Smart clothing in the mainstream
Implications of technology in the context of clothing

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Abstract

Smart clothing is far from being adopted by regular consumers and worn on a regular basis. Most developments can be found in specialized markets and all of the few consumer products so far have not been commercially successful. The first part of this thesis illustrates why this is the case and presents a few examples of concepts that show the potential of smart clothing in an everyday context.

The second part shows my own practical research into the subject and the resulting design concept. It follows a user-centered design process with participatory design elements and ends in a concept proposing clothing that can change color and style on the go. The concept tries to support a sustainable lifestyle by slowing down fast fashion and democratizing fashion design. It makes it easy for the wearer to create her own styles and to change the style on the go to adjust to different situations or different moods. The end result of this thesis is a prototype that serves as a proof-of-concept.
1. Introduction

Smart clothing can be roughly defined as clothing enhanced with electronic functionality. It can be anything from a jacket with integrated LEDs which keeps bicyclists visible at night, to a snow suit that transmit weather reports to its wearer or sends an emergency signal in case of emergency or an under shirt that monitors a soldier’s body for bullet wounds and transmits them to the base. So far, smart clothing can mostly be found in specialized markets like healthcare, sports or the military. It has not made its way into the broad mainstream consumer markets yet even though smart clothing could do a lot to improve people’s everyday life.

The few smart garments that have been launched commercially have not been very successful. But personal technology like mobile phones have become so ubiquitous that they penetrate whole societies. Most people carry their phones close to their bodies, like in their pockets or in a bag or backpack. So in a sense, we have become cyborgs\(^1\), but why do we still not see successful smart clothing in the mainstream markets?

To be commercially successful as mainstream products, smart garments need to fulfill a lot of requirements: the most important one being fashionable and comfortable to wear as well as be washable, easy to handle and easy to power. These aspects were disregarded in the early developments of wearable computing. The premise of this thesis is that smart clothing should not be bulky and solemnly functional, but should combine electronics and fashion in such a way that the clothing still feels natural and the interaction is effortless and seamless. From an interaction point of view of this thesis project, a smart garment still needs to stay a garment in the sense that you can treat it like a regular garment.

I envision mainstream smart clothing as clothes or accessories that are not only worn temporarily for specialized purposes and activities, but rather all the time - smart clothes assist people in their everyday lives. They do not have to be "on" all the time and you do not need to wear the same shirt for a week - because you would have a wardrobe full of them.

1.2 Motivation

I want to make the interaction with digital information more naturally accessible to users. In our ‘analogue’ physical world, we do not only use our finger tips and eyes to interact - our interactions are much richer and personal. Therefore I want to take functionality away from the computer screen and bring it out into the real world where the real users are.

Integrating information technology into clothing is one possible way to make adequate functionality available in a more intimate and natural way. Clothing therefore proves to be a perfect field. We wear clothing everyday and have a personal relationship with the garments we wear. They envelop our bodies, protect us and make us look the way we choose.

\(^1\) Even though we enhance our bodies and our skills with all kinds of active or passive technology like functional clothing, smart phones or even pacemakers, new technology is perceived as something slightly dangerous and invasive. The question is why.
So far researchers and the industry have not come up with a killer app for smart clothing yet - neither has any smart garment had a big commercial success in the mainstream markets so far. Therefore there is a lot of potential which is still unexplored. My intention in this project is not to come up with a product and then to bring it to market, but to explore the possibilities of this design space. The design outcome is neither intended to become a product today nor is it the one and only possible solution. I started this project with the intention of finding a killer app but I realized along the way that there might not be a killer app at all, but that the answer should rather be a killer lifestyle with many solutions. Therefore the design outcome is one of many possible solutions of tackling the field.

1.3 Research questions

- What is the status quo of smart clothing in the market, in the research lab and in independent designer’s imagination?
- Is the notion of a killer app applicable for smart clothing and would it propel smart clothing into mainstream markets?
- How can an interaction design approach shed light on the design space of smart clothing, and possibly open up new paths for the development of the area based on user’s needs and life styles?
2. Explanation of terms

Since the whole field is still rather new and all kinds of different terms are used, this chapter will highlight how different terms will be used in this thesis.

**Smart clothing / Smart garments**
"Smart clothing is distinct from wearable computers in that smart clothing emphasizes the importance of clothing while it possesses the sensing and communication capabilities. Wearable computers use conventional technology to connect available electronics and attach them to clothing. The functional components are still bulky and rigid portable machines and remain as nontextile materials." (Cho, Lee and Cho, 2009, p. 583)

**Wearable computing**
"Wearable computing facilitates a new form of human-computer interaction comprising a small body-worn computer system that is always on and always ready and accessible. In this regard, the new computational framework differs from that of hand held devices, laptop computers and personal digital assistants (PDAs). The 'always ready' capability leads to a new form of synergy between human and computer, characterized by long-term adaptation through constancy of user interface." (Mann, 1998)

**Wearables**
"The term 'wearables' encompasses a wide spectrum of devices, services, and systems. Objects from entire desktop equivalent computers to a ring with an RFID chip have been referred to as wearables." (Dvorak, 2008, p. x)
I generally prefer the term 'smart clothing' because it specifies that it has to be clothing, not just anything that a person could possibly wear. A backpack is definitely wearable, but it is not a piece of clothing.

**Killer application**
A killer application - usually shortened to 'killer app' - is "a computer application of such great value or popularity that it assures the success of the technology with which it is associated; broadly : a feature or component that in itself makes something worth having or using" (Merriam-Webster, n.d.).

**Mainstream consumer product**
In the scope of this thesis, a mainstream consumer product or just mainstream product is defined as a product that penetrates society and that is almost ubiquitous - a product that almost everyone has and uses on a daily basis. Additionally in this scope, the product should accompany its user during his or her daily activities in various locations. It does not need to be used continuously, but it should be continuously present and ready to use. An example of such a product is the mobile phone.
3. The value of Interaction Design in smart clothing

Redström and Hallnäs (2006) define Interaction design as "design of the acts that define intended use of things." (p. 23) and clarify that "Designing computer interfaces and computational interaction devices is a part of this, but it is not what defines interaction design as a specific area of design." (p. 26) Simply put, this means to me that Interaction Design is basically humans interacting with any kind of technology, ranging from computer interfaces to dishwashers, and that the Interaction Designer shapes and mediates these interactions.

Preece, Rogers & Sharp (2002) describe interaction design as follows: "By interaction design we mean designing interactive products to support people in their everyday and working lives. In particular, it is about creating user experiences that enhance and extend the way people work, communicate and interact." (p. 6) "[Interaction design] focuses on how to identify users' needs, and from this understanding, move to designing usable, useful, and enjoyable systems." (p. 5)

What does this have to do with smart clothing? It is simple: To design successful mainstream smart clothing, user needs must be identified, understood and transformed into design practice. Smart clothing should provide an enjoyable user experience and the users should know what they can do with it and how they need to accomplish that.
4. Where is smart clothing today and why is it there?

This section aims to answer the question why smart clothing has not reached mainstream markets yet and is not adopted pervasively. The chapter is subdivided into different aspects: wearability, understanding of the body, user's needs, design of smart clothing, interfaces, mass market adoption, and a comparison with mobile phones.

4.1 Wearability

4.1.1 Definition of wearability

Dvorak defines wearability as "How easy is it to put on and actually wear (as opposed to simply hang) the devices on the body; How well does it accommodate our movement as we perform our daily tasks? (Dvorak, 2008, p. 18)"

He also describes other criteria which are important for smart clothing:

- Ease of use: Is the device or service easy to use? How much attention does it require?
- Compelling design: Is it compatible with the user's sense of aesthetics? If it is visible, it must be appealing. Users might want the device to be visible since this adds status.
- Functionality: Does it provide suitable functions for the user's tasks?
- Price: Does the price reflect its value for the user?

In my opinion, wearability includes much more than just how comfortable it is to wear a piece of smart clothing. Ease of use and compelling design play a big role in how wearable smart clothing actually is. Because clothes do not only function on a physical but also on a social level, concerns of style and ease of use are essential parts of wearability. Otherwise the definition of wearability plays only on the physicality of clothing and neglects the social and psychological side.

Contrary to Dvorak, Suzanne Lee frames wearability in the following way: "Wearability means that instead of placing electronics on textiles, electronics will have to become textiles. These will have to be squashable, washable, and ultimately desirable. (Lee, 2005)" This definition primarily targets the technical side of wearability. The clothes we wear need to be smooth and flexible, but concerns of daily life need to be included too.

To summarize, wearability is comfort and flexibility of the material, desirability of the physical appearance, and ease of use of interacting with the product.

Reframing Dvorak's criteria, wearability contains the following of his attributes:

- Comfort: How easy is it to put on and how does it feel on our body? How much flexibility and freedom does it give the user in terms of movement?
- Ease of use: Is the device or service easy to use? How much attention does it require?
- Compelling design: Is it compatible with the user's sense of aesthetics? If it is visible, it must be appealing. Users might want the device to be visible since this adds status. It might show to the world that they are wearing 'the cool new thing' which in turn makes them feel cool or important and makes them interesting for the world around them.
But apart from comfort, ease of use and fashion design, the following four factors also play into the issue of wearability:

Attention and transparency
One important factor is that a piece of smart clothing does not require the user’s / wearer’s full attention (at all times) like a usual computer. When using a computer the user sits down at the table – or on the couch or any other setting with a laptop – and is focusing his full attention at the operation of the device. This is just not practical with a piece of smart clothing. You can not be fumbling around with your clothing the whole day. How would you work, eat, relax or even sleep? In this area of computing, a subtle presence of the device but not the requirement of full attention is how the interaction should be. To assist the wearer in his tasks, it needs to be always ready, but fade into the background when not needed (Weiser and Brown, 1996). This means that it is nearly transparent to use but far from being invisible. It can be visible and even an eye-catcher, but must not require the user to interact with it constantly or remind the user constantly of its presence.

Experience
The user should not be required to handle a piece of smart clothing fundamentally different than he or she would handle a regular piece of clothing. First and foremost, a smart garment stays a piece of clothing which has to comply with different expectations such as the practical handling of the garment or the social side of its appearance depicting the wearer’s identity and status.

Mobility
A smart garment obviously needs to be designed in a way so that the user can be mobile because it is worn and needs to accompany the user wherever he goes. But it should not only enable the user to be mobile, furthermore it should actively support mobility. This means that it must be designed for a constantly changing environment. The user might be in a forest and has lost Internet connection or he might be in a building and GPS is not available. In the user’s current location it might be bright, it might be dark and it might be very noisy or absolutely quiet. The smart garment needs to be able to adjust itself to all these situations.

Awareness about context and situation
To be fully able to assist a user and support him in his tasks, a smart garment needs to be aware about the context and the situation that the user is in. Situation and context refer to the user as well as his environment. Data about the situation and context can be gathered through sensors in / on the smart garment, accumulated through communication with objects / sensors in the environment and through a connection to the Internet.

Intelligence
To fade away from the user’s center of attention while still providing a good experience and being helpful, the smart garment needs to be intelligent – simply smart. Data that is collected from different sensors or sources needs to be aggregated and combined so that the smart garment can make decisions itself and be proactive.

4.1.2 Physical shape
Gemperle et al. (1998) defined 13 guidelines for wearability which are centered around the idea that a wearable computer is attached to the body. They defined the placement on the body, the form language of the wearable, weight, accessibility for
the user etc.. Most importantly, they illustrate how the mind perceives objects worn on the body and how it integrated them into the perception of self.

Dunne and Smyth (2007) point out that worn objects create sensory stimuli that make them noticeable to the wearer’s conscious attention which in turn leads to cognitive consequences. If a device integrates itself nicely into the body schema, it will not be noticed unless it creates sensory stimuli that the wearer needs to attend to. This is described to be crucial for comfort as well as acceptance.

I do not share Gemperle’s or other researchers emphasis on a wearable’s body friendly shape or definition of placement etc.. By the time most of those papers were written, technology just was not there yet, but some actually do have a different mindset. My point of view is a different one: I do not want to design a wearable computer that is tucked onto the clothing. Why put it on top if you can make electronics completely merge with and disappear into the clothing as Lee (2005) described? Making smart clothing unobtrusive and outfitting it with a body friendly shape is not that important anymore when electronics can completely disappear into the garment’s fabric. But contrary to Lee, not only the physical manifestation of the electronics and the garment is substantial: What is important is creating a garment that looks aesthetically pleasing and is equipped with a functionality that makes sense and provides a simplistic way of interaction that is easy for the user.

But the guidelines are important nonetheless for the development of a prototype as the result of this research because I will not be able to achieve the goal to make electronics completely disappear, because I do not have the technology, tools and materials necessary. Wires have been replaced with conductive thread and conductive fabric, but most other components available to the layperson are still hard and big. At the moment it is impossible to provide that technology to laypersons without the specific knowledge and most of all equipment. Even if I would find a chip scaled down to fiber size somewhere and would buy it, I would not have the skills and tools to solder anything to the headers. Maybe in the future we can just buy a small, thin and flexible version of the LilyPad (Buechley, n.d.) that can simply be ironed onto clothing or fabric which is already equipped with conductive yarns and therefore instantly connects different components together. And the power supply is woven straight into the very fabric of the garment (NewScientist, 2012) and charges wirelessly. Mass-producing theses elements would make them accessible and affordable for laypersons. But for now, I will have to work with electronics components which are much too big for finalizing a design because they are intended for prototyping.

4.1.3 Soft circuits

An important aspect of wearability is the tension between soft fabric and hard electronics. But as discussed above, this is no contradiction: “Today, technology is miniaturized to a point where chips can be scaled down to the size of fabric fibers and integrated right at the production of the cloth itself.” (Quinn, 2008, p. 11) Cho, Lee and Cho (2009) even note that it is a necessary requirement of smart clothing to integrate soft circuits. True smart clothing has to be fully made up of textile materials including the electronics, because people prefer soft, comfortable and washable clothing. But of course what is possible in a research lab today, is far from being ready for mass production. Therefore, Dunne (2010) states that the integration of hard electronic components is still a problem. Durability and effectiveness of the electronics is in contrast to the softness of the fabric.

In my opinion, getting the technology ready for mass production is one of the key factors to mass market adoption. Maybe it would be interesting to explore what the
threshold for acceptance is and how small technology has to become. Is it really necessary to make it disappear? One the one hand, mobile phones are definitely on the other end of the spectrum, but there are different requirements for clothing. In the case of the phone, it is about the actual device - in the case of smart clothing, it is more about the clothing and its combination with technology than about the technology itself.

4.2 Understanding of the body

Humans have a dynamic understanding of their bodies which can change over time and when using tools: "Psychologically, humans generate a dynamic understanding of the size, shape, and physics of their bodies. This understanding is known as “body schema”, and it allows us to navigate physical spaces and manipulate objects. The space designated as part of the body schema is surrounded by a spatial area known as peripersonal space" (Dunne and Smyth, 2007). This means that even though people do not have any nerve endings in their clothes, they can "feel" them and perceive them as part of themselves. Functionality that is accomplished by smart clothing might be perceived as part of the mind over time.

On the one hand, this leads to questions about cognition related to long-term use. An example of Steve Mann shows that it needs to be explored what health and cognitive implications the use of a wearable has on its wearer when worn over decades: After wearing his system for almost 20 years every day, Steve Mann was forced by security to shut his system down and take it off before going through an airport security check. Without the assistance of his wearable system, he felt disoriented on the way to the gate and fell twice. He finally had to board the plane in a wheel chair. Because the system was partially destroyed during the security check, he could not use it for weeks and experienced a lack of concentration and started to behave differently during this period. (New York Times, 2002)

This is definitely an extreme example and Steve Mann clearly does not represent mainstream wearables as defined in this thesis. He rather represents the opposite. Still, this example highlights the need for studies to look into the effects of long-term use relating to cognition and health. But on the other hand, of course this also leads to philosophical and ethical questions of how we understand ourselves as humans and what is human and what is not.

In this scope, the body will be considered in a practical way concerning aspects of wearability and comfort, but not in a philosophical way. The implications of long-term use - even though very important for acceptance and mass market adoption - are also outside of this scope.

4.3 User’s needs

Ariyatum, Holland, Harrison and Kazi (2005) conducted a study in which they interviewed potential consumers of smart clothing to find out their needs and desires. The outcome was that users preferred personal healthcare and sports applications that suit their lifestyle and which are aesthetically attractive and serve a practical function. The researchers also found that when buying smart clothing, the purchasing criteria for fashion and for electronics are applied at once. Because on the one hand, the consumers are buying a piece of clothing, but the functionality contained in the smart garment, is considered under same aspects of choosing an electronic device.
Duval, Horeau and Hashizume (2010) brought a humanistic perspective into their research and tested Maslow's hierarchy of needs (Maslow, 1987) against people's preference of different smart clothing applications. In a study in France and Japan in 2005 and 2006, they found as well that healthcare and sports are potential areas, which matches with Maslow's hierarchy of needs, but they also made a few other noteworthy findings: People do not want their smart clothing to disclose their emotions to the public or the people surrounding the wearer. They also note that so far, there have been no developments targeting sleep or allergens. Furthermore, Japanese participants were more ready to give their smart garment more autonomy to make decisions on its own - French participants were more conservative and required more control over the garment.

For the development of smart clothing, true needs instead of artificial ones should be considered. To determine true needs, Maslow's theory of motivation is taken into consideration. It categorized needs in a form of hierarchy:

- Physiological needs like nutrition, water and sleep are related to immediate survival.
- Safety needs are related to the absence of war and illness.
- Belonging needs include relationships of all kinds.
- Esteem needs concern respect and self-esteem.
- Self-actualization needs are the highest needs which consist of the need to fulfill one's potential.

Lower needs have to be fulfilled first before higher needs can be considered and the status of needs can vary at any time.

For the short term, the researchers considered smart clothing for physiological needs to be most effective, followed by smart clothing for safety needs which needs further research. Smart clothing that targets higher needs still has to be researched thoroughly.

On the one hand, I think that these findings are interesting and important, but on the other hand, it is hard to do user research for a still quite futuristic technology, most of all when the design outcome is not intended to become a product today. People can easily express needs or expectations about products or services which already exist and which they know, but it is harder to project needs into the future. There have been quite a few innovative products in history that fulfill needs that did not exist before. Henry Ford is famous for his quote about the faster horse: "If I had asked people what they wanted, they would have said faster horses." People did not know that cars would be a necessary asset in the future.

Therefore it is the task of the designer to figure out what is actually needed and what is superficial. This means that the answers that people give need to be broken down to people's true needs and goals: One approach is Duval, Horeau and Hashizume’s humanistic perspective incorporating Maslow’s hierarchy of needs (see above). In my opinion, the problem with their method is that they used Maslow’s theory to validate their findings and not to break them down. Another approach is Cooper's Goal-Directed Design (Cooper, Reimann & Cronin, 2007). It centers around the perspective that designing for user’s goals instead of tasks is the key for successful software or products. When using a phone, the task is to make a call, but the true goal is to talk to another person (who is not in the same location). Users might not be able to articulate the true goals and therefore Goal-Directed Design aims to educate the designer to recognize them. This is especially important for smart clothing, because wearable technology is far from common place today. Therefore the whole field is not in a phase where it is easy to improve upon existing work and where users have no difficulty to point out needs or discontent with features of existing products. Smart clothing is still in a phase on the
verge to mass production and adoption - not quite out of the laboratory yet, but at the same time already researched for some time.

4.4 Design of smart clothing

4.4.1 Aspects to consider for designers

The design of smart clothing is different than product or fashion design or designing technology. But it combines aspects of the different disciplines. Therefore, to design successful smart clothing, designers need to be aware of these aspects.

In general, there is more and more computation spreading in our everyday environment, so technology should be designed to encalm and be able to move from the user’s focus to the periphery and back (Weiser and Brown, 1996). It should not force its ways onto humans, but it should be designed according to human needs and behaviors (Weiser, 1991). In the specific case of smart clothing, designers need to think about wearability, the user’s needs and usability when designing smart garments (Ariyatum, Holland, Harrison and Kazi, 2005).

Fashion design is a critical ingredient in the process, because the outcome is still a piece of clothing. Therefore, smart clothing must be designed with fashion considerations in mind and designers of smart clothing need to stay updated about fashion trends. Like normal clothing, smart clothing has to fulfill emotional requirements (Ariyatum, Holland, Harrison and Kazi, 2005). In comparison to the design of mobile devices, branding is also much more important in fashion, because a carried device is only partly representative for the user - a garment on the other hand completely reflects the wearer’s identity. Therefore designers should be very careful during the design process, because garments also have a fixed social definition and are very personal. (Dunne, 2010)

The technology that powers a smart garment needs to be designed for the mobile and dynamic context that its wearer encounters. Combining a successful technology (that has existed as a device so far) with clothing is difficult because this approach disregards that both items (device and garment) have been designed for different contexts. (Dunne, 2010)

In terms of the technology, Cho, Lee and Cho (2009) break the components of a smart clothing system down to the following components: interface, communication, data management, energy management and integrated circuits. Wearable technology needs to be used for each of these aspects and the whole garment needs to be designed with their individual aspects in mind.

Ariyatum, Holland, Harrison and Kazi (2005) argue that electronics should not be completely integrated into the garments so that they are exchangeable which leads to a longer life cycle. While the user follows the fast fashion trends, the electronic functionality could be ported from garment to garment.

In some cases it might be worth considering not to integrate functionality into a garment, because some functions are not suited to be integrated into garments and work better as a separate device (Dunne, 2010).

In any case, I think there should be a balance between functional and aesthetic aspects, because both are important to the experience of the user. But it should still be designed in a way that retains its original function - covering the body in a fashionable way - because it still is a garment and should work as such, even when the battery is low.
4.5 Interfaces

If a smart garment is not just passively smart - e.g. in the case of a shirt that monitors the heart rate and contacts and ambulance when necessary - it needs a way to communicate with its wearer. Suggested input and output mechanisms include visual displays, sound or speech, tactile displays, touch and vibration. Dunne (2010) proposes touch and vibration as most effective interaction methods because they allow for private interaction. Based on touch, He and Schiphorst (2009) designed a wearable social network based on the Facebook poke feature. The ‘patch’ that is mounted on the clothing allows wearers to poke their friends and eliminates the need for a mediating object and therefore creates a more direct and natural experience. It transfers the human touch over a distance. Ariyatum, Holland, Harrison and Kazi (2005) found in their study with smart clothing designers and developers that electronic functionality should be added in the form of accessories like buttons or zippers. Because these can be added or removed easily and guarantee a longer life cycle of the garment, because components can be exchanged or upgraded.

Cho, Lee and Cho (2009) have collected different forms of input and output mechanisms. Among them, tactile displays which are very effective in smart clothing because of the close proximity to the skin. They also list textile buttons and switches which they claim are a simple interface mechanism that is easy to learn. But Dunne (2010) disagrees with the notion of replicating the mouse and keyboard in smart clothing and making them soft: "Traditional interaction techniques were developed for stationary technologies, under the assumption that the user’s complete attention would be devoted to interacting with the device. Mobile technologies have none of these properties: they must be operated in irregular, dynamic environments, and frequently while the user is simultaneously engaged in another task (which often takes precedence over the device interaction)." Turning mouse and keyboard into soft counterparts actually decreases usability: "[...] increasing the softness and flexibility of a keypad may promote wearing comfort, but it decreases the functionality of the interface by removing many of the tactile cues associated with keystrokes or button presses."

I agree that replicating buttons in fabric does not translate one to one and therefore other forms of interaction need to be developed. While developing them, the material and our traditional handling of clothes need to be taken into consideration. Touch and vibration, tactile displays and clothing accessories seem most promising to me because they allow private interaction and may in fact provide the most familiarity to people. Another approach could be that the whole piece of clothing serves as an input and output mechanism if the whole surface has sensing and actuating capabilities. This would allow for gestures to be performed on the surface and eliminate any visual clutter in the form textile buttons and the like on the garment. On the other hand, there is a need for cues how to interact, otherwise the smart garment has a very high learning threshold. A balance needs to be found between interaction cues and the invisibility of the underlying technology.

4.6 Mass market adoption

Smart garments have not been very successful commercially and they are mostly specialized solutions. They remain niche products and novelty items but have not yet conquered mass markets. One of the reasons is that smart clothing does not recognize or match user’s requirements, needs, purchasing criteria and lifestyle and the design direction remains unclear (Ariyatum, Holland, Harrison and Kazi, 2005). Another reason is that smart clothing requires multiple disciplines working together, but most commercial products in the area of wearable technology are creations of
either fashion or technology companies, approaching the subjects with their
traditional approaches. Nike+ is one example of such a traditional approach. The
sensor and the shoe are bought individually and the system is assembled by the
user after the purchase. (Dunne, 2010)

Additionally, there are no coherent standards for interaction or data portability yet
which guarantee that it is easy for a user of smart clothing from company X to easily
learn how to use a smart garment from company Y and transfer his data from
garment to garment. Furthermore, smart clothing does not exist as an isolated entity
in the world - smart garments need to be integrated into the ecology of existing
devices. (Duval, Horeau and Hashizume, 2010)

Another issue is the technology: Designing lightweight, long lasting and washable
power supply is still a problem. Current batteries are big, bulky and don’t last long
enough (Cho, Lee and Cho, 2009). Sensing technology is also still unreliable. Most
sensors are still big and need continuous skin contact to function reliably (Dunne,
2010).

Last but not least, the killer app that propels the whole field has not been found yet.
But researchers argue if there could actually a killer app at all: “It is commonly said
that ubiquitous computing has no "killer app," but instead is a "killer lifestyle." The
same applies to pervasive healthcare and many other wearable technology
applications." (Dunne, 2010)

Dvora on the other hand thinks that "The real killer app may not be an application at
all. It may be the total user experience of transparent, effortless access to and use
of information that integrates seamlessly into the activity flow of daily tasks. Not all of
these tasks are dramatic or sexy. But all of them assist us with the business of
everyday life." (Dvora, 2008, p. 24)

All these different challenges need to be overcome before smart clothing can
conquer mass markets: identify user needs, design fashionable smart clothing and
come up with effective interaction paradigms. But one factor is also cost.
To bring the cost down for a contemporary smart garment and make the
functionality more portable from one garment to another, a smart garment should be
turned into a modular system. (Dvora, 2008)

The actual piece of smart clothing contains only (cheap) sensors and actuators.
These can connect to a central unit which processes the input and delivers output.
Maybe the central unit has a screen which can display visual output if necessary.
Different pieces of clothing could have different sensors and actuators according to
the situations they are worn in and the needs of the users in those situations. A
formal shirt hints at a professional use context, a comfortable sweater rather to
leisure time / sports context.

The whole system should be based on an open standard so the company X can
make a base unit for company Y’s sensor enhanced clothing and vice versa. If we
take the success story of the web: having an open standard for everyone to use has
made it what it is today. On the other hand, the most probable choice for a central
unit (if the system is designed for today) is a smartphone. It is obvious: Most people
already have one and carry it around with themselves, it can communicate with the
Internet, has Bluetooth for short range communication with the sensors and
actuators, can determine its location through GPS, has its own power supply and
there is something like a standard: The two notable operating systems are iOS and
Android. The user also already has a lot of personal data on it that would help the
wearable system. The phone can act as the central unit that gathers the data from
the sensors, process them through a specific app and outputs the result through the
actuators or the smartphone’s screen if necessary. Users can customize the app on
the fly and download new programs for new sensors / clothes.
4.7 Advantages over mobile phones

Clothing has a lot of advantages over mobile phones. The obvious ones are physical: Clothing envelops us and is not easily lost or stolen compared to mobile phones. Not so obvious are psychological advantages: Clothing is perceived as an second skin that is intimate on the one hand, but on the other hand also represents us to the world around us and shows who we are. People might have a close relationship with their mobile devices, but phones can not live up to the power and established status of clothing.

Duval, Horeau and Hashizume (2010) state that mobile devices are quite good at satisfying belonging needs, but they do not succeed at higher needs like esteem and self-actualization. Therefore this could be an area that smart clothing could excel in.

In my opinion, this is a critical point and will be a central issue in this scope to find those kinds of situations or applications where it makes sense to integrate functionality into clothing that people change everyday instead of combining it with a multi purpose device like a phone that people can carry.

Multi purpose devices make it easy to carry a lot of functionality with yourself and people tend to like multi purpose devices in theory because they feel that they get more value for their money, but in practice, this approach tends to decrease usability and people get frustrated with their smart phones that can do anything but make a call. (Norman, 2011)

On the other hand, there is still the possibility to combine both approaches and design a modular system which integrated cheap technology into different pieces of everyday clothing and the central brain that connects to these components and does the computing is a portable device that can be carried.
5. Projects with mainstream potential

The following list of projects mainly includes prototypes and concepts because on the one hand, there are not many commercially available and successful products on the market, and on the other hand the products which are available do not satisfy the criteria for wearability which have been explained in the previous chapter. The projects beneath are judged based on the criteria for wearability: comfort, ease of use, compelling design, attention and transparency, mobility, awareness about context and situation as well as intelligence. All the examples are judged based on assumption. I have never had the opportunity to try out any of them. But knowing with what kind of technology (electronic components) they have been made, makes it easy to assume how comfortable they might be since I have worked with the same or similar technology before. I can image the different qualities that they have, but without having actually tried the examples, I can not say for certain what exact experience people might have.

5.1 Ping

Prototype by Jennifer Darmour, an independent designer from Seattle, USA.

Ping (Electricfoxy, 2010) is a jacket that connects wirelessly to a user’s Facebook account. When the user lifts or puts down the hood, the garment sends a message to Facebook and updates the user’s status. The content of this message can be customized through a special Facebook application. The message that is sent when interacting with the hood can be any text the user sets up in the Facebook application beforehand. When the user receives a Facebook message or comment, he or she feels a light tap on the shoulder.

All necessary components are integrated within the hoodie. There is no mobile phone needed to transfer the data. Apart from it obviously being fashionable, it is lightweight and comfortable to wear. The components used are small and light and therefore disappear into the garment.

There is no doubt that the interaction is very simple an intuitive, but it is admittedly problematic because the user might want to put on the hood if it rains without updating his Facebook status. Though this is questionable, it still is a novel example how future interaction with smart clothing can work. Replicating push buttons on clothing or integrating small screens into clothing requires more interactional effort than this natural way of interacting with clothing.

The interaction with the hood could be improved so that the garment anticipates when an interaction with the hood is actually a false positive. This could be accomplished by integrating sensors to sense either water or temperature – when the user might just simply put the hood on because it rains or because it is cold.

Martina Uhlig
This example is transparent to a degree where it completely fades from the user's / wearer’s attention when he is not interacting with it. The feedback is also not intrusive at all – it signals new messages or comment by a light tap on the shoulder which does not require to react at all.

5.2 Zip

Prototype by Jennifer Darmour, an independent designer from Seattle, USA.

Zip (Electricfoxy, 2010) is a jacket that lets the user control music in a different way. In one of the pockets, there is a headphone connector which connects the user’s music player to the headphones integrated in the collar. The volume of the music can be controlled by zipping the zipper up and down.

Again, the garment meets criteria for wearability – comfort, ease of use and compelling design – since it is obviously fashionable and comfortable to wear. Connecting a music player to the jacket is really simple and that is all the setup that is needed. It requires absolutely no attention when no functionality is needed. Through zipping up and down motion, it almost has an analogue feel. It does not specifically support mobility, does not display situation awareness or intelligence.

It could be improved in terms of awareness and intelligence: Temperature sensors could collect data from inside and outside temperatures and determine the user’s preferred temperature over time. If the wearer would zip the jacket all the way up or down in one quick fluid motion and if there is a change in temperature detected by the sensors, he actually does not want to change the volume but instead close or open the jacket.

5.3 The Hug Shirt

Prototype by CuteCircuit, a fashion company based in London, UK.

The Hug Shirt (CuteCircuit, 2006) is a shirt that can transfer the feeling of a hug to another person. If two distant partners wear the shirt, one feels when the other hugs him or herself to convey an embrace to the distant partner. The shirts are connected to their wearer’s mobile phones which run a custom application that exchanges a message between the two phones when one person hugged herself. The partner’s phone receives the hug and the shirt replays the sensation to its wearer.

It meets requirements for comfort, ease of use and good design. It requires a little setup to work with the user’s phone, but once set up, the interaction between the wearer and the shirt is very intuitive. When the user is not interacting with it, it is completely nonintrusive. It seems to be a shirt like any other. Just when a hug is received, the user becomes aware of the interactivity of the garment.
5.4 Assembly

Prototype by Lorea Sinclaire, an Industrial Designer living in Vancouver, CA. Developed as a student project at Emily Carr University.

Assembly (Sinclaire, 2011) explores safety in an urban environment. It is a jacket that lets its wearer interface with his mobile phone through gestures performed on the surface of the garment. Three gestures are presented: undoing a button will send the wearer’s location, stroking the hem line will notify a friend and hugging yourself and stroking the arms signals the wearer needs help.

Through an online service, the wearer can connect with other people and will receive feedback when someone sends one of the three signals. Vibration patterns in the garment indicate the different signals. To check who is in trouble and where the person is located, the user can view a map on his mobile phone.

The garment is comfortable and the technology almost completely disappears into the fabric. Since the interface only provides three gestures, it should be fairly easy to learn. Most of all because the gestures correspond to body positions associated with anxiety. When not using the functionality, it fades from the user’s attention and is invisible. But it has some potential for false positives, e.g. when crossing your arms. To make it more intelligent and avoid false positives, my suggestion would be to combine the gestures with measurement of body functions showing symptoms of anxiety like heart rate.

5.5 M-Dress

Prototype by CuteCircuit, a fashion company based in London, UK.

The M-Dress (CuteCircuit, 2010a) is a dress with integrated mobile phone capabilities. The wearer inserts a usual SIM card into the dress and the dress is ready immediately. When the wearer gets a call, she can just lift her hand to her ear to “pick up the phone”. How the dress communicates an incoming call to the wearer is unclear.

CuteCircuit developed the dress after finding that many women miss calls because they do not have the space (or the necessary pockets) in their garments to carry their phone close to the body.

The dress looks comfortable to wear and features a simplistic design, but I can not make any judgements about the arm piece that the wearer uses to take or make a call. The interaction and the technology remain unclear. It is unknown how the arm and hand piece are made and how soft those pieces are. It might be in the way when not using the phone and therefore not fade from the wearer’s focus when not needed.

With this dress, CuteCircuit makes a phone wearable but unfortunately does not seem to go beyond simply putting the phone into the dress. It is not aware of the environment or does it feature any intelligence beyond the phone capabilities.
I think there is definitely a lot more potential. On the other hand, the situation the dress is worn in, might not require anything more than answering your phone and making calls. But it definitely lacks the possibility to communicate asynchronously, e.g. via text messages. This also comes in handy in a location where it is loud and the other side might not understand the wearer at all when speaking.

5.6 Swift

Commercially available product as part of the fashion line Vega by Angella Mackey, a Canadian designer living in Gothenburg, Sweden.

Swift (Mackey, 2012) is one of Angella Mackey’s second generation Vega coats. It is a usual coat for different seasons, but features LEDs integrated in the shoulder region. These can be turned on by the wearer in the dark. It can be bought through Angella Mackey’s online store.

This example is representative for all kinds of light up clothing. There are evening gowns, t-shirts for partying or performance costumes like ‘Katy’s Dress’ by CuteCircuit for Katy Perry (CuteCircuit, 2010b) etc. This one though is a piece of clothing that can actually be worn in everyday life and which makes sense to be worn in such a way. During the day, it acts like a normal coat, and at night, the wearer can switch on the lights to stay safe while biking or during other activities in the dark.

Even though this is a commercial product and customers should be informed about how to handle the garment, the technology and interaction remain unclear. It is just mentioned that the garment is powered by lightweight and small 3V coin cell batteries. Therefore I assume that it should be comfortable to wear and easy to handle. It definitely features a compelling design. The garment works like a coat under any circumstances. But at night it features additional functionality. When the lights are not used, they are completely invisible behind layers of fabric. To the wearer, they go unnoticed during the day. The technology neither supports nor obstructs mobility and does not feature any awareness about the context nor intelligence (like a light sensor to turn the lights in the dark in case the coat is being worn).

5.7 Heartbeat hoodie

Prototype by Diana Eng, a fashion designer from the US. Developed as a student project at Rhode Island School of Design.

The heartbeat hoodie (talk2myshirt, 2009) made by Diana Eng in 2006 tracks its wearer’s life and her most interesting moments. A camera attached to the hood takes a picture whenever the wearer’s heart rate increases. The camera is wired to a microprocessor which is in turn linked to a wireless heart rate monitor.

I can not assess how wearable this garment is and how bulky the components were with which it was made. Since it was a prototype and developed in 2006, I assume that it is using a rather uncomfortable belt to measure the heart beat. Nonetheless, it
could be developed with a smaller integrated camera and a heart rate or respiration sensor integrated in the fabric which would make it very comfortable and wearable.

Ever since social networks are not bound to a computer anymore and are omnipresent in the everyday life of people through smart phones, the desire to document one’s life has grown very much. Having clothing document and share your life with others surely has potential. The prototype itself might not fade from the wearer’s attention so easily with the disadvantage of having a tight strap around the chest. It is also only aware about the situation of the wearer, but not the context. Adding more intelligence to the garment to determine memorable situations apart from the heart racing would offer a better experience for the wearer.

5.8 Neighbourhoodie

Prototype by Kathleen Climie, Rose Bianchini and David McCallum developed at the Canadian Film Center Media Lab in Toronto, Canada.

The Neighbourhoodie (McCallum, 2010) is a sweater that lets its wearer play survival tag together with other players. The sweater connects to an iPhone or iPod touch which runs a custom app and enables the game. It starts when all the participants have put on their sweater’s hoods. On the back, each player has a tag that lights up. To tag another player, this tag needs to be touched. It changes color and shows that the player is out.

The Neighbourhoodie is intended for teenagers and would be an good way to get them away from their computers. This particular prototype was realized by Angella Mackey (2010). It is a comfortable hoodie that offloads most of the functionality to a device that the wearer would carry anyway: an iPod touch or iPhone. Therefore the ‘brain’ can be taken out easily and makes the garment easy to handle. Still, more functionality is ‘hiding’ within the hoodie. But on the other hand, the hoodie can be worn in everyday life when the wearer is not playing. This might actually have a certain coolness factor for young people. When not used, the technology is completely transparent and fades from the wearer’s attention. While playing, the hoodie is aware of its surroundings and alarms the wearer when another player is approaching to tag him. It also highly encourages mobility.

5.9 Conclusion

Ping and Zip both demonstrate a trait that is crucial for acceptance and mass market adoption of smart clothing, namely fashionability. These examples might not be the best in terms of interaction, but both have been designed with fashion aspects and trends in mind and illustrate where I hope my prototype will be.

The Hug Shirt, Assembly and the M-Dress show novel types of communication and interaction. All the three concepts take communication on a different level and make it more natural and emotional. Even though gestural interfaces might not be as intuitive as designers who design them might think they are, but in both cases, the gestures chosen for the interaction are quite natural for the situation and context. I hope to incorporate that into my prototype as well.
Swift represents one aspect of experience and attention very well. First and foremost it is a beautiful coat that distinguishes you from others but also has additional functionality to stay safe in the dark. When the lights are not on or the battery is empty, it is still a perfect coat. The electronic functionality does not impose itself on the user. Therefore my prototype should incorporate the same aspects.

The Heartbeat hoodie illustrates the interest of self-expression. It takes social networking another step further by potentially documenting your whole life. This may seem absurd today, but maybe in the future people will not take their mobile phone or camera out of their pockets anymore to take a picture because their garment or their glasses have already documented the scene. In any event, the importance of self-expression should not be bypassed in my project.

The Neighbourhoodie is a playful concept which brings virtual gaming back to the real world. It makes the wearer get up and go out and play. But it might as well just be worn to look cool when not playing. As mentioned in the introduction, taking functionality out of the computer and integrating it into people’s everyday life is one of my major interests and will surely be incorporated into the prototype in some way.

It is quite noticeable that almost all the projects are intended for women. This may be attributed to personal bias, but I think this is also because the wearable technology scene seems to be dominated by women nowadays after it was dominated by men in the early days. The combination of technology with fashion makes electronics more interesting to women, and at the same time, recent developments in the DIY community like the Arduino (Arduino, n.d.) or consequently the LilyPad (Buechley, n.d.) have made it more and more easy for users to start making interactive things.
6. Smart clothing and fashion

The presented examples above also illustrate another important factor: fashion styles. Worsley (2011) describes that fashion has radically changed over the last century. It has lost the strong segmentation of social classes. Women's fashion has evolved immensely - largely due to social and economic circumstances like the first and second world war. Women became more and more independent from their husbands and therefore new kinds of clothing for the increasingly independent women with new requirements evolved. While at the beginning of the last century a maid could never wear a lady's dress, today everyone can (in theory) almost wear anything. Until the 1960s, fashion used to be dictated by fashion designers. This top down approach changed when Yves Saint Laurent introduced elements of subcultures into his 1960 collection for Dior. Ever since, fashion design has become a loop - subcultures inspiring fashion design inspiring subcultures and so on.

In my opinion, branding has become so important because everyone could theoretically wear anything today. If you can not show your status through the dress you wear, you have to find other ways to convey your importance - either through (expensive) brands or your own creativity in combining different styles or items of clothing.

As described in chapter 4, Ariyatum, Holland, Harrison and Kazi (2005) suggested that smart clothing should be positioned in the market just like functional clothing which would solve the incompatibility of fast fashion and the slower development cycles of electronics. But I think that this disregards the fashion side of smart clothing. To be successful it should not be clothing that works - but clothing that people like to wear, looks good and also has a certain functionality. In the end - it is still primarily a garment and not an electronic device.
7. How can smart clothing get into the mainstream?

As defined at the beginning, a mainstream product is a product that penetrates society and that is almost ubiquitous - a product that almost everyone has and uses on a daily basis - like the mobile phone. It is a reference product because it introduced a massive paradigm shift in society. It changed the way how people communicate and think of communication. But how did it get there? Over the course of nearly 30 years, the mobile phone evolved from the first portable phone in 1983 to fully ultra mobile smart phones like the iPhone launched in 2007. When mobile phones debuted in the market, they were expensive, heavy, bulky, had a very short battery life and hardly any coverage. Few people could afford them and actually wanted one. Gradually over time, mobile phones became affordable, the technology shrunk and permitted longer battery life and call charges became less expensive. The mobile phone slowly changed from an object of status to a common product that many people own.

The research on wearable computers really took off in the mid 90’s at MIT with Steve Mann and Thad Starner (Rhodes, n.d.), in the early 2000’s wearables started to become available commercially and today we have fully wearable LED displays worn by music artists (CuteCircuit, 2012). Bill Buxton predicts that "when you have a new idea in research, it almost always takes 20 years to go from standing start to maturity" (Wired, 2012). Which means that we should start seeing fully market ready smart clothing in the near future. What needs to be done to make this happen on a social, technical and economic side has been described in chapter 4. The social side was very much focused on individuals though. Looking at a broader societal context: What needs to happen to make smart clothing attractive in the mainstream markets?

7.1 Subcultures

There are ample examples of fashion styles of subcultures influencing the mainstream and moving from the respective subculture into the mainstream. Hebdige (1979) describes how the punk aesthetic - originally a counter statement against "the arrogance, elegance and verbosity of the glam rock superstars" was commercialized and turned from an expression of the neglected youth into a commodity.

So to bring smart clothing into the mainstream, should it start out as the fashion style of a subculture? Over time it would naturally become more appealing to a broader audience and would move from the niche to the mainstream? To look into the broader context and relationship between culture and subculture, Hebdige defines subcultures as such: "The word 'subculture' is loaded down with mystery. It suggests secrecy, Masonic oaths, an Underworld." (p. 4). And he also remarks that "Style in subculture is, then, pregnant with significance. Its transformations go 'against nature', interrupting the process of 'normalization'." (p. 18). This means that

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2 Motorola’s DynaTAC cellular phone

3 The iPhone was not the first smart phone, but it made smart phones popular for the masses.
there is a strong tension between culture and subculture. As pointed out earlier, smart clothing can already be found in healthcare, sports and the military, so on the one hand it might not make for a strong differentiating factor - very specific applications might though - and on the other hand, because smart clothing as a whole field exists in other areas, I do not see the provocative factor either. A very specific and narrow application would be necessary to provide both these factors but that would on the other hand contradict the ambitions to move the whole subculture to the mainstream.

Therefore I do not think that a subculture needs to be "created" for smart clothing. A few mainstream musicians are already using costumes with integrated LEDs for their performances - like Katy Perry (CuteCircuit, 2010b), the Black Eyed Peas (Waldemeyer, 2011) or even U2 (CuteCircuit, 2012). That means that there are already trendsetters who pave the way for wearable technology. Which in turn leads me to the conclusion that future mainstream smart clothing does not necessarily have to become part of a geeky subculture first before moving to the mainstream - it simply means that the target group of the early adopters within the mainstream has to be narrowed down - because smart clothing (in terms of reactive LED clothing) is already on its way, promoted by trendsetters from the music industry.

7.2 Killer app or killer lifestyle?

A lifestyle is commonly defined as the way people live - the society and culture they live in, their primary occupation, their family status, their likes and dislikes, their habits and behaviors, their attitudes etc. On a micro level it could be the music they listen to or the clothes they wear. This means that in comparison to the killer app, the killer lifestyle is made up of a lot of little things that add up, create synergy effects and are more than the sum of their parts.

Is the search for a killer app for smart clothing beneficial to the field or is this the wrong direction? The argument in 7.1 underlines the argument that smart clothing is rather a killer lifestyle instead of having a killer app. Through strategies like targeting trendsetters and groups of early adopters, smart clothing for mainstream consumers will spread slowly but constantly.

In chapter 4, the notion of the killer app was already partially rejected by Dvorak (2008) but most of all by Dunne (2010). Her argument is emphasized by Starner's work. Starner (1999) promotes the notion of the killer lifestyle for wearable computing over the killer app because he believes that integrating technology into people's everyday life and supporting networked communities of users will lead to more value for the user than technology for specialized purposes. Schmidt (2002) even believes that "the quest for the killer application [in ubiquitous computing] distracts the attention from basic research that is required to get the infrastructure in place." (p. 238). Since the field opens up new ways of interaction between people and their environment, new dimensions for applications should be explored rather than blindly searching for a killer app without understanding what really defines the field.
My design process for this project was shaped by user-centered design with elements from participatory design. Abras, Maloney-Krichmar & Freece (2004) define user-centered design as a broad term for design processes "in which end-users influence how a design takes shape" and which in most cases inquires "users about their needs and involve[s] them at specific times during the design process; typically during requirements gathering and usability testing."

Participatory design takes it a step further and integrates users as equal partners in the design to "meet the unattainable design challenge of fully anticipating, or envisioning, use before actual use, [which] takes place in people's lifeworlds." (Ehn, 2008).

Both approaches unite what I think is important in designing a product, a service, a website etc: They take the user and his needs at heart and look at what situations the user finds himself in and try to understand what implications the immediate environment has on the situation and on the interaction. I combined different design processes - user-centered design and participatory design - for this project because my professional experience prior to starting this course has shown me that user-centered design mostly does not involve real people into the design process but rather secondary research about the potential users. Therefore I drew elements from participatory design, but overall I think that the designer should still stay the expert who combines all the insights in such a project. This is most important for a project that deals with possible futures.

The process

I started by researching the field through academic literature and analyzing and evaluating related projects. The results of the academic research have already been described in chapter 1 - 7. After I had a certain overview over the field, I began with my own research: I conducted an online study about the relationship between people and clothing as well as technology. Afterwards, I carried out two workshops with students and designers. Then I approached different designers of smart clothing and tried to conduct interviews about the future of smart clothing. From the results of the literature research, the online study and the workshops, I selected and generated ideas and received feedback from potential users.
Finally, I implemented a partly functioning prototype to make a proof-of-concept of my design.

8.1 Before the project started

During the fall semester I contacted different companies and research institutions for a collaboration for my thesis: the Smart Textile Design Lab at the Swedish School of Textiles in Borås, Cute Circuit - a design company which combines fashion with electronics (mainly light) based in London, Do-Fi - a design company based in Malmö, and Diffus in Copenhagen - a design company that has done a few different projects in the field of wearables.

From these different companies / research institutions, Diffus was my preferred choice and they were also happy about me wanting to do my thesis with them. They suggested that I could either work with them on one of their future projects or experiment with two different materials they wanted projects to be done with. That would be my solemn responsibility and I would have the freedom to take all the design decisions within the constraints of the materials. Nevertheless I concluded that the different proposals either did not offer enough freedom of choice for me as a designer or were not sufficient as a basis for research.

8.2 Online study

After getting enough insights into the field through the literature review, I chose to conduct an online study to first get a broad overview before preparing the workshops and getting more detailed insights. I wanted to find out more about the relationships that people have with their clothing and with the technology they use. I was also curious about what role technology plays in their lives and what behaviors form around the use of technology. With these objectives in mind, I created a questionnaire with 11 qualitative questions aiming to get the participants’ opinions rather than quantifiable data. The questions were a mix of broad open questions concerning people’s general attitudes to a specific question about ideas for smart clothing. The detailed questions can be found in the appendix. Making the study through an online service allowed for an easier evaluation than a paper version would have been able to provide. It also allowed to get quick feedback from people not based in Malmö. I sent it out via email to interesting people and published it on Facebook to get more people involved and to diversify it. This tactic proved to be successful and I got answers from various people that I do not know.

The questionnaire was filled out by 22 people between 20 and 38 years - 11 women and 11 men - from Sweden, Germany, Iran, Russia, Thailand, Turkey, USA, Romania and the Netherlands. The participants were students (both university and college students) from various disciplines and professionals with various work backgrounds.

After two weeks, I collected the answers and categorized them into the following themes:

* Relationship with clothing
* Use of technology
* Communication
* Ideas for smart clothing
* Concerns with smart clothing

In the following sections, I included the most important quotes from the study.
8.2.1 Relationship with clothing

The most important aspects when buying clothing were look & feel and color, followed by comfort and quality and the combination of different pieces of clothing. The price was also an important factor.

- "I dress so all the colors and patterns match. If they don't, I feel bad all day."
- The material was a decisive factor correlating with comfort:
  - "The quality of the material feel, nothing rough. The quality of the material lightness, nothing heavy. The quality of the material when wearing other clothes"
  - "I like nice textures. I like cotton. I care about how the clothes fit on my body and how the seams between the fabric parts are constructed."

For some, an ecological production and fair pay was a decisive factor when buying clothes:

- "Ecological and socially correct, fancy brands, beautiful clothes and comfortable."

Others also cared about washing instructions when buying clothing:

- "I hate clothes with special washing instructions because I have bought a lot of clothes I like only to find that the washing instructions are complicated and time consuming, so those clothes get worn once and that's usually about it."

Most people cared about pricing and would not buy very expensive clothes, but some stood out:

- "Price isn't really a big factor unless it's really, really absurd."

Some liked to buy clothes that easily go with their existing clothes in their wardrobes so that they can easily combine clothes in the morning:

- "I try to buy clothes that all work together so that in the morning I don't have to think about it too much."

On the other hand, there were others who put a lot of effort into getting dressed in the morning:

- "When I get dressed in the morning, I pay attention that the proportions work, e.g. that the length of the skirt fits with the length of the shirt and jacket, that volumes fit together. [...] I combine clothes so that you can't see their origin anymore, like traditional garbs. Accessories are mostly the most expensive pieces of the outfit."

Clothing communicates the style and identity of a person. For some participants this was very important:

- "My clothes are serious, they are not fun and this is not a game, most of all they are not comical or 'casual'. They are historically aware, aware of tradition and always context sensitive."

- "So I want people to take me seriously and think I am an intelligent person, but I don't want to seem so professional as to be either unapproachable, look self-important, or look like I'm bucking for a position in management. So I guess like hip-professional."

Most were rather in the middle of the spectrum:

- "I guess they [clothes] are an extension of my identity in the sense that I communicate through them to other people that I'm a casual, laid-back person who is not at the mercy of the latest fashion trends."

For others, it was less important:

- "I wear them [my clothes] cause I like them and how I look in them, though I guess it wouldn't hurt if other's thought I looked good in them as well."

But to some participants, it was even more than an expression of style:

- "To some (those who know) my clothing would communicate a glimpse of my music taste, and therefore maybe political views."

Clothing can also communicate how people feel:
"Mainly how I feel at a certain moment in time. If I'm bursting with energy and if I'm feeling good, I like to wear red. If I'm not feeling so good (just tired or even sad), I wear something comfortable with darker colors..."

Instead of expressing people's moods, the way they dress can also influence their well-being:

"When I dress good I feel super confident. :) [...] And I am doing my best to wear some bright colors in my everyday life because I believe it makes a positive look for me from other people's view."

8.2.2 Use of technology

All the participants use a lot of technology throughout their day. But since the sample ranged from 20 to almost 40 years, that could be considered normal. But some did stand out:

"I use my smartphone at least once every 30 minutes. I check for texts, mail and Facebook notifications. So yeah, technology is something I use every single hour of every single day."

The importance of the Internet in our daily lives could not be summed up in a better way:

"Not having Internet access (when I need it) pretty much brings life to a halt."

The more devices people have, the more they diversify their usage of technology:

"A normal day looks like me getting up and first checking email (phone). Then having breakfast and checking the news (tablet). Then heading off to do research at the library or at work (laptop). I sometimes will read lengthy pdf files so I'll put those on my tablet and read them there because it's easier on my eyes than my computer screen."

But that also yields problems:

"But switching between devices, oh dear lord, it frustrates the hell out of me."

Mobile phones are always on board and used often:

"It's with me all the time."


Users like to appropriate technology to their needs:

"Even if my headphones are out of electricity [wireless headphones], I'll use them just to keep my ears warm."  
"My smart phone is mostly used for surfing, texting, gaming and calls. <--- in that order! I love to just pick it up and find some information."

But all this use of technology can also become a burden:

"Who doesn't dream about a life (or at least a day) without sitting in front of the screen."

"Technology works beautifully if you are at home, near power, not moving, have clear wifi, enough light, by yourself or with people who are being relatively quiet, and all of your adaptors and the like are within 5 meters. In any other context the value and quality of interacting with technology drops off at an alarming rate."

Hence, there were quite a few situations in which most of the participants wanted to get rid of technology:

"When a group of my friends meet up someone is always only half paying attention to what's going on because they are looking at a screen of some type."

"When trying to concentrate on some important task, maybe don't distract me with a text-message that can wait."
"When I spend time with my boyfriend and my mom calls me exactly during that time."
"Yes: on vacation / weekends / after a long day in the office."
And some also had a very conscious attitude towards their use of technology:
"I like technology, but I don't need the newest of the new in every part of my life."
But most participants still liked to have their phones close and feel their closeness and connection to the world:
"I use my cell for communication and news all the time. Without it I would be lost. Its an active extension of me out into the world and over the Internet. Its a passive notification system for the world to talk back."

8.2.3 Communication
Through the innovations of technology, our world is more and more connected and communicates continuously:
"I check my email and Facebook with a cup of coffee the first thing in the morning. I prefer: emails to paper letters, push notifications to having to check every portal all the time."
It even transforms the way we communicate and deal with information:
"I recently installed a Facebook app on my iPad which puts notifications on the unlock screen. This has completely changed how I use Facebook and my tablet. It is an awesome passive indicator of my friends and their lives."

But technology does not always have to be used actively:
"I just carry it [mobile phone] with me to be reachable or to contact people in an emergency."

8.2.4 Ideas for smart clothing
These are some of the ideas that the participants had:
"There is a whole world of unseen data (geo tags, restaurant reviews, tweets, historic monuments) I want to feel those as I move around them. I want to build a huge invisible maze in the open air, and have a shirt that vibrates in the front / right / left / and back, so when I reach a dead end I would be able to feel it and now where the walls are, and hopefully find my way out. I want a shirt to change colors when I've received enough sunlight for the day so I don't get sun burned, and i want it to change to be a different color if i'm not getting enough sunlight to begin with (possibly because i'm in doors all day and in sweden and don't get enough sunlight). I want a shirt for my gramma that buzzes very softly when I send it a message. That way she knows I'm thinking of her."
"A light (thin) jacket that acts as a good windbreaker while cycling. This jacket would come equipped with a hood that's thin enough to fit under a helmet if needed. There would be headphones inside the collar. It would have solar cells and a battery somewhere so it could charge up, but it would also have a place where I can connect it to my bicycle's dynamo to power it/charge it up. It would have a lot of low-intensity white/blue-ish-white LEDs on the material that would be triggered on and off by a light sensor. These would keep me visible at night."
"I guess I would like a clothing where I could download patterns and customize it how I wanted it to be. Photos of friends on the garment would be awesome and stupid at the same time. But a clothing that could keep me creative with it. Make me do illustrations to place on it."
"Something integrated to my bike or clothing at least. It can be fiber optics sewn in cloth and emits light when activated. Integrating rfid's somehow so I can open the doors easily. It can be nice to receive text messages and reply them without taking the telephone from pockets. Also it would be good if a piece of smart cloth can just show me which direction I should go or where I am in relation to my

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destination point. This would be handy since I won’t have to take out my handy every time I want to be sure. It can also be fun to tag the environment with this, or create augmented reality content with smart textiles.

• "1. gloves/ring/bracelet that will notify me that I am receiving a call or SMS when I am on the bike. 2. a t-shirt that will notify me gently where is a better WiFi connection in the cafe. 3. earrings that will adjust their color to fit with my clothes. 4. boyfriend’s socks that will crawl by themselves to the dirty laundry bin."

• "The cloth will help you connect to your cell phone via Bluetooth system to be able to connect to your cell phone with tiny headsets and tiny microphone. It looks like implementing hands-free headset in your hoodie. Also, it gives you hand synchronizing with your MP3 player to listen to music and the motion of hand will decrease or increase the volume of MP3 player or cell phone."

• "I would use a hat with camera functions to take pictures."

• "Since I have back pain a lot, I’d like a massage pillow integrated into a sweater. When you sit down and lean back, you’ll be massaged. Maybe combined with warmth."

• "Electricity became issue for me so I wish there was a way for all of them to get electricity charging when I am biking around or I am walking. We spend energy all the time when we move we walk and when we bike, why not our clothes could absorb it and do some fancy things for us?"

• "A hoody that has an integrated MP3-player/mobile-phone in it. Best would be on the arm, so I could check my songs and texts and stuff on the run <3"

• "A keyboard on pants in the position of the thighs."

8.2.5 Concerns with smart clothing

Some participants were concerned about health-related issues with could impact smart clothing:

• "I try not to carry my phone close to my body all the time (radiation)."

Others were concerned with practical aspects:

• "Since I wear different clothes every day I would like it to be attachable to all my clothes."

One was simply not convinced by the idea of having electronic functionality in clothing:

• "The idea doesn’t appeal to me very much."

8.2.6 Conclusion

Most findings about people and their relationship to clothing are not very surprising. The results validate what is more or less common knowledge: Clothing and appearance are quite important to most people. Their clothes reflect their identity and choosing clothing is a conscious decision - even if you deliberately do not follow fashion trends, you still make a statement through the clothes you wear. Most people have a strong desire to express themselves through their clothes. They buy certain items which correspond to their taste and combine them in ways to set themselves apart from others.

An interesting finding was to me that not only men carry their phones in their pants pockets. Some women also do the same instead of putting them into bags or backpacks so as not to miss calls. My perception before was that most women do not carry their phones in their pockets, but rather in a hand bag or backpack.

Another finding was that one piece of technology does not necessarily replace another one. It just diversifies the usage and sometimes makes it more complicated, e.g. when switching between devices. Even though most people had a mobile phone or even a smart phone which is able to play music, they were still carrying a
separate music player. Either for convenience, because their music was already on it or to prolong their phone’s battery life. This means that even though the mobile phone has a lot of different features, people (actively) make a decision not to use them and carry other portable devices because this behavior fits their needs. Therefore having smart garments would most likely not replace other technologies that are around. But on the other, I do not intend to compete with large screen devices which are very visually orientated. The context of the body requires a different method of interaction.

One interesting outcome of the study was that some people were afraid to have technology close to their bodies. Judging from the research described earlier in chapter 4, this should not be surprising. This is a fact discovered over and over by different researchers. Still, I did not think about including it in the study because I wanted to get a broader view of people’s use of technology and their relationship to clothing, but the last question concerning participants’ ideas brought forth some people’s concerns because it was targeted at the specific topic and asked for people’s ideas.

Before the last question, I introduced the topic in detail and gave three examples. I was really struggling with which examples I should provide. On the one hand, I did not want to influence the participants’ creativity by providing examples, on the other hand, I felt that without providing examples, some participants might have a hard time to come up with ideas because they can not fully grasp the topic. After analyzing the results, I can not really see that the examples had a negative influence on the participants’ ideas. Still I do not know what would have come out of it if I would not have provided the examples.

The study was a good method to get a general overview while I was still exploring the field. Combining very broad questions about technology usage and a specific question to ideas for smart clothing might seem like mixing up different perspectives, but in retrospective it proved to be working quite well. One the hand, I got a lot of broad insights into how the participants relate to clothing and to technology, but also what possible futures they could imagine for both areas. Of course it is hard to imagine what you might need or want in a (distant) future, but some of the ideas were really interesting.

8.3 Workshops

After I analyzed the results of the study, I conducted two workshops: one with students interested in the topic and one with professionals from the field. I selected the students based on their answers in the study and the professionals based on their projects in the field so far. In preparation, I designed small representations of clothing for men and women and laser cut them out of fabric in different colors. My intention was to use them in the workshop for people to glue on paper and draw or write on them. I wanted to provide the participants with tangible representations of clothing which are true to the material. The little garments were meant to inspire the participants’ creativity.
On the one hand, I made them high fidelity so the participants would treat this workshop with a certain degree of seriousness, but I made them doll sized so that the participants would have a playful interaction with them during the workshop, like with clothing for paper dolls.

For each of the workshops, I gave roughly the following introduction. First I described my thesis topic and then I introduced the participants to the materials and the procedure. I showed the materials to the participants and spread men's and women's clothing on the table, ordered by gender and type of clothing. I commented that these are small representations of clothing to help the participants to generate ideas. Also to inspire their creativity further, I put eight circles with different activities on the table: sleeping, eating/drinking, learning, working, driving/bicycling, communicating, exercising and relaxing.

Further, I explained that the participants could choose any piece of clothing they like and either pick one or more activities and combine them to come up with an idea or think freely around a piece or pieces of clothing. The different activities were just a way to help them get started, but they did not have to use them. I handed out a piece of paper and pen to everyone and told them that they could take the pieces of clothing and stick them onto the paper with double sided tape I provided and then sketch or describe their ideas around or on top of the fabric pieces.

8.3.1 Workshop with students
The first workshop was conducted with three Interaction Design students. Among others, they had filled out the study and were interested in the topic. I gave them the introduction and provided them with the small clothing samples of men’s and women’s clothing. They could either come up with something for one or more specific activities or think freely.
So they picked different pieces of clothing and glued them onto paper and described their ideas. After all the participants had filled two sheets of paper and were done with sketching ideas, we discussed everyone’s ideas and added some more pieces to some of them and even came up with new ones. The workshop lasted for two hours in total.

The highlights included the following ideas:

- A clothing system that absorbs the energy that a person generates by walking, running or biking. The energy could be used for all kinds of applications, e.g. charging personal electronics.
- A blouse / shirt that with which the wearer can poke their office mates and turns the office into a social game space.
- A pajama which communicates with objects in the home as soon as it is put on: It turns off the lights when the wearer is in bed, in the morning it raises the curtains when the wearer has to get up and turns on the alarm when he does not get up after a certain time. When the shirt is taken off, it turns on the coffee machine.
- Shoes that count the steps a person takes each day and notify the wearer if he should walk more because he has not achieved a certain amount of steps a day. Different shoes sync up with each other when the user walks over the door mat in his home.
- A hoodie that uses noise canceling technology when the hood is put on. It also turns the wearer’s phone to silent mode and his online presence to "away".
- A shirt that changes color depending on how much light the wearer is exposed to so that he could know in winter that he did not get enough sunlight and in summer if he had too much.
- A pajama that vibrates gently in time with soothing music to help the wearer go to sleep, in the morning it vibrates a little harder to wake the wearer up.
- A combination of an evening dress and handbag which are both decorated with LEDs. But the handbag only shines when it is worn by the wearer of the dress.
Animation patterns can go from the dress to the bag or to a friend with a similar dress.
- A shirt that turns color when the wearer is in a polluted area. The shirt could have different colors for different pollutants.

8.3.2 Workshop with professionals
I conducted another workshop with the two founders of Diffus, a Danish design company which has been doing different projects with wearables. My intention was to get the experts’ view compared to the view of the non experts - the students. I proceeded in the same fashion as in the first workshop. I gave an introduction to the topic, spread out the fabric samples and activities and then let them sketch their ideas on paper together with the fabric samples.

Workshop with Diffus

The workshop lasted for around 40 minutes. So unfortunately, there was not enough time to discuss their ideas all together which had proved to be inspiring with the students. But I quickly went over each idea with each one of them.

The highlights included the following ideas:
- A clothing system for teachers and students: The clothes measure body signals of the students and environment factors affecting the learning experience like CO2 levels in the air or noise. They actively cancel noise and a communication between the teacher’s and the students’ clothes takes place. The teacher is discreetly informed when the learning experience is not optimal or when the students can not follow anymore.
• A mood shirt which makes flowers (or other kinds of patterns) appear to show your feelings: In a dating situations, more flowers would appear the more you like another person.
• Socks that find each other: When a pair of socks is split up and the owner looks for the second sock, it starts blinking.
• A suit or jacket that changes color when the wearer is drunk.

8.3.3 Conclusion
The workshop with the students was more insightful because there was no pressure for time, so we had time to discuss everyone’s ideas afterwards. It would have been interesting to do this with the professionals as well.
The students came up with more ideas for the future. The ideas from the professionals were targeted to be rather realizable today and were concentrating on more simplistic issues. On the one hand, this could be because they have a more sober perspective on the topic and also think about how to make their ideas work as well as take an economic perspective into account. Their own economic interest in the topic might also have influenced the outcome.

Using tangible representations of clothing instead of making people draw everything themselves helped the participants to concentrate on the ideation instead of drawing pieces of clothing or having to write a lot. In one instance, I got a glimpse of how the material shapes the outcome: In the case of the mood shirt thought up by one of the experts, the material - a blue flowery patterned representation of a shirt - shaped the idea that came out of it. Also, having quite a few ideas relating to sleeping is in my opinion a result of the activity cards that I provided. If I would not have included sleeping in the activities, I do not think that people would have come up with something connected to it because normally it is something like eating or walking which you do not normally think about. Including it as an activity came out of the insights of the research by Duval, Horeau and Hashizume (2010) who found that there is no smart clothing related to sleeping or allergens. Therefore I thought it might be interesting to see what the participants might come up with.

8.4 Interviews
To find out more about the future for wearable technology and to get another perspective on the topic compared to the study, I contacted experts to get their input on the topic.
I sent out an email interview to nine designers, entrepreneurs and researchers who are working within the field of wearable technology. Additionally to answering my questions via email, I also proposed a meeting via Skype so that I would have the ability to react to their answers.
The only two replies that I got were from Valérie Lamontagne, a Canadian researcher and artist, and Angella Mackey, a Canadian designer living in Sweden and selling her own smart clothing fashion line (see 5.6 Swift). Unfortunately, no one else got back to me and it also took a while for the second reply to get back to me. Therefore their views could not impact my design process as I wanted them to.
In bold are the questions I asked.

**What is the future for wearable technology in your opinion?**
Valérie: I believe technologies have multiple futures. If one were to map the evolution of any one technological application (photography, sound recording, computers etc) the proliferation of uses are wide and large. Hence, wearable technologies will likely become pervasive in a multitude of fields from surveillance (as seen in recent
announcement of Brazilian schoolchildren wearing monitoring chips to curb truancy, to health and safety and in expressive and artistic applications such as the amusing rock show costumes made recently for the Black Eyed Peas etc.

**What will be the most successful applications in the next few years and where is it heading - towards even more specialized use cases or more broad applications?**

Valérie: From a commercial point of view tech companies presently looking to expand into wearable technologies are principally in the mobile communications field. Apple and Microsoft have wearables researchers on staff. From this point of view, I imagine specialized uses will become predominant in research.

**Do you think it would be more successful to integrate technology into accessories or into garments in the short or long term?**

Valérie: Accessories because of modularity, ergonomics, cleaning and context use being more open.

**What kind of use cases would make more sense with accessories and which ones with garments?**

Valérie: Accessories are modular components which follow us in many places. A garment is less of an everyday use objects because it is relative to cleanliness, temperature and context-use. So, I would imagine that accessories are more suited to wearable technologies which we use in the everyday. However, the garment has the advantage of being closer to the body, hence useful for body monitoring etc.

**Is there a concept or an idea that pops up in your mind that would be most successful as a mainstream product?**

Valérie: Yes, but that’s my ip at this time :)

Angella Mackey:
What do people want or need? When we design a garment with electronics in it are we designing electronics or designing a garment? Will people buy the electronic functionality? or the clothing functionality (style, identity and/or weather protection)? What exactly are they interested in? Can the two really merge in a way that makes them one entity, and part of our “everyday” wardrobe which makes real sense? Can the pair live beyond a fleeting trend?

With exception to the obvious medical applications that might transform a patient’s life; the sports and military applications that help people become more “super-human” and perform like machines; or the entertainment applications (the light shows on stage will continue to get stronger) I’m not sure what the killer app will be for mainstream consumption in wearables. In the next few years I think it will exist mostly in mainstream sportswear – continued heart monitoring, bio stats, and lights for joggers. I think it will also grow in the environmentally-friendly realm – anything that will power-your-phone or computer with solar or kinetic energy etc. In sports – because people will find it cool, and in the eco-world because people will really feel good about those purchases. I would.

Right now we have all the ideas, but not all of the technology. Because of that it’s hard to test out our ideas in “real life” and see if people really want them. There’s so many great prototypes coming out of company research labs and university research labs, but very few of these ideas are brought to market because the technology isn’t there, or the cost is too high to actually create a viable business.
This is what I find to be the reality of the situation – that we’re going to have to just sit and wait and have some patience for the technology to start meeting the level of our ideas… The fact of the matter is that our ability to prototype things nowadays is very sophisticated, so getting people excited by the possibilities of wearables is very accessible to designers. Our imaginations are extremely active right now. When the technology for electronics-on-our-bodies becomes cheaper and more sophisticated we’ll watch new companies spring up out of nowhere and either succeed or fail with these new types of products. Then – we’ll start to see what sticks.

So even though I’m basically saying I have no idea what's going to be the type of wearable product in the mainstream that everyone loves (Joey Berzowska once told me it was in social media use; and I read in Wired magazine a few years back that it was in checking your bio stats online…) I really enjoy engaging in the challenge of trying it out anyway! My tactic has been to use technology that already exists (bicycle lights) and redesign the boards and wiring to be lightweight and clothing-friendly. I don’t need an innovative research lab, I don’t have to pay too much for the customization, and I can sell the product knowing it will work. As an independent designer – this is the only way I can get my idea out there and test the market – by doing it now and doing it simply. I think the more companies that take the plunge into this unknown territory (now, sooner than later) the quicker we will get an idea of what's going to stick. I think it will be hard for those who do it first (including me) because we’ll spend a lot of money pointing things in the wrong direction – but at some point it will be clear where wearables “fit” in mainstream consumption. Also, we will have paved the way for other companies to swoop in and do it better. It’s a risk, it’s not easy, but it something good will come of it – I’m sure.

If I had it my way, we’d all be living in a world I like to describe as “Audrey Hepburn in space” – where we are all onboard with the idea of lights in fashionable clothes and digital fabrics that change in beautiful ways. I was a big fan of Tron, and my boyfriend and I saw it 3 times in theatres. For me, it was the fantasy of living in such a stylized, electronified world. The best I can hope for now is that the rave scene comes back extremely strong and is really into high-fashion…??

8.5 Analyzing and selecting ideas

I gathered all the insights and ideas from the academic literature, the online study and the workshops. The ideas were selected partly based on their mainstream potential (how likely would it be that the idea would appeal to large parts in a society) according to my judgement as a designer, but also based on how important they seemed to be to the participants (whether they came up multiple times for example). I wrote each idea on a piece of paper with a short description and key features.

At this point, the participatory design oriented activities in my project come to an end and I review and combine the insights gained so far with my own judgement as a designer.
Selection of ideas: finally selected ideas (1) and discarded ideas (2)

After writing down all the ideas, I went through all of them again and selected the most promising ones (1) and sketched them out so that I could show and discuss them with other people in a comprehensible format.
This idea revolves around the notion that you could change the way you look instantly - on the go. You could change the color and/or the pattern on your garment.

The garment would have the capability to store different patterns which the wearer can change wherever he or she is without changing clothes. On the one hand, the wearer could buy new patterns for an existing garment or create his or her own patterns with a special device and share patterns with other people. This would lead to less consumption in terms of physical garments which would slow down the speed of fast fashion a little in terms of production. But there is still enough room for the fashion industry to make money: through selling digital styles that the users can buy to customize their garments.

The idea was inspired by some of the comments in the online study:

- "I guess I would like a clothing where I could download patterns and customize it how I wanted it to be. Photos of friends on the garment would be awesome and stupid at the same time. But a clothing that could keep me creative with it. Make me do illustrations to place on it."
- "Earrings that will adjust their color to fit with my clothes"
- "If I'm bursting with energy and if I'm feeling good, I like to wear red. If I'm not feeling so good (just tired or even sad), I wear something comfortable with darker colors..."

The idea could also have a more utilitarian twist as one can see from the ideas suggested in the study and the workshops:

- "I want a shirt to change colors when I've received enough sunlight for the day so I don't get sun burned, and I want it to change to be a different color if I'm not getting enough sunlight to begin with."
- A shirt that turns color when the wearer is in a polluted area. The shirt could have different colors for different pollutants.
- A suit or jacket that changes color when the wearer is drunk.

Another inspiration to this idea came from Fashioning the Future (Lee, 2005, p. 82). A concept is presented there which suggests a subscription service for garments that can change color: “Fashion brands might offer downloads of the latest colours, prints and graphics. For instance, $200 a month could buy a ‘couture’ service from Chanel or $20 a month would obtain the chain-store option from Gap.”

8.5.2 Shape shifting garment

![Shape changing garment diagram]

This idea is an add-on to the color / pattern change idea. What if you could not only change the visual appearance of your garment but also its shape and form? The garment could hide or reveal different parts or grow new ones as well as extend and contract its shape. This makes a specific piece of clothing even more customizable and personal as well as even more adaptable to different situations.
8.5.3 Smart label

In this case, a garment contains an augmented label. The label can tell the wearer when he or she should wash the garment. This would mostly apply to garments that you do not change each day like jackets, sweaters, pants or even suits. Additionally, the smart label communicates with the washing machine when the wearer wants to wash it. The smart label sets the right washing settings and the wearer does not have to be worried about damaging clothes because they are washed with the wrong settings or with the other clothes that should not be washed in the same load. It could also help to save water and only use as little detergent as necessary to make the washing process more environmentally friendly.

The idea came up in a discussion and was also inspired by a comment in the online study:
- "I hate clothes with special washing instructions because I have bought a lot of clothes I like only to find that the washing instructions are complicated and time consuming, so those clothes get worn once and that’s usually about it.”
8.5.4 Harvesting energy

This idea proposes to use the body's energy (energy generated through movement) to charge personal devices like mobile phones. This feature serves as an extra motivation to keep exercising or just simply taking the stairs. Normal pedometers just tell the user how many steps he walks - in this case there would be an additional motivation to keep up the exercise.

The idea also supports a more sustainably minded lifestyle. On the one hand, the user would be encouraged to walk more than taking the car for example, but also it would lead to less energy consumption because the user would not have to charge his personal devices anymore.

The idea was inspired by a comment in the online study and two ideas in one of the workshops:

- "electricity became issue for me so i wish there was a way for all of them to get electricity charging when i am biking around or i am walking. we spend energy all the time when we move we walk and when we bike. why not our clothes could absorb it and do some fancy things for us?"

- A clothing system that absorbs the energy that a person generates by walking, running or biking. The energy could be used for all kinds of applications, e.g. charging personal electronics.

- Shoes that count the steps a person takes each day and notify the wearer if he should walk more because he has not achieved a certain amount of steps a day. Different shoes sync up with each other when the user walks over the door mat in his home.
In this case, the wearer can literally decorate her clothing with her friends. The idea is that you can customize your clothing and create your own identity while having your friends close. There are different decorative elements (like buttons) that each represent a friend. The particular friend also has a similar pin that represents the initial user.

When the wearer taps a button, the friend feels a light vibration. On the other hand, when the wearer touches her phone to the button, she can select to send a text message or call the friend. A text message would appear inside the friend’s button which can be opened up like a pocket watch.

The idea was inspired by comments in the online study and an idea in one of the workshops:

- "I guess I would like a clothing where I could download patterns and customize it how I wanted it to be. Photos of friends on the garment would be awesome and stupid at the same time. But a clothing that could keep me creative with it. Make me do illustrations to place on it."
- "Since I wear different clothes every day I would like it to be attachable to all my clothes."
- A blouse / shirt that with which the wearer can poke their office mates and turns the office into a social game space.
8.5.6 Integrated phone / MP3 player

This idea features a jacket or hoodie that has an integrated phone or MP3 player. I put both ideas into one because even though the explicit functionality is different, the idea behind is quite similar. Since it is not a new idea, I tried to find new kinds of interactions. To change the volume, the wearer would slide their hand up and down the zipper (without actually moving it), to take a call or go to the next track, the wearer would pull the laces.

The idea was inspired by comments in the online study:

- “It can be nice to receive text messages and reply them without taking the telephone from pockets.”
- “the cloth will help you connect to your cell phone via bluetooth system to be able to connect to your cell phone with tiny headsets and tiny microphone. It looks like implementing hands free headset in your hoodie. Also, it gives you hand synchronizing with your Mp3 player to listen to music and the motion of hand will decrease or increase the volume of Mp3 player or Cell Phone.”
- “A hoody that has an integrated mp3-player/mobile-phone in it. best would be on the arm, so I could check my songs and texts and stuff on the run <3”
- “Maybe a phone inside my jacket.”

8.5.7 Conclusion

In my opinion, the color / pattern change idea has the most potential for a mainstream smart garment because it is not so much about technology but about fashion. It is about the relationship of the wearer and his or her garment and exploits his or her sense of individuality. Therefore I think in the short term, this could have the most potential out of the five chosen ideas. It also reconciles the incompatibilities of fast fashion and the development cycles of electronic devices.
Harvesting energy and the smart label are also promising but both are more of a background application - they help in everyday life and make life easier but maybe do not have the "sex appeal" to get a lot of people buying them on their own.

The jacket with an integrated phone / MP3 player only made it into the final selection because of its popularity. It surprised me a little bit that at least four different people in the online study came up with this. Some even suggested a soft control panel on the sleeve which I am personally opposed to and which actually decreases usability as shown by Dunne (2010). I still included it in the final selection of ideas because there clearly seemed to be an interest on the participants’ side. So I tried to find interactions that would make more sense than a soft control panel on the arm and would exploit the physicality of the garment itself.

In the end, I decided to combine the three ideas I considered most promising into one concept: a garment that can change color or pattern, is powered by the body’s movement and has a smart label that helps to keep it clean and easily washed.
8.6 User feedback

To get feedback from potential users, I conducted informal interviews over email or in person with six people - students as well as professionals from different areas, 4 women and 2 men. Some were chosen due to their involvement in the project so far, but I also included new people to get insights from a different angle. I sent or showed them the sketch above with a description and asked a few questions concerning what they thought about the idea, if they would wear and use a garment like that and if they would create styles for themselves. The following section includes a few of the reactions.

Contrary to the study, there was no negative feedback at all. Everyone was very positive and thought that the idea was very inspiring:

"I especially like the fact that I can create my own patterns and use/share it with others. This would be a nice way to personalize my clothes and express myself through what I'm wearing. I also like the fact that you can change pattern and adapt to different situations fast - you never know when a day at the library turns around into a "night out" later during the day."

"Anyway as a person who changes clothes often I would appreciate something like that especially when there is not enough time or a sudden event comes up."

The factor of sustainability was very important:

"I also think it is important that the clothing is powered by me, for the sake of the environment. Sounds like something I would definitely love wear."

But the feedback made clear that the smart label should only be something to facilitate the washing process. Different people remarked that they could just look at the clothes or smell them to detect if they need to be washed:

"I just have to look at the shirt and see it is wrinkled, covered in dog hair and mustard stains (or, I just have to smell it)."

Some new ideas came up:

"In terms of the pen idea, I can imagine someone drawing a squiggle on their ipad or with their stylus on their blackberry and then having a shirt-program that replicates the squiggle hundreds of times in a 'font size' of your choice, to create a pattern that downloads to the shirt. Or, a photo of something, say a flower, downloaded from your handheld media (Android, iPhone), to the shirt, either on the front as a single image, or replicated every few inches (again, the idea of a font size governs the size of the pattern)."

"I would suggest a 'mirror' app for handheld devices, which makes the handheld screen into a virtual mirror, shows you the shirt on the screen with the new pattern on it before you go to the trouble of downloading the pattern/image onto the shirt you're wearing. [...] you can change the design at work on your handheld device on the dress you're already wearing, and program the dress to change its style on a two-hour delay for when you leave work [...] a woman walking out the door in the evening from an office and her dress magically changes from black to gold."

"I envision that the line of clothes would be in simple 'shapes' like American Apparel's lines or J. Crew or Eileen Fisher and other mall stores or "high street" stores to use the English word to indicate stores that you find in every town. These companies take a couple of simple shapes (a skinny pant, a wide-leg, a bootleg; a girly tee shirt, a boyfriend shirt, a boxy wide-necked shirt) and do permutations on color and fabric and number of buttons -- the detail stuff. Your clothing line could have a few "key" shapes and styles -- a black t-shirt, a basic pant -- and then the

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permutations on detail are supplied by the customer. And every year or so, the line would add a few new shapes to reflect broader trends — for hemlines, for the cut of pants. But the actual rate of fashion turnover for the basic designs (the hardware of the shirt) would be "slow", because the individual time scale for each piece is actually very "fast" — changing designs and styles every day or hour for the customer."

"Why do they have to buy styles? Can it be an open market of people being creative and sharing, for free?"

"What if the patterns fade after extended use... and you had do upload new ... or if you sat down too much they fade as the battery got low. So you had to keep moving."

"A natural interaction (for me) to remove a pattern would be to press the garment together, as one tosses a paper. Or to whisk it off."

It was also remarked that this concept could change the perception of fashion: "I like that the garment is an open material, which allows the user to implement their meaning and values to it, more freely than by just buying a garment."

"Fashion is changed by the individual at any time, and 'shared' between people in the same way that photos are shared on a Facebook wall. You can 'grab' someone's style/design for your own, and share between friends, but give it a twist [...]. It's do-it-yourself fashion, whose timespan is not the matter of months of the fashion world (spring fashion, fall fashion) but day by day or hour by hour. It also seems to be eco-friendly because you don't discard 'old' fashion, but create new fashion on what you already have."

It was also interesting that one person came up the idea of a shape changing garment again — a part of the the concept that I had cut out for various reasons - most of all to keep the concept simple. I felt that if the user would have to think about the color and the pattern of his or her garment as well as its shape, it would be quite a cognitive burden for changing a garment on the go. It could be a further development once a color changing garment is as common as a plain t-shirt is right now. Dunne (2010) also argues that designers should rather pave the way gradually instead of going for the revolution.
9. Concept

The following section describes the final concept that I came up with based on the insights, ideas and feedback from the previous chapters. First, I narrowed down the potential target group for the product, then I defined the aesthetics and interactions more closely and finally the whole circle of products and services around the garment itself.

9.1 Target group

As a promising target group, I suggest the generation of digital natives - a term coined by Marc Prensky (2001). He describes digital natives as the first generation of students who "have spent their entire lives surrounded by and using computers, videogames, digital music players, video cams, cell phones, and all the other toys and tools of the digital age". This applies primarily to people who were born after 1990. Therefore the target group would be between 15 and 25 years, female as well as male. If you consider that this concept is a product of the future and maybe a reality in 5 to 10 years, then the target group is around 15 to 30 years old. They are following the quick fashion trends more than other target groups and have grown up with the mentioned technologies and are likely to have an open mind towards technology in general. Therefore they are most likely to be the first to buy this type of smart clothing before it becomes fashionable for everyone. Their idols in the music world like Katy Perry, the Black Eyed Peas, U2 and lots of other artists already wear LED costumes today and pave the way for future developments. The proposed piece of smart clothing supports the target group’s individuality and the desire to set yourself apart, while at the same time it brings people’s creativity together by sharing styles.

Admittedly it is a broad target group including teenagers, young adults and adults which might be problematic because 15 year olds have little in common with 30 somethings. But the core group will be somewhere in the middle. When developing the idea, I thought it might target more women than men, but feedback showed that men are also interested in the idea.

9.2 The garment

The following section details the core piece of the concept: the garment which can change its style in any way the wearer wants. There are two versions - a female and a male version.

9.2.1 Mood boards

To design the garment itself, I started by collecting inspiring pieces of fashion or details from fashion websites and social networks like Pinterest. From these samples, I created mood boards to give me some inspiration for the fashion side and define a general style for the garments. The mood boards show different pieces of clothing or details that inspired the final design.

4 http://www.pinterest.com
Mood board for a female version

Mood board for a male version

Martina Uhlig
9.2.2 Product / fashion design
Following the mood boards, I made a few different sketches of the garment. In the following sketch for the female version, the parts in grey represent areas of the garments which are not reactive - the white parts of the garments have the ability to change pattern and color. This division creates an overall look and makes sure that the garment looks fashionable in any configuration.

Sketches for the female version

Sketches for the male version. Left: white part changeable; right: grey part changeable
For time reasons, I only went on refining the female garment.

Refinement of the female version: in the end I selected the one on the left
What it could look like: Different styles for one garment
Inspired by the fashionability of the related projects described in chapter 5 and the examples from the mood boards, I was aiming to create a garment that would be fashionable, but also act as some sort of "container" for the styles that the users can buy, share or design themselves. But it should also work without its function even though being out of battery should be hard to accomplish if it is powered by the body’s energy. Still, the garment should provide an already fashionable basis. On the one hand, I am aiming for a little bit of futurism, but on the other hand it is not intended to be a product in the far future, so it should still be quite "down to earth" and based on today’s fashion. What it should definitely not be is a wearable display where you can see the edges of the screen. First and foremost, it should be a garment which has the ability to change how it looks, but it should not be animated or even feature real time video. The public space is already full of moving images in the form of advertisement etc. therefore I did not want these garments to add to the frenzy of moving imagery in the public sphere. Animation in a subtle form is something like the shape changing aspect that could be considered once the garment has established itself in the market for a few years already.

Two integral but not visual aspects of the garment are the power source and the smart label. The smart label is the brain of the garment. It is sewn on inside the garment and connects the garment to a mobile device which helps to buy and organize styles. The label also assists the user to accurately take care of the piece of clothing. When the garment needs to be washed, the label communicates with the washing machine and sets the right settings accordingly therefore simplifying the washing process and making sure that the garment is handled appropriately. The core idea behind the garment is that the energy flows in a circle which means that the wearer generates the electricity needed to power the garment himself. The garment absorbs the energy which is created from the wearer’s motion and converts it into electricity which charges an integrated battery in the garment. In this way the garment promotes less energy consumption and sustainable behavior. A side effect for the user is that he does not have to remember to keep yet another thing charged.

9.2.3 Interaction with the garment
The wearer interacts with the garment in different ways to change, share, create, organize or buy styles. Most of these interactions are touch plus gesture based. That is mostly because touch and gestures do not require additional devices for interaction. Since there is no established precedent for clothing based interactions, I tried to find analogies in other areas.

Changing styles
The garment can save a number of different styles for the wearer to change on the go. When the wearer slides her hand over the front side of the garment, the current style fades out and the new style fades in quickly. To go through each of the saved style, the wearer needs to repeat this gesture.
The number of styles saved in the garment should be limited to around 5 to 10 styles, otherwise it will get too complicated to handle the collection without a screen to preview and organize the styles. The wearer can organize styles on a mobile device, but she should not be required to take out the device whenever she wants to change the style.

Sharing styles
When a user has created a style herself or downloaded a free style, she can share it with other people. To do that, the person sharing and the person receiving have to shake hands (make skin-to-skin contact in a different way) and the person sharing the pattern then performs a sweeping gesture on her garment. The style then moves from one person to the other but reappears on the first person's garment.

Apart from sharing styles for free face to face, there is also an online platform for people to upload their styles to and get other people’s styles. The style can be uploaded from the mobile device.

Styles that have been bought can only be shared for a short preview. The garment will still remember the style and the user can buy it through the mobile device later from the service where the first user has bought it, but paid styles can not be traded on the go.

Creating styles
A user can create a style in two different ways: On the hand, he can get an interactive pen to draw directly on his garment like with pen and paper, on the other hand, he can use his mobile device to create a style. There he either has the possibility to draw a style for a whole garment from start to finish or to create a repetitive pattern from a small drawing. The device repeats the drawing / picture in a way specified by the user and creates a style from that. The mobile device can also snap or import pictures and isolate the desired elements from the image and create a new style based on that.

Organizing styles
On the mobile device, the user has access to all the styles he owns and he can edit, remove, share or sell them.
Buying styles
There is also the option to buy new styles online and preview them with the mobile device. Comparable to current app stores like Apple’s App Store, the user can browse collections of styles on his mobile device and buy styles he likes. The system suggests new or popular styles, but also styles based on the previous purchases. If the user wants to get a new style but is not sure if it looks good, the mobile device can send the style to the garment which can then display it for a limited amount of time.

Reselling styles
From a business perspective, it would be desirable that users can not resell the styles that they bought because this would mean less revenue - and the revenue is already lowered because of less consumption of physical garments. If there was a secondary market where users resell their styles (possibly for less), then there is no incentive for others to buy styles from the original fashion companies. It is not like a flea market or second hand store where you buy other people’s old stuff which obviously has been used before and is not brand new - digital things do not age, so they are still brand new when they have been used by dozens of people.

From a user’s perspective though, it makes no sense why you should not be able to resell what you own. If you think about any app store today, you wonder why you can not resell the apps that you are not using anymore. The only thing you can do is to delete them and with that, the money you have spent on them goes down the drain.

As a designer with a business oriented background, I have the desire to create economically viable solutions, but on the other hand balance the user’s interest. But since this project is future oriented and concerned with new approaches, it would be time to depart from the restrictive business model of walled gardens that companies like Apple practice today. Resolution: Users should be free to sell their old styles.

9.3 Products and services around the garment
Apart from the garment itself there are a few products and services which complement the garment: an interactive pen and an app for a mobile device make it easy to create new styles and an interactive mirror helps people choosing styles in store etc. Some part of this has already been explained in the previous section.

5 http://www.apple.com/iphone/from-the-app-store/
9.3.1 Interactive pen

There are two ways to create new styles: with the help of a mobile device or with a special pen. The pen can be bought separately and makes it easy to create new styles. Like with pen and paper, the user can directly draw on the garment. To start drawing, the user pushes down the back of the pen which makes the tip come out (like with a ball point pen) and draws on the fabric surface. The garment notices the proximity of the pen and makes the currently displayed style fade out. The user can start drawing. On the side of the pen is a small touch enabled display with a color gradient that the user can choose colors from.

To erase something, the user just needs to turn the pen around like with a pencil which has an integrated eraser in the back. Once the user is done, he pushes down the back of the pen again which sends a signal of completion to the garment. The garment the saves the new style.

When the user wants to edit a style, she operates the pen in the same fashion. When the current style on the garment has faded out and the garment is blank, the user changes the style to the one she likes to edit. Even styles which have been bought can be edited.
9.3.2 App for mobile devices
There is an app for mobile devices like smart phones or tablets that the user can download when he bought the garment. The app saves all the styles that the user owns and within the app, the user can organize his styles, buy or create new ones and delete old ones that he does not want anymore. The app has a list of favorite styles which are the ones that are available for the user to change on the garment itself. The list is limited to around 10 styles so that the interaction when wearing the garment does not become too complicated. The user can add or remove styles to the list whenever he wants. The mobile device then connects with the garment’s smart label and syncs new styles which have been added or removed.

9.3.3 Interactive mirror
In a store context or another type of public setting, an interactive mirror helps the user to buy a new style for his existing garment or for a new garment that he selected in the store. The user can see his reflection in the mirror, but at the same time see the options of different available styles. He can preview the styles on his own garment and see if it is to his liking or not. The surface of the mirror is touch enabled, so the user can browse styles on the mirror and then preview them on his garment.

The user could also have such a mirror at home to preview styles when getting dressed in the morning. The mirror would also be used to organize the whole collection of styles that the user has. Instead of extensively looking through the wardrobe in the morning, the user would browse all the styles in his collection on the mirror in the bathroom before leaving the house. Basically, the mirror could be the more expensive option in addition to the mobile app.

9.3.4 Online platforms
There are different online platforms that the user deals with through his mobile device: on the one hand there are platforms where the user can only buy styles - like branded platforms by fashion houses - and on the other hand there are open platforms which are either driven by users or companies where users can buy styles from any source (fashion houses, independent designers, others users) but also share their own styles for free or for a price as well as resell their old styles.
10. Prototype

After detailing the concept, I created a partly functional prototype to illustrate the design concept. I sewed a t-shirt version of the concept from scratch made with thermochromic fabric and two covered heating circuits to provoke a color change. The prototype should be understood as a sketch of a possible future - it is neither a marketable or practical solution nor does it fully reflect the concept. It serves as a tangible illustration of a small part of the concept and it is as much as I can make working today. It reflects how one could have a shirt with different styles and how these would be changed.

Me wearing the prototype and switching between the two existing styles
10.1 Materials

To make a color change happen, I used fabrics dyed with thermochromic ink. The pigments in the ink turn from color to transparent at around 30°C. This means when the temperature of the fabric is above 30°C, the original color of the fabric appears - in this case white. It is possible to combine regular colors with thermochromic colors to achieve more intricate color changes, but in this project there was no time for a more detailed experimentation. Therefore I decided to buy dyed fabric instead of buying colors and dyeing the fabric myself.

To provoke the color change, there are heating elements made from conductive thread taped on behind the fabric. To figure out how long or short the circuit should be was quite hard. If the circuit is too short, too much electricity passes through and damages the battery and if the circuit is too long, there is not enough electricity to heat up the thread. I used conductive steel thread with a very low resistance of 4.6 ohms per meter.

A problem with the materials used is that it takes around 30 seconds for a circuit to heat up enough and therefore the pattern to become visible, and around 50 seconds to cool down and disappear again - not quite the quick pattern change that I imagined for the concept.

In the concept, the only feedback the wearer gets when changing a style is that the current style fades out and another one fades in. But if that takes very long - like in the prototype - additional feedback is needed to show the wearer that something is happening. When trying out the prototype myself, I found myself wondering almost every time whether I have touched the right position and if the pattern is changing now from the first to the second or if the first one is still active.

At first, I was trying to make more complicated patterns than the ones you see at the beginning of the section but after some experimentation I had to go back to more simple forms because the lines were bleeding and the result did not look good.

Early (failed) experimentation concerning the styles

It was also quite problematic to connect the different pieces of a pattern together. Where the conductive thread connects to regular wires to bridge the distance, it heats up more which creates a stronger (not wanted) reaction in the fabric. If the connecting wires are too short, they also start to heat up and create a color change in locations where there should be none according to the design.
10.2 Technology

The heating circuits are controlled by an Arduino LilyPad in a pocket on the back side of the shirt. The LilyPad turns the heating circuits on and off according to which style the wearer chooses. There is a touch sensor integrated on the right side in the front which tells the LilyPad to activate the other circuit when pressed. The heating circuits have their own power supply - a combination of two 3.7 V LiPo batteries connected in series which doubles the voltage.

The circuit is based on an example from an MIT course by Leah Buechley. I used stainless steel conductive thread because I found in a number of examples that this conductive thread was used for heating, but experimenting myself I found out that conductive thread made from silver works just as well.

10.3 Possible technical solutions

Even though the materials and technology used for the prototype are not suitable for a real solution, the concept is not completely pie in the sky. I think it is important as a designer not to be constrained by the material too early in the design process but on the other hand, it is important that a design concept ultimately has the ability to be turned into a reality. There are different approaches that could make this concept possible in the future:

10.3.1 Electrochromism instead of thermochromism

Meunier, Cochrane and Koncar (2011) describe a reversible color change in textiles that is not based on temperature but on electricity. The color changes within 5 seconds and only needs as little as 4.5 Volts. It is still under development and will surely still need a few years to be ready but it is a possible way.

10.3.2 Miniature LEDs

The only reason why the concept stirs away from using LEDs in fabric is because they are currently still too big and not flexible. If they would become smaller, could be integrated into the fabric during production and the fabric therefore would stay soft and flexible, then there is no reason not to go this way.

http://newtextiles.media.mit.edu/2012/?p=535
10.3.3 Piezoelectricity
The underlying thought behind the described concept is that the garment is charged by the wearer's motion. This could be possible through piezoelectric film or fiber integrated into the garment. Piezoelectric materials can turn motion, vibration or pressure on the material into electricity. Last year, the telecommunication provider Orange (2011) tested t-shirts at a festival which should keep the wearer's cellphone charged for the duration of the festival. The shirts had piezoelectric film embedded into the front which turns the vibration of the music and the wearer's motion into electricity. To keep their phones charged, people wearing the shirt could plug their phones into the shirt. If the shirts lived up to the claim to keep phones charged is unknown to me though.

10.3.4 Soft components, flexible batteries
As mentioned before, there are already plenty of electric components turned into soft and smooth counterparts like wires to conductive thread or pieces of metal to conductive fabric. But even components like batteries can be made flexible and soft - these can even be integrated into the very fabric of the garment itself (NewScientist, 2012).
11. Reflection on the design process and on the project

In this section, I have compiled a few of the insights that I gained from undertaking this project and from choosing to go about it the way I did.

11.1 Interaction design vs. fashion design

Interaction design always involves other disciplines. In this project, I ventured into fashion design based on the nature of the concept. But this does not make me a fashion designer. What separates me from the fashion designer is that the outcome of this project could have been something completely different. At the beginning of the project, the end result was totally open.

As an interaction designer, I also address what is beyond designing a garment and its implications on people's lives. It is not quite a fashion designer's job to think about how people would create styles or how these styles would be transferred to the garment.

My approach as an interaction designer centers around people and how they use products or services - both digital and physical. My concern with materials - fabrics in this case - only arises from this approach and is necessary to this project - but it is not my primary occupation and concern.

11.2 User-centered design vs. participatory design

In my opinion, user-centered design and participatory design do not contradict or rule each other out. Combining both approaches takes the best from both worlds. Of course a tension is created between the underlying philosophy of participatory design to be democratic and the rather autocratic position of the designer in user-centered design. This is why I only borrow elements from participatory design. On the one hand it is important to talk with real people, hear their stories, listen to their needs, but on the other hand, in my opinion the designer has the specific knowledge to draw the right conclusions from that and come up with a design that satisfies all stakeholders involved. This can be inspired by the users' ideas, but not the whole process should be solemnly steered by the users.

From the perspective of a participant in this process, it was clear from the start that the participants have the possibility to express their views and suggest ideas but also knew that I would not do everything they said. This was due to the nature of the project - a student project as well as research project - but also due to the setup:

The difference to other projects is that it is clear from the start that we will not see the end result happen today because it is not targeted to take form today - this takes away the pressure from me as a designer and it was clear to the participants that they would not see their suggestions being turned into a real product.

11.4 Present vs. future

It is easier for most people to improve on something existing than to imagine something new and try to envisage using it in their daily lives. So the problem with involving real people into a future oriented project is that it is hard to imagine what the future could be like and what needs and desires they might have then. What
might be a need today, could be completely obsolete tomorrow because the circumstances have changed and it is replaced by something else. But on the other hand this does not mean that therefore, real people should not be involved into the design process. Their insights are still valuable. But it takes a set of different approaches and the knowledge of the designer to decide what might be important and what might not be. I am not an expert about the future either and I do not know what it is going to be like - but at least I have tried to immerse myself in the topic as much as I can through research.

11.3 Top down vs. bottom up approach

In my own practical research, I tried to approach the subject from two different angles: from the perspective of potential users but also from the perspective of experts in the field. I have already described the problems with user research if the subject of the research is a novel idea or product. To counteract this problem, I tried to get additional insights from experts working in the field which would help me in my specific research area. I do not think that this contradicts user-centered design - for me it was an addition to the user-centered process. But including experts in the process did not work out as I would have wanted it to. A reason for this is that the experts were just not accessible to me. In most cases, contacting them did not produce any result. Therefore I relied on the insights gained from the literature research and from engaging with potential users.
I have tried to give a comprehensive overview over the design space, the academic literature concerning the field as well as covering practical examples of projects within the design space. Also I have tried to shed some light on different possible angles to the field from the viewpoint of potential users as well as from an expert’s perspective.

I evaluated and analyzed the insights gained and engaged in a design process that resulted in a design concept and prototype aiming to be an answer to the research questions asked in the very beginning. The concept and the prototype represent one possible answer out of many because in the end I have come to believe that there is no killer app for smart clothing. There are rather a lot of possible answers out there which could all contribute to a killer lifestyle.

In this concept, clothing becomes a canvas for the wearer’s creativity. There are no limits to the artistic possibilities that arise from this. Everyone could design their clothing the way they want it to look like or customize existing styles and make them personal. But in the end, this is not a must. If you do not have the time or the patience, you could still buy clothing the way you used to - just with a twist: You buy a ‘plain’ garment and then you can buy all sorts of styles as digital accessories. Fashion would change to become much more individual on the one hand and more democratic on the other hand. Like energy flowing in a circle on the micro level (between each wearer and the corresponding garment), social energy starts flowing on a macro level. Styles are freely created, shared, remixed, resold, created and so forth. Since everyone can design their looks themselves, designing fashion would not be exclusive to fashion houses anymore. Fashion cycles would move at the pace of the people, not the fashion houses. The usual order of spring, summer, autumn, winter collections would be broken up and would accelerate to cycles that last weeks or even only days. Popular styles could spread as fast and far as Internet memes do today. Even though fashion houses might lose their power to steer the evolution of fashion exclusively, I do not see fashion houses going under - they would rather have to accept the changed market order. On the one hand, they make the physical garments that make the whole thing possible and on the other hand, I think most people would still get their styles from fashion houses - due to lack of time, desire, or talent to create designs themselves.

The strategy is to target a small group of early adopters and then move from this group slowly to the mainstream. Fashion has a history of styles from subcultures impacting or entering the mainstream. Therefore this seems to be a promising route to achieve mainstream adaptation. It will take longer, but to try and target the whole audience from the start - with the absence of other smart clothing applications paving the way - seems unrealistic. Since the majority of people care about how they look, this concept could have potential in the future - but rather in ten years then in five, I assume. Issues like health implications by wearing technology all the time still need to be sorted out before most people are at least convinced that smart clothing might be a good idea.

This approach also solves the issue of fast fashion vs. the slower evolution of electronics that was pointed out in chapter 4. Since the physical evolution of fashion would be slowed down due to the use of digital styles rather than new generations of clothing collections, electronics could keep up with the pace.
To conclude, I have shown a possible solution of how we can interact with clothing in the future and how technology and clothing can fuse to be one and to be recognized as one. It shows how technology could be applied in a very non technical context like clothing, how enabling people’s creativity could have a huge influence on the way they deal with clothing and how a whole industry could become more oriented towards real people engaging with it.
13. Acknowledgements

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- all the participants of the online study
- the participants of the workshops
- everyone giving me feedback and critique
- Sveta and Marcus for being there
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Pictures:


2011. *Figure 4:* Assembly. [electronic print] Available at: <http://cargocollective.com/sinclaire/#939465/assembly> [Accessed 14 February 2012]


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All other pictures used were created or taken by myself.

Appendix

Online Study

The study was conducted through eSurveyspro (www.esurveyspro.com) and split into four pages.

**Page 1: Hello**

I started this survey and invited you to answer it because these questions are relevant to my master thesis. On the third page, you will learn more about the topic. The survey contains 4 pages with 11 questions concerning general demographics, fashion and electronics.

What happens with your answers: I will analyze the responses and include the results in my thesis documentation.

(Side note: You can answer in any language you like and which I understand. That limits the options to English, German and French. ;)

1. Please describe yourself shortly. How old are you, are you male or female, what is your occupation and which country are you from? (This helps me to qualify your answers and compare them with others)

2. What factors are important to you when you choose your clothes? When buying them as well as when putting them on in the morning.

What do your clothes express about you?

Martina Uhlig
4. Describe a usual day in your life: How often do you use technology during the day and for what reasons?

Page 2: Technology

5. What kind of things / electronics do you carry with you all the time, wherever you go?

6. How do you carry them? Do you carry any close to your body? Why do you carry them in a particular way?

7. What do you use them for and how much do you use them actively and passively?

8. Are you satisfied with the devices in appearance, form and functionality?

9. Are there certain situations where you would like to have additional technology that you don’t or can’t carry with you all the time?

10. Are there situations where you would like to get rid of technology?

Page 3: Your ideas

Introducing the subject of my thesis: Smart clothing

Put simply, smart clothing refers to clothing which has electronic functionality integrated into the fabric. So basically it combines electronic devices with clothing.

A few examples:
a shirt that continuously monitors an elderly person’s heart rate and which can notify an ambulance in the case of a heart attack
an evening gown that has integrated LEDs which light up the dress, the LEDs sparkle when the person wearing the dress moves
a snowboarding jacket which lets you control your MP3 player without taking your gloves off (when you slide your glove up and down on the front zipper of the jacket, the volume goes up and down, when you shake your right hand hand, you skip to the next track and with the left you go back to the previous track)

11. Imagine you have a piece of smart clothing. In contrast to the examples it should be something you can wear everyday. What would it do and how would you use it? (Imagine that your wardrobe is full of other clothes of that kind and that washing and powering it doesn’t matter)

Page 4: Thanks a lot!

You helped me a lot with your answers. I’m sure they are very interesting for my research.

12. If you don’t mind, could you put your email address here if I have any follow up questions?
Thesis survey

Answers marked with a * are required.

1. Hello

I started this survey and invited you to answer it because these questions are relevant to my master thesis. On the third page, you will learn more about the topic. The survey contains 4 pages with 11 questions concerning general demographics, fashion and electronics. What happens with your answers: I will analyze the responses and include the results in my thesis documentation.

(Side note: You can answer in any language you like and which I understand. This limits the options to English, German and French. :))

1. Please describe yourself shortly. How old are you, are you male or female, what is your occupation and which country are you from? (This helps me to qualify your answers and compare them with others)

2. What factors are important to you when you choose your clothes? When buying them as well as when putting them on in the morning.

3. What do your clothes express about you?
I hope you have enjoyed the reading.