SMART TEXTILE PRODUCTS AND SERVICES IN SUSTAINABILITY CONTEXT

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Abstract

Smart textile products present a bigger risk for the environmental sustainability than most other textile products. However, smart textile products also offer opportunities for the development of unique services that would generate additional value and sustain meaning in a societal and economic context.

In this article we describe our designs for three smart textile products with a different level of integration of textiles and technology and different use case scenarios. These designs were interpreted by sustainability experts and analyzed along the lines of environmental, societal and economic sustainability. We present these multiple viewpoints and our own re-interpretation of the three designs by focusing on the energy use, story telling and personalization as the main opportunities for the development of sustainable smart textile services.

With this paper we contribute by identifying a meaningful direction for the future development of smart textile products where the challenges of sustainability act as opportunities for the development of smart textile services.

Keywords: smart textiles, environmental, societal and economical sustainability, product service systems, smart textile services

1   Introduction

The development of smart textile products, which lie in the intersection of fashion and technology, raises additional sustainability challenges for the traditional garment and electronics industries. We look into existing work of CRISP Smart Textile Services (STS) project to understand the limitations and possibilities for developing smart textile product service systems (PSS) within the context of sustainability. We see interactive and dynamic properties of smart textiles allowing new kind of services to emerge within the apparel field.

1.1   Sustainability

Two major environmental risks within the development of smart textiles have been identified: increasing consumption of scarce raw materials combined with increasing amounts of difficult-to-recycle electronic waste [1]. These risks in the combination with the looks and trends driven textile-fashion industry creates concerns not only for the environmental but also for the societal and economical sustainability [2]. However, the combination of textiles and technology also opens up opportunities especially for societal sustainability. Those go beyond to the product, use, and result oriented sustainability aspects for textile products moving towards services as pointed out by Armstrong et al. [3].

The damaging influence of environmental and social problems caused by the whole lifecycle of a textile product is not going to be solved barely in material level. The sustainability thinking needs to go beyond environmental issues [4]. The textile/clothing production supply chain in relation to the whole life cycle of the garment need to be redefined, the meaning of a garment needs to reflect what its actual worth and value are. According to McQuillan [5] "The future of the fashion industry cannot lie in organic garments within the traditional fashion system, whose production still generates hundreds of thousands of tonnes of textile waste, garments that then get transported around the world thousands of kilometres only to be discarded into landfill at the end of the season. While organic fibres are a part of the solution, we need to re-make the way we make and consume clothes." To understand how the service could support the smart textiles to become more sustainable we approach the topic from environmental, societal and economical point of views often seen as main pillars to talk about sustainability [6][7]. Yet being so interconnected, it's difficult to approach them separately. The principals of combined sustainability challenge the current notion of

progress oriented to (economical) growth [8]. Growth as the underlying pillar of the present economy cannot be tackled without talking about lowering the quantity of products and waste produced. This requires a shift from linear economy to the circular economy with increasing the intrinsic durability and providing careful maintenance for the products [9]. To achieve slower consumption through increased product life spans, Cooper [9] suggests to combine both efficiency, that is more productive use of materials and energy; and sufficiency as reducing throughput of products and materials. «Meanwhile a shift to more highly skilled, craft-based production methods and increased repair and maintenance work would provide employment opportunities to offset the effect of reduced demand for new products.» [9] One way to look into the slower consumption is through meaning creation. "If the designer can connect the design outcome deeply with a consumer's emotions, identity construction, aesthetic needs and personal memories, that is, values and lifestyle, the design process can achieve a deep product satisfaction and product attachment."[10] This is an opportunity to extend the life cycle of the products and can be achieved through implementing services.

1.2   Textile service

To support sustainability as a fundamental cultural idea, The World Conservation Union suggests to look at the culture of consumerism and to redefine the economy in a way that people can get more yet consume less. One aspect they suggest for this is an economy of services rather than objects that would generate value without generating waste or unnecessary physical or energetic throughput [7].

Product service systems are seen as opportunities towards more sustainable consumption also specifically in the textile field. "The most promising sustainable design strategy is the combination of product design with service elements: PSS strategies are therefore a future path to proactive and sustainable design." [3] It is not a new approach in textiles. Hospital and hotel sheets have long history of being rented by a service provider to the facility. Third party takes care, cleans, mends and replaces if necessary the bed linen. Same goes to work wear that needs a very specific type of cleaning and machinery for it. Lindström for example provides the use of work wear, restaurant textiles, shop towels, mats, personal protective equipment and cotton towels for hygiene among other services for their clients. The service typically includes: needs assessment, recommended solution, acquisition and delivery of products tailored for the customer, consultation visit, textile wash and maintenance, optimising product quality and volume, disposal and recycling, regular communications and customer service, eLindström online service [11].

The emerging examples in apparel field include the traditional leasing model applied in new contexts: Mud Jeans [12] leasing jeans, hoodies and second hand clothes returned by the users, Nopsa Fashion Library [13] leasing new and vintage Finnish Designs; but also personalization in new way: Constrvct [14] turning any photo into a custom clothing, Sangar [15] adjusting the shirt's size, pattern and colour, fit and back type, buttons, collar type, edges, cuffs, pockets etc. as ordered to deliver fully made-to-measure shirts. The 10-year hoodie is a great example for durability (warranty) and crowd funding principles. Flint and Tinder launched a project on the most known crowd-funding platform Kickstarter, promising to deliver comfortable durable sweatshirts with guarantee of 10 years (for free mending). They promote the mindset that not everything needs to be disposable and have their sweatshirts made entirely in America, where they are selling them [16].

Traditional textile product longevity can be extended by repair, redesign, customization, participatory design, DIY, consultancy, renting services [3]. Smart textile products with their digital, electronic or Nano properties open up a whole new playground for services provided to support the textile products.

2   The smart textile products

We describe our designs for three smart textile products: The Bedtime Stories, Vibe-ing and Thermo Dance, each with a different level of integration of textiles and technology (separated, integrated, combined) and different use case scenarios (home, exhibition, performance) from the designer-researcher point of view as the initial understanding of each project.

Figure 1: CRISP STS projects from left: the Bedtime Stories, Vibe-ing, Thermo Dance. Photos: Wetzer & Berends

The Bedtime Stories is a set of children's bed linen offering a new way of storytelling through augmented reality on textiles [17]. It is a combined product consisting of a duvet cover, pillowcase, specially developed augmented reality fairy tale application and an iPad to be able to use the application. The bed linen is made of a durable textile that is designed and woven in The Netherlands. When a woven symbol (for example a flower, a wolf or a grandmother in the setting of the Little Red Riding Hood fairy-tale) on the fabric is scanned and recognized by the tablet computer held by the storyteller, the child can play with the textile to manipulate the digital visual. This creates interaction possibilities between digital and physical worlds. The value of the service could be the connection between the static durable textile products and the ever-changing digital application that allows the stories, characters or even the purpose of the application to change in time while keeping the same cloth.

The level of integration of textiles and technology in The Bedtime Stories is "separated" as they are separately fully functional items: bed linen and an iPad. The Fairy tale application brings them together to perform an additional functionality, which extends the dimensions of both. The Bedtime Stories is to be used at homes of families who like to tell and create stories together.

Vibe-ing is a self-care tool in the form of a garment, which invites the body to feel, move, and heal through the vibration therapy. The merino wool garment contains knitted pockets, embedded with electronic circuit boards that enable the garment to sense touch and vibrate specific pressure points on the body. With this design we aim to inform a multi-disciplinary audience about the opportunities of integrating textile and vibration for self-healthcare services at home or even in everyday activities. By integrating vibration actuators in textile pockets the design enables us to program the exact areas and the stimulation on the body depending on the specific person's need for rehabilitation and healing. The fully-fashioned knitting technique allows us to design garments fitting the individual's body and needs with minimal waste. The envisioned service could use the programmable motor boards fitted into the pockets to allow the garment to change its stimulation behavior according to the personal needs of the wearer.

The level of integration of textiles and technology in Vibe-ing is "integrated" as the knit has specially designed pockets for the electronics to fit in, and the microchips with the 3D printed cases are specially constructed for the knitted pockets on the body. Vibe-ing is to be used in exhibitions to demonstrate the possibilities of smart textiles to the actors in the health care area.

Thermo Dance is a concept of using thermo sensitive yarns constructing dance performance pieces. It has been used as a costume in one performance: CHACUN(E) by Angelina Deck which was based on Bach music and performed in London as well as in The Hague; and as a choreographic tool in another performance: YB-ML by a choreographer Gyula Berger and a contemporary dance theatre performer Roos van Berkel and performed in Budapest. In the case of CHACUN(E) the performer used the body heat to trigger the color change of the dyed wool and viscose yarn crochet, and in the setting of YB-ML the choreography was based on the heating up properties of a conductive thread crochet. Both designs were custom made for the specific performer and act in order to explore the properties and

opportunities that thermo sensitive yarn construction could open up for performance arts. The value of the service could be the personalization and uniqueness of each piece. It should also take into account what happens to the pieces after one-time or a series of use.

The level of integration of textiles and technology in Thermo Dance is "combined" as the yarns used for constructing the pieces are dyed using thermo-sensitive pigments. It is difficult separate them from each other. Thermo Dance is to be used in performance setting to communicate the concepts and ideas of the dancers to the audience.

3   Research method

In our study we use the multiple interpretations principle of Klein & Myers [18] to find out how the environmental, societal and economical layers relate to each other within the three described projects. Following the hermeneutic circle fundamental principles for interpretive field research of Klein & Myers [18] we iterate between the designer-researcher and experts of environmental, societal and economical sustainability to find the shared meanings and emerging themes from the three areas of the sustainability. As Klein & Myers state "The principle of multiple interpretations requires the researcher to examine the influences that the social context has upon the actions under study by seeking out and documenting multiple view- points along with the reasons for them." [18] "Moreover the researcher should confront the contradictions potentially inherent in the multiple viewpoints with each other, and revise his or her understanding accordingly." [18]

In this study we investigate environmental, societal and economical sustainability of three smart textile design experiments through reflecting reactions of three experts. Andreas R. Köhler has background in environmental risk prevention and development of the emerging smart textiles technology [1]. Alastair Fuad-Luke focuses on positive societal impacts contributing to the international debate about how design can encourage co-futuring [19]. Mika Kuisma research has been focusing on corporate responsibility performance and impact assessment, as well as innovative and eco-efficient business models and practices [20].

4   Results: sustainability implications for the smart textile products

Looking at the results from the interviews with the three sustainability experts Köhler, Fuad-Luke and Kuisma we identify the following core issues rising from the development of the smart textile products from environmental, societal and economical perspectives.

The main themes emerging from the **environmental sustainability** perspective are: materials and waste generation and treatment, people's consumption habits having the main role in the waste issue, energy use during production and use of the products and chemical use mostly in the production phase.

In the presented examples of smart textile products the textiles and electronics are separated in The Bedtime Stories, integrated in Vibe-ing and combined in Thermo Dance. This allows multiple viewpoints to be taken when talking about the **material use and disposal**. Köhler points out for example the main material impact in The Bedtime Stories to origin from the use of the iPad. "The iPad in fact has the main environmental impact in the combined product. It involves a combination of scarce and toxic materials, energy consumption to produce and to run it, e-waste in the end of life. Such equipment have a relatively heavy environmental burden over the whole life cycle." [21] Also the lifetime of the combined products mostly depends on the iPad, as bed linen typically tends to last longer than technical gadgets. In the case of Vibe-ing according to Köhler "In terms of the Life Cycle Assessment (LCA) the whole cradle to grave (disposal phase) should be considered, among which the materials and production of these materials used (cotton, wool, steel fibers, coated fibers, electronic fibers, silver coated fibers, microchips, vibration motors (metals, plastics), batteries etc.)" [21]. He adds that electronic textiles are difficult to recycle and therefore a great problem for waste treatment. Already pure textile products are difficult to recycle because of the mixture of fibers. More difficult than the recycling is the take-back & collection & sorting of post-consumer clothing. They might have another life as second hand garments, but in the end it will be disposed with batteries etc. [21]. Combining the typical issues from the textile field (water, energy use, pesticides..) with the problems arising from the electronics production (toxic waste, scarce materials) and disposal we see that it's a very critical combinations which has a lot to do with the habits and mindset of the user.

In terms of the **consumer habits** Köhler points out the main impact of The Bedtime Stories to lie on the iPad, it also carries an impact whether the family already owned the iPad or the application triggered them to get one. In the case of Thermo Dance, according to Köhler, the uniqueness of the product makes its eco footprint minimal. Producing

individual one-off or small quantity pieces is irrelevant in the context of mass production in both electronics and textile fields [21].

About the **energy use** Köhler states that "The only actual added direct impact to the environmental impact in The Bedtime Stories lifecycle is the exact use time of the iPad that is added by the augmented reality fairy tale application." [21] He mentions that using the application offline saves some energy compared to the same usage time over online streaming. Another great energy impact comes from the washing and drying the duvet cover, but that is similar to any other bed linen care procedure [21]. "The energy consumption of production and using Vibe-ing should be considered." [21] About Thermo Dance Köhler states, "To produce heat consumes relatively much battery power (as compared to logic devices). And it's questionable if the use of heat just for changing color is a smart way of using the energy." [21]

Chemical use is a vast problem in textile production due to the variation of pesticides used in cotton fields and dyestuff in coloring the fabrics. Therefore it requires careful consideration of the materials used and the way they are being developed and produced. In Thermo Dance specifically the concern is on the thermo sensitive pigments used in the yarn of the costume. According to Köhler however, "It is not extremely unusual chemistry, it is not immediately toxic, but it contains a mix of special organic chemicals (Leuco dye or liquid crystals). Some thermo chromic inks (not all) contain Bisphenol A (BPA). The chemical is also in widely used in thermo-plastics (as a softener). In a long run it has hormone toxic effects. "[21]

The main themes emerging from the **societal sustainability** perspective are: story and personalization creating meaning for the user.

For **stories**, Fuad-Luke states that creating meaning is the only way to change societal behavior and people themselves are the best agents to do it. Sustainability he sees as a societal journey – a values conversation, which is about sustaining meaning that people value. Therefore he sees The Bedtime Stories smartness in the meaning sustaining, and in the new story building through smart textiles [22]. Also in the Thermo Dance Fuad-Luke finds the individual story creation as an important aspect.

About **personalization** Fuad-Luke points out that the author of the story being as important as the story itself. He expresses worry about the author of the story, that the technology instead of the meaning would drive the story. "And we are in a desperate search for meaning. Plenty of information but not much meaning." [22] Therefore it's incredibly important that people can build their own stories with The Bedtime Stories. Fuad-Luke poses a question about Vibe-ing, whether a garment could support personal wellbeing and appreciates the uniqueness and very personalized approach of the Thermo Dance [22].

Also some insights from the **economic sustainability** support **personalization** as a strong pillar to start with the story building. Kuisma mentioned happiness as a good indicator for economical sustainability alongside with the belief that economic aspects need to serve the societal ones [23].

The economic sustainability turns out to be the most difficult one to discuss about perhaps due to the premature state of the products. We believe that service design could help with it. Therefore building to the results from the interviews we propose core values and principals for the envisioned services for The Bedtime Stories, Vibe-ing and Thermo Dance to include the main aspects mentioned in the environmental and societal spheres, as those could direct the economical sustainability as well.

5   Opportunities for sustainable smart textile services

In the following paragraphs we explore how the service element could direct the smart textile product into a more sustainable service system. We point out solutions discussed with the experts and reactions their concerns triggered. Generally, we are revising our understanding of the projects according to the findings from the multiple viewpoints, as suggested by Klein and Myers [18]. The following paragraphs are organized by the projects. The product improvement from the sustainability perspective is presented first and the proposals for the service component follow.

To minimize the environmental sustainability burden resulting from the use of **the Bedtime Stories**, both the device/digital and the textile components need to be considered. The improved concept of the application has to support all major OS systems running on the main popular smart devices. It has to be possible to run the augmented reality fairytale application on any existing device of the family. The application needs to keep working locally on the

user's device to minimize online time for less energy use. The materials for the textile need to be chosen carefully considering their environmental impact.

Important aspects of the service to be implemented for the Bedtime Stories are: 1.the textile part has to live up to its potential (live long), which means it needs to be taken proper care of. Keeping the ownership of the textile with the service provider who would offer repair service and knowledge could do it; 2.the application needs to be compatible with newer devices constantly coming out; 3.the application needs to develop over time to adapt the changing needs of the user; 4.the user must be able to create new stories; 5.the user must be able to develop and share their stories; 6.the technology must allow the freedom to create the stories freely, with no major limits; 7.the character of the story creation and sharing has to support interaction within the families.

For **Vibe-ing** to be environmentally, societally and economically more sustainable the electronic and textile materials need to be selected carefully considering their environmental impact. Also the energy consumption in the use phase needs closer attention, as well as the notion of using it efficiently (turn device off when inactive, possibility to generate energy from the use itself). The motor boards need to be compatible with the wide range and improving technology.

Important aspects of the service to be implemented for Vibe-ing are: 1.the product has to be kept in use as long as possible to gain the maximum value of the materials used. It needs a special care due to the combined textiles and electronics. Leasing it and repurposing when necessary can achieve it; 2.make sure the service supports emotional wellbeing; 3.make sure the service takes into account inclusive design aspects.

Even for a performance costume **Thermo Dance** certain aspects are important to keep in mind for assuring the sustainability. The use of electrical wires and batteries for the costume to change color needs to be optimal and well thought through. The information about the chemical use needs to be open and available. The precautions in production/ prototyping phase need to be taken seriously.

Important aspects of the service to be implemented for the Thermo Dance are: 1.the costume has to be used up to its full potential. It could serve as a performance piece first and keep spreading the concept of the act in exhibition or any other public form of presentation; 2.uniqueness of the pieces and concepts is a great value, therefore they need to be enhanced, they need to be made explicit for the wearer and for the audience; 3.the story that the costume supports to communicate has to be clear and made available via diverse medium to be accessible by everyone interested.

6   Conclusions

As we see from the interviews and analysis the main implications concerning the environmental sustainability for the smart textile products include: material and waste treatments, consumption habits, energy use and chemicals. The possibilities for smart textile services in societal sustainability lie in the personalization and the storytelling aspects in order to extend the longevity of the product through making it more meaningful for the users. Economical sustainability relies greatly on the first two and could benefit from the implementation of service systems. Additionally to the traditional textile services, such as repair, renting, swapping etc., the smart textiles interactive and dynamic properties allow services like story creation, personalization and support for wellbeing arise to contribute to the sustainable way of living.

Out of the three sustainability layers, the economic approach is the most challenging to discuss in the prototyping phase when the business model is not fully developed in the smart textile products context. Vision for the business model has to be included in the service component as the next step of the projects in order to be able to evaluate the economic sustainability.

The findings also tackle some of the main issues raised in the introduction. Smart textile PSS providing personalized items in lease basis, therefore taking care of the durability and maintenance of the product, allows slower consumption. By redefining the garment (textile product) cycle in such a way the consumption of scarce raw materials and generation of difficult to recycle waste would slow down as well. It is an opportunity to introduce the changing models into smart textile products as they are still emerging. For us the sustainability challenges act as opportunities for the service development. The proposed aspects for sustainable smart textile services are in principal about sustaining the meaning for the users. Following the advice from Fletcher "Thus the challenge of sustainability is to connect the fashion and textile identity with multiple layers of other human activity" [24] we continue to find a meaningful direction for the smart textile products.

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