Composing over time, temporal patterns – in Textile Design

BARBARA JANSEN
Dear Reader,

I am delighted you are my audience today. Warm welcome to a journey through my thesis work. Please view the interactive thesis on the CD first.

Enjoy,

[Signature]

ISBN 978-91-85659-94-4
Handle-id http://hdl.handle.net/2320/12236
Published: May 2013
Printed and bound: Responstryck AB, Borås
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Editor: Lars Hallnäs
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– in Textile Design

BARBARA JANSEN
CONTENT
PRELUDE
Textiles
With the beginning of the era of Smart Textiles, the textile designer is challenged with a range of materials which are characterized by their ability to change expressional and functional properties. These materials respond to environmental stimuli, user interaction and pre-programmed parameters and visualize their responses to the viewer. For example colour change dye systems and light-emitting technologies open up opportunities to explore new colour palettes and behaviours, and also the potential for designing with novel and complex properties and aesthetics (Berzina, 2011, Krogh, N.D., Layne, N.D., Taylor, 2010, Wingfield, N.D.). The availability of these new materials changes the conditions of conventional textile design; a textile pattern expression is no longer static, it once had one face, one gestalt or expression, whereas now it can show different expressions, a definite or indefinite number of times.

Up until now the physical dimension of a textile piece (e.g. a curtain that is 2.50x1 meter), together with a specific design brief for expression and functional needs, set the parameters that frame the design work. In this research work, the relevant parameter is time and the temporal frame, within which changes will occur, dominate the starting point of the design. Time as a design element or a material, is a new element for a textile designer to work with. This is the reason the research work conducted in this thesis aims to develop an understanding about time as a design material, in order to allow designers to compose time-based patterns when designing light integrated into textile structures.

As a textile designer I am trained to work with colour, form, structure, material aesthetics and tactility. These design elements interact within a physical two-dimensional or three-dimensional textile structure. For instance first examples of colour changing materials have a strong focus on two or several different expressions, that appear one after the other. In the case of thermo chromic colour change dye systems, the change of colour is affected by changes of temperature caused by the environment, user interaction, or pre-programmed parameters. The designer develops one pattern, one design expression, for the base temperature and one for the changed temperature state. You still could say the designer creates two static images, which will appear independent from each other (Worbin, 2006, Worbin, 2010). Likewise examples of light-emitting textile surfaces are either switched on or off depending on changes in the environment (e.g. decreasing levels of light), user interaction or settings made in programming. The viewer is able to observe
daylight and night expressions, two static expressions perceivable at different moments in time (Jansen, 2007a, Jansen, 2009). Turning to the current work carried out in this thesis, new forms of expressions appear as textile surfaces (woven and braided, integrating PMMA optical fibres as light-emitting material) emit light sequences, that continuously shift and change the levels of light intensity and the colour of the light. (Introduction to optical fibres, Appendix 1: ▶.)

Light
The following will briefly introduce the main characteristics of natural and artificial light and their impact on the human wellbeing. Thus, a background is provided that explains the author’s interest in working with dynamic lighting. “Light is the most important source of life of the planet, it is the energy that makes the heart of the world tick at its daily, seasonal and yearly rhythm. In the natural world one is the element that provides all the information about time: day and night, represented by the cycle of light and darkness. Light variations are thus the basic agents of transformation of the environment and we have been exposed to these conditions for millions of years.” (Favero, 2008, p. 5) Light is essential to the human body (Boyce, 2003, Cimo, 2006, Dess, 2007, Ehrenstein, 2008, Marano, 2003).

The main characteristic of natural light is its variability. Natural light is received on earth either directly from the sun or is reflected from the moon. Daylight varies with latitude, weather conditions, time of day and season of the year, etc. Daylight exists in two forms, direct sunlight and skylight. Direct sunlight is the uninterrupted beams of light that reaches the earth directly, whereas skylight is diffused ambient light in the atmosphere around us. “The illuminance of a bright sunshine is steady; however the skylight can differ from minute to minute as clouds occurs, change form, get carried away from the wind, or evaporate. “ (Jansen, 2008a, p.34) (Boyce, 2003, p. 27-28, Tregenza, 1998, p. 31-36)

“Daylight covers all the wave lengths of the visible light radiation in a continuously light spectrum. … Beside that, it is characterized through smooth changes of light over the day: from night to day and vice versa, passing from one phase to the other through twilight phases. Morning light is characterised by its high amount of short wavelength – blue light – and evenings through their high amount of long wave lengths – red light. These changeovers from blue light domination to red light domination, has a crucial impact
on the circadian dominated body processes.” (Jansen, 2008a, p. 34) Light has various effects on the human body: from the impact of non-visual light, such as UV radiation and infrared light, to the visible spectrum of light. Until a few years ago the lighting industry mainly focused on the production of light sources that would provide optimum lighting conditions for performing visual tasks. Just recently research has shown that the natural rhythm of daylight has more profound impact on the human body than merely satisfying visual tasks. Daylight is a strong trigger for our circadian body systems. “The circadian system – or biological body clock – controls different processes in the body in 24-hour time rhythms, for example the sleep-awake cycle.” (Jansen, 2008a, p. 36) Today, it has been established that short wavelength light (blue spectrum) exposure represses melatonin production and stimulates alertness. The impact for this has been investigated in different areas such as sleeping problems, indoor working places, where employees often are not exposed to enough daylight, shift workers, SAD, etc. (Boyce, 2003, p. 95-97, 103, 458, 478-479, 487, Cimo, 2006, Dess, 2007, Lighting Research Center, 1995-2008, Marano, 2003, NOSAD, N:D:; Berlin, 2008, Tregenza, 1998, p.19). Ehrenstein comments that especially the twilight phases seem to produce an effective time-impulse on the circadian system, although this has not been entirely clarified yet. (Ehrenstein, 2008, p.43).

Artificial light sources can be grouped into four families: incandescent light sources (an electric current passing through a wire causing it to glow), discharge light sources (an electric discharge is sent through a tube filled with gas), luminescent light sources (LEDs, a semiconductor charged with electricity will emit light), and induction light sources (energizing a discharge using a magnetic field). Currently only incandescent light bulbs emit light continuously over the whole spectrum, therefore they come close to the perception of daylight, even though the colour temperature is not identical. Discharge light sources feature mostly through irregular amplitudes of the light spectrum, and LEDs have very narrow spectrum of the light emission, thus producing a more monochromatic light (Boyce, 2003, p.31-32, Hennig, 2008, Hennig, 2011). None of the current light sources is able to span the daylight wavelength spectrum or provides the same flexibility to change the level of light intensity.

Research into light and human wellbeing has shown that future artificial light sources should be adapted to knowledge on the biological impact of light on the human body. Consequently, future light systems should incorporate
daylight as much as possible and, when daylight is not sufficient, artificial light should include: an optimized light spectrum (this means a continuous and full light spectrum), changing over the day from short wavelengths in morning and daytime to long wavelengths in the evening, and also changing of light illuminance over day from i.e. increasing in the morning and decreasing in evening. This also includes large-area light sources that cover extensive the field of sight, especially from above a 45°–90° light wave angle to support an optimal lighting for the eye (Dehoff, 2008, see graphics below), and an interactive individual controllable lighting system for the user.

Hence, light is an indispensable field of design both today and in the future. It also offers designers and artists an interesting field to work in. Although this thesis doesn’t aim to improve wellbeing through light design, scientific research strongly encourages a designer working with artificial lighting to develop an understanding for dynamic light. Yet, in earlier projects such as woven light – powered by sun light (2005-2006) and especially

10°-30°: ineffective, 30°-45°: less good, 45°-90°: good, optimal, 90°-180°: not wanted, risk for glare
in Light Shell (2008) and Light and Shadow Play – the sun as an trigger for urban textiles (2009-2011) the natural rhythm of the sun has been placed at the centre for new concepts, using it as part of the expressional and functional possibilities in design (Jansen, 2007b, Jansen, 2008a, Jansen, 2011). See Appendix 1:

Light and Textiles
Integration of light into textile surfaces opens up new possibilities in lighting design, as textile surface are flexible as media and materials. In the last years, a range of light-emitting materials have been investigated in textile applications by artists, designers, researchers and companies. The integration of LEDs, electroluminescent wires, fluorescent and phosphorescent materials, as well as optical fibres have been tested and first prototypes, art pieces, site-specific installations and products have reached different audiences and the market, both craft and industrially produced (Glofab, N.D., Nordfeldt Iversen, N.D., Nordfeldt Iversen, 2006, Layne, N.D., LBM, N.D., Lumalive, 2004-2008, Luminex, N.D., Wingfield, N.D., Worbin, 2010).

Each of the light-emitting materials supports different forms of light expressions. Three main forms of expressions can be observed and created inside textile structures: dotted, pixel like (created via LEDs), linear (created via electroluminescent wire or optical fibres), and even light surface (created via electroluminescent film or optical fibres). For example the work of Barbara Layne (Layne, N.D.) features messages emitted via LEDs embedded in woven structures, Spår (Traces) by Anna Persson and Linda Worbin (Worbin, 2010) incorporates electroluminescent wire inside woven carpet, as well as Moonlighter by Delia Dumitrescu (Dumitrescu, 2008) inside a knitted structure. Dimma (Foggy) by Persson and Worbin (Worbin, 2010) involves electroluminescent film under a tufted structure and Inner Light by Sarah Taylor (Taylor, 2010), Ikat I-III by Astrid Krogh (Krogh, N.D.) and works by Barbara Jansen (Jansen, 2007a, Jansen, 2008b, Jansen, 2009) involves integration of optical fibres inside woven structures.

The research conducted in this thesis should be considered in context of work carried out by other designers, artists, researchers and companies involving optical fibres in connection to textile structures. For example Helena Hietana (1996), Lene Nordfeldt Iversion (2001), Sarah Taylor (1996-2012), Astrid Krogh (2002, 2011-2012), and Ligorano/Reese explore optical fibres through hand crafted lacemaking and weaving. Companies such as Luminex,

Especially in recent works, Sarah Taylor, Astrid Krogh, and Ligorano/Reese explore similar materials (particularly Taylor and Krogh, who use PMMA optical fibres in combination with paper yarns/materials) and expressions, in the form of dynamic colour-changes displayed in hand woven structures, to those investigated in this thesis. Their works feature as art pieces and site-specific installations. Unfortunately, almost no information has been published about these works that discuss their inspiration, design process and technical realization of the colour-changing sequences, or the textile structures themselves. Their works present themselves as pure inspiration for their audience and aim open up the perception towards new textile expressions. However, the research work presented in this thesis aims to provide other designers with the necessary insights in order to be able to create their own time-based works, especially in the area of light-emitting textiles.

The light-emitting material used in this project is PMMA (PolyMethylMethylAcrylate) optical fibres. This type of fibres have been integrated into both industrially woven and hand braided structures, and emit light through the use of white and RGB-LEDs (light-emitting diodes, each LED incorporates one red, green and blue LED) which are controlled by microcontroller digital interfaces. There are three main reasons why I continue to use optical fibres as light-emitting materials in my work. The first two concern the structural integration of the light-emitting material (optical fibres) into textiles, and the last concerns the light quality as such.

**Textile + Light = one:** From a design perspective, PMMA optical fibres are interesting to use as a light-emitting material in a textile context, as they are in their appearance quite close to a transparent thread. Using a “light thread” offers an opportunity to make light become a textile piece in itself. In this way light and textile structure melt into each other and become indivisible.

**Light expression – even light-emitting surface:** Especially the integration of optical fibres into woven structures allows for creation of dense surfaces that spread light evenly. Optical fibres were the first light-emitting materials that crossed my path and I have explored different structural forms of integration of the fibres. The intuitive creation of an even light-emitting surface...
quickly became my main goal. Explorations in hand weaving have been continued into machine weaving. As more background research into light and health was made (see section Light) it confirmed the need to continue to develop light-emitting surfaces that spreads light evenly, because they may one day make contributions in a light and wellbeing context. Woven structures could easily be applied as horizontal surfaces or applied to ceilings in context of interior design. The woven structure in colour flow is one example of these even light-emitting surfaces.

Light quality – variation in light: also in this aspect, research into light and health supports the use of optical fibres. As they are nothing more than light-transmitting media they may be connected to a range of different light sources. They allow the surface to be connected directly to daylight via the Parans Solar System (Jansen, 2008a, p.8, 14, 42, Parans, N.D.) in future applications. Besides that for this thesis the fibres are lit up by LEDs, which can be controlled and programmed through different digital interfaces (see colour flow and rhythm exercise).

When I began working with PMMA optical fibres 2005, a white light source (LED lamp) was used to light up the structures, in order to investigate the pure structural and material impact on the light effect. Already at early stage, it became clear that using coloured materials in combination with the optical fibres are colouring/shading the light effect, which would have been less obvious, if coloured light would have been introduced too fast. During that stage the lighting mechanism was either switched on at night and off in daytime, showing two independent static expressions. However, the wish to display changing light inside the structures soon appeared. A standard light projector (Halogen) for optical fibre applications with a colour wheel was tried out and equipped with five to seven colours at that time 2006. As colours were screamingly loud and the tempo too fast instantly grew the wish to define the speed and colour myself. Next, videos were projected into the optical fibres (Light Shell, 2008). Although this allowed me to create my own colour range and tempo, it still lacked real precision in respect of colour choice, where in the structure which colour is displayed, as well as timing of changing light colours. This led to the research work presented in this thesis and the introduction of LEDs controlled through a digital interface, into my work. There is no standard LED system on the market today that is able to connect to textile applications (incorporating optical fibres). The present work uses a
special customized LED lighting device system, which has been developed in collaboration with UK based electronic specialists, Circatron Ltd. It is a further developed version of the lighting device system used by Sarah Taylor for Inner Light (Taylor, 2010). The system allows coupling of the optical fibre ends to the LEDs and a digital Mix (DMX) replay system controls the lighting sequence via various programming processes. Hence, it facilitates the research work presented in this thesis.

Movement

Inspiration for different forms of expressions of movement is found in the field of kinetic art and Avant-Garde filmmaking of the 20th’s century. With the beginning of the 20th’s century movement and time-based forms of art entered the field. In the Realistic Manifesto created by Naum Gabo and Antoine Pevsner in 1920, they state that they, “recognize in the arts a new element, the kinetic rhythms, as a base form of our perception of the real time”. (Popper, 1975, p. 29, author’s translation) Schmied also describes that the most important theme of the 20th’s century is movement. “Movement, that means the interlacing from space and time, the multiplication of perspectives, the metamorphosis from material in energies.” (Schmied, 1972, p. 13, author’s translation) Artists such as Naum Gabo, Marcel Duchanp, Moholy-Nagy, Alexander Calder, Jean Tinguely and George Rickey are well-known for their kinetic work, establishing kinetic art in the 1920-1930 and 1950-1960.

Also the early abstract Avant-Garde films from the 1920 and 1930 are inspired mainly by the search for notations of time and movement in painting. This search led artists such as Hans Richter, Oskar Fischinger and Vikking Eggeling to filmmaking and made it a part of modern art (MACBA, 2000).

One artist who bridged the areas of kinetic art and abstract filmmaking in an outstanding manner was Len Lye. He investigated how “to compose pure figures of motions” his entire life. Throught his artistic career he studied and observed movement and brilliantly expressed his unique understanding of it in his films and kinetic sculptures (Bouhours, 2000, Horrocks, 1979, Horrocks, 1981, Horrocks, 2001, Len Lye rhythms [video], 2000, Len Lye talks about art [video], 2003, MACBA, 2000). His exploration of motion always involved direct physical interaction between his body and the materials involved. He developed his own way of sketching, doodling, as a form of automated drawing, in an attempt to switch off the conscious mind whilst working, scrabbling, doodling around inspired by a deep inner bodily involvement.
This form of physical involvement in the creative act, assigns a central role to the physical process of becoming, which is similar as the action painting of the abstract expressionists. He scratched, painted and printed directly on the film strip. Springy steel in its raw form, tube, rode or flat stripe were all twisted and swung in his hands, until they create a range of unique forms of movement and movement characters. Wild and dynamic as Blade, reposing in itself, slowly circulating as Universe, loaded with energy, dynamic dancing with upraised head in Bell Dance...

I guess this is what I am looking for: I am trying to find a way to compose different forms of unique movement characters. However, first I will need to learn how to “walk”, i.e. to create movement at all. From Lye’s point of view I am still not doing proper composing or sketching of movement at all, as the movement of light is inside my textile structures and the structures itself are still. Additionally, my working process is far from his unconscious forms of doodling. At least, a last “hands on” moment is maintained as I draw time lines and events by hand. Today, this is still a very controlled process as drawings are to be translated into the language of programmig, which demands a high level of precision. Hope that one day I will be able to compose over time in a more playful and intuitive way. It is rather the process of developing the physical textile structures, i.e. playing around with the fibres in an early explorative state, that feels similar to Lye’s way of working. Feeling the weight, flexibility and resistance of the materials, and trying out different forms (braiding, weaving and variations of these techniques) they can be molded to.

However, the introduction of Smart Materials into the field of textiles allows movement-based and time-based expressions to finally enter the field of textile design and art.

Aim
The work presented in this thesis is a first attempt investigating a new field, exploring the visual effects of movement using light as a continuous time-based medium. Composing over time, temporal patterns - in Textile Design is a practice based research project that investigates the following research question: What does it mean, if time and change – constant movement – becomes part of the textile design expression? The research question has been investigated in a number of experiments that explore the visual effects of movement using light integrated into textile structures as a medium. Thereby, the textile
design pattern reveals its composition, not in one moment of time any more, but in fact over time. This thesis aims to create time-based textiles with an emphasis on developing aesthetics of movement – or to establish movement as an aesthetic moment in textile design.

Two distinct groups of experiments, colour flow and rhythm exercise, explore a range of different time-based expressions. Currently, this series of experiments consists of eight parts (two for colour flow and six for rhythm exercise) and investigates most elemental building blocks, in order to understand how to build and create complex patterns, i.e. compositions evolving over time. The experiments are driven by the need to understand how to build rhythmic structures in order to be able to fully explore the aesthetic potential of time-based patterns. Colour flow is a series of experiments looking into creating sequences of coloured light, whereas the design aim is to explore how to lead over from one action to another, how to change over from one colour to the next. The transition over time is the main focus here, i.e. how to lead from a colour before, to an in-between phase to the colour after. Rhythm exercise looks into the creation of rhythmic light sequences, whereas the design aim is to examine different ways of dividing time to facilitate the creation of different rhythms, speeds, dynamics and tensions in the composition of movement, using monochrome white light. The experiments have been displayed and explored using woven and braided textile structures which have been construct mainly through the integration of PMMA optical fibres. (Cf. the introduction to optical fibres Appendix 1: .)

The research in this thesis will develop an extended palette of textile expressions and by doing so questioning the design process for textiles whose expressions evolve over time. The challenge of creating new aesthetics implies developing new design processes for the use within the field, which in this case does not automatically grow out of textile traditions (as, traditionally, the research area in this thesis has not been explored in the filed of textile design).

The development of new expressions, demonstrated through a variety of textile objects, will form the basis for analyses in this thesis. Analyses of these expressions and their preceding design processes will define new design dimensions, that will have to be incorporated in textiles, when considering expressing movement in a conscious and considered way. This will provide the basise for strategies to effectively design with movement in textiles, and also for the technical/mechanical translation of the design process into
physical objects, viz. the development of technical proceedings (producing cloth, connecting electronics to textile structures, programming integrated light sources, etc.) to allow bringing movement into cloth. New expressions, working methods and technical proceedings displayed via physical objects, on film, in visual media and through text, will demonstrate that the research is necessary to extend the textile field towards the expression of movement.
EXPRESSIONS
“The work of designing light is always to structure the flow of time”

(Mende, 2000)
EXPERIMENTS
Colour flow

Introduction

Colour flow is the initial series of experiments, starting up to investigate time-based patterns, as an opening to compose over time. This series is looking into the creation of sequences of coloured light and the design aim is to explore how to lead over from one action to another, to change from one colour to the next. The main focus here is transitions over time, i.e. how to design a transition from one colour to another via an in-between state.

This will be displayed through experiments made in a woven textile. The woven structure is built up through the integration of PMMA optical fibres in the weft direction. Thus, individual sections of the textile structure are connected to individual RGB-LEDs (light emitting diodes that each contain three LEDs, one red, green and blue which through additive colour mixing allow displaying a wide range of custom colours) and independently programmed to create moving patterns of coloured light using a microcontroller and a digital interface.

A newly developed lighting device system, developed in collaboration with UK based electronic specialists Circatron Ltd., allows coupling of optical fibre ends (bundled in to several independent strings) to the LEDs and a digital Mix (DMX) replay system controls the lighting sequence via various programming processes, in this case the Easy Stand Alone lighting software.

The lighting device system is a further developed version of the lighting device system Sara Taylor used for Inner Light (Taylor, 2010).

In the following descriptions of the experiments of colour flow and rhythm exercise, two forms of writing have been used. One is purely descriptive, neutral form to describe the experiments as such, whereas text titled Research Diary Notes includes reflections and personal comments on the experiences during work on the experiments. Most of the latter form of writing come from my sketchbooks, in which I continuously documented the work processes.
EXPERIMENTS

Experimental Set-up:

- Laptop
- Microcontroller (DMX512)
- Driver
- RGB LED: 1
- Woven structure
An RGB LED is built up of three LEDs, one red, one green and one blue. Each LED has a dimming range from 0 - 255:
0 = light off, or light intensity = 0
255 = light full on, or light intensity = 255
Together the three LEDs can mix together an endless range of colours (additive colour mixing).

The software [Easy Stand Alone] facilitates individual control of a range of individual light fixtures. In total, it is able to control up to 512 individual channels; however different light fixtures require a different amount of channels to be steered. An RGB LED requires three channels (each LED = one channel).

Via the software, dynamic light sequences can be programmed, so called scenes. Each scene is built up of a series of steps. A scene can either be played once or be looped. Additionally a group of different scenes can be played behind each other.
There are two ways in which the LEDs can be switched on or off:

– via holding time: The change in light intensity occurs in distinct steps. Below, four values of light intensity, 0, 87, 175, and 255, have been used to build a simple phrase:

voice 1:

<table>
<thead>
<tr>
<th>R</th>
<th>255</th>
<th>0</th>
<th>0</th>
<th>255</th>
<th>255</th>
<th>255</th>
<th>255</th>
<th>175</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>0</td>
<td>255</td>
<td>0</td>
<td>255</td>
<td>175</td>
<td>255</td>
<td>87</td>
<td>87</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>255</td>
<td>0</td>
<td>87</td>
<td>255</td>
<td>175</td>
<td>255</td>
<td>0</td>
</tr>
</tbody>
</table>

– via fading time: The change in light intensity occurs through a dimming/fading process with a scale range of 0–255. Below the following scale ranges have been used to create a simple phrase:

voice 1:

<table>
<thead>
<tr>
<th>R</th>
<th>0 → 255</th>
<th>255 → →</th>
<th>0, 0 →</th>
<th>0, 0 →</th>
<th>255, 255 →</th>
<th>255 → 255, 255 →</th>
<th>255, 255 →</th>
<th>255, 255 →</th>
<th>0.</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>0</td>
<td>0, 0</td>
<td>255, 255</td>
<td>0, 0</td>
<td>255, 255</td>
<td>255</td>
<td>175, 175</td>
<td>255, 255</td>
<td>87, 87</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0, 0</td>
<td>0, 0</td>
<td>255, 255</td>
<td>0, 0, 0</td>
<td>87, 87</td>
<td>255, 255</td>
<td>175, 175</td>
<td>0.</td>
</tr>
</tbody>
</table>
There are two ways in which the LEDs can be switched on or off:
– or a combination between holding and fading time:

voice 1:

R : 0 → 255,255 → 0,0, 255, 255, 255 → 0, 255, 255 → 0.
G : 0 → 0,0 255,0 255, 175, 175 0, 87, 87 0.
B : 0 → 0,0 0,255, 0, 87, 87 0, 175, 175 0.
The following two sections will introduce colour flow. Each section is a series of experiments exploring several perspectives on how to make a transition from one colour to the next. The first section, part 1, comprises the initial group of experiments of colour flow.

To start with a photo was selected as an inspiration for the choice of colour range. Fifteen colours were randomly chosen in an attempt to sample the entire colour spectrum of the photo. Photoshop and the tool “colour picker” were used to select the colours and the RGB values of the colours were noted. The first time-line or light sequence was created by using the initial selection of colours arranged in random order. This order will be referred to in the following as colour order 1.
colour order 1

1  2  3  4  5
6  7  8  9  10
11 12 13 14 15
colour flow_part 1

The first time-line, or scene as it is called in the Easy Stand Alone software, was created by lighting up one colour after the other (1-15) in clear distinct steps. Each colour appears for two seconds, using only holding time.

Research Diary Note: zack, zack, zack, as if a roboter were to lift his arms: zick, zack, zack, ...
colour flow_part 1

The second scene was programmed to create fluidity between the colours. Introducing fading time (F) and holding time (H), two seconds remain the ground pulse. See graphic representation of the scenes on the following page.

Research Diary Note: Somehow, the exploration into what it means to compose over time starts here. I play around with different time durations for fading and holding time, using one or both of them. It all feels wrong, not smooth enough, not balanced enough... The increments (steps) are still visible and it seems the flow stops when the colours "pause"/hold for two seconds. A difficult thing to do! Well, I don’t have to be frustrated today.

You “composed a scene”. Can I already talk about rhythm or melody?

The third scene was programmed to increase fluidity between the colours. To achieve this it was necessary to differentiate the time duration of the fading and holding times.

A fourth scene has been created by playing with irregular time durations for fading and holding times in order to create a first feeling of a melody.
EXPERIMENTS

The graphics below, represent the four scenes, time-lines, from *colour flow_ part 1*. The colour order used in the illustration below does not correspond to colour order 1. In this illustration I have used clear, distinct colours to demonstrate the principles of the four different scenes. Thereby *H* = represents holding time and *F* = fading time.

<table>
<thead>
<tr>
<th>Scene 1:</th>
<th>H</th>
<th>H</th>
<th>H</th>
<th>H</th>
<th>H</th>
<th>H</th>
<th>etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scene 2:</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>Scene 3:</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>Scene 4:</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
<td>H</td>
<td>F</td>
</tr>
<tr>
<td>Time line:</td>
<td>2 seconds</td>
<td>2 seconds</td>
<td>2 seconds</td>
<td>2 seconds</td>
<td>2 seconds</td>
<td>2 seconds</td>
<td>2 seconds</td>
</tr>
</tbody>
</table>
colour flow_part 1

The video shows all four scenes, played in order. The scene fades to black to mark scene changes.
Two additional colour orders were created based on colour order 1 (below). The colours of colour order 2 were rearranged in order to create the smoothest possible colour transition from orange/apricot to red/purple and finally to Blue. The third colour order was created to achieve a multi-coloured effect (German ‘bunt’). The colour order 2 tries to enhance the smooth, fluid transition from one colour to the next. Colour order 3 attempts the opposite in order to determine if this leads to the creation of a more rhythmic feeling, a more rhythmic scene progression. Both colour orders were played using the three different time-lines or scenes.
colour flow_part 1

In the video you see colour order 2 playing scene three, followed by colour order 3 playing scene four.
Research Diary Note: Playing colour order 2 with scene three creates the best fluidity between the colours. The transition is so smooth, that it is hardly noticable. The smoother I wish for the transition to be, the closer the shade of the emerging colour should be to the one preceding it.

The feeling I get when playing colour order 3 with scene four creates a remote feeling of having achieved a first rhythmic or melodic lighting scene. Higher contrast between the colours and irregular fading and holding times impact and enhance the rhythmic feeling. Thus, the feeling of differences in speed within the same scene seems to influence the melodic sensation as well.

In colour flow_part 1, drawings have been used as a tool for reflection and simultaneously inspect visually what has been programmed. Later on, however, in the rhythm exercise chapter, drawings (which are then named notations) have been used as a composing tool. In that context, notations have been used to compose/think scenes before starting the coding process.
EXPERIMENTS

colour flow_part 2
Experimental Set-up:

Microcontroller [DMX512]
Driver
RGB LED: 3
Woven structure

Laptop
RGB LED: 1
colour flow_part 2

Colour flow_part 2 is a first sketch, a first attempt at creating a composition consisting of three parts. The three parts are variations based on the three different colour orders and the four scenes (time-lines) created in colour flow_part 1.

In the following, descriptions of the experiments, the metaphor of instrument and composition will be used. Each textile structure (in this case a woven structure) is understood as an instrument on which various compositions, i.e. light sequences, can be played. A composition can consist of one or several voices, one or several sections activated independently in the textile structure. Thus, each voice can play its own melody or play in unison with other voices.

Part one: scene one is a repetition of colour order 2 playing the rhythmic structure of scene three, creating fluid, fine-graded changes of colour. All three sections of the textiles are lit up simultaneously, using three LEDs on the same side of the textile. As all three sections are playing in parallel, displaying identical colour orders, they appear to be a single, monochrome lighting surface (see e.g. next page, scene 1: step 3. LED four, placed on the opposite side of the middle section of the structure, is not in use and remains dark/silent = black line).

Part two: scene two uses a selection of colours based on those used in colour flow_part 1 accompanied by further randomly selected, contrasting colours such as red, yellow, blue, green, etc. The smooth colour flow is now broken up through contrasting “events”. The three sections of the structure only occasionally light up in unison, as each of the sections or voices now plays individually as well. Contrast and the feeling of movement are created by movement up and down the structure (see e.g. next page, scene 3: step 11). As soon as the fourth voice is activated, voices two and four both play their sequences on the middle section. This facilitates a multi-coloured effect in this section and also opens up opportunities for further directions of movement, e.g. from left to right and vice versa (see e.g. next page, scene 2: step 9). Whilst when only one side of the structure displays the colours, there is always a monochrome colour effect at one “frozen” moment in time.

Part three: scene three further elaborates on the variations in scene two, whereas voice four remains silent for the most part. Graphical representations of all three parts can be seen both in Poster 1 and on the next page and further visualizations of steps 3, 11 and 9 are found on page 44.
EXPERIMENTS

colour flow_part 2

scene 1:
voice: 1
voice: 2
voice: 3
voice: 4

scene 2:
voice: 1
voice: 2
voice: 3
voice: 4

scene 3:
voice: 1
voice: 2
voice: 3
voice: 4

light off =
colour flow_part 2

Scene 1: step 3

Scene 3: step 11

warp direction
direction of movement: up + down
direction of movement: left + right
Scene 2: step 9
EXPERIMENTS

colour flow_part 2

Research Diary Note: So far I have been pretending that the results of colour flow_part 1 and 2 met my expectations, i.e. that the process from programming the software to the light being displayed in the woven structure was straightforward and that the expected results were achieved immediately. By expected results I mean the woven structure displaying homogeneous, single colours according to the defined numerical values for red, green and blue (RGB) in the programming process. This was not the case, as I faced a problem with colour mixing of RGB-LEDs that is very common and which still is not resolved.

Instead of the structure displaying one homogeneous colour at the programmed moment in time, a multicoloured effect, example displayed in the photo below left, occurred. As was mentioned in the introduction to colour flow, the additive colour mixing principle allows the RGB-LEDs to create a wide range of colours. Theoretically, the light of the fully lit red, green and blue LEDs creates white light and when light intensity of any of the three LEDs is varied, a range of colours appears (e.g. R: 100%, G: 100%, B: 0% = yellow). However, the fact that the three LEDs are set apart from one another spatially brings with it the complication that only a very small portion of the lit area display a 100% overlap of the emitted light and, thus, other portions of the lit area have other colours as the mix of colours of light is different there. Furthermore, “the lenses in most RGB LEDs don’t focus each color to the same spot” (Utah, N.D.), why additional measures have to be taken to enhance the colour mixing process (Neumann 2012, Newark/element14, N.D.). Diffuse scattering materials are recommended to enhance the colour

So far, several experiments have been conducted to enhance the quality of the colour mixing process. Different diffusor materials have been placed between the RGB-LEDs and the optical fibre ends. Prototype adapters have been built to increase the space between the LEDs and the fibre ends, enhancing the mixing of the light by bouncing it through an extended cylinder (adapter) between the LED and the fibre end. A combination of both techniques has also been explored.

The engineering department at the company GTEIndustrielektronik GmbH, under the leadership of Christian Specker accompanied by two physicists, has explored different solutions. One solution was to install a diffusor at the focal point of the silicon lens of the LED in order to enhance mixing of the coloured lights and also to collect the light afterwards via a converging lens to increase the luminous efficacy. Two major disadvantages was discovered with this method. Firstly, the added diffusor materials (increased interference) absorb too much of the needed light energy. The second disadvantage concerns the quality of the silicon lens, which is not manufactured in a high quality process. All commercial LED components have a high mechanical tolerance, which makes it impossible to add other precise optical equipment to them afterwards. Currently, Specker’s team has reached the conclusion that although this solution functions in a lab environment, i.e. in theory, it does not withstand technical issues relating to the conditions under which mass-production is carried out.

A second idea is to adapt a single optical fibre to a single LED chip of acceptable quality which would be possible to manufacture commercially. If this idea were to be realized, one would be able to buy three single LED chips, red, green and blue. After connecting each of the three fibres to one of the three LED chips, the fibres would then be connected to a single fibre. When the three monochromatic light beams pass this gate, we would have three different colours of light mix in a single fibre. This would have to be done for each optical fibre in the textile (3-to-1). This technique is known and used mostly for laser equipment used in research and development. It has not yet been subject to mass-production with many fibres, partly because it would be too costly. Specker and his team recommend continuing to explore diffusing materials, although the reduction of light intensity likely is an unavoidable side effect. What also increases the level of difficulty is that I am looking for a small solution and one that is suitable for use with a textile structure. Finding
EXPERIMENTS

such a solution is an ongoing process.

The films introducing the RGB-LED and colour flow_part 1 show the light displayed with the use of an additional adapter as well as diffusor foil. Although one side effect is decreased light intensity, this is currently the only way to show the “best” possible, homogeneous colour effect. To strengthen light intensity, the textile stripe was lit up from both ends (LEDs two and four, both equipped with adapter and diffusor foil and playing the same scene).

The film on colour flow_part 2 shows part one of the sequence twice, followed by parts two and three. The first time part one is played, only LEDs one, two and four are playing. This is because LEDs two and four light up the same section of the structure, one from each end, and play identical sequences. Both LEDs are equipped with additional adapters and diffusor foil, whereas the stripe beside them (LED one) does not use any additional components. This is to demonstrate identical scenes played side by side, once using only the LEDs and once with the LEDs together with the adapter and the diffusor, showing multicolour effects and the best possible colour mix side by side. Afterwards, all three parts are played in the order they were originally composed. Although all four LEDs are activated (as individual voices), only LEDs two and four are equipped with adapter and foil, as I did not have enough prototype adapters to equip all four RGB-LEDs at the same time.

How did I program fine-tuned sequences to have multi-coloured light appear in the woven structure? When I started working with colour flow_part 1, just after I was introduced to the software, I began exploring programming possibilities while I was still waiting for the LEDs I had ordered to arrive. The software has a three-dimensional preview window (“Visualize 3D application”) that displays a stage scenario (as this software was originally created to program stage lighting) in which the connected light fixtures are visible and the programmed lighting, in this case the colour changes of a LED fixture, is demonstrated in real time. Imagine my shock the first time I connected the textile and the LEDs to the system and a multi-coloured something appeared. From that moment, I have been on a journey to find out what went wrong. Did I misunderstand the programming processes? No, as it turns out I did not and solving the real problem has been much more challenging than correcting a simple programming mistake, at least in this case.

As I was finally able to program colour changes for my work, this happens – what a disappointment! I had been working towards this for years. People who had seen my first sketches were so excited about the results. I could not
stop myself from feeling deeply disappointed as the multicolour effect did not allow any precision, neither in the design process nor for the outcome I aimed to achieve. Instead of going into exploring design possibilities, the journey to resolve the issues connected to the RGB-LED colour mixing system started. However, more time was spent on exploring design possibilities relating to rhythm exercise, which uses monochrome white light.

A year after colour flow_part 1 was created, I sketched colour flow_part 2, taking into account that the colour mixing issue still had not been resolved. I did this in the form of a presentation in order to demonstrate the potential I see in the work with colours. As I am writing this, one year after the presentation, the search for a solution is still an ongoing process. I have not yet abandoned the dream of one day presenting a “perfect” colour work. More patience and funding is required as I need to involve external competence in order to conquer the challenge. However, I have not wasted my time in the meantime as we are about to see in rhythm exercise.
EXPERIMENTS

colour flow_part 2

The video displayes all three scenes. The first scene twice, directly followed by scenes two and three.
rhythm exercise

Introduction
This series of experiments explores new ways of designing with time-based parameters to create dynamic light-emitting textile structures. The series of experiments is looking to create rhythmic light sequences and the design aim is to examine different ways of dividing time to facilitate the creation of different rhythms, speeds, dynamics and tensions in movement composition. Play and pause, i.e. activity in the form of movement and silence in the form of the absence of movement, and how these two states interrelate create the foundation for a specific feeling of rhythm, speed, dynamics, etc. These explorations are displayed in the form of braided artifacts. The braids are made of optical fibres, individually braided lengths lit by white LEDs and individually programmed to create moving patterns of light using a microcontroller and a digital interface.

A new lighting device system, which is a recent development in collaboration with UK based electronic specialists Circatron Ltd., allows coupling of the optical fibre ends (bundled into several independent strings) to the LEDs and a digital Mix (DMX) replay system controls the lighting sequence via various programming processes.

The lighting device system is a further developed version of the lighting device system Sarah Taylor used in Inner Light (Taylor, 2010).

Research Diary Note: the braid is based on thirteen lengths, each length is made of twenty optical fibers and connected to an individual LED. I am now able to light up individual lengths in the braided structure in any colour and at any moment in time. I am moving the light now one by one through the structure; firstly: string one lights up, secondly: string two lights up, thirdly: string three lights up etc., each of them for half a second. It is as if the light walks up a staircase, lighting up one step at a time. Two days later, the light is flowing in endless, continuous waves through the same braid. A range of expressions from being quite static (“step by step”) to fluidity has been achieved. Suddenly everything is possible, so what to do with it? What expression do I want to achieve? I have to start somewhere.

Currently this series of experiments consists of six parts investigating the most elemental building blocks in order to understand how to build and cre-
ate complex patterns, compositions evolving over time. The experiments are driven by the need to understand how to build rhythmic structures in order to be able to fully explore the aesthetic potential of time-based patterns. In the following descriptions of the experiments the metaphor of instrument and composition will be used. Each braided structure is understood as an instrument on which diverse compositions, light sequences, can be played. A composition can consist of one or several voices, i.e. one or several strings activated independently in the braided structure. Thus, each voice can play its own melody or in unison with its other voices.

Why a change to a braiding technique? There are four reasons why I decided to work with braiding: it is a traditional technique, the way light is emitted and spread inside the structure, complex light patterns, and independency in the manufacturing process.

First: Research Diary Note: In the south of Spain I found Esparteria, an old traditional braiding handicraft in which braiding is done with Esparto grass. Over several trips to Andalusia I fell in love with the beautiful surfaces covering and protecting the windows of the old wine cellars from the heat of the sun. Still allowing the smell of wine to evaporate the façades and linger in the narrow streets of EL Puerto de Santa Maria. They made me curious to find out more. They made me curious to find out more about this technique. I discovered that Esparto is used to create a wide range of textile products, ranging from curtains and carpets to baskets and wine bottle holders and that this single technique enables the creation of two-dimensional surfaces in several shapes (rectangular, round, oval), as well as various three-dimensional shapes. The tradition has nearly died out as it is passed on from hand to hand strictly inside families, why there is hardly any form of documentation to be found on the subject. I was fortunate enough to get hold of three pieces that were considered rubbish. These pieces triggered me to try out the technique - I so wanted to know how to crack the code. It took two weeks of intensive work to do it. Well, I did not learn the traditional way of braiding these structures with Esparto grass, but instead I was able to braid it with strings of other materials or optical fibres. See photos in Appendix 1:

Second: using this technique, the textile structure is created by implementing the fibres from one direction. Weaving requires interlacing fibres from two directions, weft and warp. Braiding in this way, you start at the top and work your way down the whole length. Thus, the length and width of the
structure is created at once. Incorporating optical fibres in the weft direction of woven structures requires a quite high number of LEDs in order to light up a certain length of fabric. Braiding allows a lower number of LEDs to light up a certain length. The only disadvantage so far concerns an inability to create braids of sufficient width, as in their current format they are quite narrow. Despite that, it turns out the braided structures light up intensively.

Third: furthermore, using the structural interlacing of fibre strings in the braids achieved interesting and complex patterns of light. They are only accomplishable through this specific structure and they would not be possible to recreate in a woven structure (see the rhythm exercise experiments in the following pages).

Four: All too often I was not able to proceed with my work on woven structures as I did not have access to the required machinery or the right kind of material for the warp system. By braiding it myself using handicraft techniques makes me independent and allows me to proceed with my work at any time, unrestricted by access to machinery, material accessibility, or access to technicians.
rhythm exercise

Experimental Set-up:

- Laptop
- Microcontroller (Arduino)
  - Driver
  - LEDs: 13
  - Braid: 13in1
Each LED has a dimming range of 0 - 255:
0 = light off, or light intensity = 0
255 = light full on, or light intensity = 255

The code used facilitates individual control of thirteen LEDs [thirteen DMX channels]. Thus, each LED can be activated independently and given its very own rhythm. When the light sequence of one LED has been run once, it automatically enters into an endless series of repetitions with an identical modus.
There are two ways in which the LEDs can be switched on and off:

– via holding time: The change in light intensity occurs in distinct steps. Three values of light intensity, 0, 80, 255, are used to build a simple example phrase:

1 voice:

| Light intensity levels: | 0, 255, 0, 80, 255, 0, 255, 80, 0 |

In the composing process, the following notation is used to show this:

| Time duration: | 1500 miliseconds |

– via fading time: The change in light intensity occurs through a dimming/fading process with a scale range of 0 - 255. The following scale ranges are used to create a simple phrase:

<table>
<thead>
<tr>
<th>Voice 1:</th>
<th>Voice 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 → 255,255,</td>
<td>0 → 255,</td>
</tr>
<tr>
<td>0, 0,</td>
<td>255,</td>
</tr>
<tr>
<td>80,80,</td>
<td>0,</td>
</tr>
<tr>
<td>255,255,</td>
<td>255,</td>
</tr>
<tr>
<td>0,0,</td>
<td>255,</td>
</tr>
</tbody>
</table>

In the composing process the following notation is used to show this:
There are two ways in which the LEDs can be switched on and off:

– via holding time: The change in light intensity occurs in distinct steps. Three values of light intensity, 0, 80, 255, are used to build a simple example phrase:

0, 255, 0, 80, 255, 0, 255, 80, 0

In the composing process, the following notation is used to show this:

1500 1500 ...

miliseconds

– via fading time: The change in light intensity occurs through a dimming/fading process with a scale range of 0 - 255. The following scale ranges are used to create a simple phrase:

0 → 255,255, → 0,0, 0 → 80,80, 80 → 255,255, 255 → 0,0

In the composing process, the following notation is used to show this:

play play
There are two ways in which the LEDs can be switched on and off:– or through a combination between holding and fading time:

In the composing process the following notation is used to show this:
There are two ways in which the LEDs can be switched on and off:— or through a combination between holding and fading time:

0 → 255, 255, → 0, 0, 80, 0, 80, 255, 255, → 0, 0

In the composing process the following notation is used to show this:

play
rhythm exercise_part 1
Experimental Set-up:

Laptop

Microcontroller (Arduino)
Driver
LEDs: 13
Braid: 13in1_2 voices
LEDs: 2: Each LED light one group of optical fibre strings.
2 light strings = 2 voices
rhythm exercise_part 1

In the following, the six parts of rhythm exercise will be introduced. Each part is a series of experiments exploring several perspectives on how to compose rhythmic time-based structures. Part_1, the first part of the initial group of experiments, opens up rhythm exercise.

Each phrase, each individual rhythm is based on a ground beat of one second.

Every rhythm is based on two voices, two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

The following signs have been used as a basic notation system to allow thinking and developing time-based rhythmic structures.

The height of a vertical line represents the level of intensity of the light (pitch height in musical notation) and its length represents the time duration of the light at the indicated intensity (see example below).

The diagonal lines represent fading between different light intensity levels. The height at the beginning and end of the diagonal line define light intensity and the horizontal length time duration.

The vertical lines at the beginning and end of a sequence mark the beginning and end of each sequence or phrase. One or several voices inside one composition are connected via the vertical line at the beginning of the composition.

A single repetition of a sequence is marked at the end of the sequence using this sign.

A sequence that is repeated an infinite number of times has this sign at the end of the sequence.
rhythm exercise_part 1_1

The rhythm is based on a ground beat of one second.
The rhythm is based on two parallel voices, i.e. two lighting “pulses”.

Research Diary Note: just blinking, on - off, on - off ...
rhythm exercise_part 1_2

The rhythm is based on a ground beat of one second. The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

Research Diary Note: still very much blinking, although there starts a first shift.
rhythm exercise_part 1_3

The rhythm is based on a ground beat of one second.
The rhythm is based on two parallel voices, i.e. two lighting “pulses”.

Research Diary Note: something starts swinging, – even though it is an equal beat? Already rhythm?
rhythm exercise_part 1_4

The rhythm is based on a ground beat of one second.
The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

Research Diary Note: it starts swinging, beginning of a 3D twist, movement inside the braid, when the two voices starts fading off-set.

A fast transition occurs from the end of one rhythm to the beginning of the repetition.
rhythm exercise_part 1_5

The rhythm is based on a ground beat of one second.
The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

Research Diary Note: Therefore this rhythm was created. The decision was made to prolong the original ground rhythm in order to be able to see the twist more clearly.
rhythm exercise_part 1_6

The rhythm is based on a ground beat of one second.
The rhythm is based on two parallel voices, i.e. two lighting “pulses”.

Research Diary Note: There is immediately rhythm! why? it has accent, acceleration, dynamic...
rhythm exercise_part 1_7

The rhythm is based on a ground beat of one second. The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

Research Diary Note: this is a strict, consequent continuation of the previous rhythm, but gives an bumpy expression, the off-set cross-fading is too fast.
rhythm exercise_part 1_8

The rhythm is based on a ground beat of one second. The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

Research Diary Note: this sequence is playing with stronger variations to the original rhythm in order to create a more smooth/organic, harmonious rhythm.

This rhythm and the following one explore variations and try to create a smooth, floating, three-dimensional twist (inside the braid) at the end of the rhythm. To create the “right” feeling in the relationship between speed and “visual three-dimensional overlapping-flow”...
rhythm exercise_part 1_9

The rhythm is based on a ground beat of one second. The rhythm is based on voices, i.e. two lighting “pulses” interacting with each other, partly parallel and partly in off-set rhythms.

See all nine rhythms in one overview in Poster 2.
rhythm exercise_part 2

Experimental Set-up:

Microcontroller [Arduino]
Driver
LEDs: 13
Braid: 13in1_13 voices
rhythm exercise_part 2

Experimental Set-up:
rhythm exercise_part 2

“step by step → wavelike”

In rhythm exercise_part_2 every phrase is based on thirteen voices. The aim is to switch every LED on and off, one after the other, in chronological order through the braided structure (1,2,3, ...). See visualization below.
rhythm exercise_part 2

“step by step → wavelike”

However, this is what occurred instead:
rhythm exercise_part 2

"step by step → wavelyike"

What really happened?

Although the thirteen strings of the braid were lined up in chronological order (1, 2, 3 ...), the order in which each string was braided in the braiding process was not 1, 2, 3... In fact, the braiding process is divided between both hands: in the beginning, seven strings are held in the right hand and six in the left and the outer string of the right hand (string 13) is used to start braiding: two over, two under, two over and into the middle. Then, the left hand follows suit (string 1): two over, two under, two over and into the middle. The right hand continues (string 12) by doing two over, two under, two over and into the middle and then the left hand (string 2) does two over, two under, two over and into the middle, etc. (see drawing to the right). Thus, the textile structure and the time-based composition of lighting both influence the expression of movement, in this case the movement direction in the textile structure.
rhythm exercise_part 2

"step by step → wavelike"

What really happened?
See graphical notation of time order and movement direction below:

Time order of the individual LEDs being switched on and off.

Time order of the individual strings inside the braided structure being switched on and off.
Movement direction of light sequence inside braided structure.
rhythm exercise_part 2

“step by step → wavelike”

In order to achieve the aim of this design experiment, i.e. to switch every string inside the braided structure on and off one after the other (from one side of the braid to the other), the time order has to be changed (below):

Time order of the LEDs being switched on and off. Movement direction of the light sequence in the braided structure.
rhythm exercise_part 2

“step by step → wavelike”

One alternative possibility to achieve the aim is to re-connect the order of the strings to the LEDs, i.e. to adjust the physical set-up instead of altering the programming code (see Second set-up below):

<table>
<thead>
<tr>
<th>First Set-up</th>
<th>Second Set-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td></td>
</tr>
<tr>
<td>Microcontroller</td>
<td></td>
</tr>
<tr>
<td>Driver</td>
<td></td>
</tr>
<tr>
<td>Cables: 13</td>
<td></td>
</tr>
<tr>
<td>LEDs: 13</td>
<td></td>
</tr>
<tr>
<td>Braid Strings: 13</td>
<td></td>
</tr>
<tr>
<td>Movement inside braid</td>
<td>Movement inside braid</td>
</tr>
</tbody>
</table>

![Diagram of First Set-up](image1)

![Diagram of Second Set-up](image2)
Third Set-up

<table>
<thead>
<tr>
<th>First Set-up</th>
<th>Second Set-up</th>
<th>Third Set-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cables: 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEDs: 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braid Strings: 13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement inside braid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
rhythm exercise_part 2

“step by step → wavelike”

The continuation of the sequence was developed using Set-up three, which was presented on the previous page. Phrases are coded in such a way that the “cross-over” movement, i.e. the movement in two directions, occurs inside the braided structure. By doing so, more exciting motion patterns are generated.

The final composition, or rhythmic structure, “step by step → wavelike” is based on twelve rhythmic phrases, linked seamless behind each other. Thereby the ground beat of 500 milliseconds maintains as the continuous metrum.

Phrase 1: every LED turns on and off, “step by step”-like, in a blinking manner. Thereby the time duration of the LED being on is 500 milliseconds (see drawing to the right).

Phrase 2: every LED is turned on, “step by step”-like, holds for 500 milliseconds, and then fades out over a period of 500 milliseconds (see drawing next page).

Phrase 3: every LED is turned on by fading in over 500 milliseconds, holding 500 milliseconds, and fading out over a period 5000 milliseconds (see drawing next page).

Phrase 4 – 12: the time periods for fading in, holding, and fading out are extended by 500 milliseconds until they all reach 2000 milliseconds (see drawing below and graphical notation of the complete composition in Poster 3).
rhythm exercise_part 2

“step by step → wavelike”

Video shows all twelve phrases of “step by step → wavelike” in order.
rhythm exercise_part 3

Experimental Set-up:

- Microcontroller (Arduino)
- Driver
- LEDs: 13
- Braid: 13in1_2 voices
Third Set-up:

Code
Microcontroller
Driver
Cables: 13
LEDs: 13
Braid Strings: 13

Movement
inside braid
rhythm exercise_part 3

"Ambience 2011"

Rhythm exercise_part 3 is based on 13 voices.
The composition is based on three longer sequences, which are played in order.

1. Sequence: "step by step → wavelike"
   [Composition "step by step → wavelike" (rhythm exercise-part 2)]

2. Sequence: "Verschränkung" [interlacing]
   Variation of the composition "step by step → wavelike" with the following order of the phrases:
   Phrase 1/LEDs 1-6 + Phrase 12/LEDs 7-12
   Phrase 2/LEDs 1-6 + Phrase 11/LEDs 7-12
   Phrase 3/LEDs 1-6 + Phrase 10/LEDs 7-12
   Phrase 4/LEDs 1-6 + Phrase  9/LEDs 7-12
   Phrase 5/LEDs 1-6 + Phrase  8/LEDs 7-12
   Phrase 6/LEDs 1-6 + Phrase  7/LEDs 7-12

Phrase 1/1-6 + Phrase 12/7-12,
3. Sequence: “mistaken”
Variation of the composition from “step by step → wavelike”. In the initial coding of the composition “step by step → wavelike” major mistakes were made, which in the end generated continual changes in the original phrase. For example, two voices became “independent” and played a cross-rhythm to the other voices. Moreover, one of them created a time-overlap, meaning that voice 12 is still playing sequence 3 when all other voices go back to play sequences 1 and 2 again. Hence, there will be an endless number of variations of the original phrase. See Poster 3.
rhythm exercise_part 3

"Ambience 2011"

Research Diary Note: when the braid is rolled up, the movement sequence of the light almost becomes a dance – ein Ringle Reigen...
rhythm exercise_part 4
Experimental Set-up:

- Laptop
- Microcontroller (Arduino)
- Driver
- LEDs: 13
- Braid: 13in1_2 voices
Third Set-up:

- Code
- Microcontroller
- Driver
- Cables: 13
- LEDs: 13
- Braid Strings: 13

Movement
inside braid
rhythm exercise_part 4

“Lotterie_1-5”
Rhythm exercise_part 4 is based on 13 voices.
These five sequences explored further variations on “step by step → wavelike” [Composition rhythm exercise_part 2].

“Lottery_1-3”:
“Step by step → wavelike” is based on twelve phrases played in order which have been divided into separate sections again. Each section has been further divided into two parts, LEDs 1-6 and LEDs 7-13, the two groups create opposing movement directions on the inside of the braided structure. The twenty-four mini phrases were then used to play “Lottery” in order to create new sequences. The numbers of the mini phrases were written down on pieces of paper, which were then shuffled and new, random orders of the phrases were drawn, creating new compositions using chance as co-composer.

Research Diary Note: oh, how do I create the transition between each mini phrase? How did I do it before?

A ground beat of 500 milliseconds has been the meter, measure of time, the interval between the start of each voice sequence. Voice/ LED 1 starts by playing its rhythm or phrase for 500 milliseconds, then voice/LED 2 begins playing its rhythm for another 500 milliseconds, etc. until voice/ LED 6 plays its rhythm, followed by voices/LEDs 13-7. Directly after voice 7 has completed its sequence, the new phrase, starting with voice 1, begins to play. In each of the 12 sequences, all voices play in the same chronological order, first voices 1-6 and then 13-7, all of them starting with a 500 millisecond interval (see drawing below).
The thirteen voices are now playing in new orders and no longer repeat voice 1-13, voice 1-13, voice 1-13, etc. Instead, the following may occur: 13-7, 1-6, 1-6, 13-7, 13-7, 13-7, ..., 1-6, 1-6, 1-6, 13-7, ... . At this point, the question was how I was to create the transition between each mini phrase, i.e. between: 7-13 → 1-6, 1-6 → 1-6, 7-13 → 7-13?

The decision was made to play the transitions in the following way:

1-6 → 13-7:
As before, each voice starts playing 500 milliseconds after the previous voice has started playing (see below left).

13-7 → 1-6:
As before, voice 13 completes its phrase, like a full stop in a sentence, and then voice 1 starts playing (see above right).

1-6 → 1-6:Voices 1-6 are played with a 500 milliseconds interval. 500 milliseconds after voice 6 has started playing, voice 1 of the second sequence starts (see following page below left).
13-7 → 13-7:
Voice 7 completes its phrase and then voice 13 starts playing (see the notation below right. All notations of “Lotterie 1-3” can be found on Poster 4).
rhythm exercise_part 4

“Lottery_1-3”
Research Diary Note: Suddenly, new patterns appear, new structural phrases. Verschränkungen (interlacing), yeah, Verschränkungen is the right word for this. See detail examples from “Lottery_1” below.

How would this look like inside the braid?
rhythm exercise_part 4

"Lottery_1"
rhythm exercise_part 4

“Lottery_2”
rhythm exercise_part 4

"Lottery_3"
rhythm exercise_part 4

“Lottery_4-5”
From the original 12 phrases, five (1, 2, 5, 8, 11) were selected to create a variation on the “Lottery” game. Each phrase was used with its two separate parts (LEDs1-6 and LEDs 7-13). Each mini phrase was used three times. The procedure used to create the randomly ordered compositions were the same as for “Lottery_1-3”.

Thus, known phrases were rearranged through a play of chance, a play of chance with repeated phrases, creating patterns over time.

The transitions between the mini phrases were created in the same way as for “Lottery_1-3” (all notations can be found in Poster 4).
rhythm exercise_part 4

“Lottery_4”
rhythm exercise_part 4

“Lottery_5”
rhythm exercise_part 4

“Lottery_1-5”
Research Diary Note: ups, what was this? Sudden movement at high speed, is this correct? or is this another coding mistake? No coding mistakes can be found. But maybe ... I am just underestimating the tempo, when I am looking on this drawing (see detail from "Lottery_3" below left).

As new structural patterns appear, Verschränkungen, I can no longer predict the movement of the light in the braid. The phrases are too complex. After viewing "Lottery_1-5" several times, I begin to develop a slight familiarity with some of them (see detail from "Lottery_5" below right).

This is odd, really strange – but interesting ...

This is just not working at all ...

Oh I like this ... so why?

... smooth fading in and out ... this one is fluid ....
   it feels like a repetition with a slight shift.

Three mini phrases together form a new rhythmic unit, this type of rhythmic structure I am naming Verschränkung for now. The same thing occurs by all the other Verschränkungen, several mini phrases, minimum two, create new structural units (see examples previous page).
Limiting the number of phrases used to play the Lottery game to five original sequences, “Lottery_4-5” increases the perceived difference in speed between the different mini-phrases. Furthermore it opens up for the play with repetition of single figures/phrases/sequences. When one phrase is played twice in a loop, the repetition/repeat is clearly visible, a “moment of obvious repeat”.

However, repeating a phrase with several other phrases in-between does not necessarily bring the word repeat to my mind. Yet, phrase No. 1, step-by-step, seems to fall out of the picture a bit. It appears to be the most significant phrase, as although it has not been played for quite some time I still remember seeing it before. There I tend to say: “oh, this appeared before, it is repeated.”

There seems to be two ways to repeat a phrase: as a direct repetition and as a recurring element. Somehow these two forms of repetition are clearly distinguishable and create something different … another nuance of expression.
rhythm exercise_part 5

Experimental Set-up:

- Laptop
- Microcontroller (Arduino)
- Driver
- LEDs: 13
- Braid: 13in1_2 voices
Third Set-up:

- Code
- Microcontroller
- Driver
- Cables: 13
- LEDs: 13
- Braid Strings: 13

Movement
inside braid
rhythm exercise_part 5

“Erwacht Ihr Schläfer drinnen”
Rhythm exercise_part 5 is based on 11 voices.
The Arduino board has been replaced through the DMX Replay Unit, and the braid is playing only with 11 voices.

This experiment is exploring the rhythmic structure of the old German canon “Erwacht Ihr Schläfer drinnen” (“Awake you sleepers inside”, melody by Giacomo G. Ferrari, 1763-1842). The canon is based on three parts and each part is repeated once before the melody moves on to the next part (see notes below).

In an attend to understand something about rhythmic structures in music, this simple melody was chosen, with the original aim of later playing the three canon voices on three braids.

First, it has been explored how to transfer the traditional note notation into a more graphical notation. Each ton in the pitch range has been given a colour. The pitch range spans two octaves from C – F’ (every pitch height triggering one voice/LED). Thereby the pitches from the lower octave were represented in darker colours and from the higher octave by lighter colours, for example D = dark brown, D’ = light brown, F = dark green, F’ = light green (see illustration below right).

In the previous notation system, the length of a line represented a specific time duration. The notes below have been transferred into rectangles and the horizontal length of the rectangle represents the time duration of the note.

The height of a line represents the light intensity value and the height position of a square corresponds to the height position of the notation of an individual pitch. Together, colour and height position of a square represent a specific pitch and therewith a specific voice/LED inside the braid.
rhythm exercise_part 5

“Erwacht Ihr Schläfer drinnen”

Trying out different forms of “graphical” notation:

Canon “Erwacht Ihr Schläfer drinnen”, three parts, in coloured "graphical" notation:
rhythm exercise_part 5

“Erwacht Ihr Schläfer drinnen”
Research Diary Note: speed, tempo is something very subjective and over the last days I tried three different speeds, too fast, too slow... right. But today right seems a bit slow again. I have to take a decision. The feeling of speed might always be dependent on my daily mood... ah, how did I decide too fast, too slow etc.? I was singing the canon over and over again while watching the sequence moving inside the braid. The right tempo as part of my childhood memory and my daily mood make the decision on the right speed a very subjective matter. Decision is made, I maintain the current speed for part two and three of the canon.

About notation, I received the comment, that I should only develop one form of notation. It should be as simple as possible and as open as possible, so that it will apply for a wide range of experiments. Would that work? Several forms have been tried out, as is shown above, but somehow forcing the notation for the canon into the “grid” of rhythm exercise_part 3 didn’t work out. Translating single notes into individual colours worked well as it was a better way for me to memorize it. The graphical pattern is more distinct and thus a lot easier to remember, making the transfer into coding much more straightforward. However, the other trials show in a way the same thing.

The biggest challenge was to find a form to translate repeated notes, e.g. two F behind each other (see drawing below top), into graphical notation. How was to show, graphically, the repeated notes while at the same time...
EXPERIMENTS

avoiding making them appear as a single, longer note (see drawing previous page bottom left, top green rectangle)? In case of inserting a space between these two squares, the time line would be automatically increased, if the strict counting meter was maintained. So, how to distinct those without changing the counting time/meter? The same question applies for the coding process.

When playing an instrument, the distinction between successive notes is created though different articulations. Variations in articulation define the transitions between a series of notes and, therewith, how the single note is played. For example they can be played as: legato = tied notes, nonlegato = not tied notes. Thereby a series of tied notes is often marked via a bow covering the range on top of them, and not tied notes are often played with short breathing mark between them. Meaning the notes get shortened from its strict counting meter. (Cf. (Musik-Steiermark, N.D., Wikipedia, N.D., Ziegenrücker, 1997) Articulation over-rules the counting meter. Different forms of articulation in playing an instrument are often marked through extra symbols as they indicate to the musician when and how the strict counting meter is “overruled”. Taking this into the graphical notation system and especially into coding there occurs a problem, it can only handle precise “meters”/time durations.

The graphical notation issue in this specific case was solved by shortening one of the repeated pitches. However, the same issue concerns another series of pitches where no direct repeat of a pitch occurs (see previous page bottom right).

I received the comment the squares have a logic towards weaving construction drawings, being a step closer to traditional symbols read by a textile designer. Well, yes, it does in some way, however for me it mainly reminded to read notes and that helped towards an understand of time based patterns. Fusing everything into one notation system did not work, however, although it may do so for someone else. I have a feeling that the different kinds of drawings I make stand for different things or different views on a similar thing, although I cannot put it into words at the moment.

For the very first time, a pause (= LED turned off) no longer creates a feeling of blinking, as it did in rhythm exercise_part 1. A pause becomes another rhythmic element. A voice inside the braid, being played and/or paused equally influences the composition of a rhythmic light sequence.

I received the question: Can you do this also in the negative form? Hm, I had not even thought about this. It had always been clear to me that the melody playing on the braid would be represented by strings lighting up. Every pitch played was to be displayed by a string “switched on”. Yes, of course, now a dark line is moving inside an illuminated strip, the same way a light line was moving inside darkness before (see next page).

It is strange, the moving line doesn’t seem to appear so clear. Or?
rhythm exercise_part 5

“Erwacht Ihr Schläfer drinnen”
rhythm exercise_part 6
Experimental Set-up:

Laptop

Microcontroller (Arduino)
Driver
LEDs: 13
Braid: 13in1_2 voices
Experimental Set-up:
rhythm exercise_part 6

“39in1_6 voices” ... “playing the wrong composition”

Rhythm exercise_part 6 is based on 6 voices. Three braids, each based on thirteen strings are grouped together. They are parallel aligned side by side at a distance of about two centimeters and each braid plays two voices. The physical object 39in1_6 voices is a further development of the braid 13in1_2 voices from rhythm exercise_part 1. It is about building either a “bigger instrument” or playing with three identical instruments. How can this object, consisting of three times two voices, which are clear distinct from one another, play a more complex composition?

In order to try out this object in a fast way an existing code was played inside this piece. The final version from “step by step → wavelike” from rhythm exercise_part 3, was chosen, as it was the first completed sequences consisting of at least six voices (play below).
Research Diary Note: This gets really odd. Something totally different, seven voices are missing in this object, which creates brakes in the play, it feels too long, very static, boring … it is no longer possible to perceive the tempo of the composition gradually slowing down … it is very weird. I wonder if this cod is correct. It is.

This clearly shows that the composition is not right for this object, this instrument. In this type of work new forms of expression are based on two main elements: physical object in form of a textile structure and a specific lighting composition. I am beginning to think more and more in terms of instrument (object) and composition because one can play several compositions on a single instrument, achieving different expressions. The same composition can be played on various instruments, regardless if this causes the generated expression to become meaningless, odd, weird, etc.

"… symmetric composition? “

The most advanced rhythmic structure for any instrument with two voices in my experiments was rhythm nine from rhythm exercise_part 1 (see below). It has been used as a foundation to create a suitable rhythmic composition for 39in1_6 voices.

Rhythm nine consists of two distinct parts. Part 1 is based on a threefold repeat of a mini phrase played in parallel for both voices and Part 2 creates a floating, three-dimensional twist in the braid (created through an off-set interaction between the two voices). The aim of this experiment is to explore in which ways these two elements, repeat and 3D twist, can be played with six voices.
EXPERIMENTS

The following description demonstrate how the more complex composition has been build up out of these two mini phrases, they are symbolised through two triangles:

The completed composition consists out of six larger phrases, labelled Block A - F, which have been chronological developed. See below and on Poster 4.

A moment of silence, darkness, voice one and two start playing rhythm nine. They repeat the phrase and, simultaneously voice three and four play the same rhythm. The phrase is repeated once more. All six voices play it simultaneously. See Block A below. The six voices are introduced by launching one pair at a time.

Watching rhythm nine play, I spend most of the time waiting for the mini phrase creating the 3D twist. In Block B, one pair, voices three and four, repeats rhythm nine three times. As the other pairs join in and play Part 2, one by one the voices highlight the 3D twist. Finally, all three pairs are reunited in the last twist (see Block B below).

Accepted that Part 2, the 3D twist, is most interesting part of rhythm nine, in Block C it is repeated twice on its own in all pairs simultaneously. See below and on Poster 4.

And now? What to do next? One idea that came up was to see what would

Block A

Block B
happen if from here on the three Blocks were to be mirrored. To see if a there-
by created symmetrical composition would be perceivable being played other
time. Hence, Blocks D, E, and F were created as mirror images of Block A,
B and C, respectively. Playing Blocks A-C backwards in reverse order, so to
speak (see below and on Poster 4).

These symbols represent the appearance of the individual voice over time:

voice 1+2
voice 3+4
voice 5+6

Whilst these symbols the presence of Part 1 + 2 in lapse of time:
rhythm exercise_part 6

“... symmetric composition? ”
Research Diary Note: It appears, that I obviously neither completed to code the whole mirrored sequence, after Block E I stopped. Looking at the sequence played inside the braid it all gets so endless, boring and static…

So why did this not work out at all?

In general, the mirrored effect is hardly visible at all when played over time, despite the fact that I am expecting it. After Blocks A - D have been played out, too much time has passed since the phrase of rhythm nine (Part 1 + 2) was played for the eye to remember it precisely. Therefore Block E appears to be almost the same as Block B and Block F almost the same as Block A. The repetition of patterns that appears to be the same over and over again begins to bore the eye after a while.

In this example, I noticed a major difference between my perception of the notation of the time-based pattern and the pattern itself, the actual rhythmic structure being played. Looking at the graphical notation (see Poster 4) a mirrored graphical image or illustration is clearly visible. The eye is able to discover the mirroring effect in the illustration as it is able to take in the entire image at the same time: it can zoom in on details and zoom out again to examine the overall composition of the image as a whole. Spending a certain amount of time grasping the overall expression, we seem to be able to memorize it quite well. “Do you remember this drawing we talked about last week?” A trained eye will have memorized the main characteristics and, in our case, the basic idea of the composition was to mirror symbols. However, our perception of time-based lighting patterns seems to lack precision. In this specific case, I cannot perceive the obvious pattern of the graphical notation in the time-based composition, despite the fact that I composed it myself.

Viewing the original rhythm nine on repeat, one longs for the twist to come back again. When playing this version on repeat it feels too long, even though it changes voices. Identical rhythm and speed repeated too often cause all tension and accentuation to be lost and the eye becomes bored.

And another comment on tempo: when watching this composition over and over again, the tempo seems to be changing from day to day and always to be wrong, just like before. Too fast, too slow… always the same, monotony creeps in.
The element in Part 1 where the lights drop from “full on” to “full off” (see below) is very tiring to the eye after a while. It resembles “blinking”.

255 = full on

0 = full off
Reviewing different ways of connecting electronic components and code to influence the movement directions in the braided structure: *rhythm exercise part 2* raised a need to rethink the set-up, as the movement in the braid didn’t turn out the way it was expected to. The set-ups illustrated above show the chronological progression of my work, whilst working with the experiments.

The fourth set-up did not require any rescrewing of the braided strings to the LEDs to create endless variations on a code that allows different movement directions in the braid. This creates the least risk for the optical fibre parts to be damaged, as they are very sensible to bending, scratching etc., whilst working with different experiments.

Furthermore, this demands only a simple “click in + out” of the plugs (mounted on each cable end of the individual LEDs) to re-connect them to the driver board.

The LEDs are mounted horizontally on a bracket (which functions as a heat sink) allowing them to be numbered 1, 2, 3 – 13, either from left to right or from right to left (which has been done for all experiments). For the whole system to work, however, the LEDs are not defined/numbered until they are connected to a specific position on the driver board. It is the position that
gives the LED a specific number (channel) 1, 2, 3, etc. So, swapping the cables on the driver board, using the “click in + out” system, allowed easy renumbering of the LEDs and, consequently, altering of the time order in which the LEDs were activated despite playing the same code.

There are two moments/positions in the code where the activity on a specific LED is defined:

1) At the beginning of the code “Program constants” define that each LED (1-13) is allocated with a specific DMX channel number. For example: LED 1 = channel 1, LED 2 = channel 2, LED 3, etc.

The driver board has 13 LED connections (labeled LED 1-13), each of them has a specific DMX channel number. By defining in the code LED 1 = channel number x, each physical LED (connected to a specific position on the driver) receives its own number or position in the system. Setting the channel number in the code defines the number position of a LED on the coding level, as well as in the hardware components (driver, LED).

2) Further down in the code, in “LEDs sequence”, the individual timeline is
defined, which controls the activation and pausing of LEDs, the time duration of both state, and the form of appearance, such as fading in or being switched on in distinct steps.

As a result of this, one is able to create endless variations by changing either the channel connected to a specific LED in the code or the timelines of the individual LEDs in the code (which takes more effort).

Alternatively, what is probably the fastest way to alter a given composition/code is simply to swap the plugs of the LEDs in the driver board. The end result of changing the channel in the code and swapping the plugs on the board are the same. The difference is that one influences on the coding level = digital interface and the other the physical level = hardware components.

Of all this, what is still relevant when I change from the Arduino coding + Arduino microcontroller to another digital interface + microcontroller?

Which components/aspects maintain (even they might be controlled in another way) to compose light over time?

Definition of channel [a LED gets defined/addressed with a specific channel number]
Creating timing/timeline for each LED
Cable connection between channel number/position on driver + LED number in code/software + physical LED → string → braid → movement

Nevertheless in which way I have connected and manipulated the components of the set-up on the coding or physical level, it is important to try out and find the way which works best for you. Most important is to find a way that allows you to easily pre-predict, envision the movement inside the structure, whilst working on the coding level. However, I strongly recommend avoiding frequent re-screwing of the braided strings to the LEDs, as it is all too easy to damage the physical piece.
DISCUSSION
Expressions – achieved

The research work in this thesis aimed to investigate and define the most elemental building blocks in order to understand how to build and create complex patterns, i.e. compositions evolving over time. Placing the temporal frame, in which changes will appear, at the starting point of the design process. Two ways of creating movement, explored through colour flow and rhythm exercise, have been investigated. In colour flow, a gradually changing colour scale creates continuous movement of light. Looking into the fluidity of fine gradient colour scale changes, as well as the more rhythmic feeling created by increasing the contrast of the colour variations. In rhythm exercise, different ways of activating light (switching on and off via holding and fading time) and how these can create different feelings for rhythms, tempo and perception of the passing of time was examined (through the emphasis on monochrome lighting). A range of new textile expressions has been achieved from quite static (step-by-step, zick-zack) movements to movements of fluidity and to melodic rhythmic qualities.

Considering the current colouring possibilities using RGB-LEDs, results maintain unsatisfactory. Although the multi-coloured effect could be quite effective depending on what one is looking to achieve, opening up an area of new expressions requires more precision regarding colour output. Advertisements for RGB-LEDs claim they provide endless choices of colours, whereas the practical reality when they are used in connection with optical fibers is an entirely different matter. The colour results displayed in different structures and using different fittings (connecting optical fibers to LEDs) with different diameters are still too diverse, in order to really consciously design with them, even when you want to embrace the multi-coloured effect. I still believe that precision in the choice of colour and colour being displayed as chosen, is crucially important in order to achieve specific expressions, definite atmospheres. Especially if one is to realize concrete and site-specific applications in the future. Therefore, the improvement of the colour mixing of the RGB-LEDs remain one of the on-going research aims.

Looking at the composing of movement inside the structure, it became very apparent that the timing orders of the different voices/LEDs connected to specific sections in the structure and the order of the structural sections together created a specific movement direction in the structure. The section order has been used chronological so far, both in braiding and weaving (see
next page on top left and right), though non-chronological orders are easy thinkable and to achieve, which again would widen the range of expressions (see examples on bottom left and right).

In these examples it feels impossible to draw the non-chronological time/movement order. However, such a time-based pattern using activated light sections inside a textile structure (braided or woven) would be feasible. For the woven example, a multi-layered structure and the use of a jacquard machine would be required.
Timing order: Voice/LED 3, Voice/LED 2, Voice/LED 1

Section order: 3

Movement directions:

Timing order: voice/LED 1, 2, 3, 4, 5
Section order: 1, 2, 3, 4, 5
Expressions – future

Among all possible expressions, personal interest has led me to look into organic expressions. Over 200 sounds of water and wind have been recorded as a starting point for transferring rhythms and movements based on natural phenomena into lighting sequences. Nevertheless, on the way toward finding this kind of expressions one often finds contrary expressions instead, as can be seen in colour flow and rhythm exercise.

In the future, I will continue my work by exploring, with nature as a source of inspiration, how to re-awaken organic and captivating appearances that unfold over time. With this kind of cross-modality in my work I will bring together tactility (in the form of textile surfaces) and light, whereby the experience of those sensations/materials will stand at the center. I will map temporal patterns found in nature and investigate how they can be applied in the design of dynamic light in order to create a composed experience with traces of nature.

Rhythms found in nature are familiar and at the same time undergo constant variations. Wherever we are, we recognize the waves of the sea or a river as waves and at the same time every wave is unique, a shifting variation of the former. The work will explore how one is able to design or compose a balance between the known and the unknown, the familiar and the ongoing variations of the familiar, embedding moments of chance and surprise.

Although we today are becoming increasingly detached from the presence of nature, we are still deeply related to it through our long, interwoven evolution and the biological rhythms of our bodies, such as heartbeats, breathing or the way we age. This work aims to link our awareness back to those rhythms and doing that, I will be closing the circle created by my previous works (woven light - powered by sun energy, Light Shell and Light and Shadow play - the sun an aesthetic trigger for urban textiles), in which the rhythm of daylight was central to the design process, the expressions and the concepts.
Time – Light

Warum ziehen gewisse Dinge im Zeitlupentempo an uns vorbei …
    warum scheint Zeit manchmal endlos langsam vor sich her zu schleichen,
    wie ein endlos gezogenes Gummiband …

+ manchmal ist sie im Nu vorbei,
    schon vorbei,
    bevor es richtig angefangen hat.

Why do certain things pass by in slow motion …
    why sometimes seems time to sidle endless slowly,
    like and endless stretched out rubber band ..

+ sometimes it's over in a blink,
    already over,
    before it has even started yet.

Time and light, light and time are intrinsically tied to each other. In TimeLight, Federico Favero defines,“... Light as Time provider signal“ (Favero, 2008, page 5), “The cycle of light and dark is the most compelling physical phenomena that provide variation on earth. The presence and absence of light is the first feature of time, giving name to day and night. The presence of the sun and its continuous change of position produce variations on the natural and built environment. These series of perceived variations create physical connections between the light source, the surfaces in the space, and us; these associations are at the basis of our feeling of time.” (Favero, 2008, page 18) Furthermore he describes, that only through daylight variations (position of sun, variation of light colour, changes through clouds etc.) we are able to perceive change and with it the passage of time.

This thesis has investigated how to develop a first understanding of time as a design material in order to compose time-based patterns in and through the use of light. Can you really name time a new design material? I do think so, by giving light a time durations, i.e. activating and turning it off via fading and holding over a specific amount of time, the foundation for time-based
patterns in light is formed. Changes in lighting through the use of different time durations and levels of light intensity create our perception of the passage of time: sometimes endlessly slow, sometimes over in a moment. In this sense, time becomes a design material as well as a “thing” in itself, a new moment of expression. On the other hand, light has to appear over time in order to be perceived. Furthermore, it has to be presented to us in variations in order to be noticed.
Composition

Research Diary Note (rhythm exercise_part 7): “There is something with tension and balance... when you observe a painting, graphic work, or piece of textile design, while describing the overall expression you start talking about Bildkomposition, composition of the image/pattern. The way how certain elements of form and colour have been used and how their position, relation is to each other. Elements could be clustered creating a moment of density, concentration in a composition, therefore could create a focal point. Elements could be absolutely equally aligned over whole surface, no central area is created. Elements could increase towards a formation, a moving direction (organisation of elements towards) a focal area can be created. The overall composition has one or several directions towards ... a tension towards a formation of elements can be built up and released again, symmetry and asymmetry...”

In the case of time based patterns, change of tempo, repetition and variation of familiar phrases seem to create something like tension, monotone, balanced ...

Traditionally a textile design expression is build up through the composition of colour, form (2D and 3D), structure, touch/haptic and materiality. Usually a visual/pattern composition, inside or on top of the textile structure (created by weaving, knitting, printing, etc.), is build up through:
A pattern element may or may not have a direction. For example, circles, squares, and equilateral triangles are symmetric shapes and do not have a direction. On the other hand, ovals, rectangles and all other types of triangles have a direction, e.g. horizontal, upright, etc. The way in which one or more pattern elements are arranged, positioned and repeated creates a “direction” in the pattern as well as an overall aesthetic/expression, an overall composition of the pattern. However, what happens if time and changing forms of expression are introduced into the textile design expression, e.g. in the form of constant change and moving light?

The most elementary part, element or building block used to create a time-based pattern using light is switching the light on or off. There are only two forms of expressions the light can take on: switched on via holding or fading time or switched off via holding or fading time. A pattern unit, a phrase is created through an episode of either holding or fading times, or a combination of these. Already with these basic elements, a rhythmic structure of time and movement in the structure (using a minimum of two voices) can be created. One building block or one or several phrases create the overall composition. Thereby, the overall composition is formed by a series of unique or repeated phrases (either with or without one or several other interposing phrases).
<table>
<thead>
<tr>
<th>elements</th>
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<tbody>
<tr>
<td>= basic building block</td>
<td>= phrase</td>
<td>= composition</td>
</tr>
</tbody>
</table>
Composing

Notions
In order to be able to describe these new time-based expressions and to compose over time, new notions (definitions) and design variables, i.e. elements to design with, have to be defined in the context of time-based textiles.

I have been looking into music terminology and composing processes in order to make a first attempt to find a convergence between music terminology and light, i.e. composing music and composing light sequences (see below). Now, I wonder, if light intensity and colour are one and the same? Looking at rhythm exercise, i.e. use of monochrome light, the change of light intensity levels creates the compositions. Whilst in colour flow, however, a range of different colours form the composition. Technically speaking, light intensity levels and colour are the same when it comes to RGB-LEDs.

The higher the light intensity levels of the red, green and blue LEDs, the paler and lighter the colour of the light becomes; the lower the light intensity levels, the darker the colours. Still, it seems right to relate volume and light intensity level to each other and pitch to colour.

As the work progressed, it became more and more obvious that light, darkness, light intensity, color and duration are the new design variables to play with in the creation of time-based patterns. Different kinds of building blocks and phrases create different tempi, rhythms, movements and flows of time; thereby, creating an overall composition.

<table>
<thead>
<tr>
<th>Music/Sound</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silence</td>
<td>Darkness (?)</td>
</tr>
<tr>
<td>Volumn</td>
<td>Light intensity</td>
</tr>
<tr>
<td>Pitch</td>
<td>Colour</td>
</tr>
<tr>
<td>Duration</td>
<td>Duration</td>
</tr>
</tbody>
</table>

are these the same?

here is a relation
<table>
<thead>
<tr>
<th>Non-physical Variables:</th>
<th>Notions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>needed</td>
</tr>
<tr>
<td>Darkness</td>
<td>in order</td>
</tr>
<tr>
<td>Light intensity</td>
<td>to create</td>
</tr>
<tr>
<td>Colour</td>
<td></td>
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<tr>
<td>Duration</td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Variables:</td>
<td></td>
</tr>
<tr>
<td>textile structure</td>
<td></td>
</tr>
<tr>
<td>[colour, form, structure</td>
<td>traditional</td>
</tr>
<tr>
<td>[weaving or braiding], touch/haptic,</td>
<td>Design Variables</td>
</tr>
<tr>
<td>materiality]</td>
<td></td>
</tr>
</tbody>
</table>
Composing

Notation
In this research work, notations have been used in four different ways: as a reflection, composing, translation, and documentation tool. In colour flow, drawings, notations were used as a tool for reflection in-between the programming processes, whilst in rhythm exercise they became the main composing tool, steering the creative process of doing/drawing and thinking time-based sequences. In rhythm exercise_part 5, notations were used to translate rhythms from musical notation to another form of visual representation or notation, i.e. programming code, which were then displayed as lighting scenes. Regarding knowledge dissemination, notation was used to document and facilitate “handing over” parts of the insights I have had during my research practice.

In the process of composing time-based phrases, notation done by hand has been essential. As a counterweight to all the coding of endless rows of numbers, a feeling of hands on access felt a necessity in order to feel a last connection to a hands on practice based doing. As well as the visual representation of time-activity, event was required to grasp and develop an understanding of what it means to compose over time, as textile designers are trained to work with visual compositions in design processes. Programming codes were useless to me (not having a programming background), especially in the beginning as I was trying to envision the time-based events and movements in the textile structures. Currently notations are the most important design tool in order to create complex rhythmic structures in monochrome lighting. To make progress with the work on multi-coloured light, a new approach to the notation systems will probably be required; this is something that has to be looked into as the work grows over time. To sum up, notations are a part of new design processes whilst creating time-based patterns and can be used as a tool for different functions.

During the research process, it became very clear that the time-based composition is not alone in defining the final expression. The textile structure displaying or playing the time-based composition is equally important: both of them equal influence the movement expression. Now, one could say that the textile design/composition is based on two main elements: the instrument and the composition. Only when a specific composition is played on a particular instrument a certain expression is created. Several expressions can be created through/on one instrument when different compositions are played on it.
Design process:

Instrument + Composition

Textile structure

braid weave

Notation

programming/coding

displayed in structure

New Expressions
DISCUSSION

Practice Based Research

Research is supposed to create, record and hand over new knowledge. Coming from a practice-based discipline, Textile Design and Craft, and executing research through and for this practice, I still wonder what this is supposed to mean. What type of knowledge are we talking about? And how am I supposed to hand over this knowledge?

As was mentioned earlier, textile designers are trained to work with colour, form, structure, material aesthetic, tactility etc. This knowledge and these skills don`t derive from theory studies alone as they are mainly achieved through practical training and practice-based explorations, through which the designer over time builds a range of skills, knowledge and competence. Polanyi phrases it this way: “... we can know more than we can tell ... successful riding a bicycle is a matter of non-linguistically, or as Polanyi prefers “pre-linguistically”, and unconsciously coordinating a number of bodily experiences.”(Biggs, 2004, p.6-7) (Polanyi, 1985) Or as Josef Albers describes it in his book Interaction of Color: “In the visual perception a color is almost never seen as it really is – as it physically is. ... In order to use color effectively it is necessary to recognize that color is deceives continually.” (Albers, 2006, p.1) Therefore, the study of colour theory is less effective than studying colours through experiences in order to gain skills on working with colours, or to “develop ... - by trial and error – an eye for color. This means, specifically, seeing color action as well as feeling color relatedness.” (Albers, 2006, p.1) Butcher and Hogan describe this for another practice-based discipline: “that we learn basketmaking by doing and recorded knowledge becomes immeasurably more valuable when it leads us back to basketmaking as practiced, living tradition. It is precisely because of so much craftsperson`s knowledge is tacit that nuances of making can rarely be fully recorded and in age where we tend to value the theoretical over the practical I think it is important to remember this.” (Butcher, 2008, p. 7). All authors address with these statements that we embody more knowledge and skills as we can put in words. The examples relate to disciplines in which practice-based learning dominates and where communication and knowledge acquisition go beyond linguistic matters. The field of textile design practice based research lies for me directly there and with this the presented research work.

As my research grows out of practice, I wish to emphasize the physical out-
come of my work in the form of textile objects. The language through which a textile designer communicates is through the use of textile materials, textile creations. This is why it is very important for me to disseminate the physical objects created through my research through exhibitions and to document them via film to suit the format of the thesis. Practical explorations are integral to my research as the investigations generate physical objects that incorporate all the knowledge and skills needed to create them. Therefore, I wish to give the physical objects the main focus in my research. The processes of making, developing a physical object and its finale form are both inseparable inscribed inside the object. A textile object I create embodies knowledge, which is gained by doing, experiencing, investigation, etc., they build on all the collected experiences from previous artefacts and a life time experience in perception and doing of things. These experiences are much more a part of my body than of my brain; how often can my hand remember an act, even I cannot conscious remember how to perform.

Neither words, nor technical drawings of textile structures, nor descriptions of materials, nor programming codes can express the new aesthetics appearing in the textile piece. A textile work can only be fully perceived through the presence of all the human senses. Adding the time perspective I propose in my work makes it necessary for the viewer to expose himself or herself to the work for a certain period of time.

I believe that art, design practice and research can create new human experiences. My objects, which you may call art, design or research, are meant to create new expressions and therefore create new experiences, new insights, understandings and knowledge about the world of textiles. Therefore, the direct sensual contention and contemplation with the objects is essential.

Through my research work I wish to ‘expand notions of that it means to read a piece of work’ (Koskinen, 2008, p. 19(31)). Exposing new textile expressions in public spaces provides opportunities to open up an general preconception of what a textile is supposed to be, to show, to express, etc., therefore expands notions of what it means to read a piece of textile work. This will help to create a new platform of discussing and envisioning future textiles. Only in discourse with others can research results reach potential outside the researcher’s capacity into a future. By displaying the objects in public, it is possible to address both a professional and a general audience. Public spaces such as galleries, show rooms, etc., are some of the traditional platforms for the dissemination of art and design work (Koskinen, 2008, p. 17-17, (31)).
Another form of disseminating my research work is through implementing it into new ways of teaching. This thesis is just a tiny/petite entree in this respect. For me, the implementation work would comprise creating a framework where people are able to acquire new skills by practical means. Turning my research into teaching in a wider sense would imply developing and equipping a physical and temporal space with tools, materials and technical equipment. Presenting new design dimensions and demonstrating new technical skills, providing guidance and time for individual explorations to a group of people in order for them to have the opportunity to gain new skills. This would help them create their own understanding of what it means to design with time, movement and rhythm.
Research Results

Concluding the research work conducted so far has resulted in a series of objects that display a range of time-based light patterns/compositions inside textile structures. Thereby, demonstrating a variety of new expressional possibilities in the field of textile light design.

Coming back to my initial research question: What does it mean, if time and change – constant movement – becomes part of the textile design expression? Through the design processes a first platform and understanding about time as a design material has been developed, which allows composing time-based patterns in light design. New design variables (light, darkness, light intensity, light colour and duration), notions (tempo, rhythm, time and movement) and tools (notations, programming, etc.) have been defined and established.

The use of new design variables (light, darkness, light intensity, light colour, and duration) immediately requires new ways of working and, therewith, opens up towards new ways of design thinking whilst working with temporal forms of design and composition, especially by the use of light emitting materials and light sources. The most important tool to the creation of complex rhythmic light patterns in monochrome lighting from the design point of view was hand written notations done in order to pre-vision time-events, i.e. movements of light inside textile structures. Whereas programming (via Sunlight Easy Stand Alone software and Arduino coding) became the most important tool for technical realisation into physical matter. Furthermore, the use of new design variables lead to new forms of expressions that add new expressional qualities to the textile designer’s palette, like tempo, rhythm, time and movement.

The new expressions will hopefully lead to discussions on and envisioning of future textiles, opening up the general perception of what textiles are supposed to be like, to show, to express etc., i.e. expands notions of what it means to read a piece of textile work. Displaying the objects in public spaces allows reaching a professional audience as well as a general one and challenges both likewise in the thinking and perception of textile expressions.

I would like to end this thesis by pointing to my coming work, which aims to explore more complex compositions in coloured light. It will have the specific aim to explore rhythms over time which can be found in nature (like day-
light rhythm, rhythms of water and wind). And therewith raises the following questions: How to map temporal patterns which can be found in nature (e.g. daylight rhythm, rhythms of water and wind)? How can they be applied and transformed to the design of dynamic coloured light?

How to design and compose with the balance between the known and unknown, the familiar and the on-going variations of the familiar, embedding moments of chance and surprise?

How to develop more complex compositions of coloured light? And thereby: how to evolve design thinking and processes, in order to achieve this?
ACKNOWLEDGEMENTS
I would like to thank my supervisors Margareta Zetterblom and Lars Hallnäs for their expertise and support.
Hanna Lindholm, Fredrik Wennersten, Roger Höberg for all the patience and support in the hand + industrial weaving labs.
Javier Ferreira Gonzalez and Dan Riley supporting me with base codes.
Special thanks to Sarah Taylor for inspiring discussions and sharing the same spirit about textiles and light, and huge support enabling access to labs at Heriot Watt University and University of Brighton. As well as the contacts to Circatron Ltd. and Richard Horley Lighting, without them the current research work would not exist.
Special thanks to Ann Hardie and Prof Robert Christie from Heriot Watt University and Will Nash, Claire E. Hoskin and Simon Driver from Brighton University.
Richard Horley from Richard Horley Lighting for a personal software introduction.
Marie Ledendal, PhD Student at Heriot Watt University for splendid project cooperation and times full of intensity, laughter and english tea.
Sara Robertson for providing her house and creative thoughts every time I stayed in Selkirk.
Katja Bülow and The Royal Danish Academy of Fine Arts, School of Architecture for access to the Daylight Laboratory.
Christian Specker and GTE-Industrieelektronik GmbH for investigating in the matter of RGB-LED-colour mixing.
Lisa, Anne Britt, Stefanie and Marjan for keeping my spirits up with fikas, dinners and playtime`s with Johan :-) Last but not least all of my family and most of all my Mum and Sergio, without your love and support this thesis would not exist.

Funding support:
Altrud + Otto Jansen, Smart Textiles Initiative, The Swedish School of Textiles, University of Borås, Estrid Erikson Stiftelsen
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Page: 1-156 Photos and graphic material: Barbara Jansen

Page: 172-173 Photos: by Heike Overberg, School of Arts and Design Berlin Weißensee, 2006


Page: 175 Photos: by Heike Overberg, School of Arts and Design Berlin Weißensee, 2006


All videos: director Barbara Jansen, film and editing Filip Asphäll, University of Borås.
APPENDIX 1
Optical Fibres

“What are optical fibres?
The term optical fibres or fiber optics can be described as being long lenses. “A cylinder or rod of transparent material forming a core and surrounded by an external cladding with slightly different material. Light, when entering the fiber, rebounds on the outer cladding towards the core. This way the light advances through the fiber in bounds or steps, until it exits at the other end. … The term “fiber optics” applies really to a branch of light physics dealing with the properties of certain materials which display a phenomenon called “total internal reflection”, and not to an object.” (Cortés, 1999, p. 9)

Optical fibres are mainly made from glass, PMMA (PolymethylMetaAcrylate) or polycarbonate. Optical fibres (both glass and PMMA fibres) are produced for telecommunication as well as lighting purposes. Telecommunication fibres radiate single frequencies, however lighting fibres the full visible spectrum. Generally optical fibres can be either used as solid core bare optical monofibres – a single blanc fibre, or as a bundle of fibres in a cladding, so called clad fibres.

What to choose: glass or PMMA fibres? In general, glass fibres are more used in telecommunication purposes and the trend goes towards PMMA fibres in lighting applications (Cortés, 1999, p. 15). Comparison of some main criteria’s, see overview next page.

PMMA optical fibres are produced as bare optical monofibres, clad fibres and sidelight guides. Originally optical fibres are supposed to transmit light from one end of the fibre to the other with as less loss of light as possible and therefore are also called endlight fibres.

As more optical fibres have been used in lighting applications the wish for a side light emitting fibre grew. Today’s solutions for that are so called sidelight guides. Simple sidelight guides are based on a bundle of bare optical fibres twisted together and inserted in a transparent tube. Producers constantly work on improvement; like the Microbraid Sidelight Guides from Advanced Fibre Optics which are based on a bundle of woven optical fibres in a transparent tube (Advanced Fiber Optics, N.D.).

Most relevant for a textile application are end- and sidelight guides as they transmit the light open visibly, meanwhile, clad fibres cover the light internally in an opaque cladding (which can be flame retardant treated).” (Jansen, 2008)
Comparison between glass and PMMA optical fibres:

| MATERIAL: GLASS | MATERIAL: PMMA | MECHANICAL PROPERTIES: Exceedingly brittle, easily shatters | MECHANICAL PROPERTIES: Good mechanical properties | ADAPTATION: Dangerous to handle, harmful | ADAPTATION: Easy to handle, no body harm | TEMPERATURE: High temperature resistant | TEMPERATURE: Max. 70ºC | FLAME RETARDENCY: Flame retardant | FLAME RETARDENCY: Not flame retardant | COLOUR VARIATIONS: After 3–4m | COLOUR VARIATIONS: After 8m | RADIATION DISTANT: Long distant until 30m, by 1550nm wavelength | RADIATION DISTANT: 20–45m distant (depending on the use of one or two light projectors), by full visible light spectrum | PRICE: High | PRICE: Lower |
woven light – powered by sun energy

The School of Arts and Design Berlin Weißensee

The thesis explored three main areas of practical investigations:

Development of a solar-powered, two-ply fabric:
A functional prototype based on the integration of six thin film solar cells and superficially interwoven optical fibres in a two-ply fabric was developed in collaboration with Mathias Stark, a student of Renewable Energy Sources at the FHTW Berlin. Due to study conditions (technical and financial constraints), the prototype is a rather coarse fabric. However, it provides visual proof that my idea need not necessarily remain a vision for the distant future.

Development of solar-powered "light dots":
Small solar-powered textile surfaces with light dots were developed in collaboration with the Thüringen-Vogtland Institute of Textile Research (TITV). There speciality is to create fine, electronic conducting textiles. Here thin film solar cells have been connected to the conductive fabric, powering incorporations LEDs, to create light dots.

Development of light textiles:
All light textiles are based on the integration of optical fibres and on double sided designs. One side is light dominating (optical fibres) the other side is combined with an additional material. This second material can have characteristics from soft and fleecy, smooth and shiny, transparent to opaque, white or coloured. The different materials and material colours affect the light quality and intensity, hence the light aesthetics. (Jansen, 2007)

View examples on the following pages.
woven light – powered by sun energy,

Solar-powered two-ply fabric:
woven light – powered by sun energy,

Solar-powered “light dots”:
woven light - powered by sun energy,

Light textiles in white, gold/copper, and yellow/green:
woven light - powered by sun energy.

view into the exam exhibition:
Industrial weaving
MA Studies, 2006-07,
The Swedish School of Textiles, University of Borås

Testing PMMA opical fibres (0.5mm, 0.75mm) in the warp system of a shaft machine (Dornier). Steel and copper used as weft materials, recolouring the light colour (white LED lamp).
Testing PMMA optical fibres (0.25mm) in weft system of shaft machine (Dornier), cooperation with company FOV, Borås.
APPENDIX 1

Experimenting with relief structures, Jacquard machine.

Industrial weaving
MA Studies, 2006-07,
The Swedish School of Textiles, University of Borås
Industrial weaving
MA Studies, 2006-07,
The Swedish School of Textiles, University of Borås

Experimenting with organic patterns; sketching via photogram techniques to printing to jaquard weaving.
APPENDIX 1

Experimenting with organic patterns, Jacquard machine.

Industrial weaving
MA Studies, 2006-07.
The Swedish School of Textiles, University of Borås
Design concept 1: inhabited by one body in lying or sitting gesture, left side. Design concept 2: inhabited by two bodies in lying or sitting gesture, right side.
Light Shell
View into exhibition, December 2008,
Textile-and Fashion Factory, Borås

Design concept 1: lit up via white LED lamp and Design concept 2: has projected film inside to show dynamic lighting/daylight rhythm.
Esparteria
EL Puerto de Santa Maria, Andalusia, Spain, July 2009

Vineyard from Terry’s, El Puerto de Santa Maria
Esparteria
EL Puerto de Santa Maria, Andaluzia, Spain,
July 2009

CalleValdés/San Bartolomé, El Puerto de Santa Maria
Esparteria Pilas, Andaluzia, Spain, July 2009
TEXTILE LIGHT DESIGN
Barbara Jansen
The Swedish School of Textiles, University of Borås

How can light be integrated as an active part into a textile surface? What would it mean to work as a textile designer with light as an integrated active part of a textile surface?

The combination of textiles and light is not new – often textiles are used for lamp shades – spreading, filtering and colouring the light of the inherent light source. However the possibility to integrate light into textile structures generates new ways of lighting designs. In the last years, a range of lighting materials have been investigated in textile applications from artists, designers, researchers and companies. The integration of LEDs, electroluminescent wires, fluorescent and phosphorescent materials, as well as optical fibres have been tested and first products have reached the market, both craft and industrially produced, (cf. Philips Lumalive (2004-2009); Worbin (2006, p.23); Lene N. Iversen (personal communication, October 2006); Glofab (n.d.); Luminex (2003-2006); LBM (n.d.), SubTela (n.d.)).

Current research into the impact of light on health shows that daylight, through its dynamic changeability, has a crucial impact on the well-being of the human body. The whole wavelength spectrum, as well as increasing and decreasing light intensity triggers positively the circadian body system. Therefore future artificial lighting systems should incorporate these aspects as much as possible, (cf. Boyce (2003, p.95-97, 458; 478-479, 487); Cimo (2006); Dess (2000); Licht und Gesundheit (2008)). A design example which is investigating the interaction of light, textiles and health is Light Sleeper: a silent alarm clock a work by Rachel Wingfield (2001). The integration of electroluminescent wires in beddings simulates with their lighting a natural dawn to wake you up.

The collection of projects in this paper discusses examples of light emitting textile design research, which explore aesthetic, functional, and conceptual opportunities of PMMA optical fibres in textile applications, through a practiced based research approach. (The projects have been developed in the School of Art and Design Berlin Weißensee and The Swedish School of
Textiles, between 2005-2008. Many thanks for all the support from technicians, cooperation partners and sponsors.)

OPTICAL FIBRES
PMMA (PolymethylMetaAcrylate) optical fibres have been used throughout all projects. (Below the term optical fibres will always refer to PMMA optical fibres).

Optical fibres are very interesting to work with in a textile context, being similar in their outer appearance to a transparent monofilament makes it possible to integrate them into a textile structure as any other traditional yarn material. They are able to become a real part of a textile structure and at the same time they allow the textile structure to become a real light source.

Optical fibres are a new material in textile applications. To be able to integrate them successfully, i.e. to create a smooth light-surface, new investigations need to be carried out. (Originally, optical fibres have been developed to transmit light as fast at possible from one end to the other without shining of light at their sides.) The basic issue is to create the right bending angles in optical fibres through textile techniques to provide lighting at their whole length. The challenges and ways how to integrate them into textile structures will be described in the following Phases 1–5.

phase 1: woven light – powered by sun energy
How could a textile surface incorporate lighting in one woven structure? Hand weaving techniques have been chosen to explore how to integrate optical fibres for lighting into weaving structures.

The aesthetic aim of these experiments has been to investigate how to create an even all over lighting surface through optical fibres, which can be applied in interior spaces. Three sets of experiments have been carried out on a computer controlled shaft hand loom; optical fibres with ø 0,25mm have been used for all experiments.

The first group investigated optical fibres in different weaving structures. Light tests showed that the integration of optical fibres in double layered structures both compound weaves and double weaves generated a stronger light effect, than within one layered structures (only exception were some panama bindings). Therefore double layered structures were further investigated. Optical fibres were combined with a wide range of white materials: from transparent to opaque, from soft-fleecy till smooth and shiny. The sec-
second material has been used as a reflection layer for the light emitted from the optical fibres, optical fibres and the second material dominating each one side of the double layered structure. Using only white materials offered the possibility to see the pure material impact on the light intensity and quality. See figure 1.

The second group continued investigating double layered structures by combining optical fibres with synthetic metallic yarns. Samples, where double layered parts and parts with only optical fibres stand beside each other, showed clearly noticeable differences in light intensity. The double layered sections, using metal yarn as reflection layer, show a stronger light intensity. These samples visualized, again, the importance of a reflection layer. Beside that, the colours of the metal yarns had an impact on the light colour – testing all samples with a white LED lamp – showed slight yellowish and reddish tones by the use of brass and copper yarns. See figure 2.

The third group explored the integration of relief elements – crocheting knots into the surface during weaving, or weaving in silk petals, and additional colours. The 3D elements create shadow effects in the light surface. The piece with the integrated silk petals created, on one side, a pure light surface, and on the other side, a multiple toned yellowish light surface. See figure 3.

A further important element for all set ups were; to use a transparent monofilament warp, to cover the optical fibres as little as possible. Choosing a transparent warp material allows the two sides of a double layered structure to appear as pure as possible. Thereby both – lighting and reflecting layer – can function as optimally as possible. All samples were finally lightened up through a white LED lamp, as well as a light projector including a colour wheel. Presenting the samples with white light, showed the pure material impact on the light. Demonstrating the samples through different coloured lights opened up for future investigations towards the interplay of structure, material and coloured light.

In Summary can be said that the experiments resulted in a range of samples, which showed different possibilities of how to integrate optical fibres into weaving structures.

Phase 2: industrial weaving
Working on concepts of lighting for an everyday environment – creating big window screens for public buildings et cetera – raised questions about industrial production possibilities. Is it possible to weave PMMA optical fibres
on industrial machines? The aesthetic goal stayed the same, i.e. to create an even all over lighting surfaces through optical fibres in a woven structure?

A broad range of experiments on an industrial shaft loom (Dornier) have been set up, to see if optical fibres can withstand the industrial production process. Previous optical fibres were only integrated into the weft system of weave structure, now they were investigated in the weft- and the warp system. The thesis work The screen – a textile installation by Lene N. Iversen (personal communication, October 2006), inspired to introduce optical fibres in the warp system as well. In her thesis she had successfully integrated PMMA optical fibres into the warp system of a hand loom. Integrating optical fibres into the warp system, opens up for larger scale opportunities for lighting textiles.

Based on previous experiments double layered structures were chosen, as well as real metal yarns as reflecting material for the light emitted through the optical fibres. The experiments using optical fibres (Ø 0,25mm) in the weft system resulted in a range of samples which were able to create a lighting surface. Some bindings provided lighting over the whole width of the
fabric, and some samples were only able to lighten up parts. First light tests showed, surprisingly, a sparkling effect in the lighting surfaces. What has happened? Hand woven samples never showed any sparkling lighting. After examination of the production process, it was realized that the cylinders for taking down the fabric, were covered with sand paper. The sand paper had caused scratch damages in the fibres and therefore a sparkling effect arose. By further tests the cylinders were taped and the sparkling effect minimized. The tests using optical fibres (ø 0,5mm and ø 0,75mm) in the warp system resulted in a range of samples which were able to light up until a length of approximately seven meters, by an eight meter warp length.

In summary can be said the experiments resulted in different samples of how optical fibres could be integrated in industrial weaving process, both in weft and warp system. Extending the range of optical fibre thicknesses showed new variations in the aesthetic expression of the lighting surface. Sparkling effects could be generated, and a much more structured, linear light effect appeared by the use of thicker qualities.

Beside the already mentioned challenges of using optical fibres on an industrial machine other basic issues are to avoid: strong bending angles of fibres (thick qualities will break and thin qualities will have problems with loss of light), scratching the surface, cutting of fibres through grippers, and too insensitive feeding systems.

Phase 3: light patterns
The aim for this series of experiments has been to further explore the aesthetic possibilities of optical fibres in woven structures; how to go from monochrome textile light-surface to more complex surfaces, how to compose more complex patterns of light textiles and light tones in woven surfaces.

Nature inspired patterns have been used to investigate the composing of light and not light in one surface. Using double layered structures allows creating two coloured patterns – light and not lighting, and vice versa on the back side of the fabric. By using this traditional technique a light pattern can be generated. Experiments have been executed on a jacquard machine (Vamatex SD 1701). See figure 4.

Relief structures, based on the same two coloured pattern system, have been investigated to further explore the shaping of light in woven structures. The result is a range of samples which show how different relief structures can be generated by combining cotton, Pemotex and optical fibres. Pemotex is
a heat sensitive yarn which shrinks after heating up. Thereby by partial use in a pattern, areas of the pattern will shrink. Optical fibres however will bubble up and therefore create relief shaped lighting areas. Samples including optical fibres need to be heated very carefully. Experiments have been executed on a jacquard machine. See figure 5.

By shifting the experiments to industrial machines a crucial element of the hand weaving experiments got lost, the transparency of the warp material (as only unbleached cotton warps on the machines were available). Transparency had been a functional choice towards minimizing the blocking of the light emitted through the optical fibres. Additional to that it had created a very specific airiness and lightness of the daylight aesthetic of these pieces. Besides that a transparent warp allows to increase the aesthetic expression possibilities in one warp immensely. Being unable to use industrial machines, a shift towards hand weaving was initiated, to test the possibilities of creating light patterns in the desired material aesthetic.
Testing the double layered bindings on a transparent warp, to create two coloured patterns, was not successful. The transparency melted lighting on front and backside visually to one layer and a monochrome impression arose. Therefore three layered bindings were introduced to gain the wished effect of light and no light and vice versa on back side. Three layered binding allowed modulating even more light shades in one surface. See figure 6.

To summarize, it can be said that the series of experiments presents different possibilities of creating light patterns in a woven structure. By the use of an opaque warp, two layered bindings are sufficient to create patterns, however by the use of a transparent warp, three layered bindings are needed to create similar effects.

Phase 4: industrial knitting

Having explored light in 2D surfaces widely, investigations towards lighting in a 3D surface started, and therefore a shift towards the integration of optical fibres into knitted structures had been initiated.

The starting point was the question: Can optical fibres be knitted on industrial machines? To begin with the optical fibres have been knitted as any ordinary yarn on a circle knit machine (Meyer Relanit 0,8). Light tests were not successful; the light didn’t travel further than two to three loops and then stopped completely. The bending angle in the optical fibres, which is created by knitting loops, is too sharp to transmit the light further. Therefore the light burst out strongly at the first loops and afterwards a total loss of light becomes consequence.

Next step was to test optical fibres through inlay technique, which allows a horizontal integration of a yarn in a knitted structure, through knitting on a flat knitting machine (Stoll CMS 330 TC). Thereby sharp bending angles could be avoided, allowing the light to continue travelling. Promising inlay technique has been found in a plain knitted surface, but as the aim was to integrate optical fibres in a 3D structure, or rather a 3D shape, a new challenge appeared: in a 3D knitted object the yarn is been knitted in a constant transition from front bed to back bed, back bed to front etc, and thereby the optical fibres as an inlay have to follow from front to back, back to front etc. This transition forces the optical fibre back into a sharp bending angle and transmission of light can not be successfully ensured. See figure 7, page 8, (cf. Jansen, 2008, pages 58-59).

Independently from investigations into the integration of optical fibres
into knitted structures 3D knitting has been explored. 3D shapes have been knitted on hand flat-knitting machines and afterwards programmed and knitted on an industrial flat-knitting machine. Surprisingly, not the same shapes arose, even by the same exact use of materials, bindings and amount of loops etc. These experiments on industrial flat-knitting machine showed that 3D shaping requires a quite complex programming and production process (and that the transfer from hand production to industrial production is not as easy as changing weaving technology). Therefore the decision was made to focus on developing ways of knitting three-dimensional as simple as possible and to exclude asymmetric shapes for the moment. Hence a continuous exchange between hand knitting, hand flat-knitting machines and industrial flat-knitting machines has been explored, to investigate 3D seamless shaping.

In summary can be said that optical fibres are able to knit industrially, but a successful transmission of light has not been achieved yet. Furthermore to create a 3D seamless shape is possible, but requires quite complex development processes.

Phase 5: Light Shell
The Light Shell project is concerned with the question of how to create a space-shape which supports a feeling of well being for the human body through the media light and textile. Research has shown that daylight has a crucial impact on the feeling of well being for the human body. Therefore optical fibres have been chosen as a light source, as they can be directly connected to sunlight – for example through a Parans Solar System (Parans Solar Lighting AB (n.d.); Parans Solar Lighting AB (2008); Parans Solar Lighting AB [visit, July 2, 2008]) – or/and to an LED system, which could simulate the dynamic changes of daylight. Several experiments have been done to cre-
ate 3D knitted space-shape integrating a dense lighting surface based on the integration of optical fibres.

As industrial knitting with optical fibres has not been successful in terms of light transmission, alternatives for integrating optical fibres into knitted structures have been looked for. See figures 8-9. Finally the integration of fine optical fibres into plain knitted metal structures, produced on circle knit machine, by ‘simulating’ a similar binding as in previous weaving experiments has been tried out. The optical fibres go on top of a certain amount of loops and underneath, on top, underneath etc. Thereby two things could be generated: bending angles over the length of optical fibre, which forces the light to exit on the entire fibre length, and creating a reflecting layer for the light through the metal knit structure. Example see figure 10.

Surprisingly the light tests in short plain pieces didn’t show a difference in lighting between bended and not bended parts of optical fibres (ø 1mm). However the light tests in weaving structures, by using ø 0.25 – 0.5mm optical fibres, showed a clearly noticeable difference in lighting: from no light, little or strong light, depending on different bending angles. Nevertheless, applying this technique of weaving in optical fibres by hand into 3D shapes showed differences in lighting, as the fibres are not only bended up and down, but also around different wide curves.

Results of this project are two models presenting two space-shape con-
cepts incorporating dynamic lighting:

Design concept 1: is a horizontal lying oval shaped space, which is based on a lying body position. The space offers its visitor space of privacy for a moment of personal time-out, being surrounded by an embracing dynamically changing light. The model is presented in scale 1:10. See figure 11.

Design concept 2: is a round cupola shape, which can house two bodies comfortable in a lying and sitting body position. This concept aims as well to surround its guests with an embracing gesture of dynamically changing light for a personal moment of time-out. The model is presented in scale 1:20. See figure 12. Both design concepts could be placed in private or public spaces, (Cf. Jansen 2008, pages 7-31).

In summary it can be said that by combining industrial and craft production techniques visualisations of Light Shells – how to create spaces for well being through light and textiles – have been developed in form of models. The models are able to be connected to a variety of light sources and therefore can demonstrate a dynamic changing of light in a three-dimensional space.

DISCUSSION

The field of Smart Textiles introduces new generations of materials into the field of textile design. These materials challenge traditional working methods, techniques and production possibilities and force the involved designers
to develop new ways of working. Therefore one can say the field of Smart Textiles opens up for a shift in design practice. Not only do new materials generate new working methods and aesthetic and conceptual possibilities for textiles, they also oblige the designer to gain knowledge outside of their traditional field. Knowledge about electronics, programming, light and light technology needs to be implemented, and therefore does not only influence the field of tasks for the designer. Besides that, it will also need to involve design education, to make future designers being able to approach these new dimensions of designing. The field of Smart Textiles, for example working with lighting design, opens up more and more towards a dynamic and interactive design approach in textile design, which marks a big shift in the fields design practice.

Craft and industrial processes have been used to explore the lighting possibilities for optical fibres in textile structures. Does craft stand against industrial? No, they in fact complement each other very well in a practice based design research approach. Both feature individual strengths: craft based processes allow a very free and direct working access and high flexibility in material choices and technical decisions. On the other hand industrial processes allow testing future visions in a bigger scale. Besides that, both ways create very specific aesthetic expressions. The work in the field of Smart Textiles develops a new type of working within craft, it allows to go beyond current industrial possibilities, and thereby pushes the industry towards new potential. Being able to merge them, like in Light Shell, enables to create future visions for textiles.

The series of projects and experiments presented in this paper have initially started in weaving technology; exploring possibilities of how light can be integrated into a woven structure. A range of lighting expressions and conceptual applications areas have been investigated and are presented through samples and prototypes produced both through craft and industrial possibilities.

Out of these two-dimensional explorations into textile light design, three-dimensional investigations have been initiated. Resulting in models which integrate 3D knitting technology as well as working methods from weaving with optical fibres, by weaving in by hand optical fibres into 3D artefacts.

Transferring knowledge from one technology to the other has enhanced the possibility to create future visions of lighting design through the media textile.
This paper has discussed a varying range of examples which explore aesthetical possibilities of how optical fibres can be integrated as an active part into textile structures. The final models of Light Shell visualize experiments in creating concepts of spaces for well being through the media light and textiles.

Besides that, all examples of light investigations lay a base for new design technologies in weaving and knitting technology towards the integration of optical fibres into textile structures.

REFERENCES


APPENDIX 1


FIGURES

Figure 1–3: Photos: by author (2006)
Figure 4–6: Photos: by The Swedish School of Textiles (2007)
Figure 7–12: Photos: by Henrik Bengtsson, Imaginara (2008)
I am a textile designer working in the area of light-emitting textiles. My research interest focuses on the exploration of new aesthetics within cloth exploiting the lighting properties of optical fibres integrated within diverse textile structures. My research explores movement of colour through dynamic polychromatic light sequences, as well as the dynamics of monochromatic light through rhythm and motion. The exhibited digital artefact uses optical fibre technology within a braided structure, activated by light-emitting diodes (LEDs) and a microcontroller as an interface to realize novel, light-emitting programmable textiles.

In previous work [1], I have explored the potential of light-emitting textiles, incorporating optical fibres within a variety of textile structures. The main emphasis has been to explore the aesthetic qualities of static light within different textile structures using a combination of fibre optics and additional materials. The lighting mechanism was mainly switched on at night and off in daytime, showing two independent static expressions. However my current research explores the visual effects of movement using light as a continuous time-based medium. Now the textile design pattern reveals its composition, not in one moment of time any more, but in fact over time.

DESIGN CONTEXT

The availability of new materials and technologies offer unique technical function and the potential for novel aesthetics. Due to their unique position, textiles are ideally suited to exploit these new challenges. As established technologies, for example colour-change dye systems and light-emitting technologies cross over into new product areas such as textiles; designers will more readily explore the availability of new colour palettes.
and the potential opportunities to design with novel and complex properties. [Cf. 2, 3, 4, 5, 6]. This exhibit is an example of practice-based research aiming to exploit the creative potential of light as a medium for novel, time-based aesthetics within textile artefacts.

**rhythm exercise**
The exhibit 13in1 is an example of my PhD research work which aims to answer the following research question: What does it mean to explore time and changing expression, in the form of continuous movement as an integral part of textile design? The aim is to create time-based textiles, which examine the aesthetics of movement as a fourth-dimensional element in textile design. Light, in relation to textile structure is the main medium of the investigation.

The exhibit is part of a series of experiments, named **rhythm exercise**, which explore new ways of designing with time-based parameters to create dynamic light-emitting textile structures. This series of experiments focuses on the creation of light sequences, which explore how different expressions of movement, rhythm, tempo, play and pause create dynamic tensions.

The three-dimensional braided artefact is based on thirteen lengths of optical fibre. It is lit by LEDs and programmed to create moving patterns of light using a microcontroller digital interface. It has been designed to display different qualities of lighting interplay using varying rhythms and speeds.

The piece uses a newly developed lighting devise system ®, developed in collaboration with the UK electronic specialists, Circatron Ltd.[7]. It is a further developed version of Sarah Taylor’s lighting devise system for *Inner Light* [5]. The system allows coupling the optical fibre ends to the LEDs, and a digital Mix (DMX) replay system controls the lighting sequence via diverse programming processes.

The results of the ongoing research project highlight novel, time-based aesthetics in textiles. The creative use of light within the exhibit promotes the concept
of designing textiles using a new visual language, the use of new design methodologies for realizing this and new mechanisms for design implementation. The desire to challenge new aesthetics using established light-emitting technology has been driven by creative, practice-based enquiry. Whilst both the aesthetic and the mechanical properties of the optical fibres and its related technology are understood, the commercial lighting systems offer limited capacity for advanced, visual enquiry for specialized areas such as textiles. The use of the customized LED lighting design system @ allowed for greater design flexibility. The adoption of a microcontroller linked to the digital programmable system offered an exciting tool for designing and realizing monochromatic lighting effects. The exhibit shows a glimpse of the new design possibilities and the potential for creative exploitation within this field.

ACKNOWLEDGMENTS
Thanks to:
Lars Hallnäs, Hanna Lindholm, Javier Ferreira González at the University of Borås, Sweden, and Sarah Taylor, UK

Thanks for fundings to:
The Swedish School of Textiles and Smart Textiles Initiative at the University of Borås, Sweden

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Light and Shadow Play – The sun as an aesthetic trigger for urban textiles

The project investigates how the sun can be utilized to enhance aesthetics through textile surfaces in urban environments. The project explores the interplay of textiles as a sun-screening element within the outdoor public architectural space.

What happens when we use the sun's heat and light to trigger a light and shadow play through a textile surface?

What happens when designing with an unpredictable parameter – the sun – in relation to the predictability of the textile design processes?

The exhibited objects; an interactive 3D model, two animation films and six storyboards, will summarise the research process and results. The interactive model is open for the audience to interact with via their own observations and explorations.

With this project we put forward the concept of dynamic, energy generating sun sails which incorporate printed solar technology. In this way we can create areas of shadow and generate energy at the same time. We also use thermochromic dye (heat sensitive dye) for a playful colour change in the sails. The sun's changing light will create a dynamic light and shadow interplay. Thus its variation in heat will trigger colour changes. Thereby the aim is to enhance aesthetic experiences within the urban environment.

The emphasis of this project has been to develop design dimensions/solutions to be able to create pattern compositions for a continuously changing pattern. No longer is the designed pattern purely on the textile surface, a second pattern is created. The textile surface and the sun form a constantly moving light- and shadow pattern in the 3D space.
DESIGN CONTEXT
Textiles are widely used as sun shading elements in urban environments, be it in old historical environments, like in the south of Spain, or in modern architecture. (Cf. [1])

“Why should sunlight always be shut out? [2]” Why not capture both light and heat and make use of it in design. We believe that the integration of solar technology in textile structures offers a great deal of potential for designers in the future. “Increased flexibility and mobility to generate energy are elements which speak for the integration of solar technology into textile surfaces. Developing new surfaces for energy generation through renewable energy sources is an environmentally friendly answer to humanity’s ever-growing energy need. [3]” The current development within solar technology points towards possibilities for printed solar cells onto textile structures. [4]

We have taken this as a base to develop a conceptual application for the future. This project has been based on a real street scenario, however it has been investigated on scale model.

DESIGN SCENARIO
LAT.:37,23, LONG.: 5,58. South of Spain. Seville. Calle Sierpes. It is summer and heat is trapped in the city. Hot, dusty air makes it, at times, nearly impossible to breathe and the sun is burning down on the ground. Horses, Feriar. Flamendo. Wide avenues and narrow streets. The river. Abanicos, the typical traditional fans, waving in the hands for a flow of air. Light - a lot of bright light. Laughter. People buzzing around. Shopping malls. The heart of Andalucia. The Calle Sierpes is covered with sun sails. What a relief. No burning sun on your head anymore creating a play of light- and shadows on the flow of people in the street. Life is pulsing in and out of the boutiques in one of the most popular shopping streets of the city.
DESIGN PROCESS
The starting point of the project has been to use Seville as a scenario to base our observations and explorations in.

A mood board has been created to define the atmosphere in the selected environment. Words and visuals described the mood: happiness, 'A sunny day', alive, 'lived in', housing environment, traces of living, fragility, rhythm, movement, pulse, etc.

Based on the mood board, basic forms have been selected. Over 200 sails with forms/shapes/patterns have been created using laser cutting technology.

A simplified 3D model of a street section has been built, in which the sun sails have been displayed.

The sun laboratory at The Royal Danish Academy of Fine Arts, School of Architecture in Copenhagen has been used to investigate the sun sails in the 3D model under an artificial sun. The artificial sun creates light and shadow patterns in a street environment during a 24 hour sun path simulation. The main focus has been to observe the changes of the light and shadow patterns in the street environment, created using various sun sail patterns.

The design process and results have been documented, analysed and evaluated.

Thereupon more complex pattern compositions have been developed based on the newly defined design criteria created for this project.

At the second visit to the daylight laboratory in Copenhagen more complex pattern compositions have been tested. The light and shadow play during a 24 hour period from two pattern compositions have been made into animations.

The results have been documented, analysed and evaluated. The results have been formulated in the shape of animations, photos, graphic material and text.

EXHIBITION
The designer can no longer just develop a pattern composition on a 2D surface. The scenario shows that the challenge of the designer is to visualize the coexistence of a three dimensional pattern in space. What will this look like? To what extent can the design be predicted? Or will it be completely unpredictable?

Through experiments and observations we have tried to develop design dimensions, variables, required whilst working with this type of scenario.

Parts of our process and findings will be presented and highlighted in an installation based on eight objects:

The first object is an interactive 3D model of an abstract street. The street is equipped with sun sails and people. The audience can interact with the model. With the aid of a strong spotlight, it will possible to hold and subsequently twist the model in order to observe the moving light and shadow patterns in the street during a 24 hour period. The model can be set-up for any specific day in the year using a mounted sundial diagram.

The second and third objects are two animated films which show two different pattern compositions – one emphasizing a pattern along the street and the other a pattern across the street through a 24 hour sun path. The sun sails will create constantly moving light and shadow patterns in the street scenario.

The fourth to ninth objects are storyboards which contain; an introduction to the project, the main conceptual ideas, illustrated documentation of the design process and results, as well as instructions for how to interact with the model.

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ACKNOWLEDGEMENTS
Thanks to:
Prof. Lars Hallnäs, The Swedish School of Textiles, University of Borås, Sweden.
Prof. Robert Christie, School of Textile and Design, Heriot-Watt University, UK.
Sarah Taylor, textile designer, UK.
Ann Hardie, School of Textile and Design, Heriot-Watt University, UK.
Katja Bülow and the Daylight Laboratory at the Royal Danish Academy of Fine Arts, School of Architecture, Copenhagen, Danmark.
Henrik Bengtsson, photographer, Imaginara, Sweden.
Pierre Ledendal, photographer and film production, Film & Bildstudion, Sweden.

FUNDING ACKNOWLEDGEMENTS
Thanks to:
Smart-Textile Initiative.
Estrid-Ericsons Stiftelse.
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Images previous pages: Daylight laboratory: moving artificial sun, Daylight laboratory: observing the model, Photo: Henrik Bengtsson. Film stills Animations_1 / Animations_2. This page: Daylight laboratory: set up for animation films, Photo: Pierre Ledendal