LUX
Exploring interactive knitted textiles through light and touch.

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LUX - Exploring interactive knitted textiles through light and touch.

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1.1 Representative Images of Work
1.2 Abstract

LUX studies the combination of electronics and knitted textiles from a textile design perspective. The thought of experiencing textiles without touching them sparked the idea of designing textiles where touch is essential for the visual appearance. The aim is to design knitted textiles that light up when touched, in order to create an interactive experience for the viewer. Optical fibres were chosen because of their ability to transmit light and copper yarn works as an electrical conductor that triggers the reaction of light. The shapes of the knitted textiles have been created by utilising the characteristics of the optical fibre. LUX introduces a working method in which the optical fibre is given an important role not only as a light source but also as a tool for shaping the textiles. The result of the work is three textiles that display how electronics, consisting of sensors and light, can be merged with textiles and contribute to interactive behaviour.

1.3 Keywords

Textile design, Knit, Optical fibre, Smart Textile, Touch, Interactive.
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2.1 Introduction to the Field

Textile materials are a part of our everyday life. They are close to us in the form of clothing, we sit on them in buses and cars and we fall asleep between layers of them in the night. Textiles are generally perceived as tactile materials, they are often sensed through touch. For instance, when you try on a new sweater, your senses make observations regarding the material. Does it feel soft, itchy, thin, thick, light, heavy, cold or warm? All of these factors relate to your personal taste and form an opinion of the sweater.

This work has been inspired by light-emitting textiles and interactive installations. It focuses mainly on how to integrate light into knitted textiles and proposes a few ideas for interactive behaviour.

Textile design

Various artists and designers such as Astrid Krogh, Barbara Jansen, Anke Neumann and Malin Bobeck use the medium of light in their work. Krogh uses optical fibres in her woven textiles, that change colour gradually due to a rotating colour wheel placed at the end of the fibres (Krogh, 2016, fig. 1). In her thesis work, Jansen (2015) explores how light can be integrated as an active part into textile structures. She weaves optical fibres and uses coloured light that is programmed to perform certain actions together with sound (fig. 2). Neumann (2016) creates lighting, wallpaper and art where the optical fibres are integrated into paper during the paper making process. She often uses white light and her focus is on the combination of smart materials and traditional techniques (fig. 3). Malin Bobeck uses optical fibres in her woven textiles, her textile installation “Tactile Refuge” (fig. 4) has embedded sensors that react to touch and thus intensify patterns created by the light (Bobeck 2017).
Interactive installations

Companies such as Loop.ph, and Annica Cuppetelli and Cristobal Mendoza (Loop.ph 2017, Cuppetelli and Mendoza 2012), use projected light and various sensors. An installation called “The SOL Dome” by Loop.ph (fig. 5) has an onsite CO2 sensor which collects data that is transformed into a rhythm of the light projected on the dome. In their work “Notional Field” Cuppetelli and Mendoza have created an installation of cords that are placed next to each other vertically on a wall (fig. 6). The installation utilises video cameras that detect the movement of a body and project light accordingly, making it look as if the cords are moving.

In addition to textiles and interactivity, this work relates to the field of smart textiles. According to Tao (2001), smart materials can be divided into three main categories based on their behaviour. Passive smart, active smart and very smart.

Passive smart materials can only sense the environmental conditions or stimuli: active smart materials will sense and react to the conditions or stimuli; very smart materials can sense, react and adapt themselves accordingly.

(Tao 2001, p. 3)

The textiles designed in this work could be categorised within the frame of active smart materials. They will detect the sense of touch, and react by illuminating.
2.1.1 Key Terms

Optical fibre
An optical fibre is a fibre that has the ability to transmit light. It consists of a core and a cladding that surrounds the round fibre. The core has an internal reflection that transmits the light and the cladding prevents the light from leaking out (fig. 7). Bending an optical fibre as well as damaging the cladding affects its ability to transmit light (MIT 2001-2017). The fibres used in this work are plastic PMMA optical fibres with a diameter of 0.75 mm (fig. 8). The cladding has been damaged by hand with sandpaper, in order to leak out more light.

Conductivity - the ability to transmit electricity
To be able to use a touch sensor, a conductive part is knitted into the textile. Metal yarn is used as an electrical conductor and it is hooked up to the touch sensor to instigate the reaction of light.

Arduino, Open software
In order to make the textile responsive, the copper yarn and the light source were connected to a power supply and a circuit board. Arduino is an open-source electronics prototyping platform that was used in this work when designing various behaviour of light. (Adafruit 2017).
2.2 Motive and Idea Discussion

In a store, textiles are free to touch and explore, but in the context of a museum or an exhibition, it is common that touching textile artefacts is forbidden. The thought of experiencing textiles without touching them sparked the counter-idea of designing textiles where touch is essential for the visual appearance. Light was chosen as a medium to represent the visual change in the textile, and the factor that contributes to this change, is the touch of the viewer. Touch sensors were chosen to be combined with textiles because of the fact that textiles are commonly experienced by touch.

Due to its properties, the optical fibre is often woven into a textile, both Jansen (2015) and Krogh (2016) use weaving techniques to create surfaces where the entire textile is illuminated. The intention of this work is to focus on a single line of light instead of a big surface of light, using the optical fibre to highlight the edge of a shape. In this work the optical fibre is not woven, instead it is integrated in a knitted structure thus providing it with its own defined place in the textile. The fibre is stiff and bending it affects the transmission of light and might even break it. This work does not aim to challenge the bend-ratio of the fibre but rather to utilise the stiffness and flexibility, in order to create shapes with it together with the knitting technique.

In the installation Tactile refuge (Bobbeck 2017) the sensors are hidden from the viewer, this work on the contrary, wants to hide the sensors in plain sight. The copper yarn is visible and stands out from its surroundings, hoping to attract the viewer to touch it.

The findings of this work will hopefully bring new point of views to the field of textile design in questions such as: How to apply the optical fibre into a knitted textile and how to utilise the characteristics of the optical fibre in order to create three-dimensional shape. How a touch sensor can be used as a part of an interactive textile and how the programming of light can affect the interaction between the viewer and the textile. How the electronics can be made subtle and not feel as if they have been attached on top of the textile.
2.3 Aim

The aim of this work is to design knitted textiles that light up when touched, in order to create an interactive experience for the viewer.
3.1 Design Method and Design of Experiments

Process
This work follows the principles of basic design research through an experimental research method inspired by John Chris Jones (1992). The design process is divided into five parts: A, B, C, D and Z (fig. 9).

A: The problem is defined and a research question is formulated. The result, part Z, is defined. In this case: three examples of knitted textiles with integrated electronics.

B, C and D: These are necessary steps that need to be taken in order to get to Z. In this work these steps consist of sketching, knitting and analysing.

Z: A selection process will lead to this step, the production of the final design(s).

An alternation between the three steps, B, C and D, was continuous throughout the process. In addition to sketching, knitting and analysing, methods such as brainstorming and evaluation were performed during the design process. During the selection process, every prototype was questioned and challenged to fulfil the aim.

In pursuance of finding the visual aesthetic of the work, a mood board was made during the pre-study (fig. 10). This mood board has influenced the design process, in particular steps B, C and D.
Pre-study
During the pre-study it became clear that the optical fibre could build the shape of the textiles because of its stiffness, thus a conscious decision was made to let the fibre decide the shapes. Cavities for the optical fibres were developed and the fibre was inserted between rows of monofilament instead of attaching it on top of a knitted structure (figs. 11,12). The restrictions in time and access to the industrial machines pushed the work to focus on and be more exploratory in the hand knitting machines. By using the hand knitting machines, the fibre could be inserted in a desired way and knitted in between rows by hand. To be able to define the visual aesthetics, sketches were made both two-dimensionally and three-dimensionally (figs. 13,14) and a mood board was set to work as a guide throughout the design process (fig.10).
**Technique**

Knitting was chosen as the main technique because of its ability to build shape directly in the hand knitting machine, distinctly described by Delia Dumitrescu in her doctoral thesis, Relational textiles: surface expressions in space design.

..knitting technology has mainly been developed in connection to applications intended to be worn on the body. Thus, in order to be able to follow the shape of the body, the textile logic of knitted constructions has developed into a system capable of handling three-dimensional modelling.

(Dumitrescu 2013, p. 47)

Shape was created by combining various materials, techniques and bindings. One of the most important aspects of this work was to let the optical fibre decide the shape of the textiles. The fibre was never forced into a desired shape, on the contrary, it had a major impact on the development of the shapes.

**Material**

Material choices were based on the properties of the material itself. When knitting the paths for the optical fibre, a transparent plastic monofilament yarn was chosen to let the light of the optical fibre shine through. Bindings were chosen according to the characteristics that were sought after. For instance, when looking for an elastic quality, a rib was chosen over a plain knit due to its elastic characteristics. In pursuance of bringing stiffness into the knitted shapes, a blend of plastic monofilament and various polyester and wool yarns were chosen. The monofilament made the shapes more rigid and able to stand up with the help of the optical fibre. Figure 15 shows the chosen materials.

![Fig. 15 From left to right: Copper yarn, plastic monofilament, polyamide and wool.](image-url)
Touch and program
To be able to detect touch, copper yarn was used as an electrical conductor. The yarn is charged with a small amount of electricity and whenever the yarn is touched, the electrical charge flows through the human body to ground. The capacitive touch sensor detects this change and reacts with a pre-programmed behaviour of light (Orth 2009).

Copper was chosen over silver due to its outstanding conductivity. In order to let the viewer know that the textiles are interactive, a resting time light was programmed. If the textiles are not touched for at least ten seconds, all the LED’s will fade in, shine on maximum brightness for ten seconds and fade out hoping to catch the viewers attention. This loop will continue until the textile is touched.

Light
High-wattage white LED’s, light emitting diodes, were used to light up the optical fibres (fig. 16). The behaviour of the light was programmed intuitively based on the visual appearance of each textile. The optical fibre was chosen because of its comparability to a textile fibre. It has the appearance of a plastic monofilament fibre and It does not have any electronics embedded into it. Electroluminescent wire was looked into in the beginning but it was discarded because of its bulky aesthetic and the fact that it made a humming noise whenever it was switched on.

Couplers were 3D-printed in order to make the connection between light and the ends of optical fibres as precise as possible. This work utilised a 3D-design, made by Magnus Bratt, that has been used previously by students at the Swedish School of Textiles (figs. 17,18).
**Colour**

The work is striving to be visually open for interpretation by the viewer. Starting off with heavy black shapes during the pre-study, transparency, in the form of bindings and materials, was brought in during the design process to bring some lightness to the aesthetics. Colour was added to bring some depth into the knitted shapes.

When deciding the hues for each textile, the RGB colour model was used. RGB is an additive colour model based on light, where combining the three main colours: red, green and blue become white, see figure 19. Since the work uses white light, the decision to use tones of red, green and blue was made. The intention of the colours was to complement the black, therefore they were used in moderation in parts of the textiles together with black. The melange look was not desired and ruled out the use of light colours in combination with black (fig. 20). Dark tones were chosen so that they would not be visible in an instant, giving the work some depth without taking over (figs. 21, 22).
**Transparency**

When adding transparency to the textiles, 14 material combinations were tested and two were chosen to be used. Each combination consists of one thread of transparent 0.20 plastic monofilament and a thread of various black yarns. Materials that were tested: cotton, viscose, polyester, wool and lurex amongst others. The tests were carried out in order to determine the amount of transparency and the ease of knitting. Figure 23 shows all the samples that could be knitted. Samples 4, 7 and 10 were difficult to knit and the black yarn broke constantly, which can be seen in the samples.

Samples 2 and 8 were chosen to represent black and grey in the textiles. In addition to black and grey, each textile has the touch points in copper and its own hue, red, green or blue. This adds up to four material combinations per textile:

<table>
<thead>
<tr>
<th>Material combination</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monofilament 0.20 + Copper</td>
<td>Copper</td>
</tr>
<tr>
<td>Monofilament 0.20 + Wool Nm 28/2</td>
<td>Black</td>
</tr>
<tr>
<td>Monofilament 0.20 + PA</td>
<td>Grey</td>
</tr>
<tr>
<td>Monofilament 0.20 + PA + PES Sewing thread 160</td>
<td>Red / Green / Blue</td>
</tr>
</tbody>
</table>

**Scale**

Due to the complexity of the work and the fact that the author had no previous experience in dealing with smart textiles, the scale was dialled down and left to be explored in a future development of the work. The scale has been related to the average size of a human hand. The knitted textiles are meant to be easily accessible and touchable by palms and fingertips.
3.2 Development & Design Rationale

**Discarded prototype - Chute**
This prototype was discarded early in the design process. The positioning of the optical fibres was not fulfilling the aim as they did not play a key role in creating the shape of the textile. The fibres were passing through knitted layers and they had their defined paths in the textile, however they did not define the shape of the textile. In this work, defining the shape of the textile with light means that the light, the optical fibre, acts as an edge for a shape it has created.

Fig. 24 Sketching process of Chute.

Fig. 25 The first knitted prototype of Chute. Both silver and copper yarns were tested at this point.

Fig. 26 Side view.

Fig. 27 Close-up.
Discarded prototype - Cocoon
This prototype was discarded for a number of reasons. The optical fibres were not shaping the textile nor were they defining the outlines of it. When the theory of bending the textile into a cocoon shape was tried out in practice, the textile became wobbly when it was touched and this enhanced unpleasant associations with insects and jelly (figs. 30, 31). Since the sense of touching is at the core of this work, there was no interest in proceeding with a shape that brought up these kind of associations.

Fig. 28 Sketching process of Cocoon.

Fig. 29 This large scale knitted prototype of Cocoon is 70 cm long and 50 cm wide.

Fig. 30 A look inside the hollow structure of the prototype.

Fig. 31 The prototype fully bent.

Fig. 32 Each ridge made of transparent monofilament contains an optical fibre.
3.2.1 Textile one - Dart

Development
The development of the shape of the triangles went through many phases. The main technical difficulty during the knitting process was the transition between yarns. Stitches were easily dropped and holes appeared and were discovered when the shape was taken out of the hand knitting machine (fig. 34).

Fig. 33 Sketching process of Dart.

Fig. 34 The result of an accidentally dropped stitch.

Fig. 35 The optical fibre makes the knit curl and twist. In this picture the optical fibres are illuminated.
The positioning of the optical fibre and the touch was challenged throughout the design process. Figure 36 shows different stages of development. For instance, in sample C the optical fibre was inserted through the middle of the shape but since it was not locked in the structure, it could easily slide out of its place. Samples D-I show various ideas of how to add touch to the shape. D and E are knitted with a technique called pile-knitting, they became heavy and would not stand up on their own. Samples G and H have the same problem, they are knitted with a blend of shrinking yarn and copper. Sample I was able to stand up, it has an optical fibre on the edge and it is knitted with the same material blend as sample H.
Construction
Dart consists of triangular shapes standing in a cluster. The shapes have emerged by inserting an optical fibre twice in the same partially knitted triangle, thus creating a horizontal V-shape during the knitting process. All triangles were knitted using the same recipe and then rotated 90 degrees with the wider part down along with the ends of the optical fibres (fig. 40). The optical fibre makes the shape stand up. If the exact same shape is knitted without the optical fibre, it will not be able to stand up (fig. 36 H). The shapes are attached to a wooden base which hides the electronics (figs. 42, 43).

Light
The touch-points in this textile are the triangular shapes knitted with copper.

Light has been programmed to emphasise the pointy shapes: a pulse will emerge when one of the copper-triangles is touched. All in all there are three touch-points that light up three various light sources each with its own group of triangular shapes.

Fig. 40 Technical drawings.
Fig. 41 Building the 3-LED circuitboard.
Fig. 42 Attaching the shapes to the base.
Fig. 43 View inside the box.
3.2.2 Textile two - Column

Development
This textile is a good example on how the optical fibre was used as the main developer of shape. When bringing in transparency and changing material from shrinking yarns to polyester blends, a rib and a tubular knit was tried out. Two rectangular samples were knitted, each with an optical fibre on one edge (figs. 45, 46). When left on its own, the optical fibre in the rib sample bended and created a circular shape. This lead to textile two, Column.

Fig. 44 Sketching process of Column.
Fig. 45 Rectangular sample, tubular knit.
Fig. 46 Rectangular sample, rib knit.
Fig. 47 Close-up of the edge.
Fig. 48 Small illuminated cylinder.
**Construction**

Column consists of 19 knitted cylinders in various sizes. The cylinders are knitted as rectangular shapes with an optical fibre inserted on one edge (fig. 49). Once the shape is removed from the comb, the optical fibre bends and creates a circle, thus creating a cylinder shape. The cylinders are placed next to each other. Some tests were made where the shapes were placed inside each other, but this idea was discarded because it was perceived as visually too hectic (fig. 50). In the interest of hiding the light source and the electronics, holes were drilled through a wooden base and the optical fibres and the copper yarns are drawn through the base and connected underneath (fig. 51).

**Light and touch**

The sizes of the cylinders vary, so the light source has been programmed to behave randomly. The touch-points can be found as stripes on the upper or lower edge of a cylinder. This textile has five LED’s that blink in a random order when a conductive part, the copper, is touched. The viewer will not be able to control which circles are lit and in which order. The idea behind using seven blinks instead of five is to challenge the viewers perception of how many light sources there actually are.
3.2.3 Textile three - Helix

Development
This textile started off as a prototype made with shrinking yarn and conductive silver yarn (fig. 54). Since transparency was brought in halfway through the design process, it changed the relationship between the optical fibre and the knit. The samples made with shrinking yarn made the edge with the optical fibre wavy (fig. 55). But once the yarn was changed into a monofilament-polyamide blend, the optical fibre had more freedom to stay relatively straight. As a result the optical fibre started to twist around itself and the helix shape was discovered (figs. 56, 57).
Construction

Helix is built up by knitted rectangular shapes that are placed on a base systematically according to size and colour (fig. 58). There are five different types of rectangles, three of them have an optical fibre on one edge, one of them has both an optical fibre and a conductive edge and the smallest one is fully conductive without an optical fibre. This textile is presented hanging on the wall with the rectangles attached vertically to the base (fig. 59). To be able to see the depth of the piece when viewed from the side, transparency has been used with the help of various yarn combinations and sizes of ribs (figs. 60, 61, 62).

Light and touch

Because of its smooth shapes the textile has a calm sense to it. This is why the light has been programmed to behave in a calm manner. When touching the copper, the light will slowly glow stronger, when released, the light will fade away. The light is dependent on the touch of the viewer in this textile. If the touch is released before reaching maximum brightness, the light will fade away and the viewer will not see the full brightness of the light.

Fig. 58 Planning the attachment. Fig. 59 Shapes attached to the base. Fig. 60 Close-up of blue 1x1-rib. Fig. 61 Close-up of grey 2x1-rib. Fig. 62 Side view of the shapes. Fig. 63 Natural bend of copper-monofilament rib.
4.1 Result

This work results in three textiles that study various knitted shapes with light in the field of smart textiles. Compromises were made mainly regarding the scale. All textiles are knitted on a Silver Reed hand knitting machine gauge 4.5.

Fig. 64 This table shows the elimination process performed when determining the colours.
Textile one - Dart

Size of wooden base: 50 cm x 50 cm (depth 10 cm).

Technical details:

<table>
<thead>
<tr>
<th>Material</th>
<th>Number of units</th>
<th>Stitch length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monofilament 0.20 + Copper</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Monofilament 0.20 + Wool Nm 28/2</td>
<td>6</td>
<td>1.1</td>
</tr>
<tr>
<td>Monofilament 0.20 + PA + PES Sewing thread 160</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>Monofilament 0.20 + PA</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.

Width: 60 needles
Rib: 1:1 (every second needle)
Technique: Partial knit

Knitting recipe:
Cast-on + 6 tubular courses of monofilament
— Insert optical fibre —
1 rib course of monofilament
— Change material —
3 rib courses
Begin partial knit with carriage on right-hand side.
— Figure 65 —
End partial knit with carriage on left-hand side
2 rib courses
— Change material —
1 rib course of monofilament
4 tubular courses of monofilament
— Insert optical fibre —
1 rib course of monofilament
Bind-off.

Fig. 65 Instructions for partial knit.

Fig. 66 Dart as exhibited, left side shows the work when it is not touched, right side is illuminated by the resting time program.
Textile two - Column
Size of wooden base: 80 cm x 80 cm (depth 10 cm).

Technical details:
Cylinders were knitted in various widths and sizes using a 1x1 rib. The limit regarding width was reached at 180 needles when the optical fibre did not stay as a circle anymore, it became wavy instead. The height limit was reached at 250 courses when the cylinder was not able to stand up on its own anymore, the shape collapsed.

Fig. 67 A cylinder sample where the optical fibre does not stay as a circle due to its size.

Fig. 68 Column as exhibited, left side shows the work when it is not touched, right side is illuminated by the resting time program.
**Textile three - Helix**

Size of wooden base: 100 cm x 60 cm (depth 10 cm).

**Technical details:**

<table>
<thead>
<tr>
<th>Size</th>
<th>Height (courses)</th>
<th>Width (needles)</th>
<th>Rib</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS</td>
<td>10</td>
<td>150</td>
<td>1x1</td>
<td>Monofilament 0.20 + Copper</td>
</tr>
<tr>
<td>S</td>
<td>20</td>
<td>160</td>
<td>1x1</td>
<td>Monofilament 0.20 + Wool Nm 28/2</td>
</tr>
<tr>
<td>M</td>
<td>30</td>
<td>160</td>
<td>3x1</td>
<td>Monofilament 0.20 + PA + PES Sewing thread 160</td>
</tr>
<tr>
<td>L</td>
<td>40</td>
<td>160</td>
<td>2x1</td>
<td>Monofilament 0.20 + PA</td>
</tr>
<tr>
<td>XL</td>
<td>50 + 6 (copper)</td>
<td>160</td>
<td>2x1</td>
<td>Monofilament 0.20 + Wool Nm 28/2 + Copper</td>
</tr>
</tbody>
</table>

Table 3.

The ribs for rectangles L and XL were knitted on every second needle to get more transparency in the rib.

Order of attaching the shapes to the wooden base:

XS - S - M - L - XL - L - M - S - XS - S - M - L - XL - L - M - S - XS.

Number of twists for each shape:

XS: 10  
S: 7  
M: 5  
L: 5  
XL: 3

Due to severe technical difficulties and lack of time and knowledge, Helix never worked properly. It was speculated that the humidity in the air of the exhibition space interfered with the program. The sensitivity of the touch sensor was adjusted several times but a solution was not found. It was either too sensitive, or not sensitive enough. During earlier tests of the program in a different space, it ran as planned and there were no problems detected. When Helix was displayed at the exhibition, the touch sensor was disconnected and the light was looping the resting time program (fade in / fade out).
4.2 Presentation (exhibition)

Presenting the textiles
The desire to hide the electronics resulted in a solution of building wooden boxes for the textiles to stand on. The boxes were painted dark grey, the same colour as the walls of the exhibition space. This choice was made to emphasise the contrast between the line of white light and the dark shapes. The grey however turned out to hide the dark textiles and they seemed to drown in their background. The top of the boxes were painted white instead to enhance the knitted structures in the textiles. This was a compromise since it meant that the original idea of having a visible contrast between the light and the shape was lost. The white background made the optical fibre disappear and it is only seen when it is illuminated. This solution however made the textile seem more three-dimensional and brought up details in knit that would have been lost against a dark background (figs. 70, 71).

The idea of having one textile on the wall came from the interest in how we touch things differently whether they are vertical or horizontal. Helix was chosen to be hung on the wall because it had shapes that were relatively low in height from its base. When placed vertically on the wall, it could be easily seen from a side angle, giving it more depth (fig. 72). Both the shapes in Column and Dart have a higher distance from their base and are able to stand on a horizontal base. The biggest cylinders in Column did not keep their form when the work was placed vertically. Dart could be placed on the wall without any problems, but since the piece is quite small in size and there was a given exhibition space that needed to be filled, it made sense to use a bit more of the floor space and display it on a podium.
4.3 Conclusion

LUX presents a suggestion on how optical fibres can be integrated into knitted structures. It proves that electronics can be hidden and that copper yarn together with a touch sensor can bring a textile to life. It challenges the optical fibre to contribute with a new dimension to the work, functioning not only as a light source but as a building tool as well. Although the development of the interactive part is still at an early stage, LUX introduces three various reactions of light for further development.

Feedback at exhibition (opening day)

During the opening day of the exhibition reactions were observed and notes were taken. Since there were a lot of people, the work was touched regularly. When one person touched the work, other visitors were encouraged to touch it as well. As soon as a moment went by where the work was not touched, people became more shy and did not have the courage to touch it. This reflects on the fact that people are used to not being allowed to touch objects at an exhibition in a museum, which is a good thing since not all objects should be touched. It also became clear that the visitors did not realise that copper was the conductive part that triggered the reaction of light. Many visitors kept on touching all parts of the textile without realising what actually made it light up. Darkness might have played a part in this as well, since the different colours were not that clear in the dim lighting. However the visitors that had read the sign explaining the work quickly found the touch points.

The same issue was raised when visiting the installation “Tactile Refuge” by Malin Bobeck (Bobeck 2017) in Stockholm. It was unclear what the sensor was and to what it reacted, which resulted in not finding the sensor nor getting a reaction from the installation. This miss in communication reflected negatively on the experience of the installation.

![Fig. 73 A sign was made for each textile to encourage visitors to touch.](image)
Further development: Touch.
One development to consider in this work would be being more aware of the role of the touch point. Is it something that should be easily understood by the viewer or should it stay as a mystery? How important is it to know where to touch?

Further development: Scale.
Taking into consideration the fact that the work was inspired by large scale installations, a further development would be to look into scale and increase the size of the knitted shapes drastically. All three textiles could be translated into industrially knitted shapes to increase the scale. Whilst the optical fibres cannot be inserted by hand during the knitting process, especially not in Dart where the same fibre is inserted twice, they could be inserted afterwards by hand instead.

Fig. 74 Think scale.
4.4 Discussion

The aim of this work is to design knitted textiles that light up when touched thus creating an interactive experience for the viewer. When analysing the findings, it is clear that the aim has been reached. The work did not set out follow the footsteps of woven optical fibres, a field where designers such as Astrid Krogh and Barbara Jansen are performing their explorations (Krogh 2016, Jansen 2015), instead it took on a less investigated area where optical fibres are given their defined place in a textile construction. An approach closer to the way in which the textile “Moonlighter” by Delia Dumitrescu was constructed (2008). Due to choosing this path of investigation, the amount of optical fibres used in this work is relatively low. Hundreds and thousands of fibres are often used in woven surfaces where the optical fibre plays the role of a weft thread. Having hundreds of fibres requires more light sources. The couplers used in this work could accommodate up to 40 fibre ends (diameter 0.75 mm) each. All optical fibres in this work have both ends connected to a light source in order to get the maximum amount of light transmitted through the fibre.

Commercial context
The concept of textiles that are illuminated when touched could be used in the context of a space, for instance a lobby. When waiting for someone your eyes might study your surroundings and an interesting structure or perhaps the glitter of copper might encourage you to touch a surface, resulting in a change in your surroundings. An interior that reacts to the touch of its visitors could create an interactive experience not only for one person, but for many people at once. The embedding of sensors in daily life is increasing in popularity and a knitted touch sensor could easily be applied and commercialised in interior design such as lighting. The “Essential Dimmers” by Maggie Orth is a good example of smart textiles used as a practical solution (Orth 2009).

Working method
The working method used in this work, a subconscious experimental research method inspired by John Chris Jones (1992), provided a freedom to explore shape and material. Alternating between mediums such as watercolour, knitting and analysing was essential for the development of the work. If only knitting would have been allowed, the design process would have got stuck fairly quickly.

Fig. 75 Watercolour sketches.
Acquired knowledge

Due to the diversity of the various aspects of the work, knowledge was acquired from many different fields. Within the field of textile design, the confidence in the use of knitting machines increased. Being able to combine different techniques, to program and to understand the advantages and the limitations of industrial machines reinforced the thought of calling oneself a textile designer. Within the field of smart textiles, the surface has only been scratched. Programming an Arduino, understanding the basics of electronics and how they can be connected with textiles and realising the simplicity of how optical fibres function are just a few of many things learned. Interactivity was briefly touched upon when it comes to behaviour of light, a future development would be to dig deeper into the field of interactivity.
5 References


Borås: URL: http://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-3670


Photograph: Presentation (exhibition). Figure 72, page 33. Norrsell, A. (2017)

All photographs and illustrations: Blomstedt, B. (2017)