Smart Textiles as Raw Materials for Design

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Abstract

Materials fabricate the designed artefact, but they can also play an important role in the design process; as a medium or method used to develop the design. Textiles can, with their soft and flexible properties, be easily transformed and altered in numerous ways; for example, by cutting, folding or printing on the material. This transformative character makes textiles interesting sketching media for surface explorations when designing artefacts. The development of transformable materials; for example, fusible yarns and colour changing pigments, have expanded these inherent transformative qualities of textiles and have opened up the design field of smart textiles. Accordingly, this new material context has created a new area for textile designers to explore, where it is possible to enhance and play with the alterable character of their textiles, and control their transformation through physical manipulation and programming. However, these expanded transformative properties also open up a new task for textile designers; to design "smart textiles as raw materials for design". By this term we mean, textiles that are not finished in their design but that can be developed and enhanced when they take part in a product or space design process.

In this article, we explore and start to define what smart textiles as raw materials for design can be, and look at how these materials can come into and add something to another design process. The foundation for this exploration is a number of textile examples from the “Smart Textiles sample collection” and our experiences when developing and designing with them. (The Smart Textiles sample collection is a range of textiles that is designed and produced by the Smart Textile Design Lab, to give students, designers and researchers direct access to different types of smart textiles). The possibilities and limitations of smart textiles as raw materials for design are explored by looking at the textile examples from two perspectives: firstly, by looking at the considerations that come with designing this type of textile design, and secondly by looking at what these transformative textiles can bring to another design process. Each example is analyzed and classified according to what transformable design variables for structure and surface change can be embedded in the textile design, and what design variables this subsequently creates for a design process that uses these materials i.e., describing what type of transformation different examples of smart textiles introduce to the design process/design space; whether the change is reversible or irreversible, and whether the change occurs through physical or through digital manipulation of the material.

This article ends with a discussion of how smart textiles in the form of raw materials for design could influence how we design textiles and how we design with textiles. Can transformative materials enrich material explorations in a design process? Can further development and alteration of the material design be introduced or defined by the textile designer? Could smart textiles as raw materials for design open up a stronger connection between the design of textiles and the design of the product or spaces where they will be used?

Keywords: smart textiles, design affordances, sketching methods for artefacts.

Textiles as design materials: inherent and smart qualities

Textiles can form shells for products, spaces, or the body, and can have either a structural or a non-structural function in artefacts. Alongside functional usage as covers, textile materials are also media which express decorative qualities; consequently, they define the aesthetic surface appearance of artefacts by offering a specific visual and tactile language for design (Albers, 2000). Subsequently, there are two perspectives that are of value in relation to the design of textile artefacts; one which considers surface appearance and the textile's visual expression, and another which focuses on the physical surface characteristics; for example, tactility, elasticity, and pliability. These basic design features are dependent on structural decisions, such as the construction techniques chosen, yarn quality, type of binding, and/or surface treatments; for example, printing, coating, and dyeing. These variables and techniques define the basic character of a textile, and thus define or suggest a desired expression or use in a specific context.

In terms of the character of the surface, textiles, with their soft and flexible properties, can be easily transformed and altered in numerous ways; for example, by cutting, folding, or printing on the material. Pliability as a key material characteristic means that textiles can be used to define and/or enclose a three-dimensional shape; thus, they are used for sketching processes in fashion; for example, by draping or folding the material. Subsequently, the transformative character of textiles means that they are not simply materials to be applied to a specific product or context, but can also function as an interesting sketching medium for surface explorations when designing artefacts.

The development of transformable materials, such as fusible yarns and colour changing pigments, has enlarged the range of inherent transformative qualities of textiles, and has introduced the field of "smart textiles". These are materials with dynamic properties, and are designed to sense and respond to environmental conditions or user stimuli (Addington & Schodek, 2005; Ritter, 2007). "Smartness" as a descriptor relates to a large category of materials, which have complex surface properties or are enhanced by digital technology. Consequently, the design of smart textiles combines traditional methods for textile fabrication with advanced technology, and so smart textiles have created a new area for textile designers to explore; one in which the ability of the designer to alter the characteristics of the textiles is enhanced, as this can be controlled by both physical manipulation and digital technology.

The transformable properties of smart textiles have been used to create innovative products, such as "Portable Light" by KVA (KVA, 2014) or "Skin: Dresses" and "Fractal: Living Jewelery" by Philips (Philips, 2014), where changes in the surface or structure of the material allow for new thinking regarding the uses of products or new ways of designing for environmental interactions. Alongside examples of product development, research programmes with a focus on the development of design methodology have explored different perspectives on smart textiles: "IT + Textiles" (Redström, Redström, & Mazé, 2005) examined the relationship between textile design and digital technologies as a means of integrating new textiles into our daily lives, while Buchley and her research group investigated the inherent characteristics of handcrafted textiles and sought to propose methods for expressing new technologies and computation through textiles (Qiu, Buechley, Baafi, & Dubow, 2013). Additionally, Worbin expanded this field with a new methodological framework, which outlines basic dynamic principles for textile design (Worbin, 2010). Through textile interaction design, Hallnäs and Redström connected textile aesthetics and technology and, in so doing, offered a new perspective on smart textiles based on interaction design methodology (Hallnäs & Redström, 2006). Consequently, they described the relationship between material function (what the textile does) and interaction (what one can do in relation to the textile) as one which is essential to consider when discussing new methods for the design of smart textiles (Hallnäs & Redström, 2008).

In a complementary manner to the previously mentioned explorations of smart textiles, our article and the research programme that it presents focus on the possibilities of smart textiles as explorative materials when designing, in terms of how the transformable qualities of traditional and smart textiles can be defined and used as sketching tools when creating artefacts. Accordingly, the perspective on textiles is here shifted, from materials with finished expressions to developable sketching mediums; at the same time, relating the design of textiles to research into interactive material-based sketching tools.

Interactive material-based sketching tools

Materials not only give form to the designed artefact, but can also play an active role in the design process, as an influential medium through which the design may be explored and expressed (Bolt, 2007). The emerging field of interactive sketching tools, which combine physical materials and digital design technologies, highlight and expand the possibilities that accompany working with materials in this way. The tools and other research performed in this field open up for design processes where materials may function as active partners when forming the design, and can assist in generating questions related to how we can interact with materials when designing, and how the more or less designed properties of materials influence this interaction.

When discussing the design of such complex design tools, it becomes of interest to examine the ways in which inherent material expressions and properties inform specific actions during the design process. Norman refers to "affordances as the perceived and actual properties of a thing, primarily those fundamental properties that determine just how the thing could possibly be used" (Norman, 1998, p. 9); thus, his theory relates the appearance of designed objects to the way they suggest a specific action. Moreover, Nordby and Morrison introduce the term "design affordances", that is, the affordances that materials introduce to form-making processes (Nordby & Morrison, 2010) and, in so doing, expand the concept of "affordances" by relating material properties to the design activities that the medium in question affords during a sketching process. Consequently, each material can also be regarded as a way of opening for not only a specific use in daily life, as is argued by Norman, but for ways of operating in a design space, thus shifting the perspective on to the designer as a user.

These new digital and physical sketching methods for designers facilitate an explorative use of materials; for example, through direct manipulation of the artefact in physical space, and enable multiple iterations in the early stages of the design process. “Skin Tool” is a project which provides sketching methods that allow ceramic artists to explore surface imagery in relation to three-dimensional shapes; this allows the user to project dynamic patterns and textures on to ceramic objects while simultaneously manipulating the material and shape in physical space, allowing greater control over the final surface expression of the artefact (Saakes & Stappers, 2009). “Illuminating Clay”, “Relief”, and “Bosu”, are related examples of interactive and tangible design tools, wherein computational behaviour complements different materialities, such as clay, sand, and shape memory alloys. These tools not only illustrate a new way of sketching artefacts, based on the basic character of different materials, but also allow for the design of dynamic affordances (Ishii, Lakatos, Bonanni, & Labrune, 2012). Accordingly, such a methodological framework relates static and dynamic affordances, which is based on the basic and programmable character of material tools; thus, “facilitate”, “restrict”, and “manipulate” are criteria with which to design programmable behaviours (Follmer, Leithinger, Olwal, Hogge, & Ishii, 2013); these define multiple form iterations during the design process in relation to the interaction. Such sketching tools also suggest a shift in design thinking; away from the traditional use and expression of materials, and towards defining interaction forms during the design process. With regard to textiles as materials for design, then, the concept of sketching tools for designers is one which requires exploration, as textiles, in the same way as clay, sand, or ceramics, afford and facilitate certain processes while, at the same time, being in and of themselves a design.

Exploring Smart Textiles as raw materials for design: a design program

Smart textiles can, as the examples discussed at the beginning of the article illustrate, be used to create interactive and transformable artefacts. However, we believe that combining smart textiles with the process of designing products, spaces, and so on, also opens up another application for these materials; as interactive design tools/media. This article and the design programme that it is based on focus on exploring this possibility, specifically in terms of how the transformational character of traditional and smart textiles can be used when sketching and developing designs. To do this, we created the concept of smart textiles as raw materials for design; by this term we mean textiles with an unfinished design, where the expression can be explored, developed, and enhanced when they are used in a design process. In this article, we explore the concept from two perspectives:

- Firstly, by looking at how to design textiles, which, as a result of their transformable qualities, allow for further development of their properties and expression.
- Secondly, by considering what these textiles can bring to other design processes; the actions in the sketching process that they, through their properties and expressions, influence and/or suggest.

The foundation for exploring these perspectives is a collection of smart and transformable textiles, which includes thermochromic printed fabrics and heat-reactive knits, along with our own experiences of developing, designing, and giving workshops with them. The samples come from the Smart Textile Sample Collection, and were originally designed to give students, professional designers, and researchers direct access to and hands on experience with smart textiles. The samples are not designed for a specific context or application, but are instead intended to function as examples that provide an understanding of the material, and may be further developed to suit a specific context or design. Some samples originate from textiles that were designed for a specific context in other research projects, as is the case with the knitted textiles produced for "Touching Loops" (Dumitrescu & Persson, 2011), other textiles were designed specifically for this collection (see Figure 1).

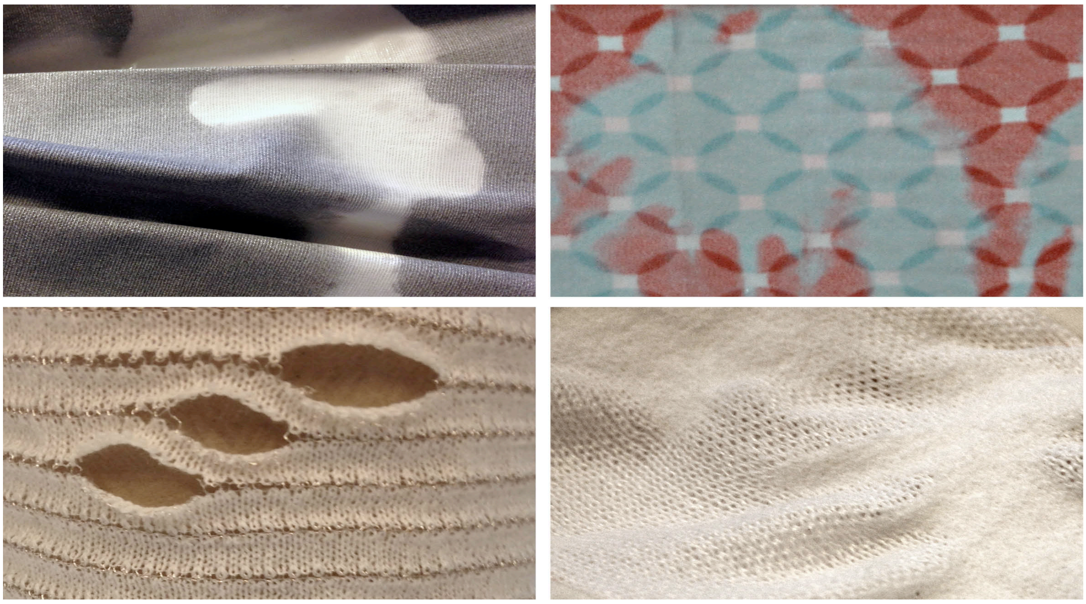

Figure 1. Printed and knitted fabrics in the Smart Textile Sample Collection.

To better understand the connection between textile design and the expressions and methods that textiles open up in a design process, we held a series of workshops in which designers and students worked with the different materials of the collection in relation to their own area of interest or current project. The first workshop was conducted with textile design students, and the second with a group of designers and researchers from various design backgrounds. The diversity of design backgrounds represented by the participants facilitated the exploration of the properties of the various textiles in relation to different types of sketching processes; for example, the textile design students worked primarily with structure and surface explorations, while other participants generally focused more on form-making processes and three dimensional prototypes.

Smart Textiles as raw materials for design: a methodological framework

In order to better understand and discuss the ways in which smart textiles as raw materials for design influence the sketching methods and design processes that they are a part of, we created a methodological framework, and examples from the Smart Textile Sample Collection and workshops were used to develop and test its structure. For us, the key to understanding the connection between textile and process is to look closely at the transformation that takes places in the material, and the actions this opens up in a design process; this relationship is thus the focus of the framework.

Similar to the perspective on smart textiles in relation to textile interaction design methodology (Hallnäs & Redström, 2008), our framework is divided into two sections; one which defines the transformation of the textile (TEXTILE), and another that deals with what the designer does with the material (DESIGN PROCESS). Each section is divided into one part that looks at the transformation in its basic form, which is to say the material variables and possible actions in the process that define the main character of the transformation, and another part that looks at how the transformation is expressed, the specific changes that take place in the textile, and the design activities this opens up (see Figure 2).

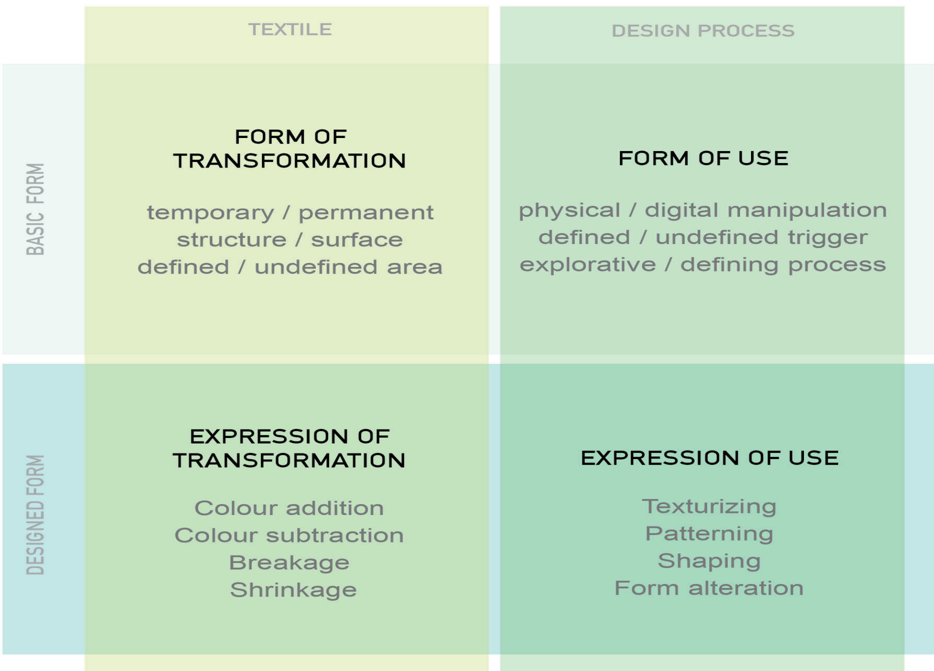

Figure 2. Graphical representation of the methodological framework for Smart Textiles as raw materials for design.

TEXTILE

The form of transformation describes the changes embedded in the material as a result of the basic properties of the transformable materials; for example, thermochromic inks or melting yarns, and how these are incorporated into the textile. Basic textile variables define, whether the change in the textile is temporary or permanent, or whether the changes occur at a structural level or only on the surface.

The expression of the transformation describes the specific changes that the textile expression, through its design, allows for. This could, for example, be the addition or subtraction of colour from the original expression, or the changing of the expression or properties of the textile by shrinking or breaking.

DESIGN PROCESS

The form of use describes the basic actions in the design process that a textile allows for, which is to say the basic ways it can be experimented with in a design process. This could, for example, be whether the material can be manipulated by physically or digitally interacting with it, or whether what triggers the changes in the textile is defined in the material or not.

The expression of use describes the specific sketching methods that the textile opens up; these may include explorations of pattern designs and explorations of patterning in relation to three dimensional form.

We see this framework as a basic structure for discussions, which can be introduced when designing smart textiles as raw materials for design or in the initial stages of design processes where exploration of the meeting between material and shape are essential in defining the end product. The textile properties mentioned in the framework and the following examples are related to the materials that we have worked with so far, and should be seen as examples, rather than general variables, which can be applied to all smart materials explored in this context. Below, the framework is applied to four examples from the Smart Textile Sample Collection, illustrating the type of transformations that can be embedded in a smart textile when it is used as a raw material for design, and the impact these choices can have on the way materials can be used when designing.

Examples of smart textiles as raw materials for design

Raw print: thermochromic colour

This sample is a woven cotton fabric with grey thermochromic ink printed evenly over the whole surface. The ink becomes transparent at 32 degrees C, temporarily revealing the white colour of the base fabric.

Form of transformation: The properties of the ink create a temporary change in the surface, from grey to white, as the colour reverts to its initial state when the textile returns to ambient temperature. The area of transformation is not defined; it can take place throughout the fabric, as the entire surface is printed with thermochromic ink.

Expression of transformation: The expression of the surface can be temporarily redefined through subtraction of the grey colour from the original design. The new expressions that can be created are influenced by the heat sources used to create the colour changing effect, and can range from gradient effects to distinct forms created on the surface.

Form of use: The trigger of the transformation in the textile is not defined, as there is no conductive yarn or other trigger embedded in the textile. The textile allows for multiple forms of physical manipulation, as the surface can be transformed using any type of heat source, including warm water, a hair dryer, or a clothes iron. The temporary nature of the surface change allows for an exploratory design process in which multiple design possibilities can be created and considered.

Expression of use: The temporary colour changing effect embedded in the textile facilitates exploration of patterning by, for example, working with the visual organization of patterns, graphic forms, or gradient effects. The textile also suggests patterning in relation to form; exploring where and how a pattern should be placed, or testing pattern scale in relation to a three dimensional form (see Figure 3).

Raw print: thermochromic pattern

This sample is a woven cotton fabric, printed with a combination of thermochromic ink and pigment colour, in a halftone pattern consisting of lines and circles. The ink becomes transparent at 32 degrees C, temporarily revealing the pigment colour; in one version the change is from grey to blue and, in another, from red to blue.

Form of transformation: The properties of the ink create a temporary surface change, as the surface colour reverts to its initial grey or red state when the textile returns to ambient temperature. The area of transformation is defined by the arrangement of the pattern on the surface, as the colour changing effect only takes place in the areas of the textile that are printed with the pattern.

Expression of transformation: The expression of the surface pattern can be temporarily redefined through the addition of blue colour to the original design. The new expressions that can be explored are directly influenced by the heat sources used in the sketching process, and how these relate to the geometric forms in the initial pattern design. The character of the transformation is determined by the heat source used to create the transformation, and can encompass a vast spectrum of effects, from gradient colour changes to distinct blue forms added to the pattern.

Form of use: The trigger of the transformation in the textile is undefined, as there is no conductive yarn or other form of trigger embedded in the material. The textile allows for multiple forms of physical manipulation; the surface can be transformed using any type of heat source, including warm water, a hair dryer, or a clothes iron. The temporary nature of the surface change allows for an explorative design process, in which multiple design possibilities (in relation to the surface pattern) can be created and considered.

Expression of use: The temporary colour changing effect embedded in the textile opens up re-patterning in the form of exploration and recomposition of the visual organization of the pattern, and re-patterning in relation to form, which is to say explorations of where and how different colours in the pattern should be placed so as to create an interesting meeting between this pattern and a specific form (see Figure 3).

Figure 3. Raw prints: placement in the methodological framework.

Raw knit: breaking textile

This sample is a simplified version of the interactive knitted structures designed in the "Touching Loops" project (Dumitrescu & Persson, 2011), which explores interactive textile tactile patterns. This example is a striped design knitted in single jersey, made from a combination of wool yarn, a melting/fusible Grilon yarn, and a low resistance conductive yarn. The one inch gap between each conductive yarn in the knit makes it possible to use the conductive threads to both sense and react to touch, by sending an electrical current through the manipulated area. One wale of melting yarn is placed in the knitted structure between the conductive and wool yarn; when a current passes through the conductive threads, the Grilon yarn melts, breaking the structure and making it possible to tear apart the affected section and create holes in the material.

Form of transformation: The melting property of the Grilon yarn creates a permanent change in the structure of the knit in the areas that are exposed to heat. The area of transformation is defined by the placement of the three different yarns in the knitted structure, specifically the meeting points between the conductive and fusible yarns, where holes in the textile can be created.

Expression of transformation: The expression of the knitted structure can be redefined by exploring breakage so as to create new expressions in the structure; for example, by creating open and closed areas on the surface or creating different tactile textures.

Form of use: The trigger of the transformation is defined in the textile. Thus, the conductive yarns embedded in the structure make it possible to explore the expression of the textile through digital manipulation; for example, by programming the material to create different transformations in the textile in relation to interaction. The expression of the textile can also be transformed through physical manipulation from sources of heat, including warm water, a hair dryer, or a clothes iron; however, the transformations are restricted to the areas where conductive and melting yarns are embedded. The permanence of the structural change suggests a defining design process, wherein alterations to the structure may gradually be added to the expression of the material, but never removed.

Expression of use: The permanent structural change embedded in the textile opens up for texturizing the surface of physical artefacts, in terms of both visual and tactile expression. Using this type of transformation in three-dimensional form-giving processes, by shaping objects or adding to or altering the form by breaking and removing parts of the material (see Figure 4).

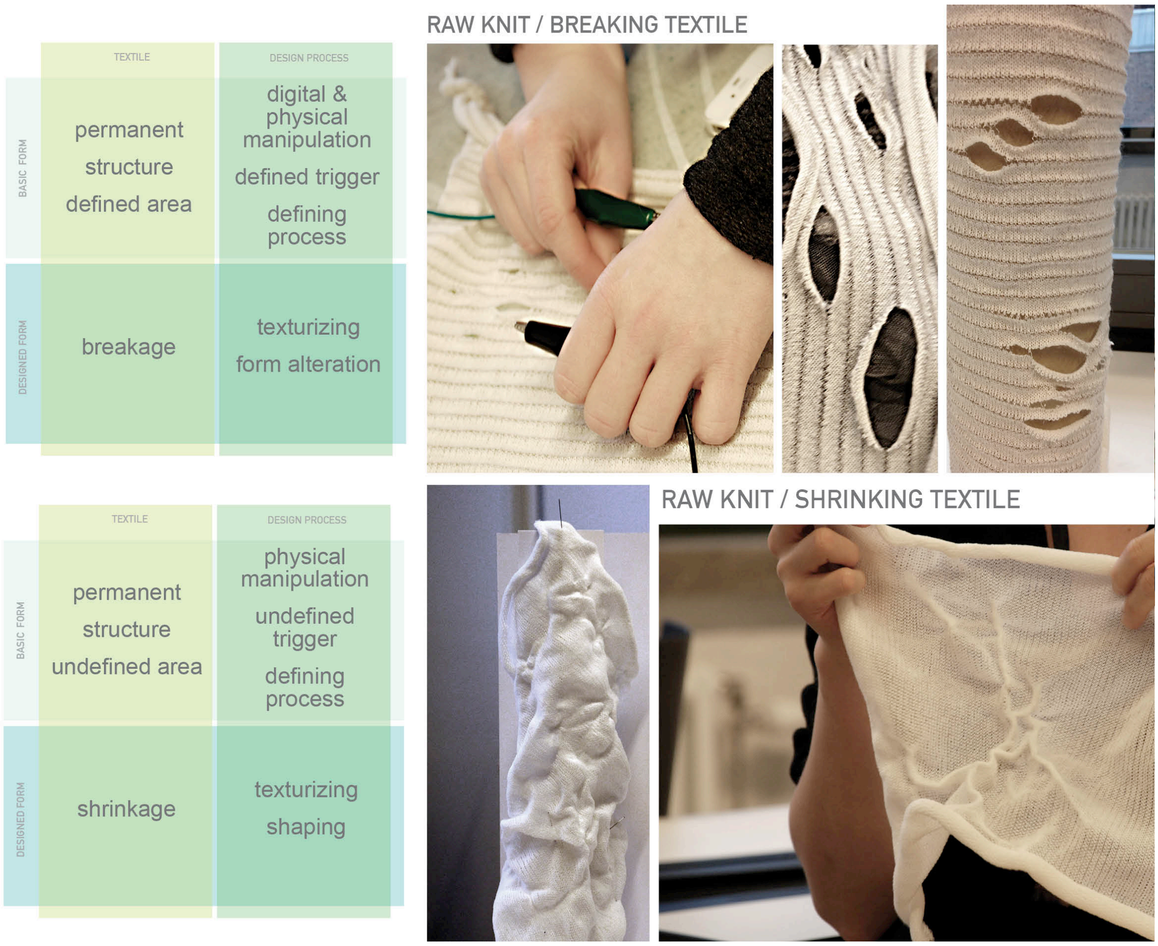

Figure 4. Raw knits: placement in the methodological framework.

Raw knit: shrinking textile

This sample is also a simplified version of the interactive knitted structures designed as part of the "Touching Loops" project (Dumitrescu & Persson, 2011). The textile is knitted with Pemotex yarn in an interlock structure. The yarn shrinks when exposed to temperatures of up to 100 degrees, transforming the affected area from loose and elastic to dense and thick (see Figure 4).

Form of transformation: The properties of the Pemotex yarns create a permanent transformation of the structure following exposure to heat. The area of transformation is undefined, as the whole structure is knitted using the same binding and yarn, and therefore reacts in the same way throughout the fabric.

Expression of transformation: The textile expression can be transformed through shrinkage; development of the textile can be done by shrinking part of the structure or creating areas with different opacities, tactile textures, or permanent folds.

Form of use: The trigger of the transformation is not defined in the textile, as there is no conductive yarn or other trigger embedded in the structure. The textile allows for multiple forms of physical manipulation through direct interaction with the material; the structure can be transformed using any source of heat, including warm water, a hair dryer, or a clothes iron. The permanence of the change suggests a defining design process, in which alterations to the structure may be gradually added to the material but never removed.

Expression of use: The possibility for permanent structural change that is embedded in the textile opens up for texturizing surfaces (of prototypes), for example, in terms of both visual and tactile expression. This type of transformation can also be used when shaping objects in three dimensional form-giving processes, by altering the form through shrinking part of the material (see Figure 4).

Discussion

This article has presented a new approach to the use of transformable qualities of smart textiles and, in so doing, opens up a new task for textile designers; to design interactive textile sketching tools. In relation to this, the methodological framework in this article introduces a perspective which encompasses both methods for sketching and interacting with the material that the transformation of the material opens up, and textile variables that should be considered when designing the materials in question. Taken together, this methodology makes it possible to examine the connection between the design of a transformable textile and its design affordances as a means of facilitating artefact design.

The design affordances (Nordby & Morrison, 2010) of the textiles discussed in this article relate to the discussion of dynamic design affordances (Ishii et al., 2012), as in both cases the actions of a designer can be facilitated and restricted by a combination of the physical properties of the material and actions, defined by computation. However, when compared to using interactive tools which combine digital technology and materials such as clay, designing tools with textiles becomes more complex, as (smart) textiles, unlike many other materials, are in and of themselves a design, with a large number of static and dynamic variables to consider (Worbin, 2010). Similarly, small changes in the design variables for smart textiles as raw materials for design can have a large impact not only on the materials themselves, but also on which design methods they introduce or suggest for other processes. For example, each smart material, such as yarn or ink, allows for certain transformations, but precisely how these transformations take place, and which design approach is facilitated is, to a large extent, defined by how and where the textile designer decides to incorporate these transformations into the textile.

This can be seen when comparing the two thermochromic samples discussed above, which have a similar form of transformation but differ in terms of the area of transformation; in the first, the area of change is undefined, while in the second this area is defined. These differences facilitate different approaches to the sketching process; in the former case, we observe a wide range of possible visual expressions, while the latter has clearly defined limitations regarding exploration, and is therefore used primarily to consider and develop that particular pattern in relation to a specific three dimensional form, context, and/or interaction scenario. The open and pliable qualities of textiles as design materials also mean that, when compared to other programmable physical tools (Saakes & Stappers, 2009; Ishii et al., 2012; Follmer et al., 2013), it can be more difficult to facilitate and restrict specific actions in the design process. As such, textile materials that may be altered through digital interaction can often also be manipulated physically (see Figure 5).

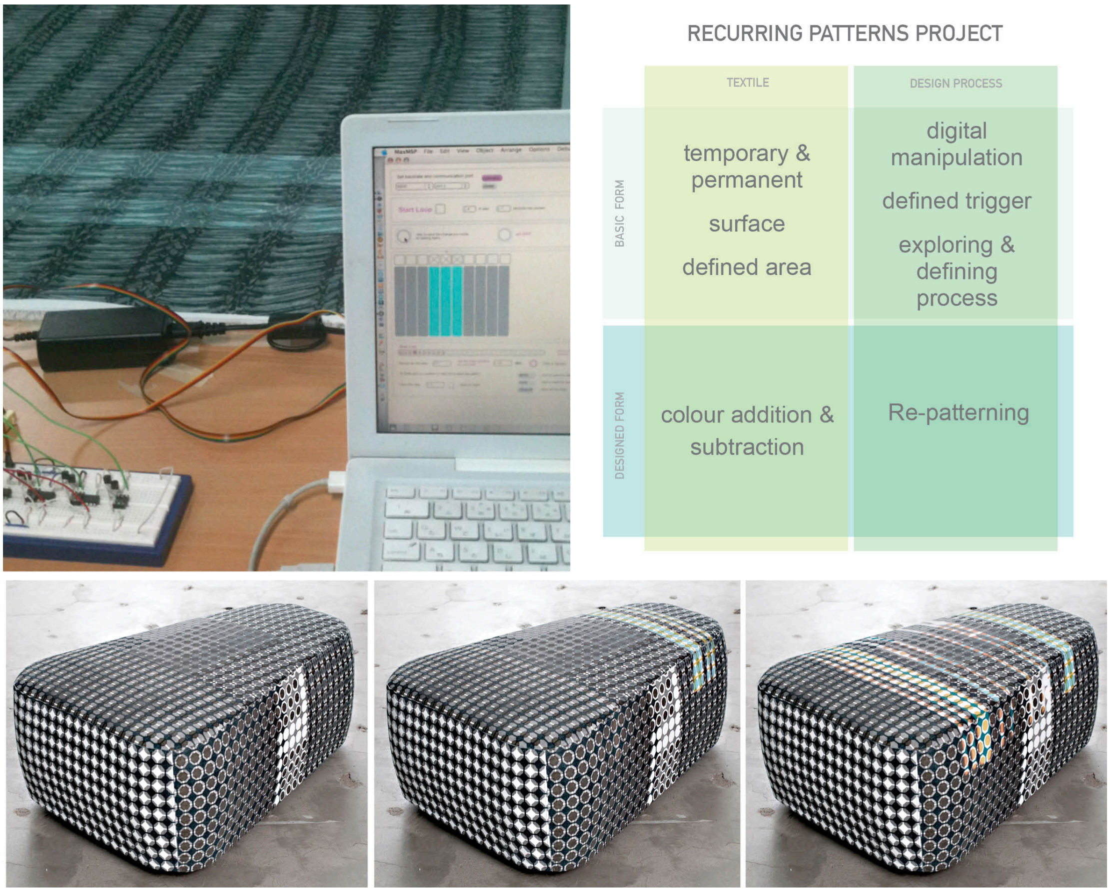

Figure 5. Photographs depicting different ways of sketching with the Raw print: thermochromic colour textile on a form.

In the article, a methodological framework was used to describe existing textile samples from the Smart Textile Sample Collection; this framework, however, also has the potential to aid in developing new smart textiles that may be used as raw materials for design, by helping designers to see the potential in smart textile prototypes and materials designed for other purposes. As shown in the picture below, this was made with a set of interactive furniture prototypes created as part of a project entitled “Recurring patterns” (Nilsson, Satomi, Vallgårda, & Worbin, 2011). Here, a form of “textile system” was created, consisting of a thermochromic print, a woven fabric with conductive threads, electronic components, microprocessors, and a graphic interface; in sum, a programmable dynamic textile surface that can change continuously or be activated by events occurring at various distances from the textile. Our framework suggests that this combination of materials and techniques could create interesting raw materials for design, which could allow for both temporary and permanent surface change, and re-patterning through digital programming of the surface (see Figure 6).

Figure 6. The smart textiles in the Recurring Patterns prototype placed in the framework.

The Smart Textile Sample Collection currently includes textiles that allow for fast-paced explorative sketches (such as raw prints) or for defining sketches, where changes to the materials are gradually added (including raw knits). Our experiences from the workshops and working hands on with these materials suggest that the transformable properties of smart textiles have the potential to introduce a stronger synergy between material design and three dimensional form in the sketching process. More complex smart textiles technologies, such as the materials and programming used in the "Recurring patterns" project, suggest more elaborate methods that are both explorative and defining in character, which could possibly further develop the meeting between material and form in the design process; for example, when designing interactive artefacts.

In order to more extensively explore this way of working and the role of smart textiles as raw materials for design, we need to develop the samples in the collection further. Those presented in this article are basic examples, representing the possibilities of a number of separate smart materials and techniques. As such, an interesting next step could be to develop textiles with more complex forms of technology; for example, to explore what other opportunities for smart textiles as raw materials for design, and the design processes that use them, could come from incorporating more advanced programmable behaviour.

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