was experienced as aloof.

Denim and viscose know many different purposes, but silk is mostly used in hot surroundings.

Silk and viscose both have a very nice flow which feels feminine natural and is attractive and comfortable. Also, the structure of silk and viscose is perceived as pleasant; viscose has a clear structure which makes it elegant. Silk has a very smooth structure which gives it a chic luster. The crease in viscose was experienced both as positive when it's part of the structure, but negative when it wrinkled heavily.

The functionality did not work accordingly or was not investigated.

figure 52. Usertest group 3

figure 53. Examples of the statementcards of group 3

7 USER TEST CONCLUSION

The materials that came out of the material test are very divers. Testing them on different types of user groups gave insight on the quality, possibilities and limits of each of the materials.

Overall attention has been paid to the luster, flow, weight, feel, shape, texture, use-cues, interaction, color, pattern, context and ways to wear.

Toughness and flexibility play a large role on how the material is explored and held. The tough material was being scratched, folded, stretched and weighed. By doing this a verdict is given on the quality. The flexible materials were being wrinkled, fiddled, dropped and waved.

Next to the type of color, having a pattern also attracts or repels people. A pattern should fit a person's style or social environment. This could also be used when wanting to label a certain group of people.

The functioning of the smart part of the material should be clear and well responsive. Adding use-cues helps to understand where to touch the material in order to let something happen. The type of interaction should fit the type of material, but is also dependent of the placement of the material on the body. An unfamiliar shape raises curiosity, but also makes users insecure how to approach the material.

Denim
Denim is a very stiff and tough material that knows various types of garments and is unisex. It is a comfortable and nostalgic textile which users have associations with quickly, e.g. best friend and childhood memories.

It could serve to protect the body during work, but it is also worn at home to relax in.

Denim is seen as masculine due to its color, but also due to its toughness. The type of color and weave structure are important factors to wearers to like or to dislike the material.

The interaction here was too subtle and therefore did not fit the material properly. Still, a subtle type of communication is favored, since the material expresses friendly and comfortable emotions.

Silk
Silk is a very lustrous, playful and mysterious material that is inviting users to explore by its physique. The luster shows the movement of the flexible fabric. The feel is very soft.

Silk is seen as feminine due to its color, luster, softness and flow. The quality of the silk is very important in order to be liked by the wearer.

The material is seen both in a social and in a personal context in which temperatures are rather high. The social context is mentioned by the men and explained as letting others enjoy the type of interaction while the wearer interacts with it. The personal context is mentioned by the women and is explained as the wearer wears the garment directly on the skin when interacting with it.
The transparency of the fabric showed the placement of the stainless steel fiber clearly which was a use-cue where to touch the material to get a response. Even though the interaction was clearer, the response was not. The flashy light did fit the material in terms of a social context.

Viscose
Viscose is a very playful, natural, soft and pleasant material. Being able to see the structure made the material elegant and unique. It is a lot stronger than it looks. A natural crease in the structure can be unique and playful, but easy crease due to wearing or carrying is unfortunate.

Viscose is seen as feminine due to its softness, flow and in this case print. Women can relate to it very well. The fabric fits well in various contexts.

The colors of the light from the RGB LED did not fit the colors of the print well. Next to that, the nervous flickering of the light did not fit the soft and calm emotions that the fabric expressed. Though, the flow of the material made interacting with the light playful.

Which material is most interesting to work with in this research and design project?
All three materials have high potential to become an interesting smart garment. Though, only one material will be used.

Viscose is a material that is very broad and could be used for multiple purposes. Though, its man-made recipe is not attractive to work with. Denim and silk on the other hand can be made straight out of nature. Denim is made from cotton plants and silk is made from silk cocoons. Though denim has already been investigated in smart touch garments and is therefore less interesting to work with.

The mystery and unique qualities of silk fit the smart textile innovations very well. Therefore this project will continue to explore the qualities of silk and stainless steel in smartwear.

SIX

Material Choice - Stainless Steel

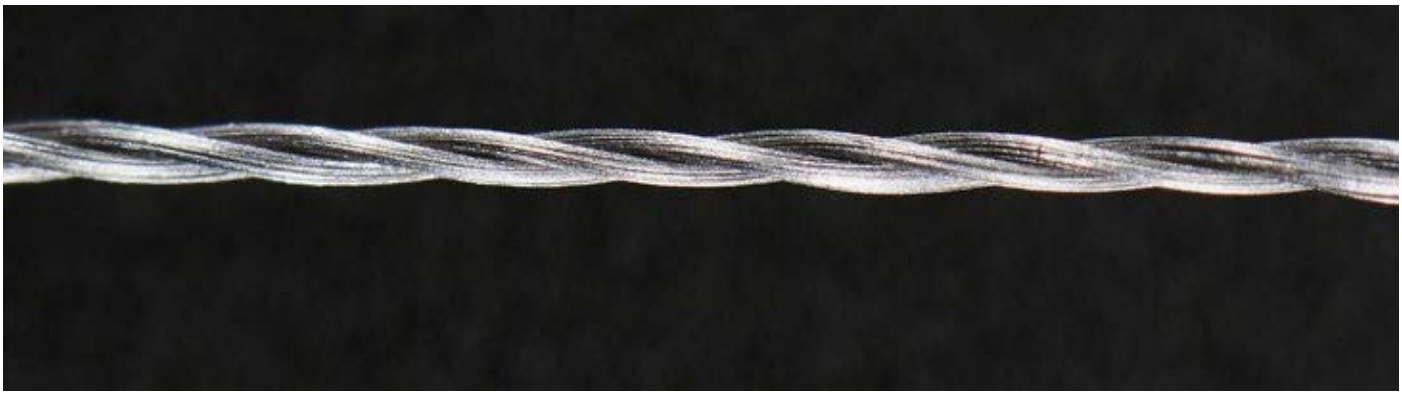


figure 54. A 3-ply stainless steel fiber

Stainless steels are alloyed steels with large amounts of chromium (Design, 2011). This leads to good corrosion resistance, but when exposed to air and humidity, a thin layer of chromium oxide sets on its surface, which reduces the surface conductivity. Stainless steel also has an amount of nickel in them, which could cause an allergic reaction with some users.

When used in woven structures, due to very high contact resistant, the current is not able to spread uniformly through the stainless steel filaments. This may lead to local hot spots and could possible burn the skin of the wearer (Banaszczyk, 2009). Though, this could only happen with a high current running through the wires.

Stainless steel is available as a pure filament, yarn and blended with polymeric fibers (Bekaert, 2011). Their mechanical properties make the material stiff and heavy, which may cause damage during processing techniques like weaving and knitting.

SEVEN
Material Choice - Silk

1 MATERIAL PROPERTIES OF SILK

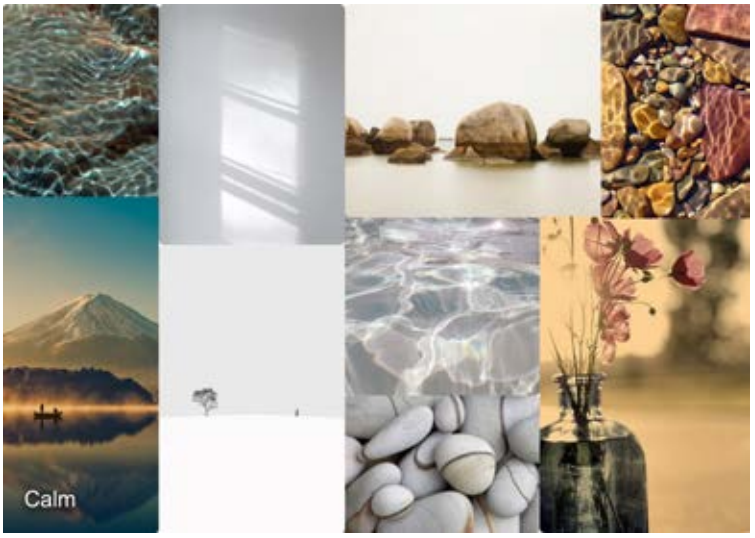
figure 55. *Silk butterflies and silk cocoons; the source of silk fibers*

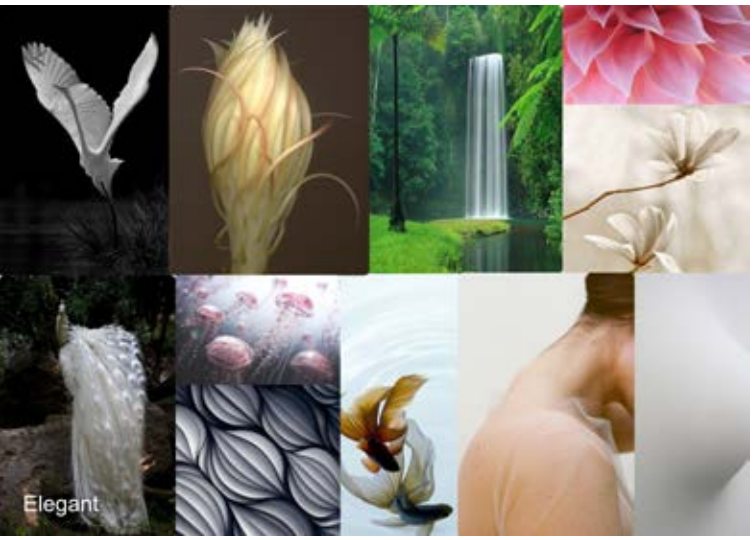
Silk are the threads that silkworms use to spin themselves a silky cocoon. The fibers consist of fibroin and sericin. One silk fiber is about 3000 meters long from which you can use 600 to 900 meters. This is due to both the outer and inner parts of the cocoon are too firmly pasted together and therefore unable to untangle (van Paassen, 1974). To make sure that the butterflies don't destroy the cocoon, the cocoons are being boiled and then untangled. This makes for the highest amount of silk fiber from one cocoon. A more animal friendly way to gain silk fibers is to let the butterfly leave the cocoon and afterwards untangle it. This will result is a less amount of fiber, but is not cruel to the animal. The material processed this way is called peace silk (*Kulkarni, 2007; Sankar, 2012*).

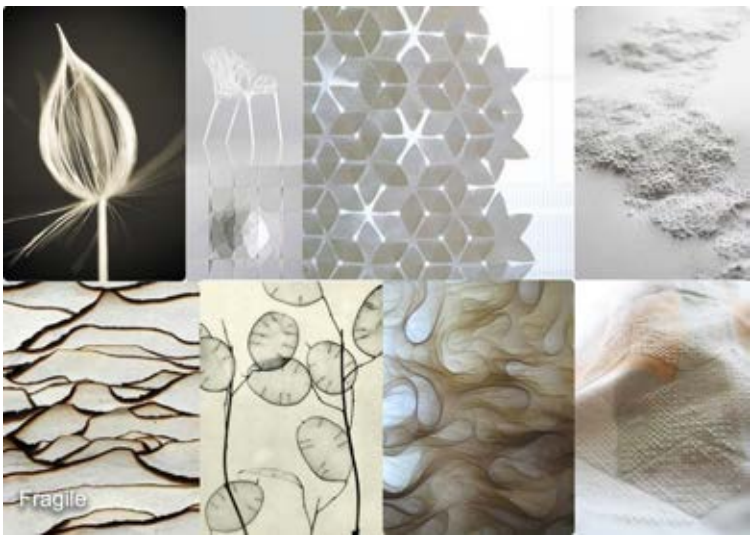
Silk is very hygroscopic and can absorb up to 30% of moist, without feeling wet. In retail the acceptable level of moist is around 11%. To create the soft, white, lustrous silk that we know, the raw silk is washed in warm soap-water which dissolves the natural resin. Silk will dissolve in a warmed lye solution as well as in a solution of chloride. Silk is the finest animal fiber though the most strong. Plant fibers are stronger. In wet conditions, silk loses its strength temporarily by 15 to 20 % (van Paassen, 1974).

The fineness of the silk fiber is expressed in titer. In general the titer articulates the amount of deniers for 450 meters of yarn (1 denier = 1/20 gram). A strand of Td 20 to 22 has 8 cocoon fibers and thus 16 primary fibers of Td 1,14 to 1,25 (20/16 to 22/16). In general simple silk yarn has a tensile strength of 3 to 5 grams per denier. Silk has a high bend and a mean stretch flexibility. The high bend flexibility results in that silk does not crease. The elongation at break is mean, namely 20 to 25 % in dry conditions and 25 to 30 % in wet conditions (van Paassen, 1974).

2 EMOTIONAL VALUES OF SILK







Understanding the emotional values and combining them with the material properties creates an understanding about the uniqueness of the material combination. Since silk will be used as the main material and functions as a bed for the stainless steel the focus of the emotional values and connection with the material properties will be focused completely on silk.

The pictures displayed on these pages are moodboards that illustrate the emotional characteristics of silk. They have been mentioned and discussed during the material research by users and by myself, though they are displayed much more explicit here to function as both inspiration and reference to the material.

figure 56. emotional values of silk put into moodboards

EIGHT
Context and Target Group

1. MATERIAL AND CONTEXT

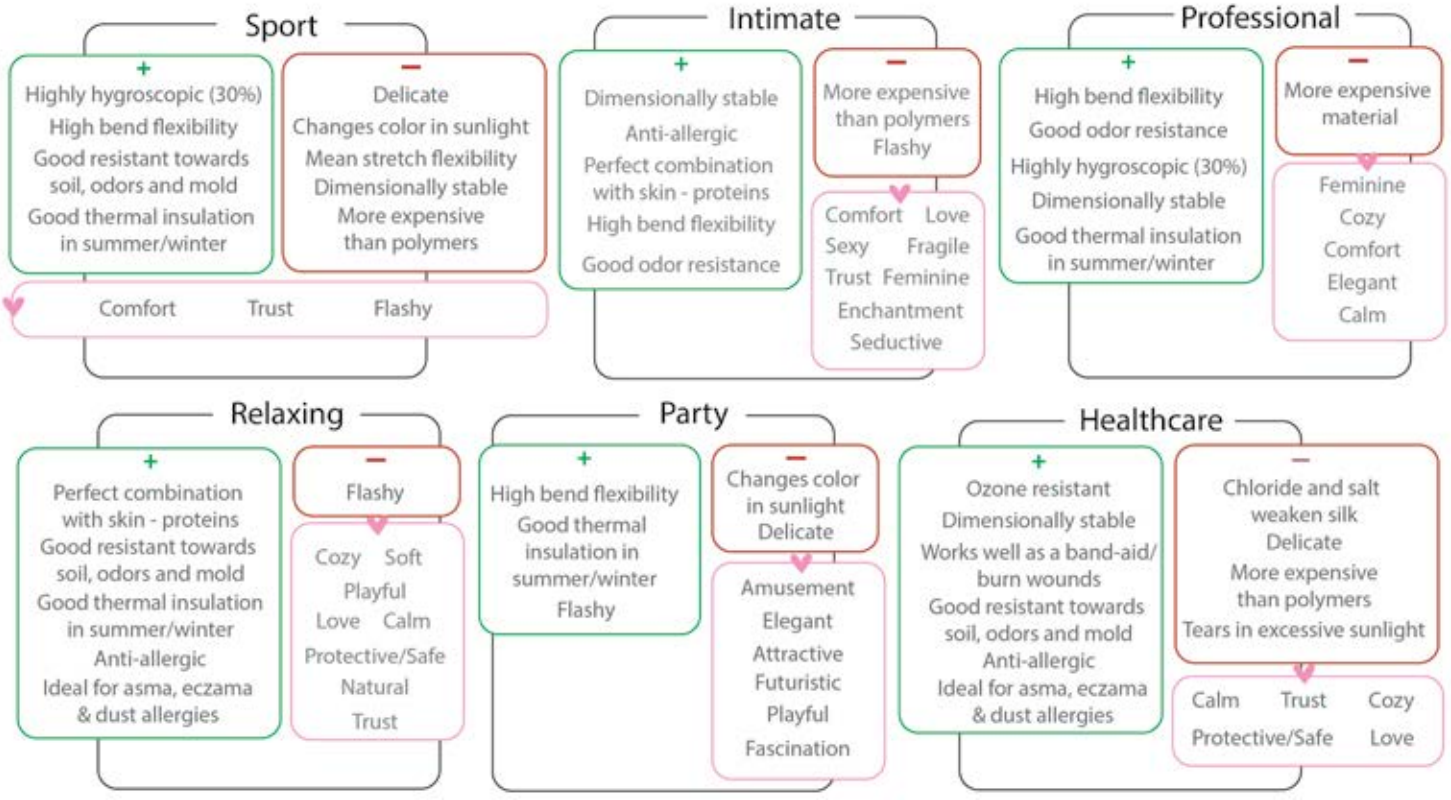


figure 57. Context exploration

Combining the emotional characteristics (♥) with the positive (+) and negative (-) material properties gave insight into what could be interesting contexts for further development of the smart textile. They are sport, healthcare, relaxing, formal, party and intimate (see figure 57).

Discussing the fields with fashion designer Linda Plaude, recent graduate on wearable technology at AMFI, the fields were discussed. Sport and healthcare seemed to be difficult to combine with the material properties of silk so they are therefore not interesting to pursuit. Next to that party-wear does not seem to have the deeper meaning. It's merely aesthetically driven. Professional wear is a direction that has not been researched intensely in literature and has a lot of connection to the emotional, material and aesthetic qualities of silk. Combining them with intimate and relaxed would be an interesting challenge (see figure 58 and 59).

To understand how silk and stainless steel as a smart textile can contribute in the professional context, the user needs have to be identified.

figure 58. Moodboard professional context

figure 59. Moodboard relaxing context

2 JOB MARKET ANALYSIS

Changes in the job market
The Dutch job market is growing positively. There are more jobs and job offers available and the amount of unemployed is decreasing. In the last quarter of 2016 there were about 10.1 million jobs taken (see figure 60).

The total increase of jobs since last year is 167 thousand, which consists for the largest part out of flex workers (109 thousand). The amount of permanent employment did increase, but not as much as last year, which means an overall increase of 1% flexible employment (see figure 61).

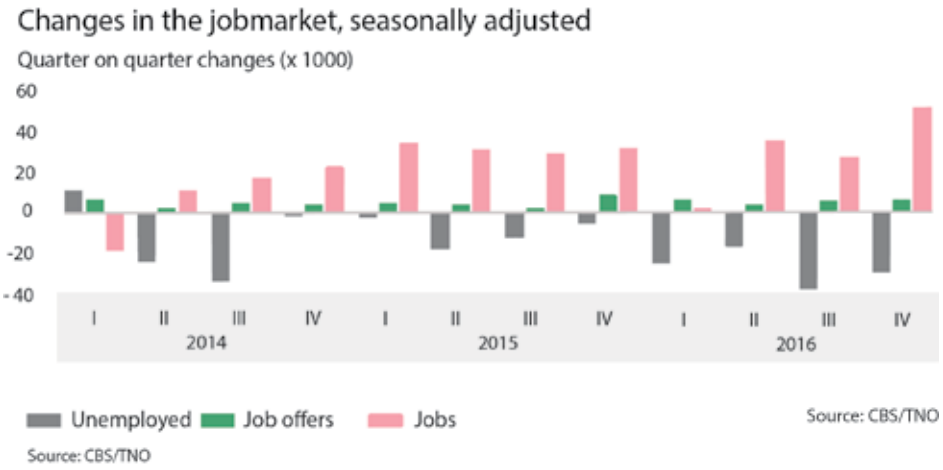


figure 60. Changes in the job market, seasonally adjusted

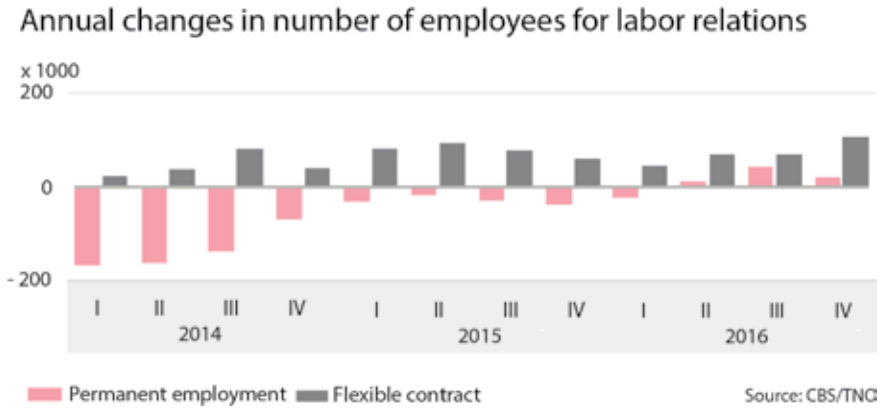


figure 61. Annual changes in number of employees for labor relations

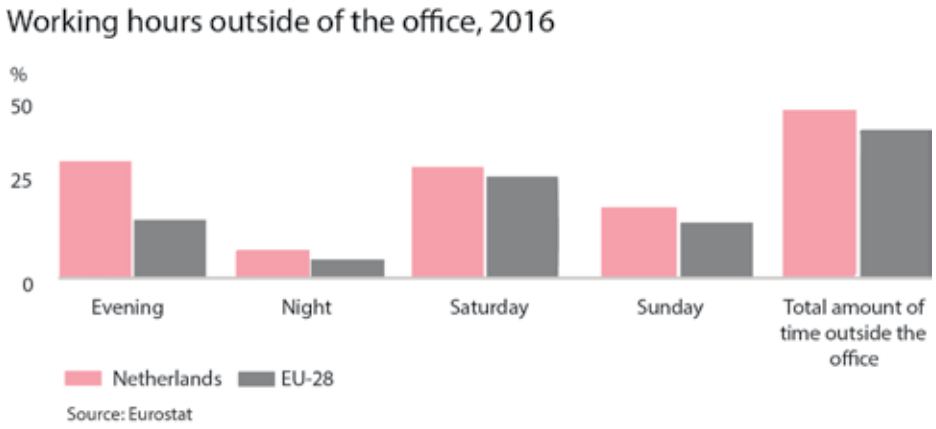


figure 62. Working hours outside the office, 2016

Workload

The average time spend on work is also slightly increasing. About 3.6 million people keep working in the evening or at night (between 7 in the evening and 6 in the morning) during the week or in the weekend. Another 1.9 million does that once in a while (see figure 62). Comparing this behavior with the average behavior on the matter of the European countries (38.5%), it shows that the Netherlands (44%) has a higher amount of working done outside office hours.

This might also give indication about the high workload experienced by employers and employees in the Netherlands. Working fast, a lot and extra intense in a short period of time are the aspects of having a hectic job. CBS data shows that the workload experience has increased over time. In 1980 37% of employees thought they had a heavy workload, thirteen years later that has reached almost 56% and it has been increasing slightly to 66%.

Regardless of the occupation, workload can cause strain reactions due to stressors. Stressors can be for example:

- too little time for a task;
- too high quality demands;
- too complicated tasks
- work that does not connect with previous schooling;
- too little autonomy
- too much responsibility; or
- technical defaults;
- too demanding clients;
- conflicts with the employer;
- unclear job description;
- lack of breaks/ holidays; or
- employees having a hard time saying no;
- employees that are perfectionists;
- employees that have trouble at home that ask a lot of attention.

The body responds to such stressors naturally by preparing itself for the fight or flight response. In most heavy workload cases, this response is not the best method for coping which may lead to health problems and strain (Lundberg, 2006). Examples of complaints can be physical (increased blood pressure, heart disease, headaches, dizziness, hyperventilation, RSI and decreased resistance) and psychological (fatigue, insomnia, depression, worry, addiction, voracity, stress, burn-out and aggression) (Pratt, 1988).

It is thus important for employees to relax and detach from work during leisure time. Several studies though indicate that employees have trouble to do that when there was a heavy workload present during the day (Sonnentag, 2005; Cropley, 2003; Appels, 1997; Rau, 2006). Especially the group of 25 to 35 years old experience high levels of workload (see figure 63); 32 per cent of the employees aged thirty do not feel energized after a night of sleep. About 10 per cent of them said they are not able to relax at all. 18 per cent of the employees aged 20 indicate they should take it slower. Among employees aged thirty this statement has been given by 26 per cent.

However, research shows that specific recovery efforts during leisure time help to reduce the negative impact of an experienced workload (Sonnentag, 2008; Repetti, 1989).

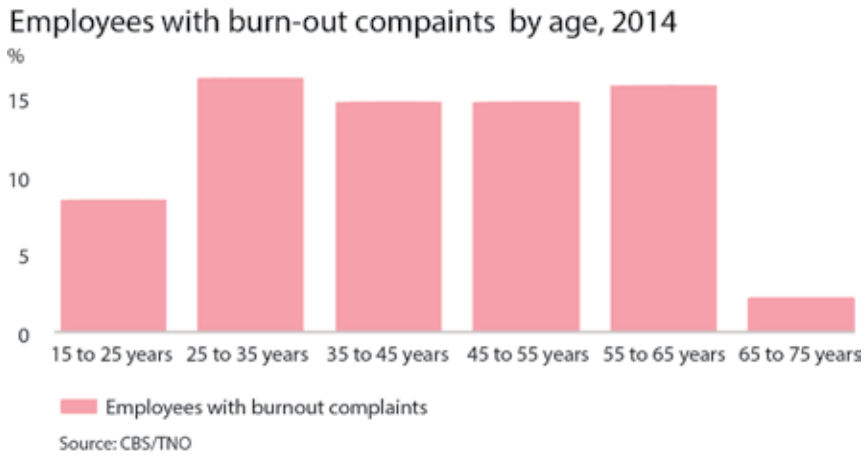


figure 63. Employees with burn-out complaints by age, 2014

Recovery

Recovery is the process that repairs the negative effects of heavy workload and lets the body become at peace again (Sonnentag, 2004). During work the human body uses both physical and psychological resources (Meijman, 1998). At one certain point those resources might get depleted due to the experienced workload. This may lead to a long-term strain process (see figure 64). The first indication of such a process is the need for recovery (Jansen, 2002). Especially during the last hours of work or right after a workday need for recovery kicks in. It is characterized by temporary feelings of overload, irritability, social withdrawal, lack of energy and impaired performance (Siltaloppia, 2012).

The recovery process is explained through two theoretical models. The Conservation of Resources Model (Hobfoll, 1989) states that people always strive to obtain, retain, protect and build personal resources. Thus, after work, employees will attempt to restore them. The Effort-Recovery Model (Meijman, 1998) states that investing effort at work is unavoidable, which causes acute load reactions. To recover from those load reactions, off-job activities should not occupy the same type of resources needed for work. Also, activities that have a compulsory character, like doing the household, paying the bills or taking care of children draw on the same resources. Activities that do help the recovery process are low-effort, relaxation, social, physical and creative activities (Durepos, 2016).

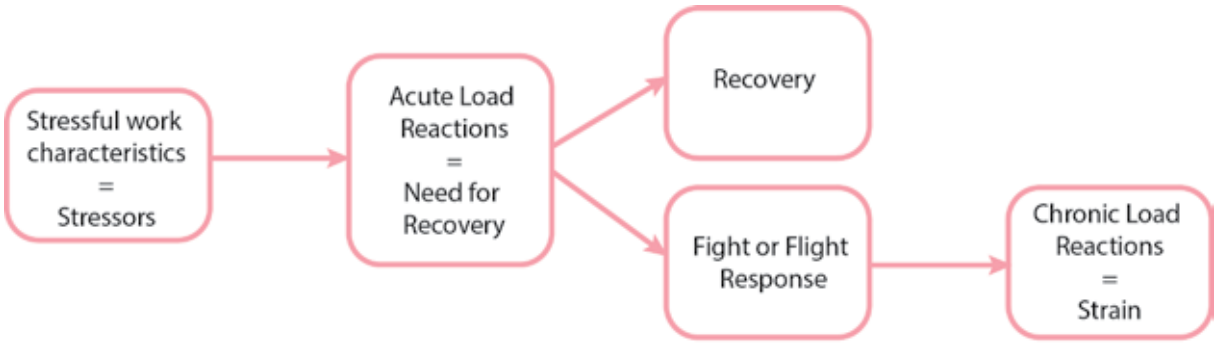


figure 64. Model of work, recovery and health (Geurts & Sonnentag, 2006)

Low-effort activities
Passive activities that require hardly any effort are part of low-effort activities. Examples are watching television, listening to music or just doing nothing. They do not ask for any bodily resources that are normally used during work, which helps the recovery process.

Relaxation activities
Activities that are not demanding and do not require a lot of effort are named relaxation activities. Examples are meditation, yoga, taking a bath or doing breathing exercises.

Social activities
Activities that include spending time with other people are named social activities. Examples are going to a party, having a family dinner or phoning a friend. They work on different resources than normally used during work and they enable people to open channels of social support (Sonnentag, 2001).

Physical activities
Activities that include exercise, training and sports are named physical activities. Not only do they work on different resources than used during work, the physiological mechanisms that play a part in these activities elevate a person's mood and help to maintain fitness of the body (McAuley, 2004).

Creative activities
Creative activities or hobbies help the recovery process, because they provide opportunities for personal fulfillment, skill acquisition and are overall emotionally rewarding experiences (Winwood, 2007). Examples are painting, sculpting and drawing.

Recovery Experiences

Sonnetag and Fitz (2007) suggest that the experiences behind the above mentioned activities form the key to recover from job strain. They present four distinct experiences, namely psychological detachment, relaxation, mastery and control. All of them are supported by both the Effort-Recovery Model and the Conservation of Resources Model.

Psychological detachment

Psychological detachment happens only if employees are able to switch off from work mentally. Whenever an employee does not detach and keeps thinking about job related issues, the same resources will keep being used and full recovery will not occur.

Relaxation

Relaxation is described as an experience that has a state of low activation and increased positive effect (Stone, 1995). It is an active experience that involves relaxing of the body and mind. Examples are yoga, muscle relaxation, meditation or taking a light walk in a natural environment.

Mastery

Mastery experiences function as a distraction from work by involving employees in learning activities and challenges outside of their work field. Those experiences build up new internal resources like skills and competencies. Examples are learning a language, learning how to paint or trying out a new recipe.

Control

Control is the experience when somebody is able to make their own choice on what activities to pursue and how to pursue them. The desire for autonomy is part of the natural behavior of the human kind and control experiences will act on that desire plus it adds to the feeling of competence.

Recovery on the job

Most recovery happens after work during the weekend or in the evening. This is called external recovery (Geurts, 2006). It does happen sometimes that external recovery fails due to domestic tasks that need to be done which results in resources not being rebuilt before starting work again.

Considering the amount of time people spend at work it could be beneficial to look at recovery possibilities there. Breaks taken at work are called internal recovery moments which help the employee to stay focused and productive on the work at hand (Geurts, 2006). These breaks can vary in length and in recovery result. A lunch break with co-workers for instance does not necessary contribute to recovery, but employees that engage in activities that have a mixture of recovery experiences (psychological detachment, relaxation, mastery and control) report higher levels of attentiveness and less fatigue (Fritz, 2013). Recovery experiences on the job could thus support the employee during work, but could also minimize the need for recovery after work.

Differences between sexes

The amount of women at the workplace has increased the last 25 years. In 1975 only 30% of the women had a paying job, in 2000 this already reached to 54%. Social Cultureel Planbureau. If in a relationship, the homework balance is different for men and women. Women spend about 17 hours doing household chores, whereas men spend about 7 hours. Then, taking care of the children is still mostly done by women than men. This results in women working more part-time (29 hours) than full-time (41 hours). Next to that most women tend to work in social occupations which ask a lot of them emotionally as well. Thus, the more women work, the more exhausted women get since there is very little time left to relax.

Jettinghoff and CBS/TNO argue to the importance of research on the psychological complaints women have that work full-time. A big part of those women ends up in the WAO very young due to those complaints. Research on this subject should not only be done per individual, but also on groups. In some industries experiences of heavy workloads are much more common than in others, but thus also differences between the sexes are important to investigate.

A research done by CBS/TNO on burnout among managers has shown a big difference between men and women. 29 per cent of female managers felt empty multiple times a month at the end of a workday. Also 17 per cent of the female managers told they felt exhausted in the morning when confronted with work. Men are 4 to 5 per cent less affected by these complaints. Next to that women feel they have to work more, harder and faster more often than men feel (see figure 65 and 66).

Also female managers seem to be less in control of deciding at what pace to work, the order of tasks, when to take time off or which times to work than men (see figure 67).

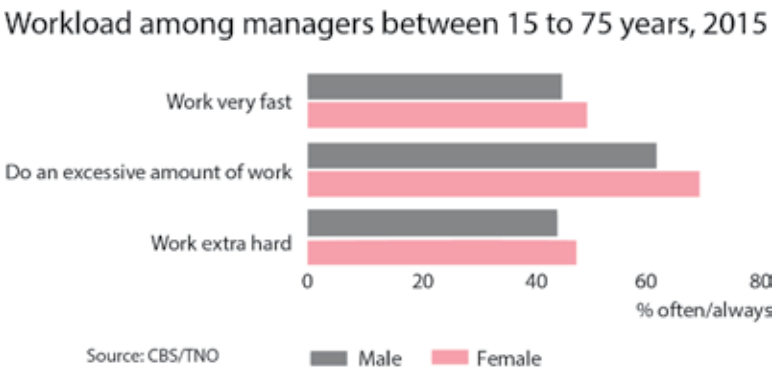


figure 65. Workload among managers, 2015

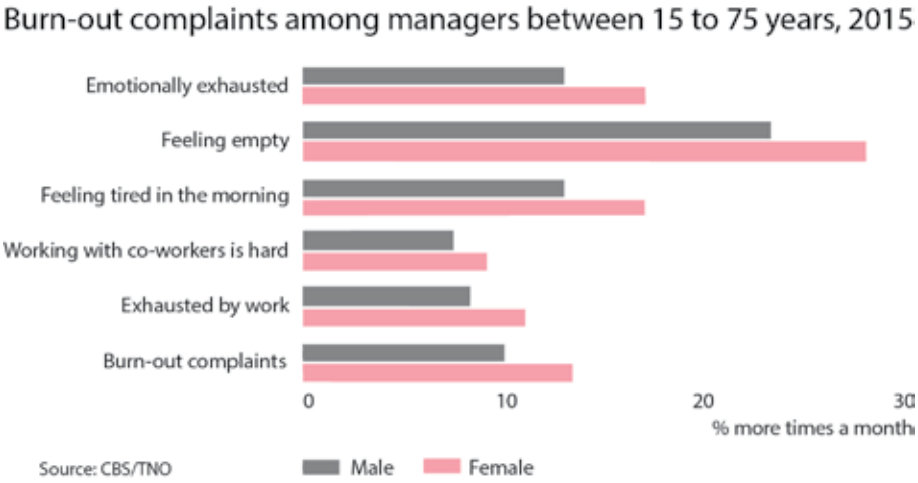


figure 66. Burn-out complaints among managers, 2015

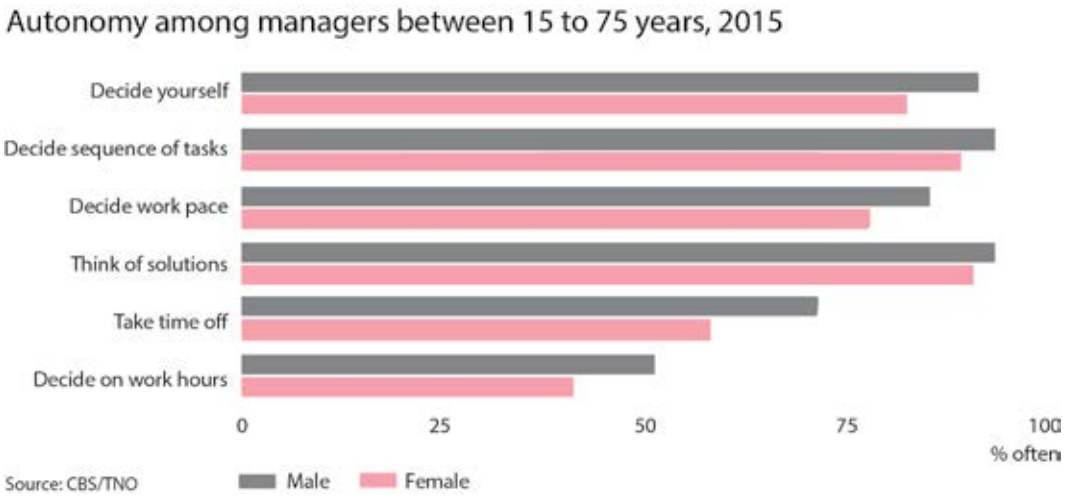


figure 67. Autonomy among managers, 2015

Conclusion

Burn-outs, stress and workload are increasing complaints on the Dutch workplace. Complaints are also higher compared to the European average. Especially people aged 25 to 35 experience a higher level of workload compared to the other age groups. About 10 % of this group says they are not able to relax from work at all.

As employees spend a substantial part of their day at work, on the job recovery might represent a feasible alternative for recovery as sometimes individuals might have insufficient opportunities to engage in recovery activities during their off-work time.

In these sets of studies we see that combining different recovery experiences can help employees to recover during work. The next step is to find out which activities are suitable for the work environment. In general doing an activity that does not draw on the same resources already called upon during work, help the recovery process. Depending on the type of work in the office the recovery process should thus draw on other resources.

Then, there is a big difference between how men and women experience their job. Data shows that women feel less in control (within the same industry as men) and experience a higher level of workload psychologically and physically. Therefore the specific target group to focus on for the smart garment will be women between 25 and 35 working within office environments in Dutch companies and help them to fully relax from workload.

3 VISITING THE OFFICE

To get a better understanding what an office looks like and what activities happen there, an observation was performed at an office in the Hague.

The company has about sixty employees which work in different spaces around the building. The picture are made in the space of Communication, which is an open office space. The office manager sits in the same room as the rest of the employees. Meetings are held outside of this area, but short discussion, small chats and questions happen within the office space.

Only seven of the twenty available workplaces are occupied. The rest of the employees are out for meetings. During the 30 minutes observation two of the seven employees left for a meeting for 15 minutes and the manager walked out for a meeting with two clients as the observation started.

The manager stated that the team has a lot of projects going on and have to work on a strict schedule. This can be observed as well; almost everybody had plugged in headphones to listen to music working focused on their tasks. From the observation it is clear that almost all activities besides meetings happen on-screen.

The space and interactions happening in this office show great resemblance to the interactions happening at the white tables in the hall of Industrial Design. Even though that is a flex area, people have the same type of attitude towards their tasks; listen to music, stay focused on tasks at hand, leave for long meetings and stay for short social interruptions. Future observations and tests within an office context can thus possibly also be performed at the white tables at Industrial Design.

Now a clearer understanding of what an office is has been formed, the research can continue in more detail on what specific activities can help relax the human body in office spaces.

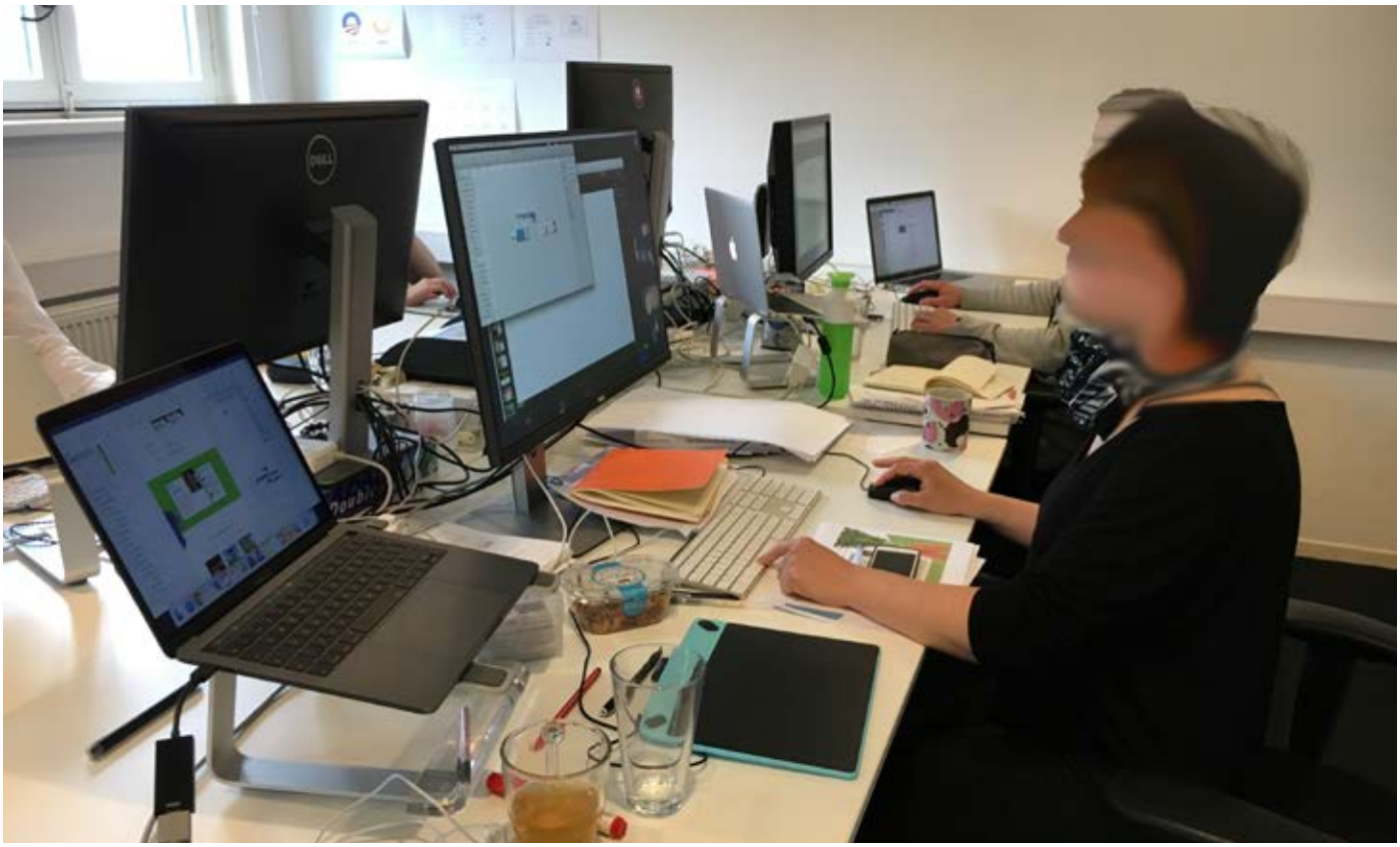


figure 68. An example of an office space

figure 69. An example of office activities

figure 70. Observations front of the human body

Looking at how people touch themselves and others in the office helps to understand the interactions happening with their clothing. Some are unconscious which must be taken into account since the interaction should be controlled by the user. Next to that an understanding about the location of the interaction input can be derived from these movements. It should be a natural way of interaction, not distracting others, and a personal experience.

In the pictures above it is clear that people interact with themselves in the front of their upper body. Thus placing the interaction on the front part of the upper body will be most logical. Next to that shoulders are places that are being touched by others when wanting attention. A lot of the observed fiddle or play with their garments which gives an interesting angle on the design.

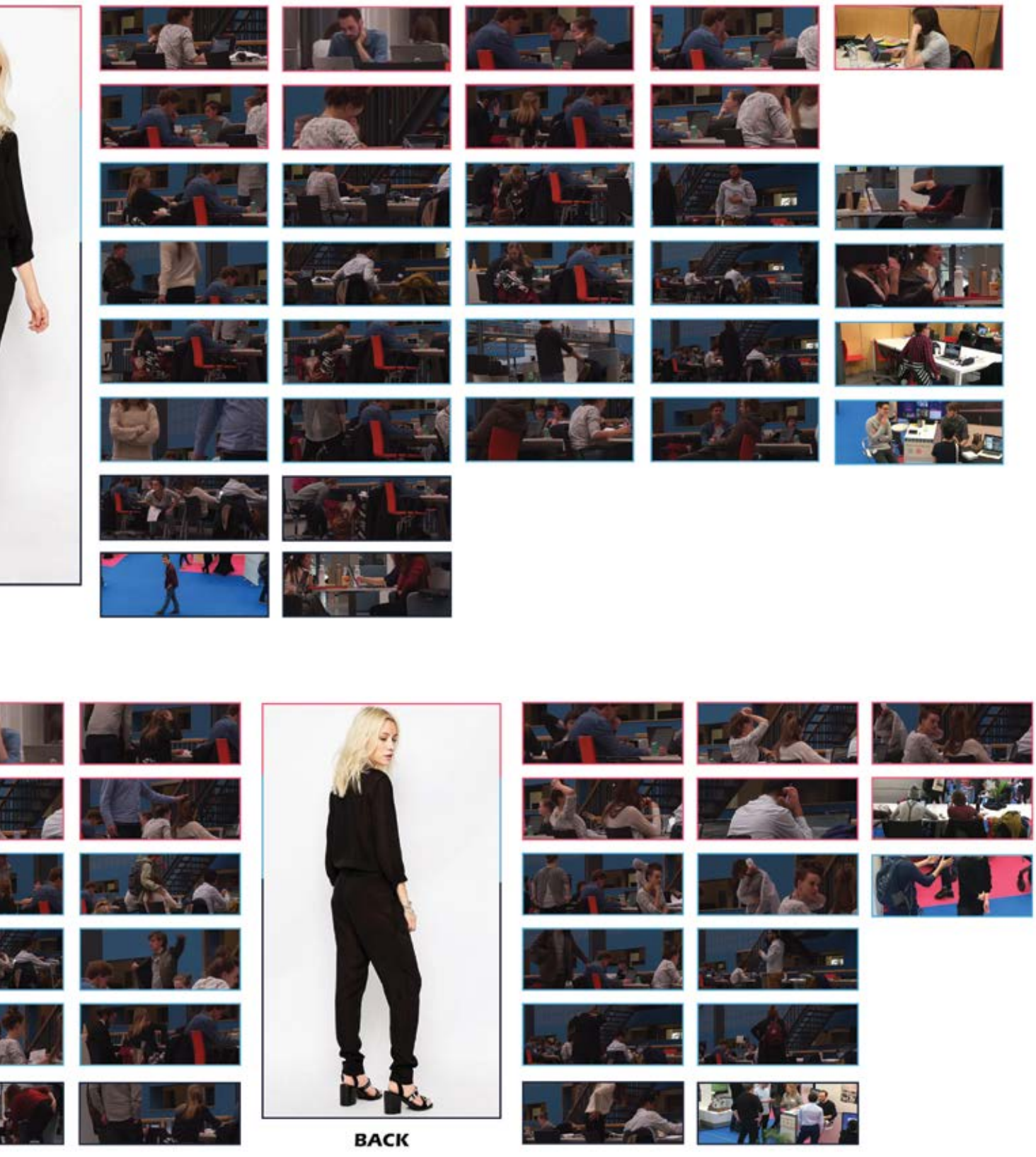


figure 71. Observations back of the human body

figure 72. Examples of relaxation response practices: a. meditation b. yoga c. zen d. Buddist prayer wheels e. meditation f-h praying i. jogging j. walking the labyrinth k. symbol of buddism l. yoga m. zen

NINE

Relaxation and Recovery

In this chapter several relaxation techniques will be discussed. The techniques draw upon different resources of the body so recovery of the body and of the mind can take place.

Meditation

Meditation is derived from the Latin word meditari, which means to heal. The practice of meditation is to be said to lead to a person's physical, mental and spiritual well-being (Makvana, 2016). The English meaning of meditation is therefore linked to healing and relaxation of body and mind.

By practicing meditation you will learn to see the patterns and habits of your mind over time which leads to a more positive way of being. With regular practice the focus state of mind that is achieved through meditation can lead to a peaceful and energized state of mind (thebuddhistcentre.com).

Walking the labyrinth

Walking the labyrinth is an active way of practicing meditation. The intention of the labyrinth is to create physiological, affective and spiritual outcomes that are similar to sitting meditation. The labyrinth is a path that winds back and forth, clockwise and counterclockwise, taking the walker from the side to the center and back towards the side until the walker reaches the center. The center, or rosette, is a circular shape with six petals.

The walker goes through three stages during her walk. The first stage is releasing in which the walker is encouraged to empty the mind by repeating a chant, a word or a prayer; or by posing a problem to be solved; or by recalling a dream to reflect on. When in the center, the second stage of engaging happens in which the healing process commences. The third stage is returning in which the walker goes back to her day-to-day thoughts with every step she takes (Sandor, 2006).

One of the most famous labyrinths is located at the Chartres Cathedral in Chartres, France, which is 800 years of age.

Yoga

Yoga is a group of physical, mental, and spiritual practices composed by the Indian sage Patanjali in ancient India almost 2000 years ago. The 195 gestures are collected in the Sutra; a philosophical guidebook for yoga practitioners. It also outlines eight limbs of yoga: the yamas (restraints), niyamas (observances), asana (postures), pranayama (breathing), pratyahara (withdrawal of senses), dharana (concentration), dhyani (meditation), and samadhi (absorption). The eight limbs make yogi able to refining their behavior in the outside world which will lead eventually to samadhi.

Most of the people today practice the third limb, asana, which is a set of postures that help to balance body and mind. The practicing of this third limb is called Hatha Yoga and starts from the body, towards the muscles, then to the breathing, the mind which finally leads to the balance and calmness of the mind. This balance is called Samatva and is said to be the ideal state of body and mind (Nagendra, 2015).

Another technique that works in similar ways as yoga is Tai Chi Chuan, often called Tai Chi, which finds its origin in the Chinese martial art discipline. Tai Chi also focuses on relaxed breathing and mental focus, but combines this with slow sustained physical movements.

Mindfulness

Mindfulness is derived from the Buddhist word sati and is defined as bringing one's complete attention to the experiences occurring in the present moment, in a nonjudgmental or accepting way (Brown & Ryan, 2003). The intensity of practicing mindfulness varies a lot. On one side is everyday mindfulness, which is most often performed by Buddhist monks and on the other side is to have mindful moments. On these moments the practitioner is momentarily disengaged from her daily activities by taking a long, deep breath and asking herself questions like "What am I feeling right now?" "What am I doing right now?" "What is most compelling to my awareness right now?" (Germer, 2004).













Praying
Prayer comes from the Latin word precari, which means to ask. It is used to worship, request guidance or assistance, confessing to sins or to express one's emotions and is directed to a deity, spirit or a deceased person. Most often it is a form of religious practice, be it communal, public or private, in which it is expressed in words, a song or complete silence. When language is used, the prayer can take the form of a hymn, incantation, a statement or a spontaneous utterance in the praying person.

People pray for all sorts of reasons such as personal benefit, asking for divine grace, spiritual connection, or for the sake of others which may help them find an inner sense of meaning (James, 1985).

Progressive muscle relaxation
Progressive muscle relaxation is a method which teaches practitioners how to relax their muscles. This is done in a two-step process. The first step is to tense a particular muscle group for a few minutes, e.g. the neck and shoulders. Then, the practitioner releases all the tension and notices how muscles feel when they are relaxed. By repeating this exercise the practitioner will have a better understanding when muscles are too fixated and when a body is relaxed.

The exercise will help lower bodily tension and stress levels. It can also help reduce physical problems such as insomnia, headaches and stomachaches (Jacobsen, 1925).

Massage
Massage is derived from the Traditional Chinese Medicine technique of Tui Na, an ancient Chinese method to take away stress and pain from a body by applying pressure to that body. The masseuse used her hands, fingers, elbows, knees, feet or a device to massage the body. Massage is a very common technique in Western cultures as well when to release pain from the body. Examples can be found in professional sports and in health care.

The basis of massage lies in the meridian system or how the Chinese call it: the theory of Jing Luo. It is explained as a distribution network for the fundamental substances of qi (pronounced chee), blood and body fluids throughout the body (Shen-nong.com).

The system has twelve regular meridians that form the major structure. They are distributed symmetrically on both sides of the body and are paired with their corresponding internal organs creating an interior and exterior relationship. Blocking the channels causes pain which may results into health problems. Unblocking the channels can be done by applying pressure which leads to a mind and body balance (Shen-nong.com).

Some examples of massage are hot stone massage, in which heated and cooled stones are applied to the body with gentle pressure, hand massage, acupuncture, in which needles are used to unblock channels and muscles and reiki, in which subtle stationary hand positions on points of tension or injury lead to energetic restoration and relaxation.

Conclusion

Most relaxation activities are focused on finding a balance between the body and mind. They do so by performing a sort of repetition of an activity while breathing consciously and focusing on bodily activities like the heartbeat (Sieratzki, 2002).

Medical doctor Herbert Benson (1974) has been researching body and mind relaxation techniques since 50 years and found a connection between the before-mentioned techniques. This connection is a phenomenon that happens when practicing one of the above mentioned techniques. It is what he calls the relaxation response.

The basics of the relaxation response are as follows; the repetition of a sound, word, phrase, prayer, or muscular activity and a passive return to the repetition whenever distracting thoughts occur. By doing this for minimal 10 minutes, a series of physiological changes are triggered that help to protect the human body against stress which are opposite from the fight-or-flight response to stress.

Eliciting the relaxation response makes practitioners use less oxygen, produce less carbon dioxide, breathing slowed down and brain wave patterns were slower.

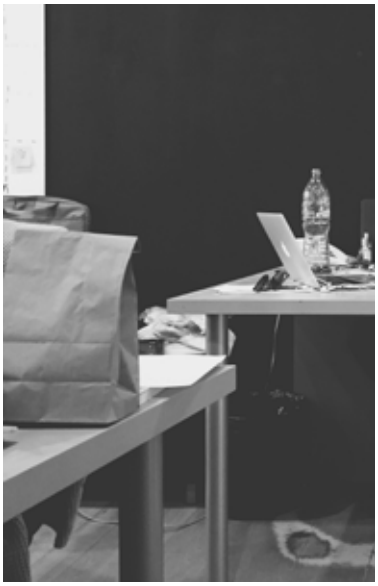
Even though the relaxation response was discovered due to the research on people practicing meditation, other ways of eliciting the relaxation response are possible; Zen, yoga, mindfulness, progressive muscle relaxation, hypnosis and exercises like jogging are practices that have similar results to meditation.

Over the past years, other research is done to test the added value of the relaxation response in the treatment of for example muscle tension, pains, infertility, insomnia and psychological problems. For these diseases there is good evidence that the relaxation response can help undo some or all the damage caused by stress (Benson, 1992; 2000).

The relaxation response is thus a valuable method to use when experiencing tension in the body and in the mind. This could mean a solution for the people suffering from a heavy workload in office spaces. Letting employers touch the smart garment in a repetitive manner could potentially elicit the relaxation response, which enables the body to relax, detach mentally from work and recover.

TEN

Vision - On the Job Recovery



CONTEXT

The chosen context is an office environment. Offices show great potential for the implementation of a smart garment specially one that is made from a combination of silk and stainless steel.

TARGET GROUP

The chosen target group are female employees aged 25 to 35 that deal with a high work-load in an office environment and find it hard to relax.

EFFECT

An on-the-job recovery experience is expected to help the female employees to relax and detach from work which ultimately enables them to stay in control of their body and mind activities. With use of the relaxation response these effects are probable.

IDEATION

Now the analysis has come to an end it is time to set the guidelines to shape the final design. By doing so no insights will be left out during the evaluation of ideas.

Ideation is about creating ideas. In this chapter technology meets fashion and user needs.

ELEVEN
List of Requirements

The material research and user needs give a list of what the garment should do and what it should look like. All these requirements help to form the final design and are listed below. Requirements are marked with an (r) and wishes with a (w).

Material usage
- Silk must be used as an insulator. (r)
- Stainless steel must be used as capacitor. (r)

Use aspects
- The interaction can only work between the hand and the conductive fibers. (r)
- The usage can be done sitting behind the desk, standing during a presentation or walking towards a meeting. (r)
- The garment enables the user to have a direct interaction without distracting others in her environment. (r)
- The user is invited to touch the places where capacitive fibers are situated. (r)
- The garment must relax the wearer after use. (r)
- The garment should be used at least for 10 to 20 minutes a day with a continuous usage for at least 5 minutes. (r)
- The garment invites the user to touch it in a repetitive manner. (r)
- The garment should enable the user to detach mentally from their screen for at least 5 minutes. (r)

Functionality
- The system must function within an environment with a office levels of electric magnetic noise. (r)
- The system must be electro static discharge (ESD) compliant. (r)
- The system must be able to work with average humidity levels of human beings. (r)
- The maximum weight of a system component must be 5 grams. (r)
- The system has a battery lifetime of at least 12 hours at maximum usage. (r)
- The maximum heat generation of the system components should be 50 mW. (r)

Target Group

- The garment should be aesthetically appealing to women between 25 and 35. (r)
- The garment design must fit within casual chic office wear. (r)
- The garment should enable women between 25 and 35 to wear it throughout the day in and outside the office. (r)

Aesthetics

- The garment should comply to the latest fashion trends. (r)
- The color of the garment is light. (r)

Production

- The silk textiles are environmental and animal friendly produced. They are either manufactured according to the GOTS (Global Organic Textile Standard) or are Ahimsa (peace) or Tussah (wild) silks. (w)
- The silk textiles are fair-trade. They have received a World Fair Trade or an Ökotex Fair Trade label. (w)

TWELVE

Interaction Vision

An interaction vision is a metaphor or a analogy that helps to generate and communicate interaction qualities by creating a representation of the mood, feeling and experience that the product should give the user when interacting with it. It explains the quality of the relationship between the product and the human using the product (Hekkert, 2011).

The interaction vision is stated as taking a warm bath. Taking a bath will relax you and afterwards gives will give you a rested feeling.

The interaction qualities are calm, natural and intimate.

figure 73. Interaction Vision visual - taking a warm bath

THIRTHEEN

Storyboard

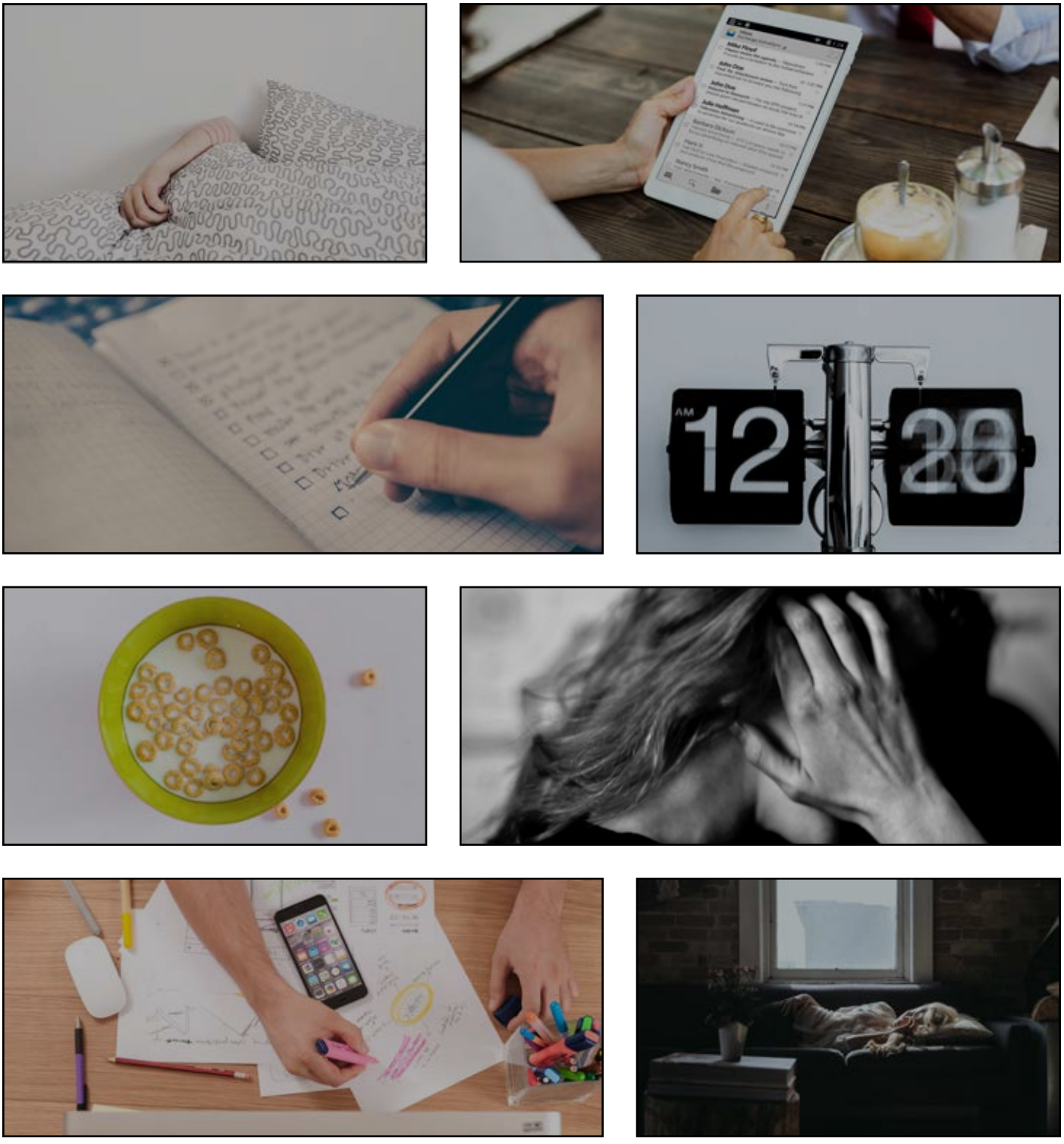


figure 74. Regular day of an office employee whom experiences a heavy workload.

The following storyboards show the contradiction between the office as is experienced right now and how the experience could change when using the smart garment.

The employee will feel much more rested in the morning, focused during the day and energized during the evening when taking a few minutes a day relaxing with the smart garment.

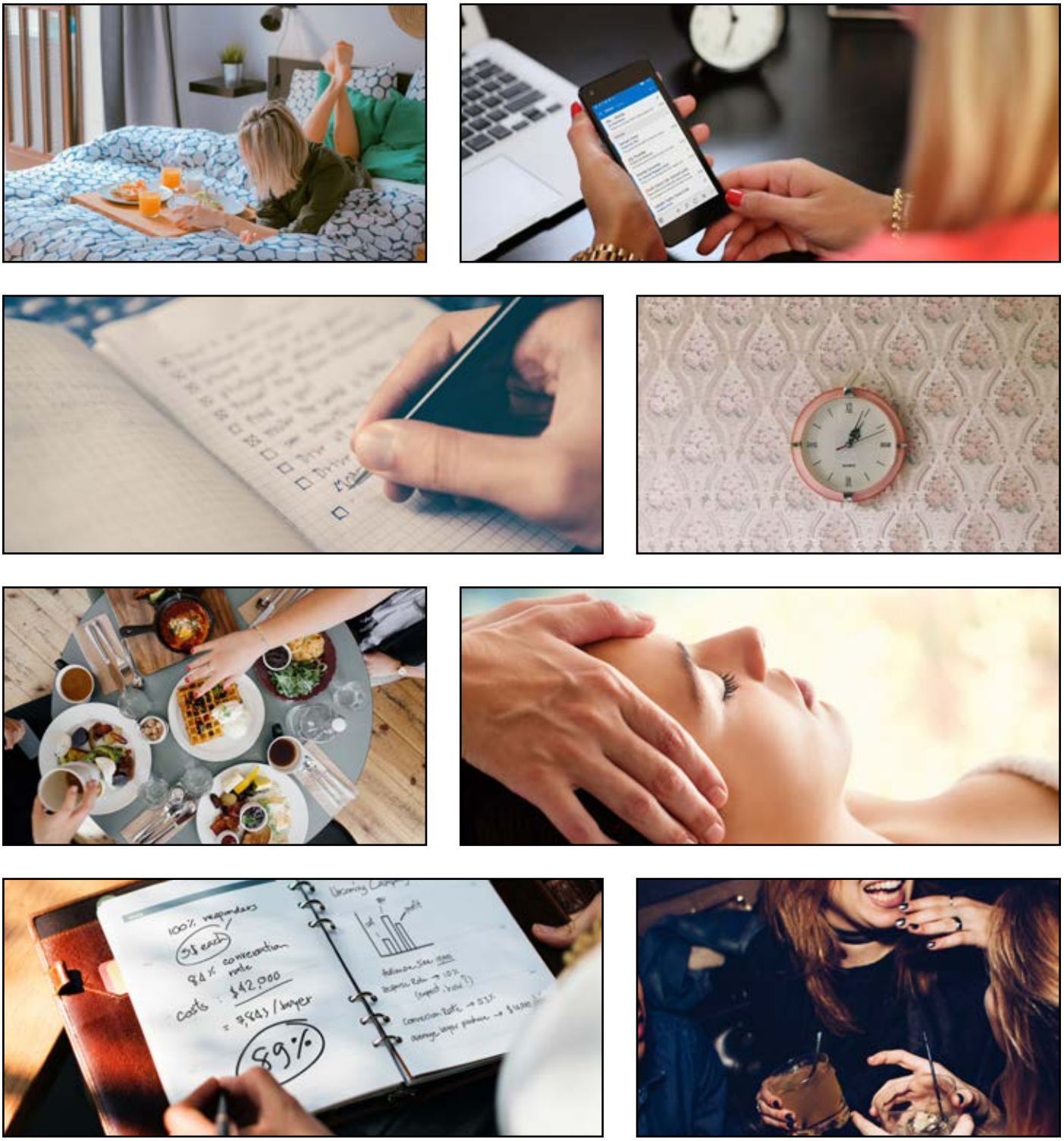


figure 75. Regular day of an office employee who engages in on-the-job recovery

FOURTEEN

Recovery & Technology in a Garment

1 BODILY ACTIVITIES

The moment where the employee gets into the relaxation will last approximately 10 minutes. During this time the employee will interact with the garment physically in a rhythmic way, breath consciously but also focus on bodily experiences like feeling the heartbeat.

While the physical activity of the garment would be touching the capacitive fibers in a rhythmic way, an output should be designed as well to strengthen the recovery experience.

Breathing and the beating of the heart are also rhythmic sensations, thus they could have a beneficial impact on the recovery experience and function as an output of the system.

Right breathing of a person in rest takes about 8 to 10 breaths in one minute (labuitslag.nl-1). A right way to breathe is 2 counts in, 1 count rest and 1 count out. Especially the moment of rest gives a relaxed experience (Bishop, 1978; Hantayo.nl).

Breathing is something that you can make visual, audible or sensible. Though the most calming effect will be visual or sensible since hearing somebody's breath could also become eerie. Therefore making the breathing output visual and sensible could both work well.

A heartbeat of a person in rest takes about 60 to 100 beats per minute (labuitslag.nl-2). A heartbeat has a couple of peaks, but the one that we can feel in our body is the QRS complex (see figure 77 and 78). This beat takes about 0,04 to 0,10 seconds.

A heartbeat is something that you can make visual, audible or sensible. As Allan Fenigstein states in the discussion of his research that hearing of feeling a heartbeat at rest leads to greater self-focus than does exposure to an irrelevant sound. Something that is important when wanting the relaxation response to be effective.

Making a heartbeat audible is not practical in the office environment, therefore making the heartbeat sensible makes more sense.

figure 76. Visualization of experiencing a relaxing moment at work.

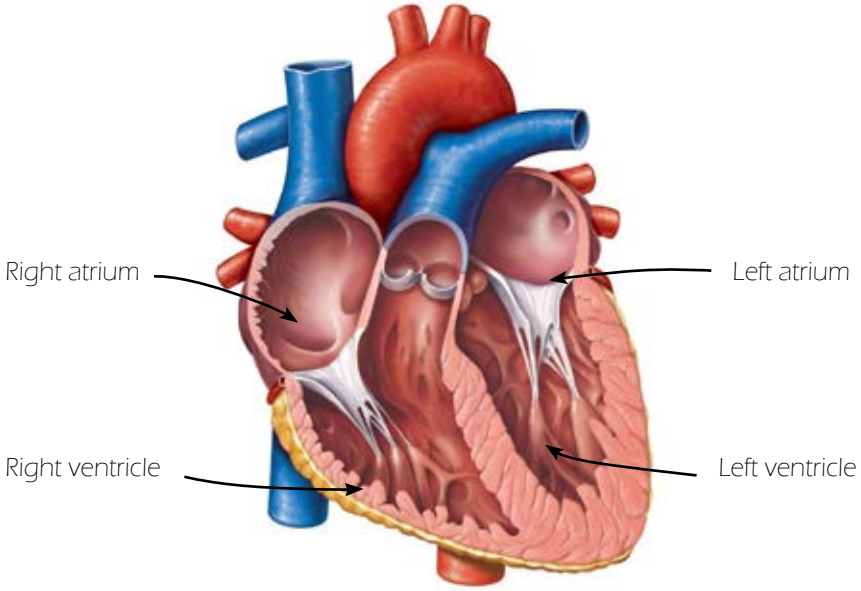


figure 77. The anatomy of the human heart with the right and left atrium and left and right ventricle.

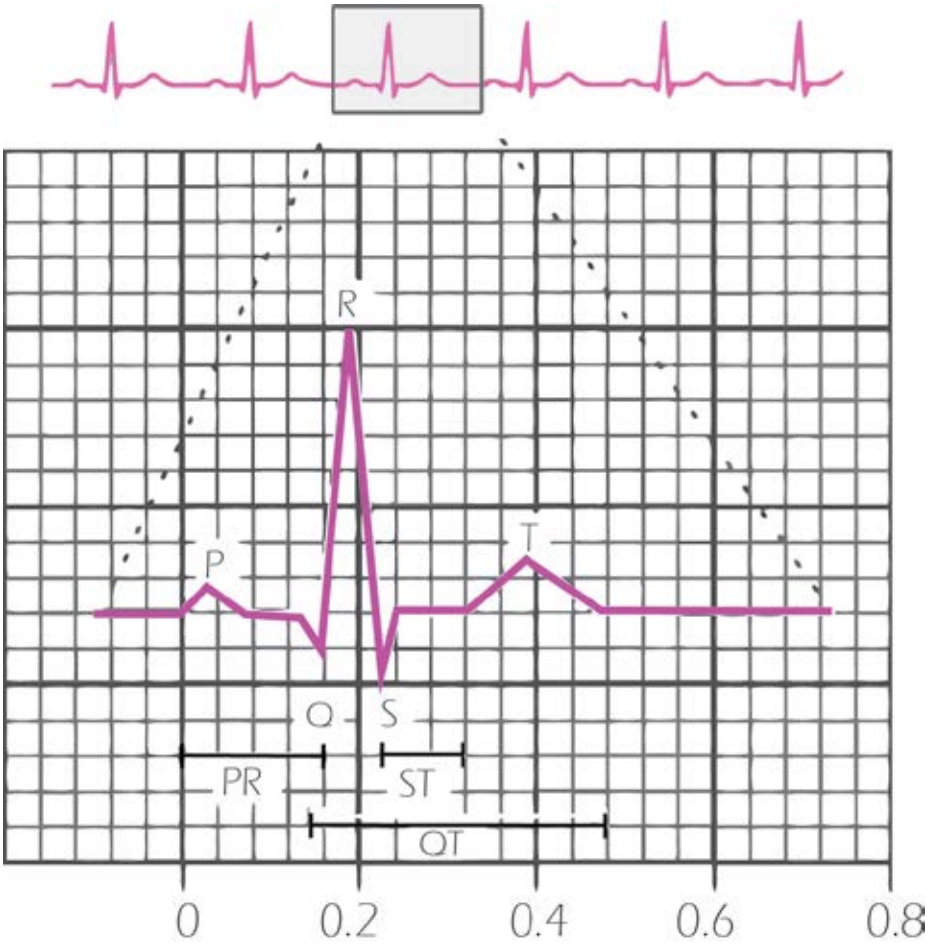


figure 78. Components of the ECG trace. An enlargement of one of the repeating waveform units in the rhythm strip shows the P wave, QRS complex and T wave. Each wave represents the time that is needed to first fill the ventricles with blood from the atria, this is the P wave. Then the ventricles pump the blood out of the heart during the QRS complex which ends with a recovery wave T that fills up the atria again. *Derived from the book Cardiovascular physiology concepts by Klabunde (2011).*

2 BODILY ACTIVITIES TRANSLATED INTO ELECTRONICS

Examples of breathing made visual and sensible can be found in picture 79 and 80.

The dress by CuteCircuit (figure 79) is made, in part from graphene - an ultra thin, light and strong material - and features a breathing sensor which powers LED lights. The idea is that the lights on the smart garment change color depending on the wearer's emotions, analyzed from how fast or slow they are breathing. The lights glow orange and green for shallow breathing, and blue and purple for deeper breaths.

In this dress the output is meant as an aesthetic feature for the viewer. In the office garment design the output is meant for the wearer and is much more intimate. It is thus important that the visual output needs to be placed within the eye-sight of the wearer. The most obvious placement will be on the arms, wrists or hands.

The dress by Ying Gao (figure 80) is embedded with eye-tracking technology that responds to an observer's gaze by activating tiny DC motors to move parts of the dresses in specific patterns.

The movement of the motors is visible, but the DC motor is invisible. This will also be the case for the office garment. The rotating movement of the motor should be transformed towards a more linear way of moving as is done in the dress by Ying Gao.

The tactile experience should be a part of the body that can sense subtle movements because the fabric has close contact with the skin. This can be the shoulders, neck, breast and wrists.

An example of a heartbeat made sensible can be found in picture 81. The Fan Jersey is a shirt that fans can wear to feel major plays on the American football field. Connected via Bluetooth, the haptic vibrations occur in real-time with the game, creating an emotional attachment for the wearer.

This output is also a sensible output and should thus follow the same guidelines as the breathing sequence's sensible output. The placement of the vibration motor should be on the same place as the sensation will take place since the vibration experience cannot be transported.

Using the same technology from these examples makes the functionality of the office garment much more probable. LEDs, DC motors and vibration motors will provide the needed functionality to create a breathing sequence and heartbeat sequence.

The exact placement of the electronics is dependent on the design of the garment.

figure 79. The first Graphene dress by CuteCircuit - 2017

figure 80. (NO)WHERE (NOW)HERE by Ying Gao - 2013

figure 81. The HugShirt by CuteCirquit - 2002

FIFTEEN
Aesthetics

1 TRENDS

Neither fashion nor aesthetics are timeless and therefore, the aesthetics of fashion is constantly evolving based on prevailing tastes and cultural dispositions (Slater, 2002).

In January and February the big fashion houses exposed their new pieces during different fashion shows in Milan, Paris, New York and London. The trends for autumn and winter of 2017 are displayed in the pictures on the right. They serve as an inspiration for the design of the smart garment.

As you can see there is a lot of voluminous garments displayed on the runway. Oversized layers and long lengths are being put in focus as seen in Elizabeth and James. Any bodily imperfections will be well hidden with this trend.

The eighties are back on the runway as well. The ruffles, overalls, squared shoulders, shiny materials, voluminous sleeves, and other key markers of the era were all over the runways again. Ports and Lanvin are some of the designers who presented this style once more.

The voluminous sleeve trend has grown in size as well. Bell or buffed, tiered or trumpet, bat-wing or bishop; loads of possible shapes and sizes. Examples can be found in Carven, Hermes and Emilia Wickstead.

Then the sheer trend is continued but a little more refined. Specific parts of the garment are highlighted with use of sheer pieces. The same can be said for shine; Some garments have pieces of shine mixed with sheer materials, but also shiny and matte material are combined as can be seen in the blue Celine dress.

Pleats are the classically timeless style with a lot of charm. It also pairs well with the rest of the trends to give that feminine look an extra boost.

There are a lot of mixtures between the trends which creates a playful pallet of styles. Puffy sleeves are perfect for placing capacitive fibers since they will not be pressed against the skin too much. Using layers in the design is also perfect to cover up electronic components and electrical wires.

Considering the type of garment, a blouse would be a good fit with the office space and the silk material. Also a blouse enables the wearer to combine it with other garments like a trouser or a skirt to let their personal style be incorporated in the final look as well.

figure 82. Designers 1. Elizabeth and James 2. Ports 3. Emilia Wickstead 4. Marissa Web 5. Sies Marjan 6. Roksanda 7. Hermes 8. Carven 9. Celine 10. Hermes 11. Lanvin 12. Ports

2 EXPRESSION

figure 83. Modern look

figure 84. Preppy look

figure 85. Relaxed look

The mood boards help to find out what expression fits the target group, the material properties and qualities of silk, the context and the trends.

The modern look (figure 83) is very hard to make with use of silk. Its straight cut is simply not possible.

The preppy look (figure 84) seems to be too youthful for the target group. It looks too much school girl instead of working woman.

The relaxed look (figure 85) seems to be a logical fit with the envisioned interaction and target group, but perhaps is too casual for in an office environment. It should look and feel comfortable yet credible.

The romantic look (figure 86) fits these areas best and displays a women that is confident, in control and super feminine.

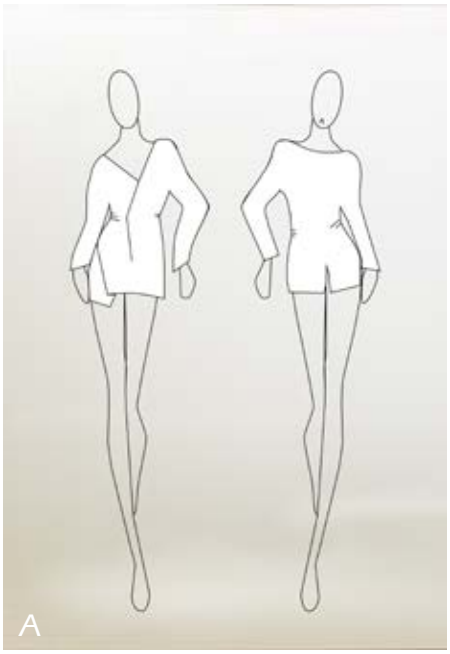
figure 86. Romantic look

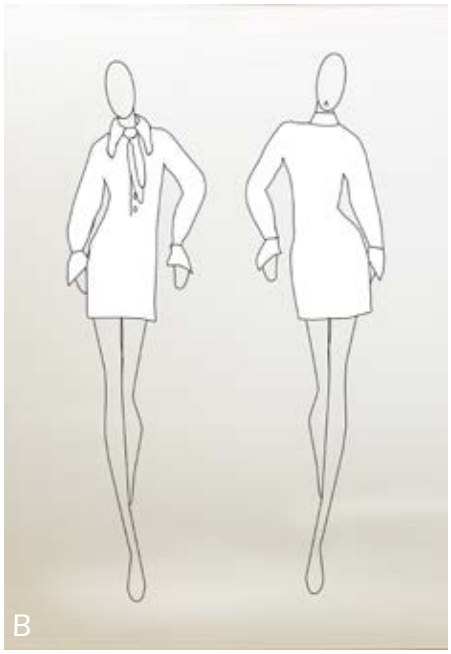
3 SKETCHES

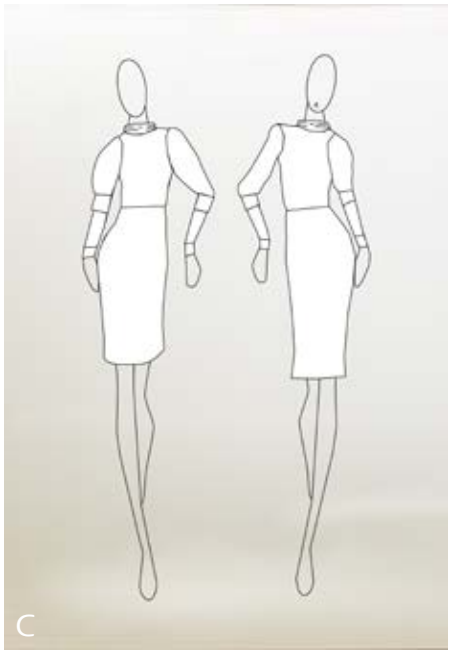
The sketches are based on the trend analysis and show possibilities for the design of the smart garment. With every sketch more influences from the playful silk came into mind.

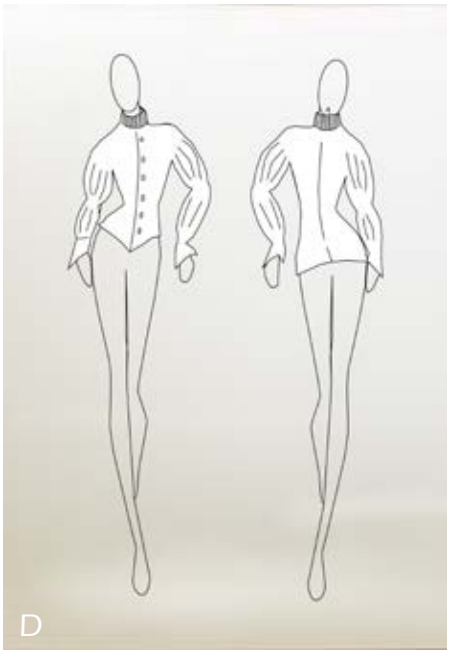
While sketching you have to keep in mind the target group, the material, the trends and the interaction qualities. With silk it is not possible to design a garment that is very body tight since it is not a stretching fabric nor can you make stiff of straight lines in the garment because the fabric is so flowy and drapey. Therefore sketches C and D are not possible to wear with silk.

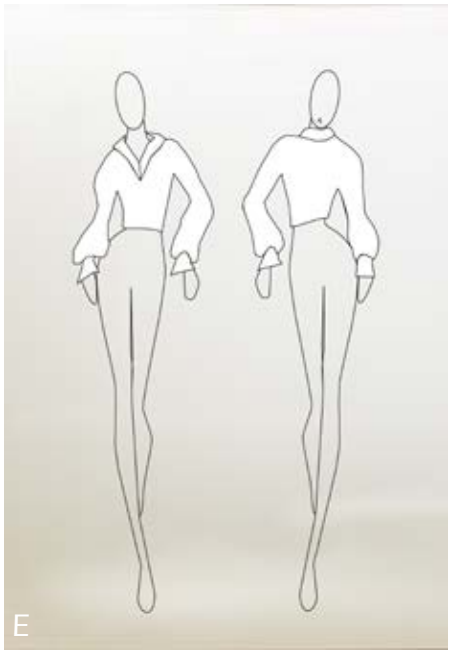
It should not become too bold of an garment because it needs to fit the office environment and look presentable. It is not a high fashion runway show. When putting the garment in a user perspective it should be a garment that thinks with the user. It should relax the user almost throughout the day. Therefore a garment that can be adapted to different situations would be an interesting design direction. Therefore sketches H and I are used as a base for the final garment design.

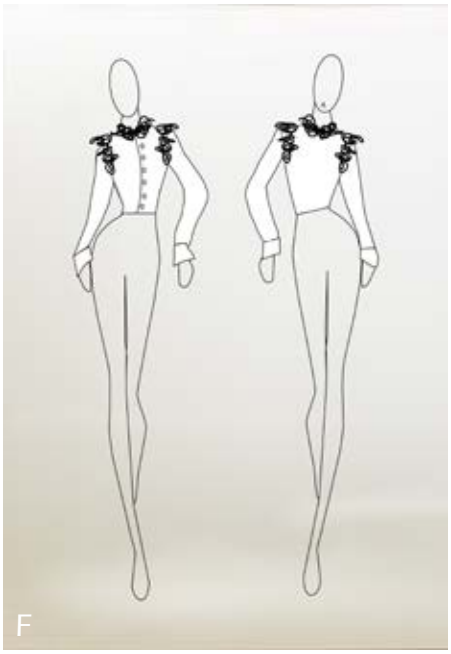


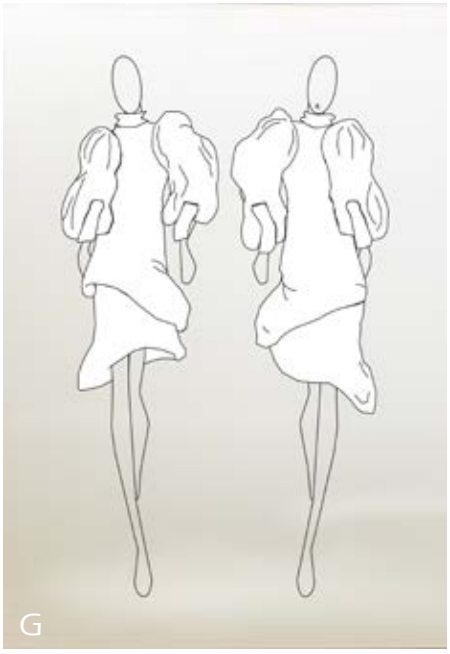


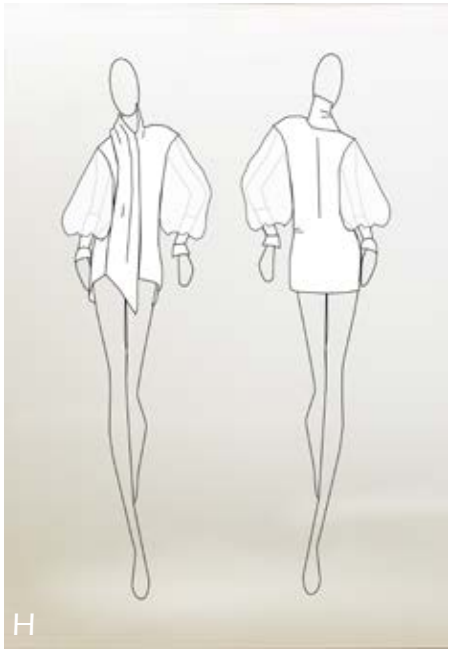












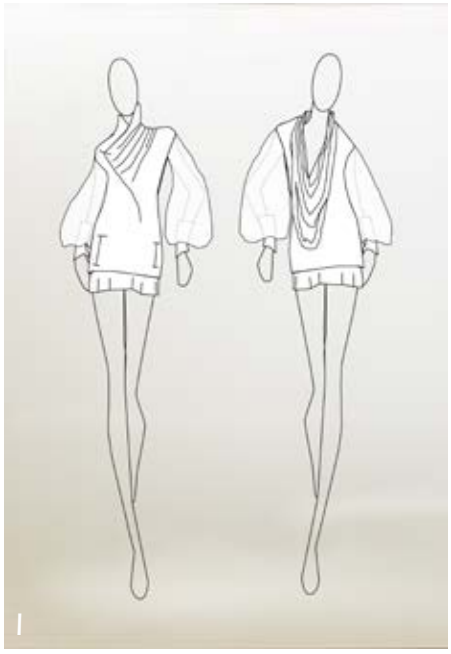


figure 87. Sketches

EVOLUTION

To get to final design iterations were performed. These are design cycles in which prototyping, testing, analyzing and adapting takes place. With every step the design gets more detailed which evolves ultimately as the final design.

SIXTEEN

- Iteration 1 -
Testing the Relaxation Response

Testing the relaxation response is needed to find out if it could contribute to on the job recovery. This is done by creating a prototype that works with the principles of the relaxation response; by performing a repetitive activity, the body relaxes from work. In this case a breathing exercise is derived from meditating techniques and is displayed as a blue LED that shows the breathing sequence at rest on the users wrist.

In order for the breathing exercise to start a repetitive physical activity is used as an input. The activity is done with use of the user's finger as the capacitive fiber is set to only work with the touch of a hand. On the cuff of the garment a pattern is displayed for the user to follow. The pattern is inspired by the labyrinth (see figure 40 j) which allows anyone that enters it to meditate or resolve questions by following its rhythmic pathway.

The pathway used on the cuff finds its inspiration also in the looks of neurons in the human body. Neurons are influenced if stress-hormones stay in the human body for too long. The pattern is thus a metaphor that the user can be in control of its own recovery.

The test will help to answer the following research questions:

1. Does the relaxation response work; Will the participant feel more relaxed after using the garment?
2. Does the breathing sequence of the light help to get the body in a relaxed state?
3. When would the participant use this?

Procedure
The user test is set up in two parts. In the first part she will experience being back in the office by doing a task that is similar to what the participant does normally at work. Then, to experience the workload at work a deadline will be set to finish the task. During this period the heart rate will be tracked.

During the second part the participant uses the shirt to relax from the work. The heart rate will be tracked here as well.

Participant
The participant is a 26 years old UX designer at the department of Online Communications at Schuttelaar & Partners in The Hague. She works in a flex focused environment at the office.

Part 1 - the task
The participant was asked to design a poster for a competition focused on basic human rights, from freedom of expression to the universal right to healthcare. It was a call for entries by the company Poster For Tomorrow. http://www.graphiccompetitions.com/graphic-design/poster-for-tomorrow-2017-call-for-entries. To add a stressor, she had 10 minutes to come up with an idea and to make a poster in color.

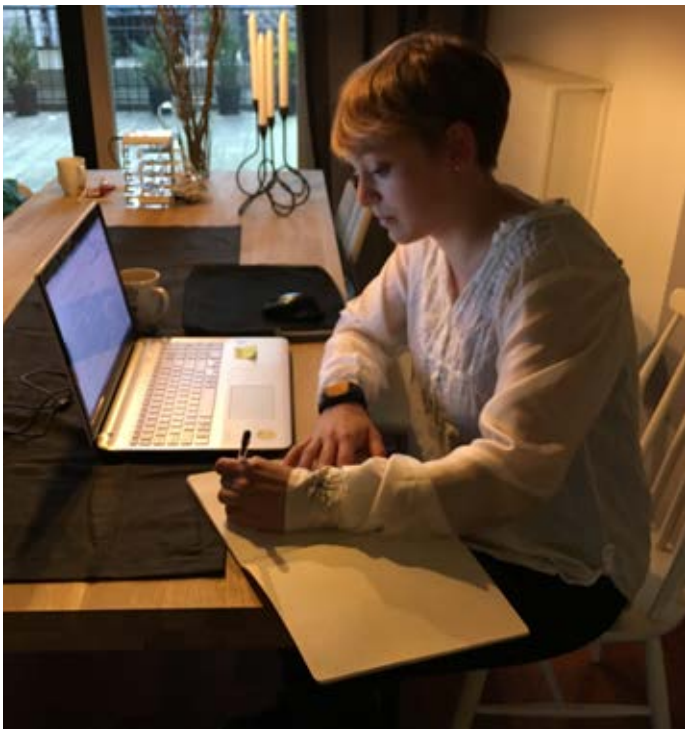
Results
Heart rate results during the task:

At the start	64
After 2 minutes	118
After 5 minutes	130
After 7 minutes	110
After 10 minutes	97

Part 2 - the relaxation response
Directly afterwards the participant was asked to follow the path displayed on her cuff with her finger which led to a breathing exercise.

Results
Heart rate results during interaction with the garment:

At the start	97
After 2 minutes	88
After 5 minutes	73



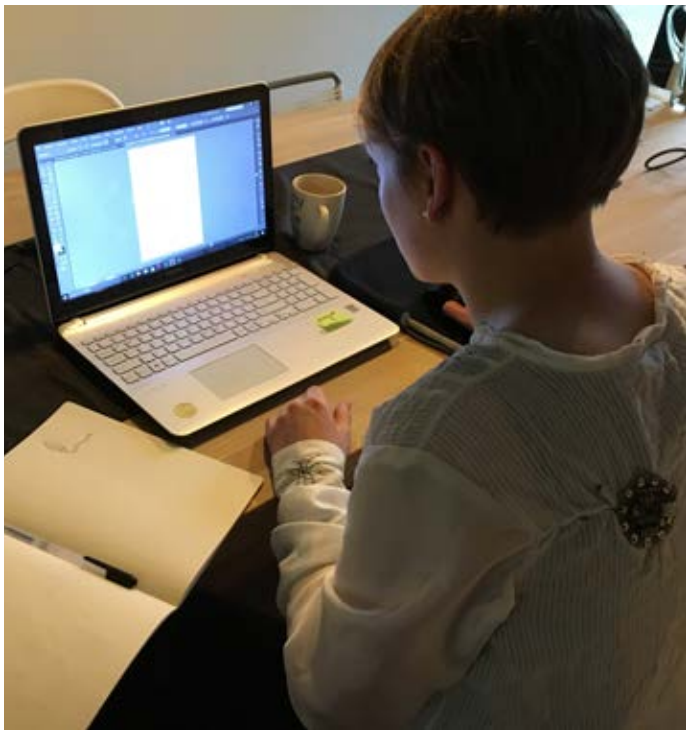


figure 88. Participant performing the task

Insights

The garment helped to relax the participant, though there were some side-notes on the functioning.

Positive things of the design

- Distracted from work at a fun way;
- Distracted from the screen;
- Has a familiar way of interaction; 'Looks like the interaction you do with your phone.'
- Ideally to use behind your desk; 'In the space I work there's a couch to relax on, but nobody uses it because of the social control in the room. Therefore I take a break behind my desk.'

Improvements of the design

- The feedback must be closer together; 'You can't look at two things at once. The path is too hard to follow just by feel.'
- The type of interaction and feedback must be similar; 'You don't want to make fast movements in order to make the light work; the light is too slow for the fast movements you do with your finger.'
- The interaction is not playful enough; 'The path you follow with your finger is too long and gets boring after a while.'
- The thickness of the fabric is too much; it's nicer to feel your own skin a bit, can be like giving yourself a massage while interacting with the garment.

The relaxation response has potential to be used within office environments to relax/distract yourself for a while from work, specifically behind the desk in a personal intimate setting. More research needs to be done on the type of interaction with the fabric and on finding a correspondence between the input and output of the device. In order to create a relaxing interaction, the movements the user makes with the garment should be relaxed as well. Next to that, the interaction should be made more playful in order to be interesting. Finally, the interaction asks specific characteristics from the material as well.

SEVENTEEN

- Iteration 2 -
Extending the Relaxation Response

To find out what types of touches are relaxing a relaxation session with different types of silk was organized. Three office employees explored in which way silk comforted them, supported them and relaxed them. To talk about the materials easier, they were given names that linked to Zen, meditation and Buddhist marks.

Participants and materials
Three office employees were invited to take part in the session which was arranged in the living room. The ambiance of the room created a calm and trusting atmosphere.

Four silk materials each with their own characteristics were used during this test. The fabrics and names are displayed in figure 89.

Procedure
The participants were asked to each take a fabric and to explore it until they had found the most relaxing interaction on their body with the fabric. During this time, the participants were observed in order to discuss their movements afterwards. After each exploration the participants were able to explain their search and why a specific type of interaction was so relaxing.

After the participants explored all fabrics, a concluding discussion was held to find out which fabric caused what type of relaxing interaction.

Results
The types of interaction that were found relaxing were surprisingly different for all different types of silk. For example Enso, because of its weight, was considered most relaxing and comfortable in the neck and on the shoulders. Then Aum was found to interesting because of its light weight and smooth surface. It made the fabric stroke the body in a very gentle way, especially the arms and top of the hands. Then Dharma seemed to be a less persuasive combination of both Enso and Aum. It was a little lighter than Enso and not as smooth as Aum. It was found most interesting due to its volume and puffyness. Finally, Tao, was found interesting because of its stiffness which worked best in the participant's hands. Squeezing this material was found most relaxing.

Most interesting interactions were situated around the lower arms, softly sliding the fabric over them was done intensively, but also wrapping the fabric around the back and neck like a scarf was done often. This made the participants feel covered, protected and at ease.

Insights
Exploring these materials through the eyes of office employees generated a perspective on how the final design could look like. Implementing different types structures of silk in the final design results in having different tactile experiences while wearing the garment. The interaction could also be strengthened by using a specific type of silk.

figure 89. Silk fabrics Enso, Aum, Dharma and Tao

figure 90. Zensession with silk - exploring relaxing interactions

EIGHTEEN

- Iteration 3 -
Adding Technology to the Garment

The test with the different types of silk showed what type of fabric could be used for specific garment parts. Now it is time to put the electronics into the garment. During the first iteration the LEDs were enough to get the attention of the user, but the interaction was not really clear as a breathing sequence. By adding a DC motor that also provides the movement of breathing the sequence will probably be clearer.

Next to that to the heartbeat sequence will be added to provide another interaction that calms the user. This way the user can use the garment in multiple ways which increases control of the desired relaxation process.

Procedure
The test is done using a Teensy 3.2 microprocessor. Connected to it are a shaftless vibration motor, a brushed DC motor with gearbox and four LilyPad Micro LEDs.

The vibration motor is used to create the heartbeat sequence of the system and the DC motor and LEDs are combined to create the breathing sequence. The codes can be found in Appendix E.

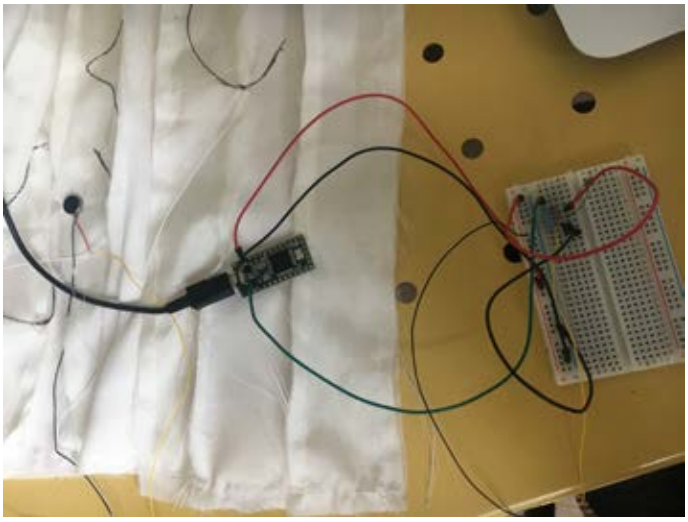
Results
The vibration motor beats in a rhythm that is similar to a human being at rest with a beat of 80 milliseconds and a rest of 1200 milliseconds.

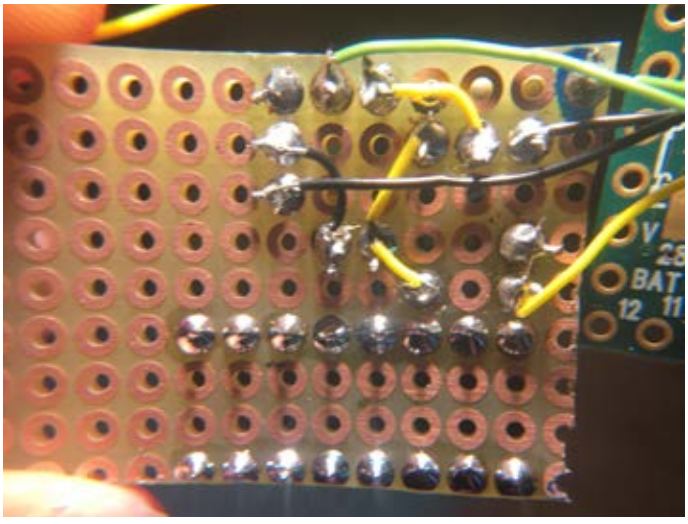
The LEDs are fading in slowly to become fully lit after about 2000 milliseconds. This is almost the same time as the DC motor is running in one direction before changing direction. The fade out is slower so the motor is driving on a lower speed to get back to its begin position. The fade out of the LEDs take about 2500 milliseconds to become off.

Insights
The different elements show a good resembles to the bodily activities of heartbeat and breathing. The DC motor needs to change its movement though from a circular one to a linear one. This has to do with the fact that a circular movement takes too much place in the garment. A linear movement solution has to be thought of.

Also the vibration motor is too powerful at this point to hold close to your skin. It does not feel comfortable so this has to be changed in the code.

To let all elements function at one single microprocessor, the code has to be combined. This can be done by working with function elements in the code.





NINETEEN

- Iteration 4 -
Testing the Aesthetics

Testing the pattern design is also done in iterations. As explained with the sketches, the idea is that the garment is adaptable to the mood and occasion the wearer is situated in.

Iteration 1
The first two tests are made with use of a dummy fabric. This way you don't spend too much money on materials that will only be used as a quick trial. The material used is nylon which is used a lot as an artificial silk. Even though the color is not the same as the final product, the look can be evaluated easily at a lower cost.

The first try out (figure 91) shows puffy sleeves and a playful collar, but is very small on the body. In order to test it on people the garment should be medium or large sized. This way a larger group of people could be tested. So the size should be made larger.

To give the collar more power it could use some extra length in the front and in the back. Also this type of nylon does not show the drapyness of the Crepe silk. This should be changed in order to evaluate the look better.

Iteration 2
The next try out (figure 92) the collar is made from a viscose mix that shows close relation to the Crepe silk. There is a small tube attached to the back to make sure the collar does not glide of the shoulders. The seam on the back reminds me of a hoody which is not ideal. Therefore the pattern has to be organized differently.

The body fits a lot better, but is still a bit small. The sleeves are made larger as well to complement the body but are now too large. They should be taken in a little bit. The back panel shows two darts that could also be taken out by changing the waist width.

Iteration 3
The final try out (figure 93) is made from silk fabrics. The front panel of the collar is made from strips of two different materials: Enso and Tao. Tao is a very stiff fabric which relaxes the user when rubbing it with the hands. Though the stiff property of the fabric makes the whole design look stiff. Therefore, to have the same effect a small piece of Tao could be implemented into the front which will be made out of Enso.

figure 91. Pattern iteration 1

figure 92. Pattern iteration 2

figure 93. Pattern iteration 3

FINAL DESIGN

In this final chapter the final design is discussed in terms of aesthetics, design features and functionality.

figure 94. Interaction possibilities with the final garment

TWENTY
Final Design

1. LOOK AND FEEL

figure 95. Final Design

Ensō is a blouse designed for female employees that work in office environments aged 25 to 35 that are not able to relax from work. In Zen, ensō is a circle that expresses enlightenment, strength and elegance (figure 96). Ensō provides an on-the-job recovery experience that can be accessed whenever the wearer wants to.

By using body and mind relaxation techniques a choice of electronics was made that could imitate bodily activities. These are a vibration motor that resembles a heartbeat at rest, a DC motor that mimics the movement of the body while breathing and LEDs that provide a breathing exercise for wearers to engage in.

The look and feel of the garment is displayed on the following pages. On the right side you see the interaction possibilities the user has with the garment.

By closing the garment the user can control when she wants to start the relaxation process (figure A and B). The small piece of Tao fabric functions as a fidget tool to keep focused while working (figure C). She can start the breathing exercise by caressing the left sleeve (figure D). The experience the user has with the garment can be found on *sachafranken.nl*.

figure 96. Enso symbol


A


B


C


D

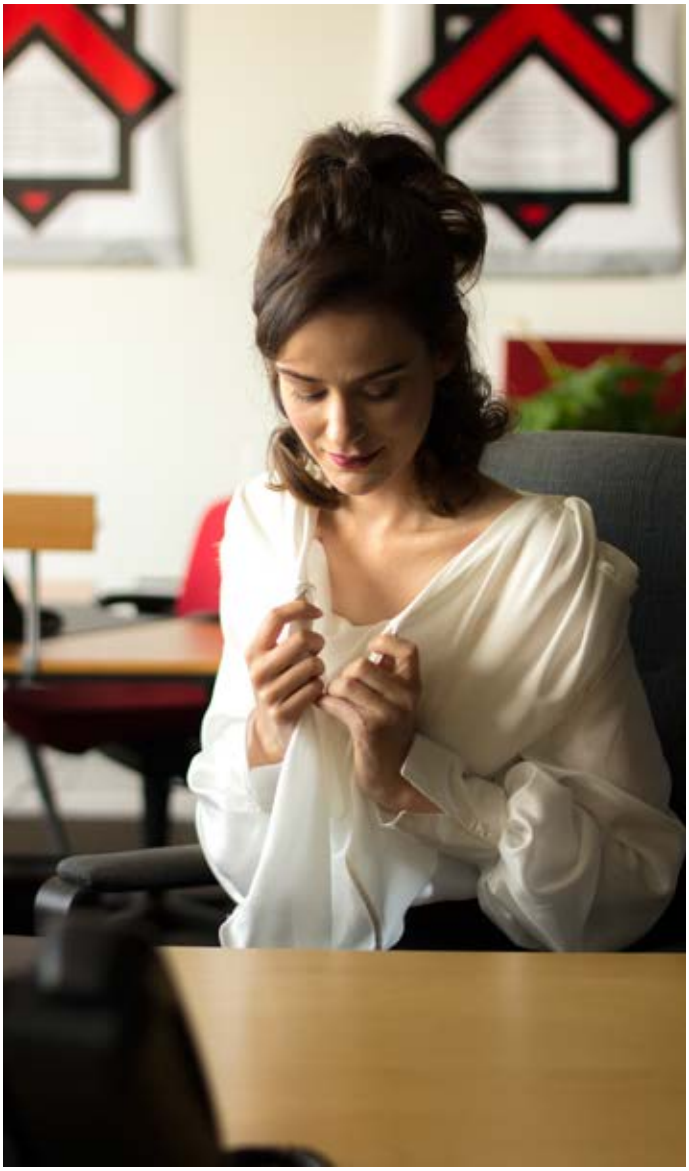


figure 97. Final design in the office context

figure 98. Final design in a relaxed surrounding

2 TECHNICAL DRAWINGS

The blouse makes use of four different types of silk: Crepe de Chine names Enso, Tussah silk named Tao, Ponge silk names Aum and Habotai silk named Dharma. The pattern is displayed in figure 100 and shows how much fabric is needed.

The design of the garment is displayed in figure 101 and 102. It shows four types of possible ways to wear the garment; half open/half closed, open front, open back and fully closed. This is a feature that works well for women with a busy schedule since they can adapt their outfit to the situation they are in.

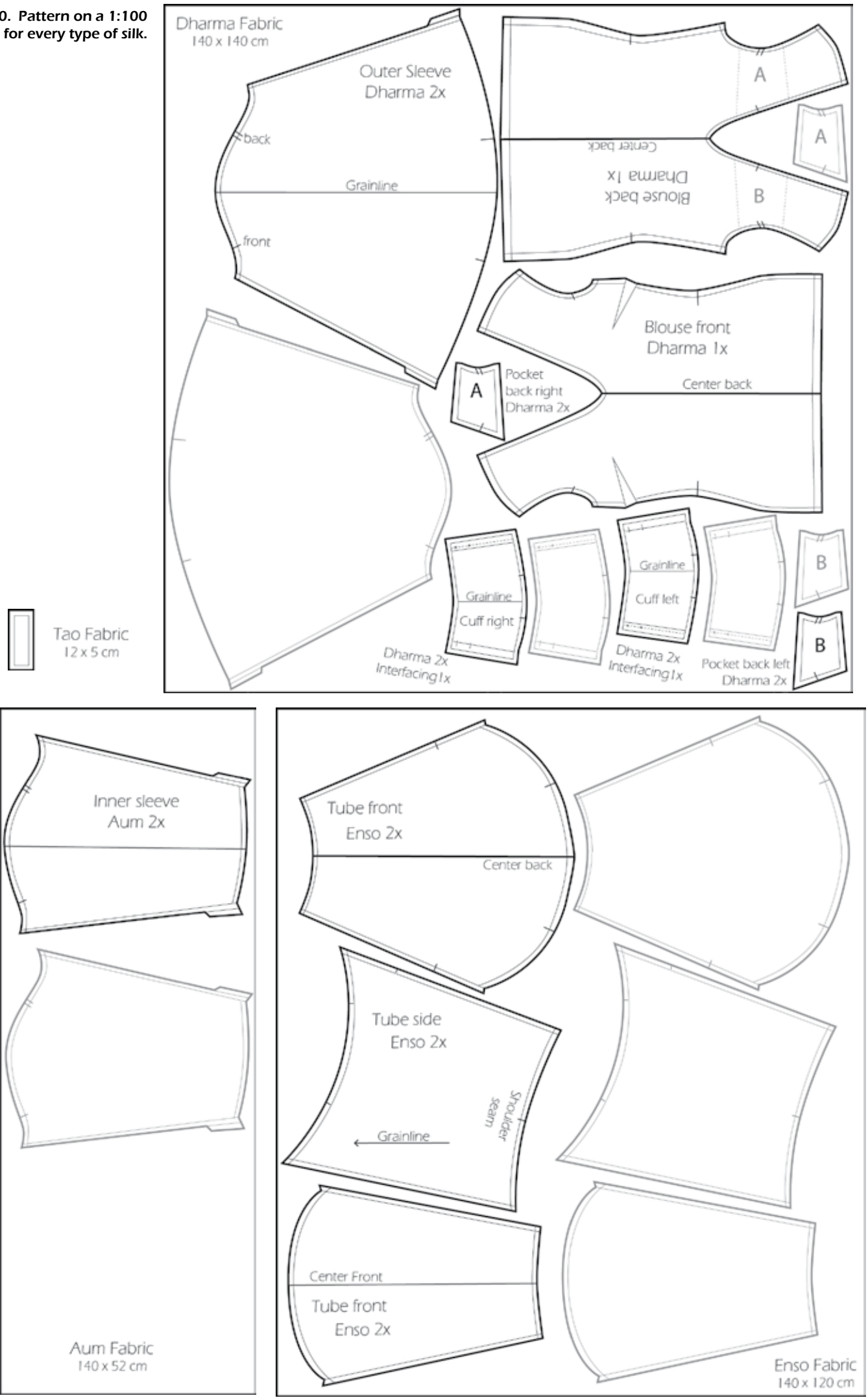
Next to that it shows close relation to the trends. The puffy semi see through sleeves and the layered collar are coming straight from the runway. The collar is inspired by the blue tube dress by Celine (see figure 99), but will become much more playful when made in silk.

Whenever the user wants to use the relaxation mode of the garment, she should close the front with two little magnets. This interaction closes first of all the electric circuit. Next to that it is an activity that expresses taking a step back from work almost literally; you pull the sides of the collar to the front and close bring the magnets together. In Dutch we call this 'je even terug trekken'.

To close the blouse a blind zipper and four see through buttons are used. The look of these notions is calm which fits with the total expression and interaction qualities of the garment.

figure 99. Tube dress by Celine

figure 100. Pattern on a 1:100 scale for every type of silk.



front

back

TOTAL OPEN

front

back

FRONT OPEN

front

back

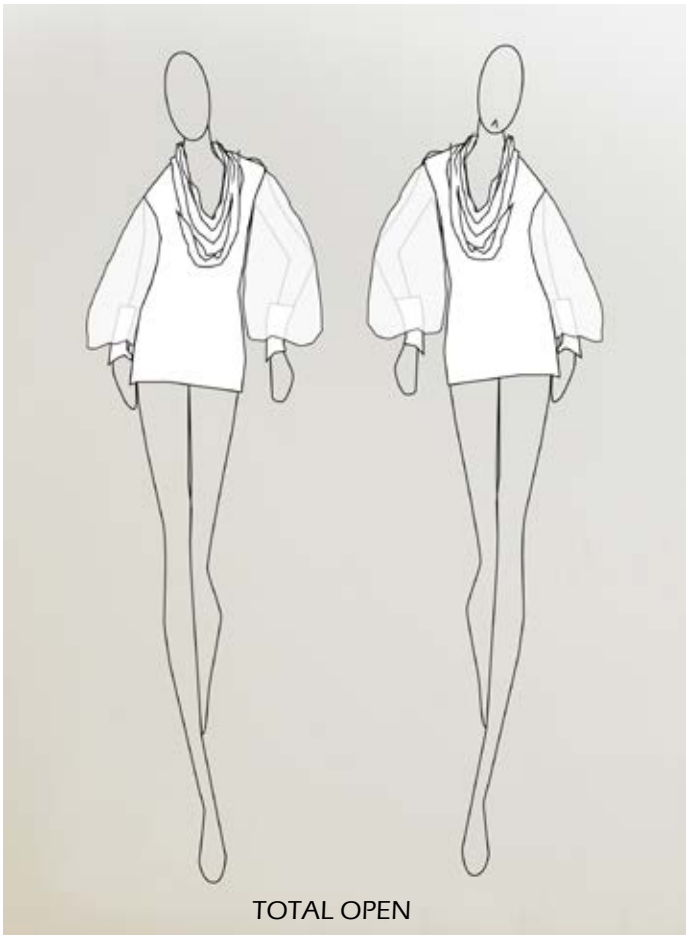
BACK OPEN

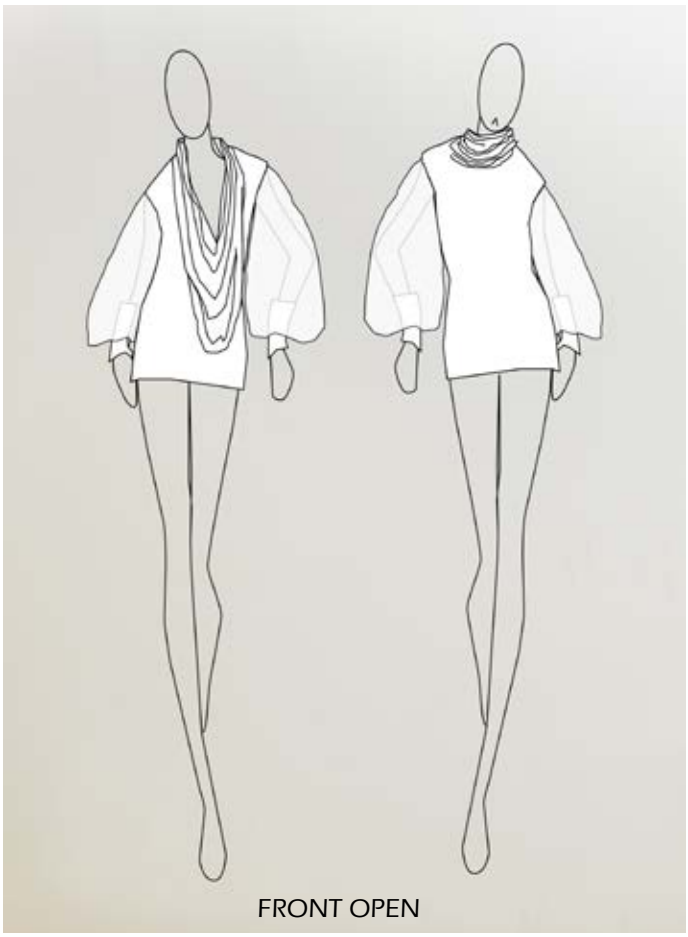
front

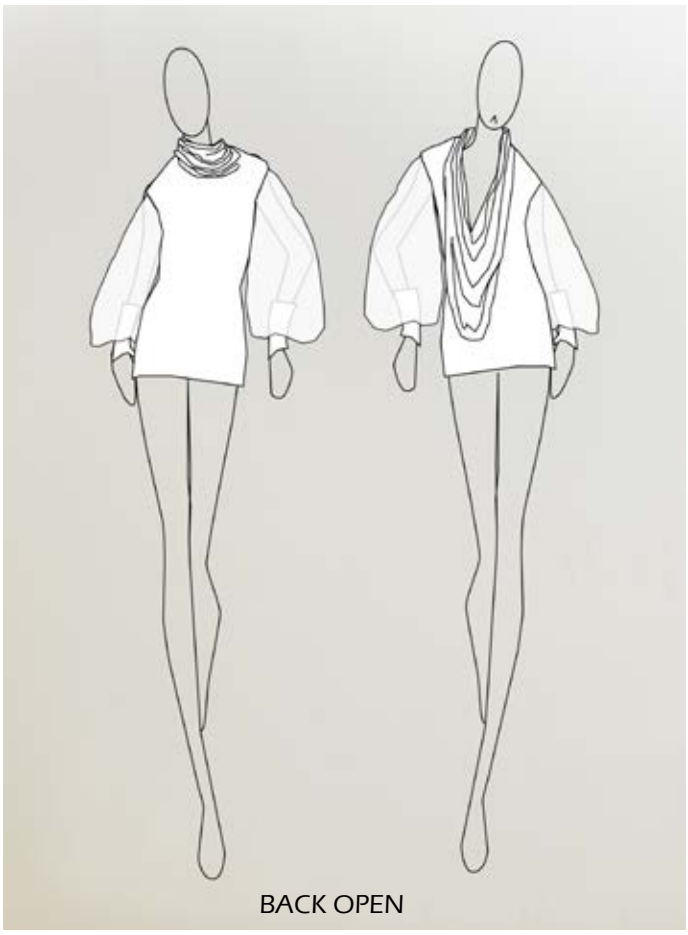
back

TOTAL CLOSED

figure 101. Technical drawing of the garment







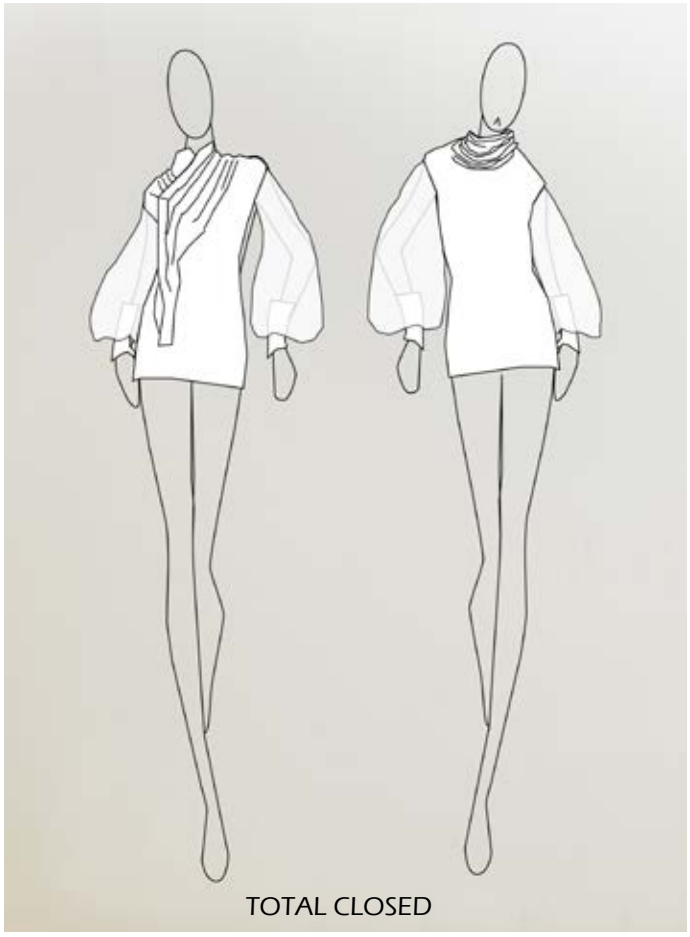


figure 102. Sketch of the final look of the design on a body

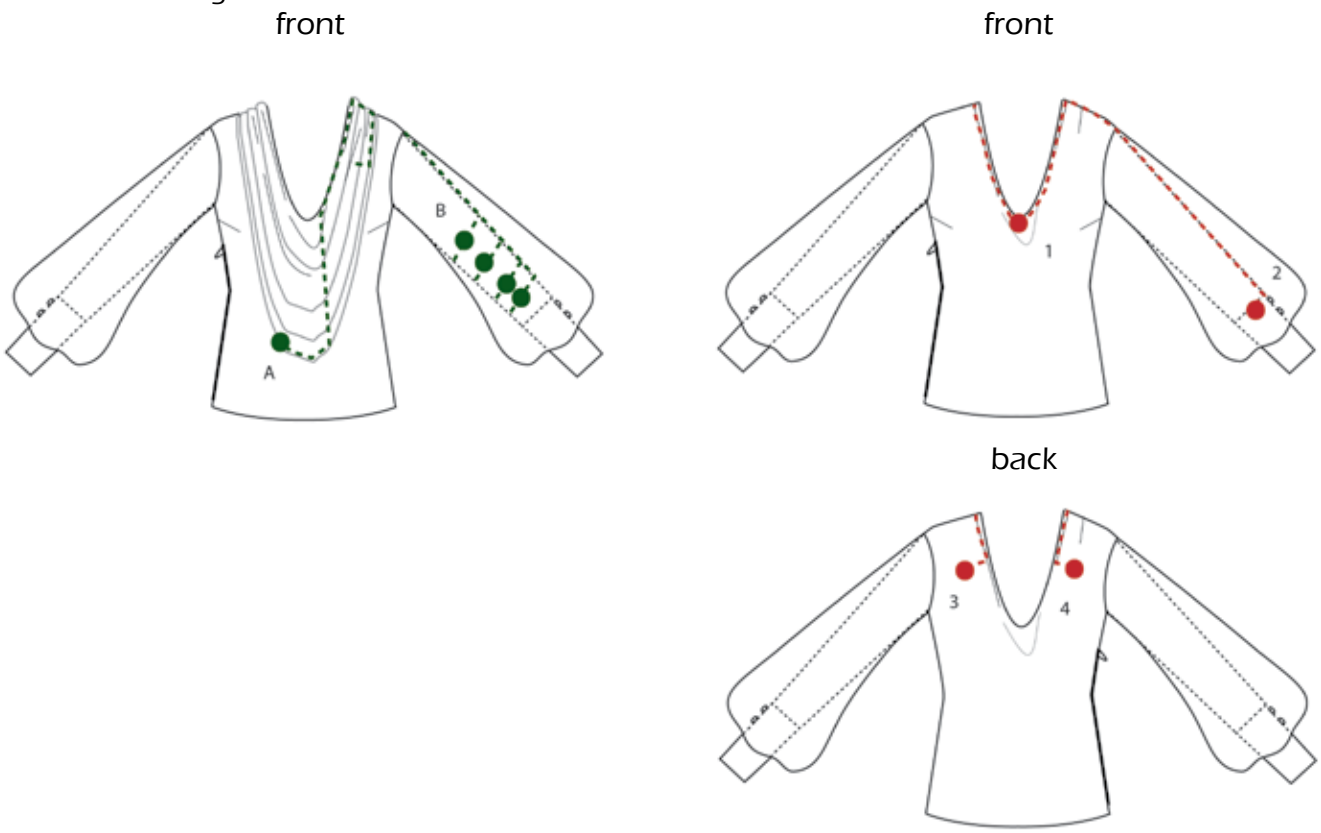


figure 103. The electric wire route

The electric wire route is also displayed in picture 103. The system switch is displayed in figure 104 and the system components can be placed in the garment as is displayed in picture 105.

A. capacitive sensor for the heartbeat sequence.
B. capacitive sensor for the breathing sequence.

Z. system switch; by connecting the two magnets the electric circuit is closed and the relaxation experience can commence.

1. vibration motor that mimics a heartbeat at rest.
2. LEDs that mimic a breathing rhythm at rest.
3. The microprocessor Teensy 3.2 functions as the brain of the system. All the wires end/start here.
4. The DC motor that brings into motion the fabric at the front via a little tube. This movement resembles the breathing movement of a body at rest.

An eleborate explanation of the system components is given in the next section.

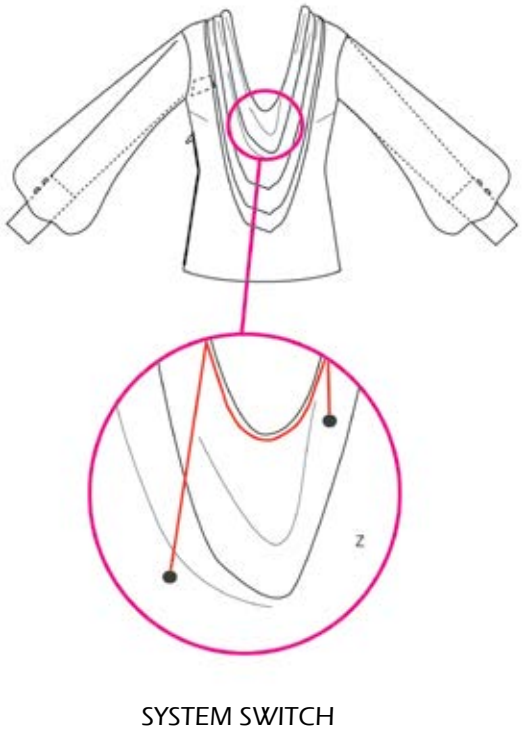
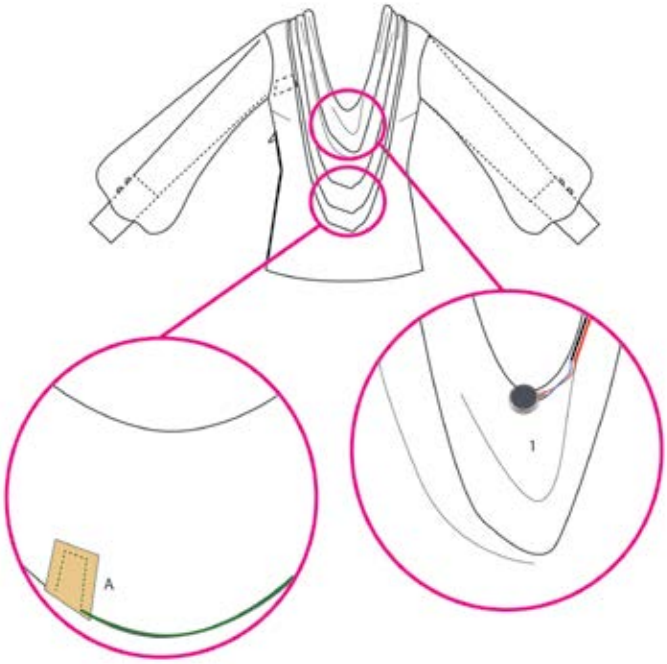


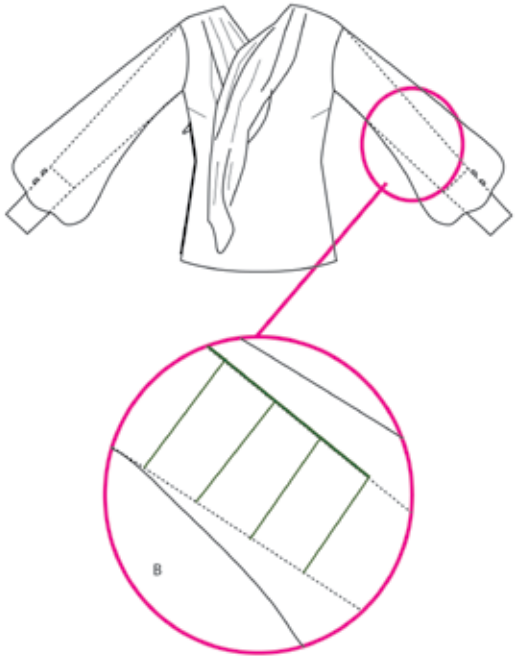
figure 104. System switch with two magnets that can close the electric circuit

front



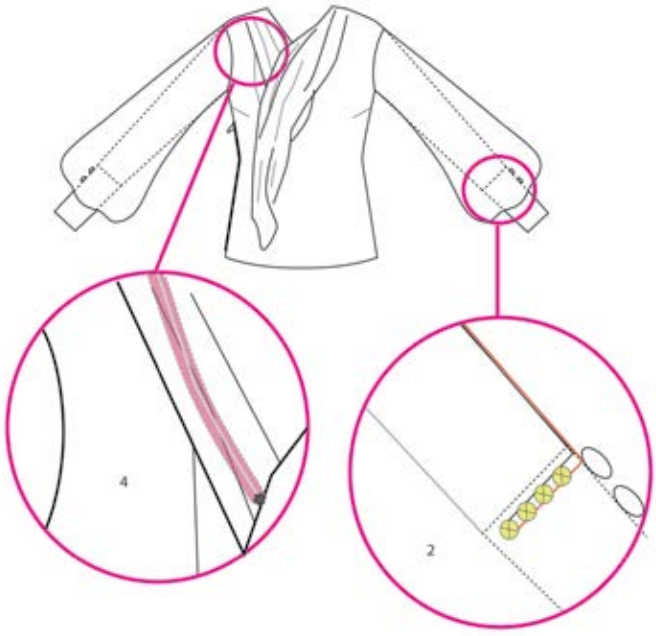
HEARTBEAT INPUT AND OUTPUT

front



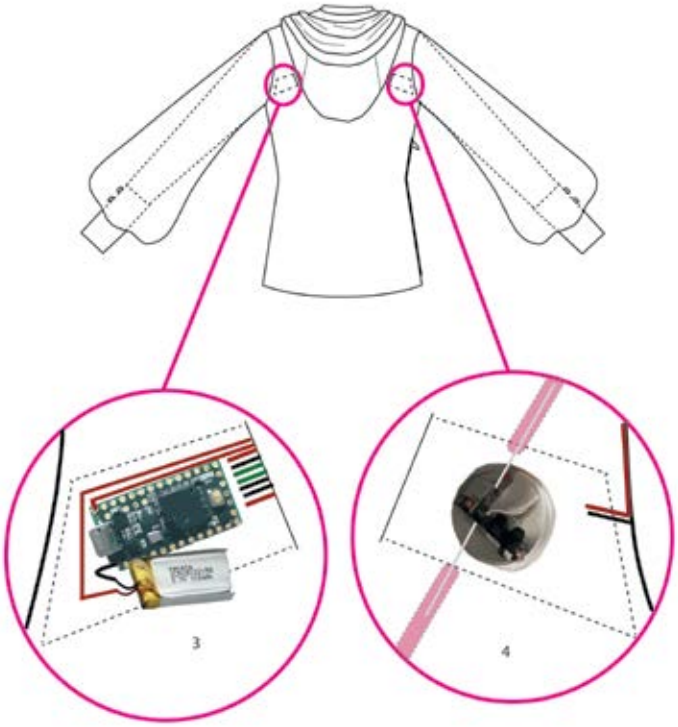
BREATHING INPUT

front



BREATHING OUTPUT

back



BREATHING OUTPUT AND THE TEENSY 3.2

figure 105. *System components placement*

3 ELECTRONIC COMPONENTS

The entire system works on a Teensy 3.2 microprocessor which is the tiniest microprocessor on the market that can function with simple Arduino code. Therefore the perfect brain for the smart garment. It is powered by a 3.7 Volt battery with an electric charge of 500 mAh. With a continuous use of the breathing and heartbeat function the average supply current is 83% for the breathing function and 8% for the heartbeat function. The Teensy uses 66 mA continuously, the breathing function uses 60 mA when operating, the heartbeat uses 33 mA when operating. The average total supply current adds up to 120 mA, which results in a battery lifetime of 4,2 hours when used constantly. The system is advised to be used for about 20 minutes a day which will result in an estimated battery lifetime of 323 hours which is about 13 days.

The Arduino code can be found in appendix E. The datasheets of the system components can be found in appendix F.

Heartbeat sequence
The vibration motor makes up the heartbeat sequence of the garment (see figure 108). The motor that is used is a 3 Volt shaftless vibration motor from Adafruit. The part number is ADA-1201.

To create a heartbeat sequence, the vibration motor is hooked up on the Teensy. To provide current amplification a 2N2222 NPN transistor is added in the scheme. This will make sure the Teensy is able to drive the vibration motor. A 1KΩ resistor is placed to make sure not too much current flows from the output of the transistor.

Finally, a diode is connected reverse biased in parallel to the motor. This is done in order to protect the Teensy against voltage spikes that the motor may produce.

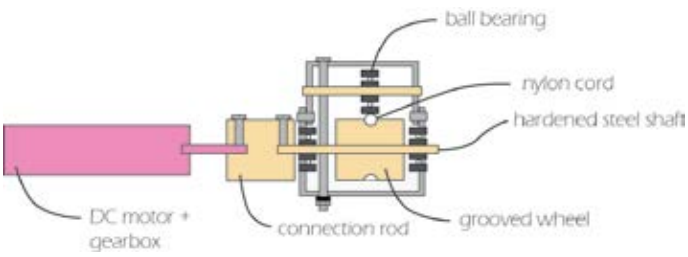


figure 106. DC motor as a friction wheel drive mechanism sketch

Breathing sequence
The LEDS and the DC motor make up the breathing sequence of the garment (see figure 109).

Four LilyPad Micro LEDs from Sparkfun are connected parallel to each other. Their part number is DEV-10753. To create a breathing sequence they are hooked up on the Teensy. Again to provide current amplification a 2N2222 NPN transistor is added in the scheme. This will make sure the Teensy is able to drive the LEDs. Also, a 1KΩ resistor is placed to make sure not too much current flows from the output of the transistor.

The DC motor is a tiny, cylindrical gearmotor which consists of a coreless brushed DC motor and a 700:1 plastic planetary gearbox from Pololu. The part number is 2357. The entire motor assembly has a diameter of just 6 mm and weighs1.3 g. A perfect actuator for a smart garment. It has a free run speed of 90 RPM and stall torque of 900 g-cm at 6 V.

The DC motor enables the wearer to breath with the rhythm of the fabric; the motor is connected to the fabric which makes it move up and down. In order to reverse the movement of the DC motor, the voltage has to be reversed. To do this with use of just a Teensy is very hard. Therefore an H-bridge is introduced in the schematic. For this project a SN754410 quadruple half-H driver is used. It provides a bidirectional drive current up to 1 A at voltages from 4.5 V to 36 V. A 18 Ω resistor is placed to make sure the motor is running at the right speed.

figure 107. DC motor as a friction wheel drive mechanism

The circular rotation of the DC motor is translated into a linear output to make the fabric go up and down. This is done by a friction wheel drive mechanism (see figure 106 and 107). A 1 mm in diameter nylon cord is pressed into a grooved wheel by a pretensioned ball-bearing. The pretension is adjustable. The grooved wheel is attached to the output shaft of the gearbox of the DC motor. The noise of the DC motor is muted by applying dense cloth in the inside of the package.

Heartbeat Sequence

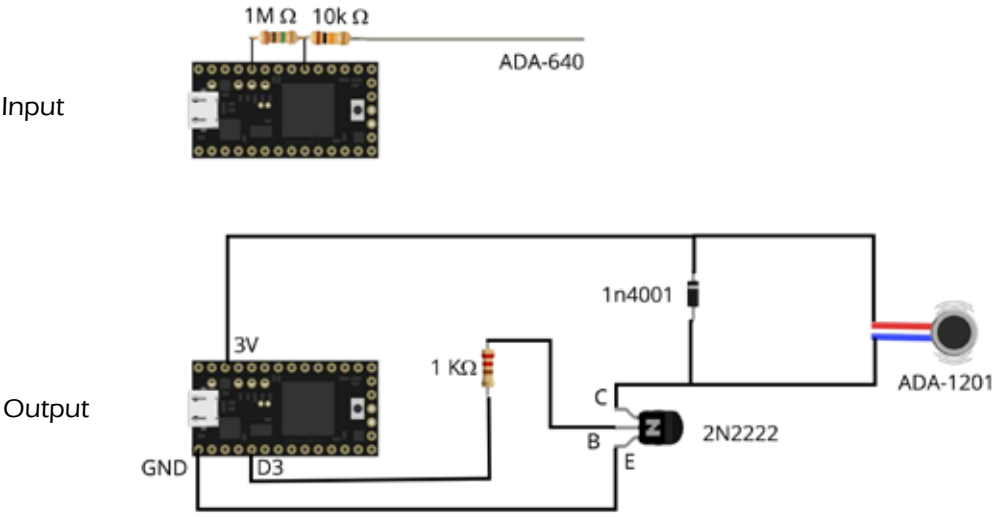


figure 108. Heartbeat sequence circuit schematics

Breathing Sequence

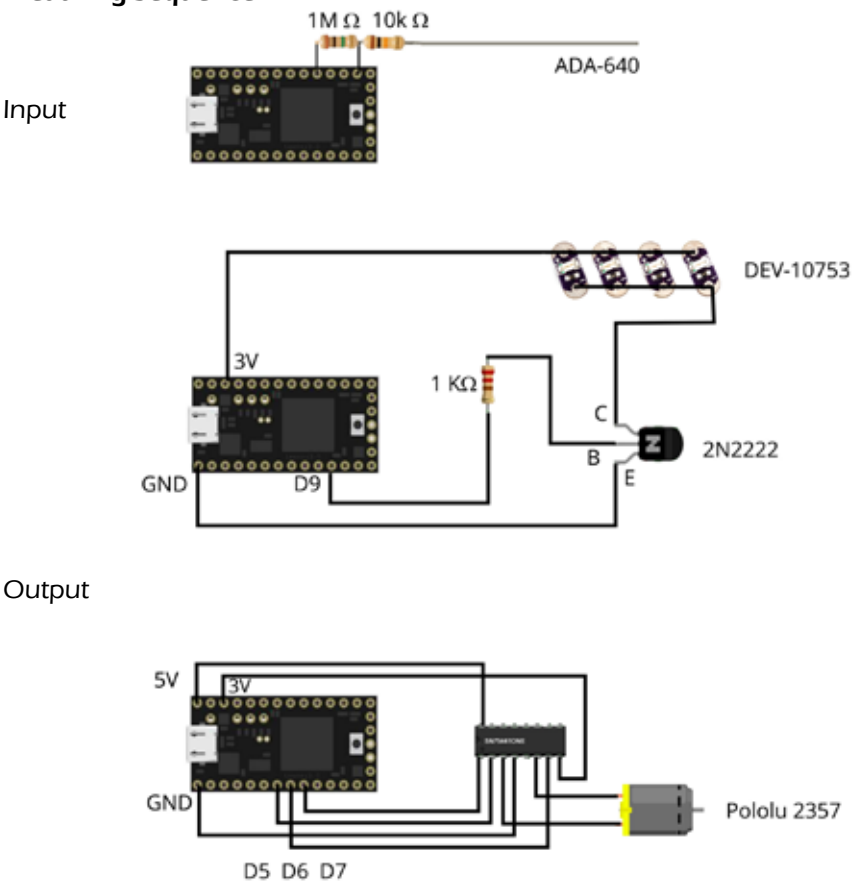


figure 109. Breathing sequence circuit schematics

TWENTY ONE
Final User Test

To understand if the final design meets the set requirements it is important to do a final user test. During this user test different aspects will be tested. These are usability, comfort and aesthetics.

Subjects
Subjects were three female office employees between 25 and 35 that have experienced work load within the office environment.

Procedure
The participant was asked to wear a heart monitor and the blouse throughout the experiment which lasted an hour. The experiment had three parts. At the start of the experiment the participant was asked to engage in a stressful game of flappy bird, an annoying yet addictive game for the iphone. The participant engaged in this game until the heart rate had gone up considerably.

The next part is getting back to a relaxed state by using the garment. The participant is free to explore the garment as they please.

The final part of the experiment is answering a questionnaire which will be discussed afterwards. The questionnaire has a rating scale on experienced usability, comfort and aesthetics. There is also room for comments or recommendations (see appendix G).

Results
All participants were able to put on the garment. Though with 3 of the 4 participants the garment was tight either around the waist, around the bust or around the shoulders. This did not affect the overall level of perceived comfort. This can be traced back in the questionnaire in which almost all participants stated they wanted to have a bigger size.

Exploring the blouse was done enthusiastically by the participants. One participant wanted to find the sound of the DC motor, but she could not find the source. Another played with the collar for a long period of time. And finally one participant thought she got an electrical shock while bending her elbow.

All participants found the heartbeat sequence to be relaxing and comfortable. The breathing exercise movement was not detected by any of the participants nor was understanding the lights to be a breathing exercise. Most of the participants found the LED light interesting, but too bright and too visible as LEDs put on a row.

Insights
The functionality of some of the system components needs to be enhanced. The garment was successful in mentally detach the person from her environment and helped most participants to relax. The relaxation experience could be enhanced by changing the DC motor into one that produces less noise so the wearer and her coworkers are not distracted by the sound. The movement made by the DC motor was not detected by any of the participants and should be enhanced as well. The movement should be made more intensely, still slowly. Enhancing the DC motor might help to experience the breathing exercise on a deeper level. This should be tested when adapted.

The LED lights should be placed less visible and more playful. Either placing them in the sleeve or making them more diffuse in the cuff would be solutions that need to be tested.

The aesthetics though very outspoken were highly appreciated by the participants. Even if it was not one's personal style, they still liked the design of the garment.

The perceived comfort overall was successful. This was due to the choice of fabric and the garment design. The size around the upper body was too tight for most participants. The size should therefore be made adjustable to a single person or become a commercial size M and L.

Participants answers to the open questions can be found in appendix G.

figure 110. Rating scale outcome of the functionality of the garment

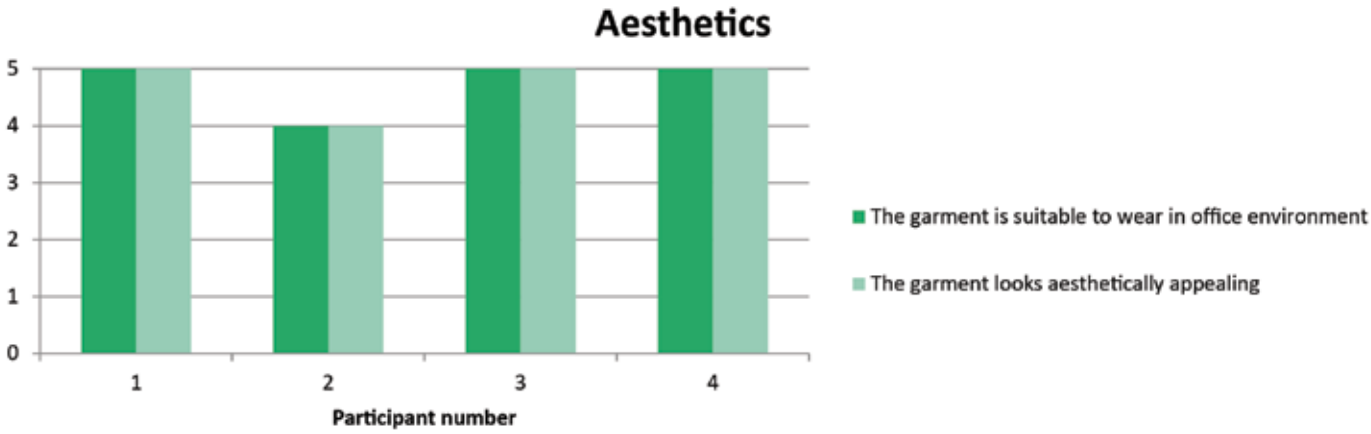


figure 111. Rating scale outcome of the aesthetics of the garment

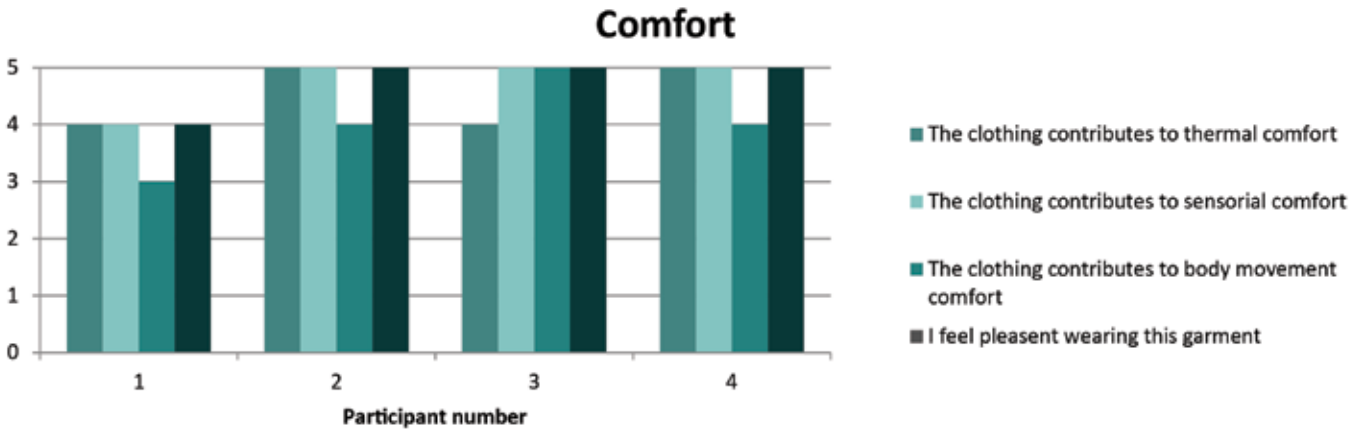


figure 112. Rating scale outcome of the comfort of the garment

TWENTY TWO

Conclusion and Recommendations

To evaluate the success rate of the final design it is time to reflect back on the list of requirements.

The material usage in the final design has not changed. Silk is used as a insulator and stainless steel as a capacitor. This still is a fruitful combination in the final design. The silk that is used has the right environmental friendly labels.

The interaction is only possible when actively being touched by the user. This can be in a sitting, standing or walking position.

The distraction of others in the office space can still be accomplished by looking into other more advanced DC motors. Other than that the system does not make any noise, extreme movements or asks for out of place activities.

Through the design of the garment the user is invited to touch the sleeves and the collar of the blouse. Their look is playful due to excessive length, layers and volume.

The repetition that is needed to elicit the relaxation response can be traced back in the output of the system via the heartbeat sequence and the breathing exercise. The touch is made repetitive in a more abstract way; touching the same place on a garment while doing the same movement instead of following a precise path was found an improvement to the functionality of the system.

Most of the participants got relaxed after usage, though one participant was very exited to explore all the options of the garment which increased her heart rate.

To understand if the garment enables users to use it 10 to 20 minutes a day an extensive research should be performed. The blouse was briefly researched within an office environment and was done on a very small scale with just one prototype available. In order to do this properly at least two more prototypes should be made available in different sizes to enable research within an office space on a bigger scale.

Psychological detachment is successful as all participants stated they did not think about their environment during the exploration of the garment. To understand if this effect will last, an extensive research within office space is necessary.

The garment is able to function well within of office with electric magnet noise and is not affected by ESD.

The system components are very light weight, though the LEDs could be replaced by LEDs that generate less heat and are equally light and flat. Next to that the LEDs should be made less obvious and visible in the garment. This can be done by replacing the LEDs in the garment or by making them diffuse.

The function of the breathing sequence needs to be improved. Therefore, the code needs to be enhanced. The output of the system needs to respond to the capacitive touch of the wearer more accurate.

When the wearer engages in the relaxation experience the system is activated, else the battery is off. The system can be used continuously for about 4 hours.

The garment was found appealing by all participants during the final user test. Although it did not match with all participant's personal style, the garment was found to be office appropriate and innovative.

The size of the garment needs to be adapted around the bust, waist and cuff to fit a wearers body perfectly or needs to be re-made in a commercial size M or L to fit more bodies.

Overall conclusion
This report concludes that the design of the smart blouse was found successful. It provides the female office employees aged 25 to 35 with a psychological detachment from work for a few minutes and enables the wearer to have control over when and how the relaxation process is happening. Next to that, with the right adjustments, the smart blouse can become an intimate experience that can be initiated within an office space without distracting others.

Recommendations
- Longer term research is needed to optimize the benefits of on-the-job recovery using the smart blouse.
- Improve the motion of the DC motor.
- Reduce the sound of the DC motor by looking for more advanced models.
- Change the visibility of the LEDs.
- Change the code of the breathing sequence so it responds better to the touch behavior of the wearer.
- Improve the size of the front, back and cuff panels of the pattern.

Limitations
The report also investigates the fact that the final user test conducted has limitations. It was briefly researched within an office environment and was done on a very small scale with just one prototype available.

Personal reflection
Working with smart textiles was an absolute blast. I worked with new technology, new design methods and turned the design process a bit upside down by starting off with the materialization.

The most fun part was doing the analysis, exploring all the possibilities of smart wear and performing the material research. But also making the garment that has so many steps. It is a difficult but amazing challenge to design a smart garment.

The hardest part was finding the abstract values of silk and its new design insights. But in the end I think I succeeded by creating a smart garment in a context that nobody else has designed for yet. Another difficult part was creating the pattern and the look of the garment. It is the lack of experience with pattern making to understand how a 2D pattern looks in a certain fabric on a body. This summer I will look for classes on pattern making, because smart textiles is a field that I absolutely enjoy working in.

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