Abstract: Currently, the field of Smart clothes is twofold: On the one hand Smart clothes are driven by technology and on the other by art and Haute Couture. In both cases clothing neglects the needs and wants of customers and the requirements of daily use. Clearly, Smart clothes are hybrid products. They afford interdisciplinary cooperation and an integration of reliable technology into socially and culturally acceptable pieces of clothing. Starting with a mapping of the state of the art this paper investigates, from the perspective of product semantics, the character of Smart clothes. A scheme for a detailed design briefing was set up and in collaboration with a product designer and a textile designer we developed designs that should overcome the gap between technology-driven and art-driven pieces of clothing.

Key words: Product Language, Product Semantics, Smart Clothes, Practice-based research.

1. Introduction

Smart clothes have the potential to offer additional value to customers and to give companies a competitive advantage. [2, 7, 12] Research laboratories in industries and universities such as the Swiss Federal Institute of Technology (ETH) in Zurich are advancing the technical development. Generally scientists consider Smart textiles and clothing as a means for “achieving closer interaction with technology” or as an enabler of “intimate man-machine interactions”. [15] When it comes to the implementation in terms of marketable products the focus is still mainly on technical aspects, rarely on appealing or emotive garment results. [7] The integration of the technical components into the garment is deficient, partly because components – particularly the batteries – are bulky and heavy, and partly because on the engineers’ side, a lack of understanding of the role of fashion in society is prevalent. [3] At the same time the available technologies inspire artists, costume designers and couturiers to create conceptual pieces that are neither suitable for daily use. As always when new technologies are in status nascendi they act as "amplifiers of fantasy", [11] resulting among other things in oddities. Without underestimation of the contribution of engineers and artists to the development of Smart clothes, in both cases, customer needs are neglected. Cultural and social acceptances of Smart clothes as well as requirements of daily use are out of focus. Sometimes even the intended use value does not make much sense. Clearly, Smart clothes are hybrids, which combine elements from technology and textile. [7] Since they compete with traditional clothing and fashion, they have to fulfil aesthetic and semantic expectations of customers, – regardless of improved or additional practical functions. [9] Thus, textile and fashion designers are faced with the challenge to
adapt the novel hybrid clothing to customer expectations and to define its character, which might differ according to function, area of application (health, wellness, security, information, lifestyle, fun etc.) and target groups.

Based on this preliminary analysis and two precursory research projects conducted at the Lucerne University of Applied Sciences and Arts – one of them exploring appropriate fields of application for Smart technologies developed at the ETH Zurich, the other an adaptation of the so-called theory of product language [13] from the field of industrial and product design to the field of clothing and fashion [14] – the ongoing research on user-centred design and semantics of Smart clothes is undertaken.

The project pursues two objectives: First, we scrutinized whether there are generic criteria for the design of Smart clothes that help to overcome the current difficulties. Identification of such criteria should be a useful guideline for future product developments. Second, we investigated the question of whether in terms of semantic product expression Smart clothes can and should signify their innovative character. Do Smart clothes form a clothing category in its own right, as for example sportswear or festive dresses? Or should they look like traditional garments? At least in the field of industrial design, the opinion is prevalent that if a "product contains any new ideas then it is absolutely essential that the product be visually different". [10, 6] If this recommendation is also valid in the field of clothing and fashion, then we have to face the question, what design strategies are suitable to communicate the "smart" character of these clothes?

Methodologically the research is built on literature and web research, the analysis of the state of the art, inference of hypothetical design criteria and a design project that puts these criteria into practice. The next step will be to present the designs to potential users for qualitative interviews in order to get insight into user preferences. Finally, the outcome of the interviews will provide the benchmark for an evaluation of the designs and the underlying design criteria.

2. State-of-the-Art of Smart Clothes

In this research project the term Smart clothes describes garments that feature a function (in- and output) in combination with an intelligent material. When energy is used to activate an in- or output or data has to be collected and converted the third component (technology) is necessary.

**Functions**
- Input: - Energy (battery, solar energy, movement, etc)
  - Component to activate the output (sensor, switch, etc)
  - Activator output (person active/passive, environment active/passive)
- Output: - visual (colour, light), sound, scent, vibration/touch

**Intelligent material**
- Dye (thermo chromic ink, fluorescent ink, reflective ink, etc)
- Light (LED’s, EL-Tape/Ribbon, EL-Wire, etc)
- Intelligent materials in nature (sea sponge, liana, water spider, etc)
- Electronic Systems (servomotor, air pumps, solar panels, etc)
- Shape memory alloys (smart spring, smart wire etc)

**Technology**
- Physical computing
- Sensor technology
- Embedded system design, etc
2.1 Relating Design Excellence and the Functional Surplus of Smart Clothes

Based on an investigation of the state of the art, we positioned ca. 40 products – products established on the market or market-ready as well as experimental pieces – in a quadrant-model. The intention was to shed light on to what extent Smart clothes are on a high creative-artistic level and to obtain a functional surplus by means of integration of technology. Since both parameters are not mutually exclusive, we chose a quadrant-model. (Fig.1)

The lower left-hand quadrant (Q1) includes smart clothes, which characterize neither an appealing design nor additional objective benefit. Gadgets such as ordinary T-shirts with blinking lights or electroluminescent decals at the front and awkward boxes containing electronic and batteries are to be found here. [17] The lower right-hand quadrant (Q2) assorts products, which exhibit a verifiable surplus but are in terms of design likewise average. From the perspective of product semantics this means that these Smart clothes look like reference products devoid of smart components. Smart technology active wear apparel such as hoodies with integrated speakers and dedicated storage compartment or vests and jackets with inside heat panels, a separate wireless remote control and rechargeable batteries can be cited as examples. The integration of the technology is unobtrusive, even indication signs that announce the supplementary function or show how the smart clothes should be operated are reduced or omitted. In other words, the technical novelty is not reflected in the design. [17]

The upper left-hand quadrant (Q3) includes Smart clothes that are explicitly designed with focus on artistic expression and special effects. Embedded technology does not serve any utilitarian function but the embodiment of artwork, poetic visions or critical comments. Artistic fashion as for example pieces designed by well-known couturier Chalayan Hussein, by his colleague Ying Gao and many others is representative for this category. As experimental and one of a kind, they are presented on fashion shows and in galleries, require elaborate handicraft and tricky programming and operate at the borderline of what is technically feasible. They are marvels rather then garments, since they qualify for the catwalk rather than everyday wearing. [17]

Figure.1 Mapping of Smart Clothes (for information about the products see references [17])
Finally, the upper right-hand quadrant (Q4) contains Smart clothes, which offer simultaneously a challenging design and utility value. At best, the integrated technology or an innovative electroluminescent print facilitate daily life and indicates the innovative character of the item and at the same time in an appealing manner. This kind of synergy between useful application and novel design attains for example a motion responsive sportswear created by textile designer Kerri Wallace. Her sports apparel uses the correlation between heart rate and body temperature as a trigger for the visual representation of the activity level by changing the colour pattern of a printed motive. This colour change results from usage of temperature specific thermo-chromatic inks and liquid crystal inks that respond to body temperature. It communicates the biometric values of the sportsperson and furthermore it indicates highly visibly the smart character of the garment in an appealing manner. [17]

2.2 Product Language of Smart Clothing Technologies

With respect to the research question, whether and how semantic product expression can communicate the innovative character of Smart clothes by means of design; three categories derive from the products discussed above. First, the chosen technology or the smart material itself communicates the innovative character of the Smart clothes due to natural indication signs. For example, flashing LED’s, electro-luminescent and thermo-chromatic inks that change the colour of a textile print as well as actuators that transform the shape of the garment autonomously leave no doubt that new technologies are involved. Garments in quadrants Q1, Q3 and Q4 feature some of these effects. Second, intentionally designed artificial indication signs communicate the innovation. In case of the application of conductive or heatable yarns, touch or ultrasonic sensors etc. the integration of Smart technology is not visible for the beholder. In this case, either the garment looks like traditional clothing – or the designer succeeds to create a sign or a symbol, that communicates the distinctiveness of the high-tech garment in a more or less subtle and appealing manner. Examples for this design strategy can be found in quadrants Q2 and Q4. Finally, there are those Smart clothes where product language does not get across its novel character. The additional value is not visible to the beholder, either because it is the intension that the product looks like a "normal" clothing or because semantic aspects were not under consideration by the designer. Products with these characteristics can be found especially in quadrant Q2. Assumingly the choice of the design strategy depends on the smart technology itself, the area of application and the preferences, needs and wants of the target group.

From the perspective of product semantics, the design of artificial indication signs deserves attention. In the case of the Etip glove (Fig.2), which allows operating a touch screen with gloves, two fingertips are made out of conductive thread and the palm exhibit ornamental lines. These imprinted silicone lines prevent that the device slides off the hand, and at the same time they connote a circuit layout. Thus the gloves refer in terms of product language to consumer electronics. It has to be noted that this token polarizes users. On web logs, some users appreciate this very detail as a “stylish eye catcher”; others criticize it harsh as “incongruous” and prefer very subtle designs such as the iPhone gloves. [16].
2.3. Hypothetical Design Criteria for Smart Clothes

Since Smart clothes are defined as hybrid products, which integrate elements from technology and clothing and fashion, [7] we suggest that setting up generic design criteria has to take into account both criteria that are relevant for the design of consumer electronics and criteria that are relevant in clothing and fashion design. Depending on the technology, the application of the clothing and the target group these criteria will need specific weighting.

1. Basically, the sophistication of clothing and fashion with respect to design, material and workmanship should be on a par with the technological sophistication. Embedding high-tech into cheap-looking and low-cost garments does not make sense. If Smart clothing is sold on a high price, product character as a whole must communicate high-quality. [3]

2. Depending on the embedded technology, handling of Smart clothes is sometimes more alike the handling of a PDA than that of clothing and fashion. In those cases generic criteria that are relevant for the design of electronic devices must be taken into account. For example, connections between various components, shape, size and position of switches, plugs, displays etc., letterings, icons and the interaction itself, in other words, all components that the wearer has to operate, need comprehensive consideration. For product designers this is routine work, but for textile and fashion designers, who approach design more intuitively, this might be a challenge. As a basic principle, handling, usage and maintenance of the Smart clothes should be self-explanatory and very easy; the design of all components should indicate correct use. [4, 10]

3. The symbol functions of clothing and fashion is much more differentiated and sophisticated than that of most other industrial products. [1] Thus, if smart technology enters the market in the form of Smart clothing, the customs of this field set the benchmark. This means that – depending on the functional surplus of the embedded technology – the semantic expression of Smart clothes has to meet the taste and expectations of highly segmented target groups. Furthermore, typical stylistic features of various concept styles (working garment, outdoor clothing, sport clothing, underwear etc.) might be taken into consideration. [14] For product designers who have been active in the field of electronic devices, i.e. a field with non-customized products – this distinctiveness of the clothing and fashion market might be unfamiliar.

3. Two Design Projects as Case Studies for Testing the Hypotheses

Based on the previous investigations we drafted briefings for two design projects, – a shirt for prevention of back pain and a child security jacket. The design briefing is structured according to the product expression model by
Josiena Gotzsch [5], which is based on the Offenbach theory of product language. Gotzsch’s model divides the semantic product functions into three types of expressions: *expressions about the product itself (product identity); expressions related to its user (user identity); and expressions related to the company (company identity).* In textile and fashion design such a detailed and systematic briefing is a novelty (Tab.1). Since the project is in a pre-competitive stage, corporate identity aspects remained out of consideration. We commissioned the Swiss textile designer Andrea Schumacher and the Dutch product designer Stijn Ossevoort to create designs according to our briefings.

Table 1. Design Briefing for Smart Clothes, Using the Example of a Prevention Undershirt

<table>
<thead>
<tr>
<th>Design Briefing:</th>
<th>Prevention Undershirt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Product Identity</strong></td>
<td></td>
</tr>
<tr>
<td>Practical functions</td>
<td>Signaling in case of sitting in a bad posture</td>
</tr>
<tr>
<td>Smart Technology</td>
<td>Sensors, measurement device, batteries, feedback device</td>
</tr>
<tr>
<td>Textile/ material</td>
<td>Jersey: elastic, soft, cushy, washable</td>
</tr>
<tr>
<td>Manufacturing technique</td>
<td>Print, stitchery</td>
</tr>
<tr>
<td>Indication function: Communication of smartness</td>
<td>The shirt should communicate its smartness by means of a subtle and intelligent design, for example by embedding and highlighting the carbon fiber sensors using decors or patterns.</td>
</tr>
<tr>
<td>Indication function: Communication of handling/ use</td>
<td>All operating devices (removable connections between shirt and electronic devices, On/- Off-switch etc.) must be cognizable and easy to operate (grip, feedback etc.)</td>
</tr>
<tr>
<td>Symbol function: Associations to the product</td>
<td>Shirt: high quality (material, finish, details), modern, discreet, distinct, appealing details (not “simple”); sophistication of the design should be on a par with technical sophistication Additional devices: technical, factual, modern, reduced</td>
</tr>
<tr>
<td>Symbol function: Style/ aesthetics</td>
<td>Shirt: look-and-feel of “usual” high-quality garment, First-Skin, Sports Underwear. Easy to combine with other garments (of various styles), thus minimalistic and reduced. Additional devices: modern electronic device, factual,</td>
</tr>
<tr>
<td><strong>2. User Identity</strong></td>
<td></td>
</tr>
<tr>
<td>Age group</td>
<td>25 – 60 years</td>
</tr>
<tr>
<td>Sinus milieus</td>
<td>Modern Mainstream, Intellectual milieus, Traditional milieus</td>
</tr>
<tr>
<td>Gender</td>
<td>Predominantly female, but also male users</td>
</tr>
<tr>
<td>Values of the users</td>
<td>Presumably a physician or employer will prescribe the product when first symptoms appear; thus the target group will not voluntarily wear the product.</td>
</tr>
<tr>
<td>Expectations towards the product</td>
<td>Shirt: Wearing comfort, easy-care, self-explanatory handling and usage, safety, reliability, performance Additional devices: comprehensible functionality, self-explanatory handling and usage, handy</td>
</tr>
<tr>
<td><strong>3. Corporate Identity</strong></td>
<td></td>
</tr>
<tr>
<td>Corporate style</td>
<td>Not yet relevant in the pre-competitive stage of product development</td>
</tr>
<tr>
<td>Values of the company/ brand</td>
<td></td>
</tr>
<tr>
<td>Design awareness</td>
<td></td>
</tr>
</tbody>
</table>
3.1 The prevention undershirt

The shirt for prevention of back pain makes use of a so-called back-manager, developed by Corinne Mattmann [7] as part of her PhD-project at the Swiss Federal Institute of Technology (ETH) in Zurich. The garment system measures elongations in textile and enables the determination of body postures and gives feedback in case the wearer is sitting in an unhealthy bent posture. It comprises three components: a shirt with strain sensitive textile sensors from EMPA, Switzerland; a small box for measuring the sensor data and transmitting the results via Bluetooth; and a feedback box which provides an audio or vibration signal and optionally more detailed information. A prototype by Mattmann proves that the technology is operational, but the design is still insufficient.

The integration of the technical components has to be improved and the garment system should meet the aesthetic preferences of the users, notably people who spend most of their time behind a workstation, i.e. predominantly women but also men, aged 25 – 60 years. The prevention shirt designed by Stijn Ossevoort is a tight fitting garment, which is common in sportswear. While the front is kept plain to keep the concept unisex, the back of the shirt shows two shades of grey similar to the muscle tissue in our back thereby emphasizing the function of the garment. The connections of the sensors are very visible in order to keep the functionality of the shirt clear to the user. All wires are guided to one side of the shirt where they connect to a measurement box in the shape of a pendulum via a textile cable. The pendulum has two buttons, which allow the user to detach it from the shirt. Once attached the pendulum switches on and feedback is given by a separate feedback box. The box has a textile inlay with the shape of a person sitting. The spine of the person is represented by a curve of LEDs, which flash up to attract immediate attention. The box has two thumb switches on the side, one to switch the device on and adjust the volume, the other to select the desired acoustic feedback signal. (Fig. 3) While the

Figure 3 (above) Prevention Undershirt: Front and back side of the shirt; pendulum shaped measurement box; and feedback box (front view, side view) (Design Stijn Ossevoort)

Figure 4 (below) Prevention Undershirt: front side and pocket for the measurement box; back side of the shirt with various ornaments; several possible feedback devices (Design Andrea Schumacher)
look-and-feel of Ossevoort’s design tends to be clinical, clean, pure, minimalistic and contemporary. Andrea Schumacher embellishes the components of the garment system in various ways. She developed a range of decorative patterns for the backside of the shirt in order to embed and emphasize the sensors. The measurement box is attached to the sensor wires via snap-fasteners and is stowed away in a pocket attached to one side of the shirt. For the feedback she designed various accessories such as a medallion or a key ring pendant that gives an acoustic signal, a chair cushion for vibration, or a small button that emits light and sound. (Fig. 4)

3.2 The child security jacket

The child security jacket uses photo chromatic and phosphoric inks and yarns that respond to the light conditions of the surroundings. In daylight the jacket appears to be “nothing special” showing no indication of its innovative character (mode 1); when exposed to sunlight the jacket changes colour (mode 2) and at nightfall it glows with a shimmer of light (mode 3). In terms of product language as mentioned in chapter 2.2 the jackets to discuss belong to the first category of smart clothes where the product innovation is indicated through the use of smart material itself. Starflake (Fig. 5), designed by Andrea Schumacher, is a winter coat concept for girls the age of 6 – 10. The design in the three modes is inspired by the winter season and the night sky. Imagine a girl takes her winter coat out of the closet (mode 1), running out of the house to play in the snow, snowflakes appear on her jacket in different forms and sizes, looking like they are dancing when shined onto by the bright winter sun due to the use of photo chromic ink (mode 2). At sunset the snowflakes disappear from the jacket and stars begin to twinkle in a geometric pattern to protect the girl on her way home. The geometric lines are aroused by phosphoric yarn and the sparkling stars are intensified by the use of reflective yarn both woven into the textile.

The Claw jacket (Fig. 6), designed by Stijn Ossevoort, is a winter coat concept for boys the age of 6 – 10. The design is inspired by the metamorphosis of a werewolf due to weather condition. The arms and pockets are
covered with a green fabric layer defining the monster legs when the child puts his hands in his pockets (mode 1). When the coat is subject to sunlight the monster legs will become more apparent due to the change of photo chromatic ink printed onto the green fabric (mode 2). The same fabric panels contain a phosphoric yarn that glows a dragon skin like pattern in the dark (mode 3). The phosphoric yarn is woven into the textile.

4. Conclusions
Generally it can be said that the design briefing, which takes into account conflicting aspects – semantic product expression, usage properties, handling of the technology and last but not least user identity and (assumable) user expectations towards Smart Clothes – facilitates a holistic and integrated approach. Although the drafts from the product designer and the textile designer show particular strengths and weaknesses – Stijn Ossevoort elaborated a convincing handling of the devices and Andrea Schumacher accentuated decorative aspects – both of them took the design criteria described in the design briefings into account. The results exhibit a vast integration of Smart technology into the garments and also into daily habits of usage.
Concerning the semantic product expression of Smart clothes, the question of whether the design of the child security jackets Starflake and Claw are signifying their innovative character can be answered with yes. Even more, the question seems needless to ask, because the added value is so apparent. The two designs offer a clear surplus both in a charming and playful way appealing for girls and boys and for the third target group, the parents. The security aspect is not a mere sign (reflect bar) taken from other known security products patched onto the garment, but give a surprise that at the same time fulfils the requested security function. In the case of the prevention undershirt the innovative character is not as apparent. Clearly, both designers paid special attention to the visual integration of the sensors and the measurement box. Since the sensors are visible in any case, they formed the starting point for various ornamental designs on the backside of the undershirt. Thus, from the perspective of the researchers, the shirts show aesthetic appeal and have nothing in common with traditional modalities or prevention aids. Doubtlessly, the shirts and the related devices designed by Ossevoort and Schumacher show diverse character or style. At the same time, symbolic expression of the garment systems follows current conceptions of looks, gender styles, concept styles and target groups in order to meet individual tastes and preferences. Thus, the aesthetic dependence on “normal” shirts question the hypothesis that in terms of symbolic functions and product expression Smart clothes represent a clothing category in its own right, even if a specification in respect of technical and physical qualities is possible. The intended interviews with the target groups will provide deeper insight into user requirements, expectations and social acceptance of the innovative clothing.

5. References


[17] References to the Smart Clothes in Figure 1 (including links to further information) are available at http://blog.hslu.ch/product