ELECTROLUMINESCENCE

a user-oriented material driven design

Graduation thesis by
Josien Verhoeckx

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Master thesis
Delft, November 2018

Author

Josien Verhoeckx
Design for Interaction (DfI)
josienverhoeckx@gmail.com

Supervisory team

Kaspar Jansen
Professor Emerging Materials
Industrial Design Engineering
Delft University of Technology

Frans Taminiau
Design Conceptualisation& Communication
Industrial Design Engineering
Delft University of Technology

Delft University of Technology

Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands

THANK YOU

I want to thank a lot of people, because even though graduating might feel like a lonely process, you don't really do it on your own. So here we go.

> First of all, thank you team. Kaspar, for your knowledge of the material, but also for your optimism; no idea was ever impossible to make according to you, which elevated the project. And Frans, thank you for your guidance when the process got hard. You always seemed to ask they right questions and have a word of wisdom when the project got stuck.

> Thank you mom, for your enthusiasm and belief in the project. For the long calls when I needed them or the long walks when I needed those even more. And thank you for sending pictures of Miepje and Yume, they always make me smile.

> Thank you Majors, for all the much needed breaks I had with you guys: the wisdom, the laughs, the beers, the discussions, the ideas, the help and the optimism. Together we are an odd group but I guess that makes us strong.

>Thank you Veer, for reading my report twice without complaining. For all the 'zeikmomentjes' we had without judgement. And for all the couch potato times (special shout out to our other potato Soof).

> Thank you Linda, without you the prototype would be a blobbering mess. But also thank you for the nice chats.

> And thank you Tim, for being so down to earth and always telling me to just breathe deeply when things seemed impossible.


breathe

EXECUTIVE SUMMARY

The assignment

Electroluminescence (EL) is a characteristic of a material which enables it to emit light when an electric current or an electric field is applied to it. This phenomenon has been discovered many years ago, but research is still being done about its possibilities and opportunities; making it thinner, more flexible, stretchable and so on. New materials, or materials that gain new properties through research, can open up new possibilities for consumer products. The difficulty in a material driven design project is to find an application that is not only innovative, but adds meaning to the users life. This is especially hard in a material driven project because there is no specific problem to solve. The project starts out with (a part of) the solution, and a fitting problem has to be found. The aim in this graduation project was, therefore, to find a meaningful application for the electroluminescent phenomenon.
> Page 10

The research

No specific context or direction was given at the start of this project, these needed to be found through research. We can place EL in three different contexts:

1. The context of the technology of EL and similar products
2. The context of light.
3. The societal context.

These three contexts have been researched and led to some conclusions which helped to narrow down the scope of the project to a search area fitting to the brief. Investigating the technology context concluded in a list of strengths and weaknesses for the EL material. These helped to see the opportunities of EL, for instance its possibility to be printed on fabric due to its flexibility and very low thickness. The studies of the context of light and the societal context generated a vision, which which inspired the generation of a generation of a meaningful application.
> Pages 17 to 55

The quantified self

The ‘Quantified Self’ is a term that indicates the collection of personal data through technology. The collection of data in this domain is always done with the use of a ‘smart’ tool. A well-known example is the smart watch, tracking the activity of their wearers, like the Fitbit or the apple watch. Besides these tracking devices, there is also a large amount of mobile apps available that collect data. Sleep trackers, step counters, food trackers, they all fall in the field of the quantified self.

The quantified self is a promising direction for implementing an application with EL. It is rapidly growing in market share, so there is a consumer demand. It is focused on learning from

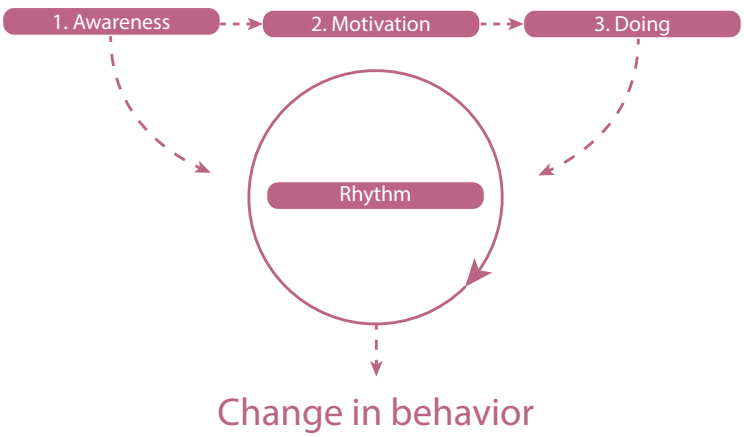

figure 1: Awareness about a behaviour is the first step in changing that behaviour.

and improving oneself, with a big focus on physical health. This makes it a meaningful search area. This field is closely linked to the wearable business. With its opportunity to be printed on fabric, EL can be turned into a flexible, non-intrusive wearable that does not bother its wearer.

What was found in a research among users of quantified self tools is that the data generated through these tools creates awareness about one's behaviour. This gain in awareness is the first step in the process of behaviour change (see figure 1). This theory about the awareness of behaviour formed the starting point for the concept generation.
> Pages 60 to 70

The design

The Awareable is a smart wearable designed to make the user aware of its physical activity. It does so by communicating the progress of a daily goal with light. Four electroluminescent panels light up when either 25%, 50%, 75% or 100% of the goal has been reached. The garment slowly becomes more appealing due to the addition of light, which works as a reward for the user.

Because the garment is worn so closely to the skin throughout the whole day the awareness effect is increased. Clothing is a very personal subject, and links to the personality of its user. It is something that can become very personal. By making it smart, it becomes a friendly companion. Emphasising positive associations with the product increases the chance to successfully change behaviour.
>Pages 74 to 104

The verification

A small test and interview session was conducted to gain insights in the opinion of people about the increase in awareness and the having of a daily goal.

Also, a prototype has been made to validate that EL is indeed a suitable addition to the smart wearable industry. It also serves as a proof of concept, proving that the light panels make its wearer become more aware. Now the prototype was tested by making it, and a small wear test. However, to fully validate the effect of the Awareable on its wearer a more extensive user study with a fully functioning prototype should be done.
>Pages 108 to 122

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BRIEF

This graduation project started out with a simple question; we have an unique material at hand, electroluminescent light, what can we do with it? When looking closer at the question, we can see that it consist of two components: on the one hand we have the material and on the other hand we have the application of this material. These two components influence the assignment significantly.

The material;

The material of electroluminescent light is the subject of this assignment. Once in a while a new material is developed or an existing material shows new opportunities. In this particular project we are talking about the latter.

Electroluminescence is light (luminescence) produced by electricity.

At the TU Delft, research is being done about this phenomenon, especially in the planar form (see figure 2). To find an application for this new material, it is important that the application can not be imitated by other forms of light in the same quality. If this were to be the case, the new electroluminescent material would be redundant. This uniqueness can lie in costs, production method, aesthetics, etcetera, but it has to stand out in some way.

The application;

This is the objective of the assignment. How we apply the material in the product is dependent on the material itself and on the context. Because no context is given specifically in this project, we will take the broadest sense of it: the world.

Innovation in consumer products is driven mostly through either market pull or technology push; either the market demands a solution for a problem or a new product is made of which customers did not know they wanted it, but now they do. This project is somewhere between these lines. It will be pushing a new technology. But at the same time we will also look at the context to see which desires can be fulfilled with an electroluminescent material. The objective of this graduation project is to create a novel product that fulfills a demand of the customer: It has to be a meaningful product.

These two components both have their own demands regarding the assignment, and should be taken into account in the brief. The final assignment statement which will be used in this project is the following >

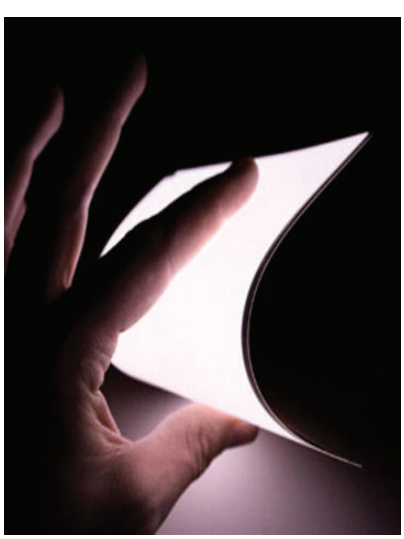


figure 2: electroluminescence in planar form

“The aim of this project is to design a meaningful product with electroluminescence as the core component, which preferably cannot be done with other forms of light.”

APPROACH

'Regular' design projects usually start out with a set problem or context. In a material driven project, none of these are given and need to be defined through research. This influences the approach of the design project.

The approach of this project drew inspiration from the method Material Driven Design (Karana, Barati, Rognoli and Zeeuw van der Laan, 2015) and the ViP approach (Hekkert & van Dijk, 2011). The ViP approach calls for a deconstruction of the product, interaction and context. Because we lack these things somewhat due to the openness of the project, these terms were interpreted differently:

- The product is seen as the context of the electroluminescent material and its competitors.
- The interaction is seen in the context of light, and how we interact with this.
- The context is seen in its broadest form: the society of today and tomorrow.

The Material Driven Design approach calls for an analyis of the material on a more experiential level. Inspiration from this is used in the the analysis of the context of light, were a lot of attention was laid on the experience of light. Electroluminescence is not really a material, but more a collection of properties, out of which emitting light is a very important one. So examining the experience light gives us is very valuable.

The full approach of this project can be seen on the next page. It shows the lay out of this book, and the steps taken in this project.

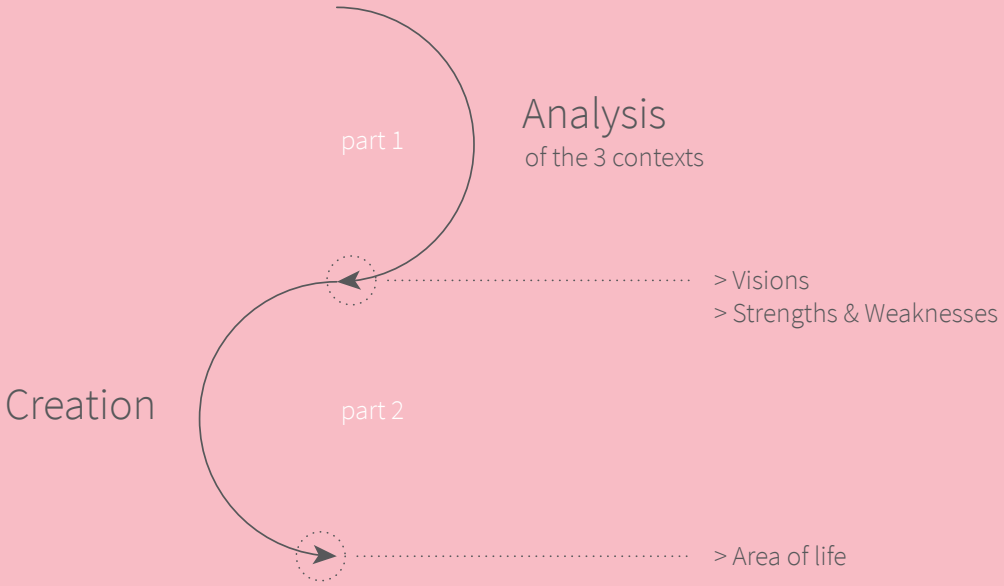
Every phase of this project is described in its own book. We have the:

1. Exploration phase
2. Personalisation phase
3. Materialisation phase

These phases are in turn divided in two parts, an analysis part and a creation part. In the analysis part, evoked questions from the previous chapters are being researched. The conclusions of these analysis parts are then turned into something more tangible in the creation part, like a search area or a concept.

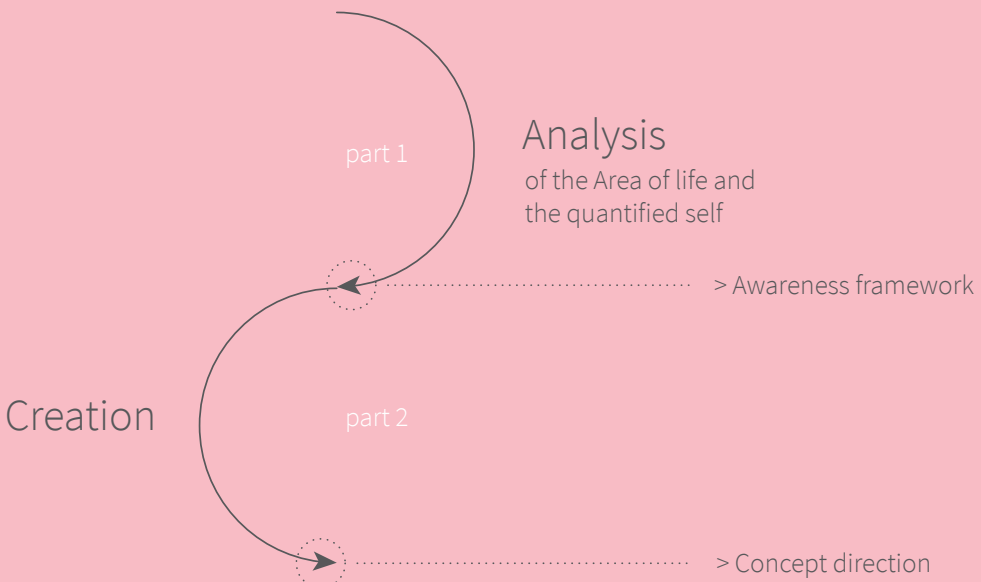
Book 1

exploration



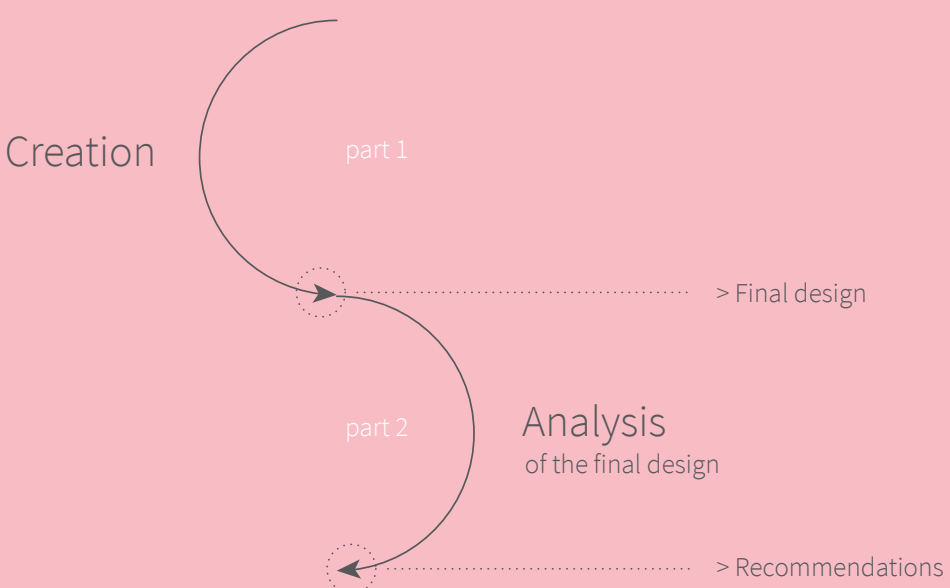
Book 2

personalisation



Book 3

materialisation



BOOK 1
EXPLORATION

PART 1
ANALYSIS

A material driven design project, like this one, is a bit different than 'normal' design projects. No predefined context, user or problem is given. Instead, these need to be found through research. In order to get a grip on the first step of a material driven project, it is important to map all the facts that are available. We can place EL in three different contexts (see figure 3), varying in scale:

1. The context of the technology of EL and similar technologies. What are the benefits of this material? (Page 17)

2. The context of light; what makes light valuable to us and how do we use it? (Page 32)

3. The societal context; what is happening in the world and what will we value tomorrow? (Page 38)

These questions will be answered in the following chapters and in the end we will conclude in a list of strengths and weaknesses, and with two visions, one for the light context and one for the societal context.

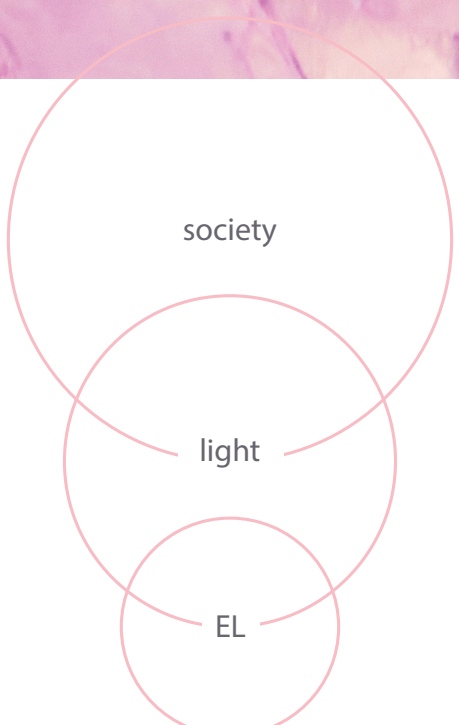


figure 3: The three contexts relevant for this project, varying in scale.

THE TECHNOLOGY

Before we can start analyzing promising design directions for the use of electroluminescence (EL), we first have to know the technical details of it. What are the unique properties of this material? In this chapter, we will investigate the opportunities and limitations of the material to form a base of knowledge and inspiration to build further upon. This chapter starts with a general introduction to the technical basics of light and a general introduction to the electroluminescent material, to give context to the strengths and weaknesses that will be discussed later

The technical basics of light

So what is light? In order for us to understand the phenomenon of electroluminescence, a form of light, a refreshment in the overall behaviour of light is useful. It helps us to understand the basic principles of the different components EL consists of, which will be explained on the next pages.

The theory of classical electromagnetism describes light as a wave. The wavelength of these electromagnetic particles influences the color of the light, where violet colored light has the shortest wavelength and red has the longest (see figure 4). If you go out of the visible light spectrum, we come directly in the spectrum of either ultraviolet or infrared light.

Quantum theory however, describes light as little balls of energy called photons. Here light is described as a particle, rather than a wave. This theory is helpful to understand the behaviour of light at a molecular level. The energy level of the photon influences the wavelength outcome and thus the color of the light.

Combining these two theories with the relativity theory gives the quantum electrodynamics theory (see figure 5). This is regarded as a complete theory to describe the behaviour of light (Stark, 2018). This, of course, is only a technical description of light. Light can also be described by its interaction values, what it means to us as humans, which will be elaborated more in part 2; the context.

figure 4: The wavelength of light determines the color output

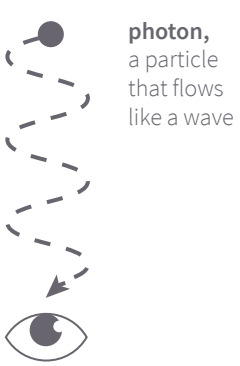


figure 5: Light, behaving as a particle and wave at the same time

The basics of EL

We refer a lot to the 'EL material' and 'material properties', but strictly speaking electroluminescence itself is not a material. Electroluminescence is a characteristic of a material which enables it to emit light when an electric current or an electric field is applied.

The phenomenon of electroluminescence was discovered as early as 1936 by the scientist George Destriau. Fourteen years later companies started using EL in practical applications for consumers (Whelan, 2013). Well-known applications of EL are the dashboard lighting in cars (see figure 7) and the small night light plugs. Many have developed the technology ever since, to enhance light output, making it thinner, developing colours, etc. LED lighting is, for instance, a descendant of the technology and also laser and other diodes fall within the name electroluminescence. It is a very widely used term, describing more than one form of light.

This is why, for the scope of this project, we cannot focus on all forms of electroluminescence, this would be too broad and the application space would differ too much depending on the category. figure 6 shows the different categories of electroluminescence (Haranath, Shanker & Vrij, 2004). This project will only focus on EL in planar form, which falls within the powdered phosphor category (highlighted below). The planar from of EL means that the light emitting component is distributed in a thin film on a surface. This is the form of EL that is being researched at the TU Delft, because it has a high potential to be enhanced with current knowledge; making it thinner, brighter or even stretchable. It is also the form of EL that is not yet being widely used in consumer products, despite its unique properties.

figure 7: Product example incorporating electroluminescence

When further referring to the name 'EL' in this project, we will only mean the form of electroluminescence that falls within our focus.

figure 6: categories of electroluminescence

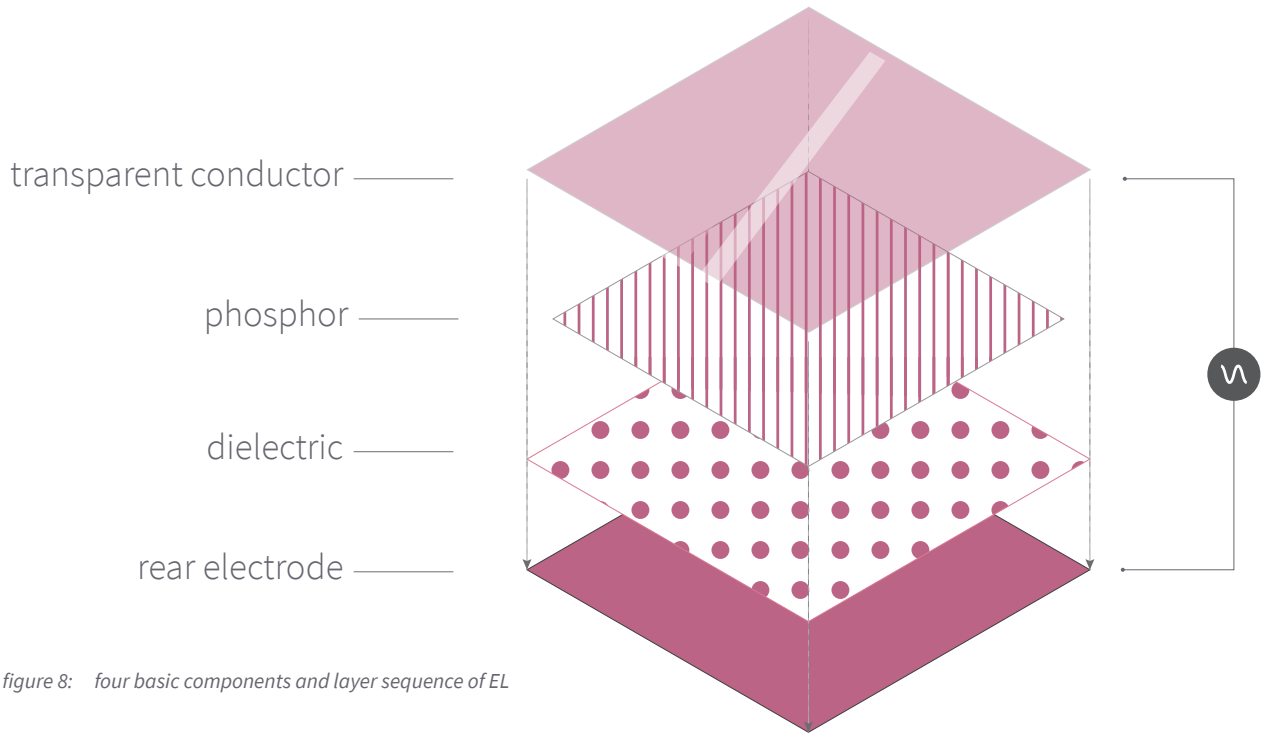


figure 8: four basic components and layer sequence of EL

Working principle

There are multiple ways to produce an electroluminescent material, but they all come down to a basic building sequence consisting of four components (see figure 8). The configuration of these building blocks can vary widely. Some of these components can be merged together, some can be made from several different materials and some can be assembled in different ways. In the end however, these four basic building blocks are always present in some way.

The basics are as follows: The phosphor layer is the one emitting the actual light, but in order to do that, an electric field is necessary. This happens when an alternating current is applied to the transparent conductor and the rear electrode. Due to the electric field, the electrons in the phosphor layer come in an excited state after which they 'fall back' into their normal state, releasing energy in the form of light (see figure 9). This happens only once when the electric field is generated, therefore an alternating current is needed. Every time the current shifts, so does the electric field and a photon is released. This photon release happens evenly in the layer of phosphor, which is why it generates a homogeneous plane of light.

The fourth component in the basis of EL is the dielectric layer. This layer functions as an insulator, making sure that the conductor and the electrode do not touch. If this were to happen (due to too thin layer or an uneven spread of the dielectric), it will create a short circuit, which can in turn damage the system. These four layers need to be applied to a base material, called the substrate. The substrate is not part of the EL principle but serves as a carrier.

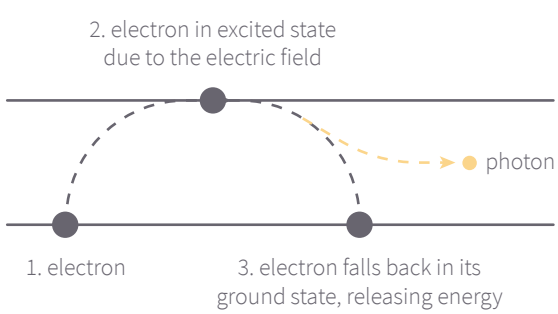


figure 9: the physical processes within the phosphor layer that result in the emission of light

The purpose and the construction material of the four different components will be explained more elaborately:

1. Transparent conductor

The top layer, the transparent conductor, is one of the two electrodes. It is important that this layer is transparent, else the light would, of course, not be visible. This can be achieved with different materials. A very popular example is Indium Tin Oxide (ITO), it is optically transparent and can be easily deposited as a thin film (Mannerbro, Ranlöf, 2007). Its downside is the vulnerability of the film. ITO is easily scratched off. PEDOT:PSS is currently widely used when a paint is needed as an conductive top layer. Paint can be applied as a very thin layer, preserving the flexibility of an EL application. The downside of PEDOT:PSS is that the paint has a dark blue hue, which can be aesthetically unwanted. An unusual example of something that can be used as the top conductor is water. If a layer of water is in contact with the alternating current it will serve as the transparent conductor. This allows for interesting applications, where the electroluminescent material reacts to water and lights up.

2. Phosphor

This is the light emitting layer. A phosphor is a luminescent compound, and there are various different types of configurations of compounds. The configuration of the host material and a so called dopant (an "... impurity deliberately added to a semiconductor for the purpose of modifying its electrical conductivity" (The Editors of Encyclopaedia Britannica, 1998)) determines the colour of emission. Because of this, only limited colours are available in electroluminescence.

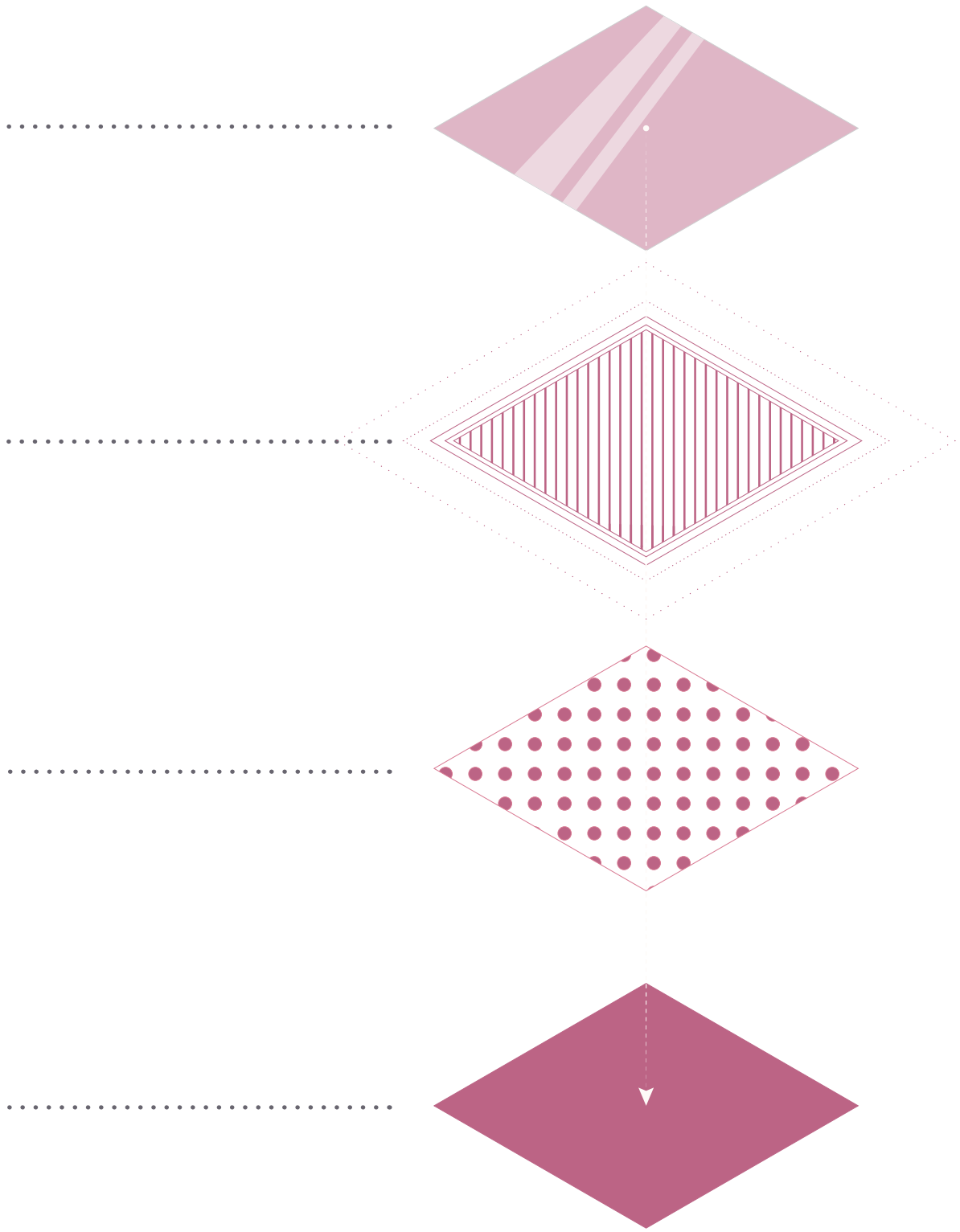
3. Dielectric

The dielectric layer, as said before, makes sure no short circuit is created. This layer can be made out of any non-conductive material. The thicker this layer is, the less chance there is on an electric breakdown. But, increasing the thickness also decreases the light output of the EL panel. The layer should therefore be as thin as possible, without failing in its function.

A dielectric material can also be added to the phosphor powder. Combining these two eliminates applying one layer, which decreases production time. However, the compound should be made carefully in such a way that the properties of both layers are not lost.

4. Rear electrode

The rear electrode serves the same purpose as the top electrode, but it can be opaque if the application does not require two sided illumination. Any material that is conductive can be used. When flexibility and a low thickness are required, a good option is silver ink. The downside however is that this is a very expensive paint.



Production

As mentioned before, there is not one superior production technique when it comes to electroluminescent materials. It all depends on the final application. Also, new production methods and materials are still being discovered which influence the quality of the EL sample. In December of 2017, for example, a student graduated on a new technique, optimizing the production time from 2 hours to 15 minutes for a DIY application of EL (Wajwakana, 2017).

One technique that is widely used is that of screen printing. It allows applying an electroluminescent on a wide variety of materials like paper, plastic and textiles. Screen-printing is a very old printing technique where a fine mesh screen is used to make designs (see figure 10). A part of the screen is blocked; the part of the design that does not require paint. This leaves the rest of the design open. The mesh screen is then placed on top of the substrate, the material on which the design has to be printed, and ink is placed on the closed part of the screen. With the use of a rubber tool called the squeegee, the ink is dragged over the open part of the mesh. The mesh is then removed and the process is done.

A limitation of using screen printing is that the printing needs to be done on a flat surface, since the screen itself is flat. An option is that the plane is curved after printing it on the substrate, but this can compromise the quality of the EL.
A more logical option if one wants to apply electroluminescence to a curved surface, is spray painting. Spray painting is, unlike screenprinting, not a DIY production method. The skill needed to apply all the layers correctly are that of a professional. For large quantity production this is not a problem, but the application time might be: it takes 3 to 5 hours to complete all the steps (Lumilor, n.d.). Suitable substrates for spray painting are wood, plastic, metal, fiberglass and carbon fiber.

These two are the most basic production techniques for planar ELs. Playing around with different components and combining the techniques gives a wide variety in production options to choose from, each with its own strengths and weaknesses. For now, I will not limit myself to one option. This gives enough freedom to find a meaningful integration of EL. The production method will have to adapt to the concept, instead of the other way around. However, it is important to map them, so I can keep the opportunities and limitations of EL in mind.

figure 10: the screen printing technique

Technical specifications

Because of the high variety of production methods and materials, these technical specifications are based on the currently commercially available EL panels.

Electrical properties

The input for an EL panel varies widely. For example the Adafruit EL panel has an operating voltage range of 60-250 V, a frequency of 50-5000 HZ and a current draw of 0.14 mA per cm2 (Adafruit, n.a.). The lumilor spray paint ranges between 110-170 V and a frequency of 950 HZ with a current draw of 0.16 mA per cm2 (Lumilor, n.a.).

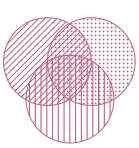
Thickness

EL Sheet: 0.5 mm

Spray Painted: 0.11684 mm

Illuminance

21 lux per m2



Colour

The colours available in EL are limited, because they are dependent on the phosphor compound and dopant combination, which are limited. However, it is possible to create new colours or shades with the use of different coatings. The basic colours available are:

- *White*
- *Light Blue*
- *Deep Blue*
- *Orange*
- *Aqua*
- *Red*

Substrate

It depends on the production method which substrates can be chosen, but there is a big overlap in there. Also, some options have not even been explored yet. Some materials that are known to be suitable are:

- *Plastic*
- *Textile*
- *Paper/cardboard*
- *Wood*
- *Metal*
- *Fiberglass*
- *Carbon Fiber*

Recycling

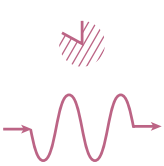
VynEL, a producer of EL panels makes its products using only eco-friendly materials (Vynel, n.a.). Making it a recyclable product.

Heat resistance

-50 to 65 degrees celsius (Adafruit, n.a.).

Water resistance

The phosphor decays when in contact with water. A protective layer has to be applied. If this is done properly water can even give a new dimension to the EL panel, as said before, by making it react to water.



lifespan

25000 hours. This is however dependent on the colour and the lifespan is cut in half if the EL is exposed to sunlight regularly (Lumilor, n.a.).

Technical benchmarking

With this gathered knowledge of EL, we can start comparing the material with other technologies so we can see the value and disvalue of these properties. A requirement for all the competitors was that the product emits light and has one or more of the following extra qualities:

- *flexibility*
- *planar lighting*
- *low energy consumption*

Suitable competitors (see figure 11 to figure 20) and their properties have been laid out next to those of an EL panel, of which a table can be found in appendix 1. The result of this benchmarking study is a list of strengths and weaknesses of EL. The list, which can be seen on the next page, is rated by uniqueness. The most unique properties are rated highest, but can be either positive or negative. A strength or weakness which, next to EL, only a few others have, is scored higher than a property a lot of competitors share.

figure 11: EL strip. Image by Adafruit (n.d.)

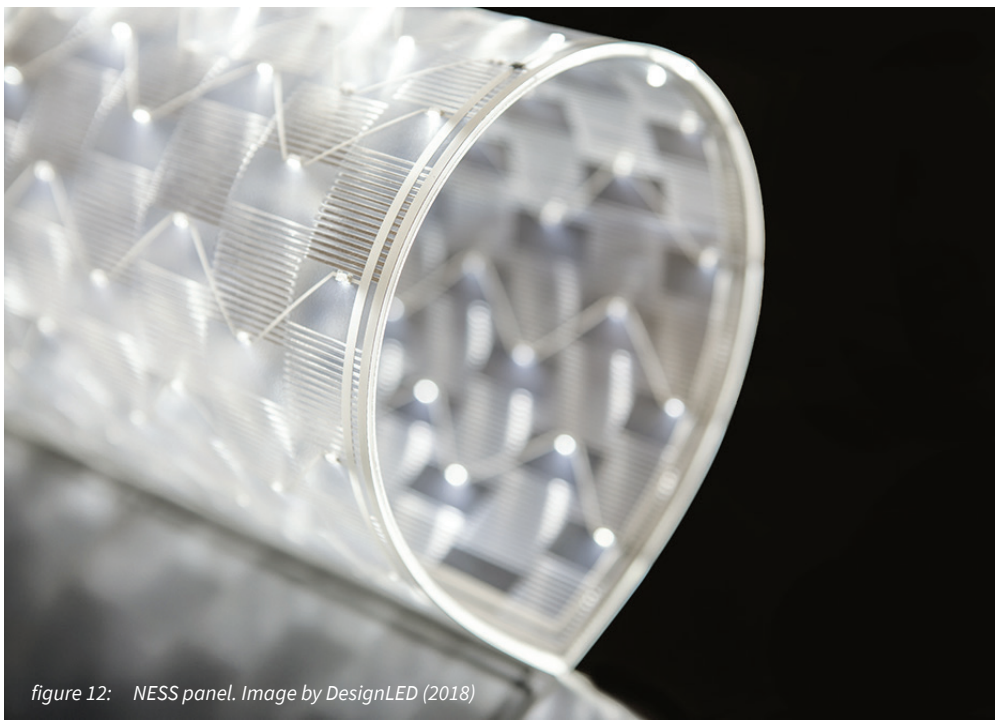


figure 12: NESS panel. Image by DesignLED (2018)

figure 13: flexible OLED. Image by LG (2018)

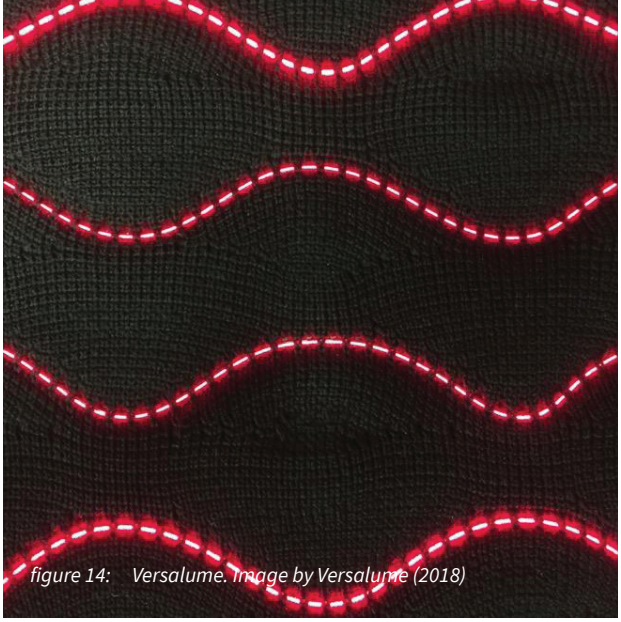


figure 14: Versalume. Image by Versalume (2018)

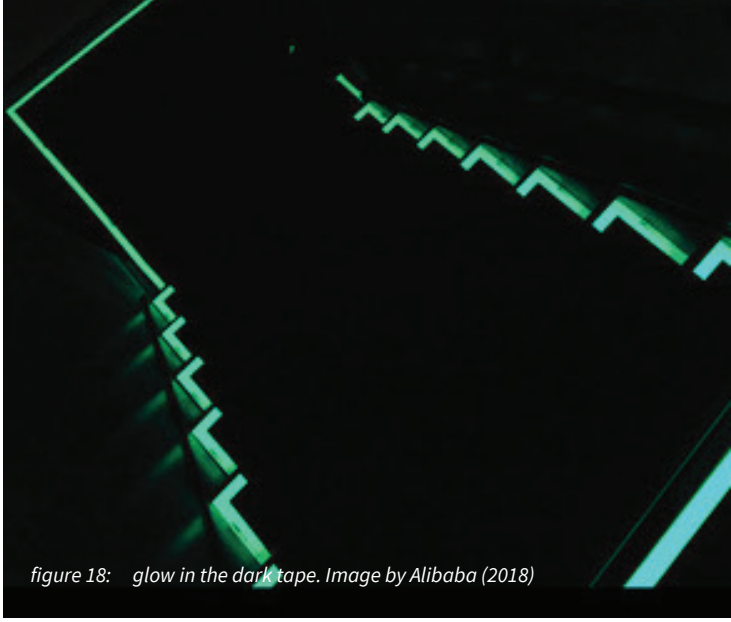


figure 18: glow in the dark tape. Image by Alibaba (2018)

figure 16: IKEA Floalt. Image by Ikea (2018)

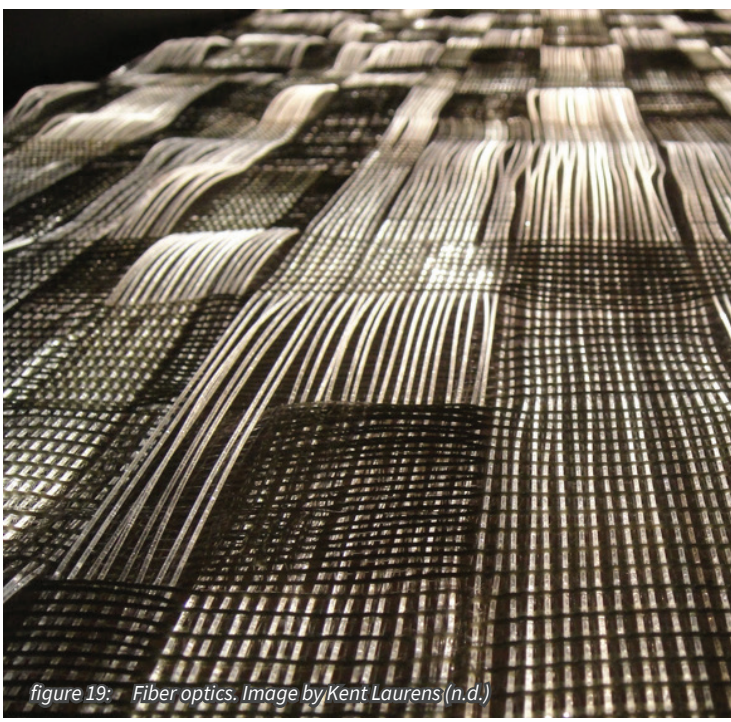


figure 19: Fiber optics. Image by Kent Laurens (n.d.)

figure 17: LED strip. Image by Static (n.d.)

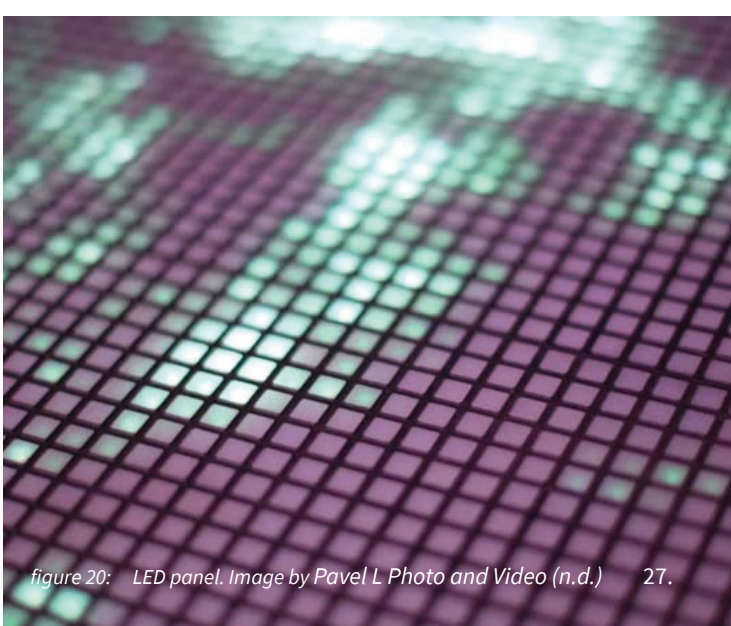


figure 20: LED panel. Image by Pavel L Photo and Video (n.d.)

WEAKNESSES < > STRENGTHS

WEAKNESSES		STRENGTHS
		••• Shape freedom
		••• Can be printed on a lot of materials
		••• Immidiate interaction effect in different ways
		•• Very high flexibility
		•• 2-sided illumination
		•• Transparent
		•• Low weight
		•• Thin
		•• Vandal-proof
		•• Portable
		• Stays cool
		• Homogenous light
Power consumption	•	
Lifetime	•	
Cost	•	
Limited colours	•	
Illuminance value	••	
Degrades faster in sunlight	•••	

Conclusion

The knowledge gathered in this chapter about the the technical opportunities and limitations of EL, will help to determine a suitable application for the material. It will limit the possibilities and guide decisions about promising search areas, which is very much needed in an assignment were the context is as broad as the world. In the following chapter these contexts will be explored and chosen by means of the strengths and weaknesses .

TINKERING SESSION 1

Through tinkering, a deeper understanding of the subject is derived at and it can answer questions about the subject by doing. We have looked at the material in a theoretical manner, and learned about its opportunities. Now it is time to look at the material in a practical manner, to test some hypotheses. This is the first of 2 tinkering sessions and focuses on the possibility to print EL on fabric.

Research question

In part 1 we found several strengths and weaknesses of the material. Two of them sparked inspiration about possible applications; the fact that EL can be printed on a high variety of substrates and its high flexibility. This raised the following question:

Can the EL material be printed on fabric?

A full description of the creation of the samples can be read in appendix 2. Included in there is the layer composition of the DIY EL samples.

Results

After a trial and error period of getting the right layer composition, a working sample was made (see figure 21 and figure 22). This proved that the EL material can be printed on fabric. Other interesting finds were:

- *Some highly flexible fabrics lose their flexibility after the layers of paint are added, probably because they soak in a lot of the paint. More sturdy fabrics keep the same flexibility. Faux leather is a good substrate if a flexible EL sample is needed.*

- *Highly absorbing fabrics can be used but a base layer has to be applied first, to satisfy the absorbance.*

- *EL printed on very smooth fabrics can start to delaminate. A base layer should be applied to enhance the adhesion of the layers to the substrate.*

- *The EL print cannot withstand high stretching and will tear.*

figure 21: working sample of EL on faux leather

Conclusion

After this tinkering session we can conclude that it is possible to print EL on fabric. It does however, still have some problems to overcome before it can be implemented in a consumer product, especially regarding the ability to stretch the EL. The results of this tinkering session led to the following requirements for the substrate, in order to get the best outcome in printing EL on fabric (note that these requirements are not set in stone, they only produce the most flexible and least failing sample):

1. The fabric should not absorb the paints.
2. The fabric should not be stretchable.
3. The fabric should be able to withstand oven temperatures of 130 °C.
4. Smooth fabrics should be treated with a base layer first.

figure 22: working sample of EL on polyamide fabric

LIGHT

It is good to have a more global understanding of light and its interaction values for this assignment. In the first chapter light was described in a technical way, but it is also valuable to look at how light is experienced. Putting EL in this broader context will show which application areas are, and are not suitable for EL. We will look at light on two levels: an application level and on an aesthetical level.

Light on an application level

Man made light has been around since the 'invention' of fire and played an important role in our history. It kept us safe and enabled us to do things even though the sun was not up, giving us more time even. The usages for light have changed over time, growing with the needs in society and new developments in artificial lighting.

For this analysis we will be focusing on artificial light. Implementing natural lighting is not an option for this project since we are bound to EL. Looking at artificial light as it is now defines application areas but can also hypothesize future uses. To get a global understanding of artificial light in the modern world a mind-map was made, see figure 26.

Three key usages for light have been found through the mindmap. In every design that incorporates artificial light, one or more of these uses have been applied. These usages give meaning to the light; they are the reason that a product has a light-source implemented in its design.

Task light

These light forms enables you to see your surroundings clearly, enabling you to do certain tasks (see figure 23). Think of a desk lamp that illuminates the book you are reading. A lot of research has been done in this field which resulted in guidelines and regulations regarding lux values per task (Rensselaer Polytechnic Institute, 2002). Task light is generally the first thing that comes to mind when one mentions the word 'light'.

Indication light

It addresses you to a certain state or a change of states (see figure 24). Think of the red light on your television, signaling you the television is in standby mode. LEDs, due to their small embodiments, made it possible to incorporate indication lighting in even the smallest household objects.

Decoration light

These lights make a design (object, house, street, etc.) more visually appealing (see figure 25). Think of Christmas lights or the Philips hue.

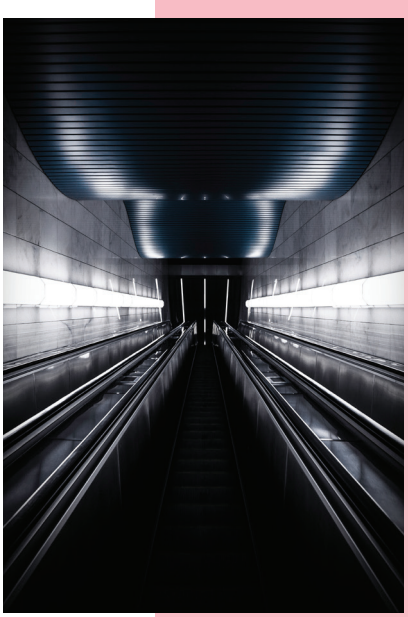


figure 23: an example of task light

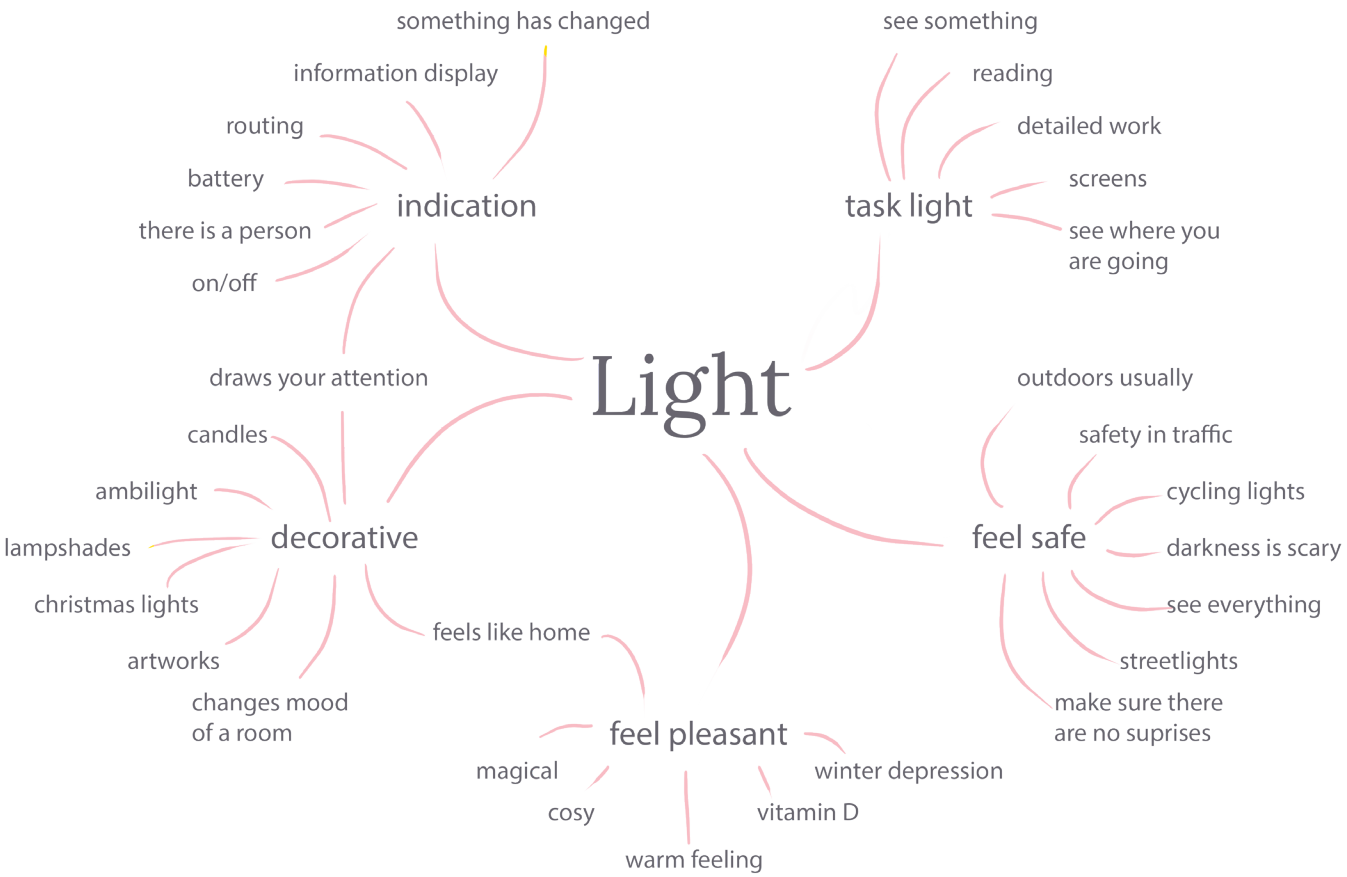


figure 26: Mind map about light

figure 24: an example of indication light

figure 25: an example of decoration light

With its illuminance value of 5,3 lux (for an 0,25m2 EL panel from 2m distance), EL panels are not sufficient for task lighting. The simplest visual tasks already need 100 lux and up (Rensselaer Polytechnic Institute, 2002). Therefore, for this project we will not be focusing on applications where EL is used as task light. The other two uses, indication and decoration, do have possibilities in them for EL. Which is why one, but preferably both of these uses of light will be focused on in the final design

Visionising

Now that we got an understanding of the present uses of artificial light, we can hypothesize the future purpose of light. The timeline of artificial light of figure 27 visualises this development of light in the past, present and the future.

> The communication between human and light has become more and more complex. In earlier days the interaction was one sided, the user decided whether or not the light is on. This changed however, with the rise of devices and sensors. Not only the users, but also the device decides whether the light is on and can therefore communicate something. This was still not a very complex dialogue; it was not possible to react on each other. Now, with the rise of the Internet of Things, this is changing again. Objects are now becoming smart, learning from the behaviour of their user and communicating this with other devices. Philips and Ikea are, amongst others, selling light bulbs already which are connected to the internet. They can communicate incoming messages, phone calls or act as the ambilight of your television.

I hypothesize that in the future this dialogue will develop even further, and a fourth usage of light will arise: companion light. As we are less and less limited to outlets due to the developments in portable batteries, light will be set loose from its boundaries and bulkiness. It will be invisibly incorporated in our lives. This hypothesis let to future vision of light (see following page and figure 28).

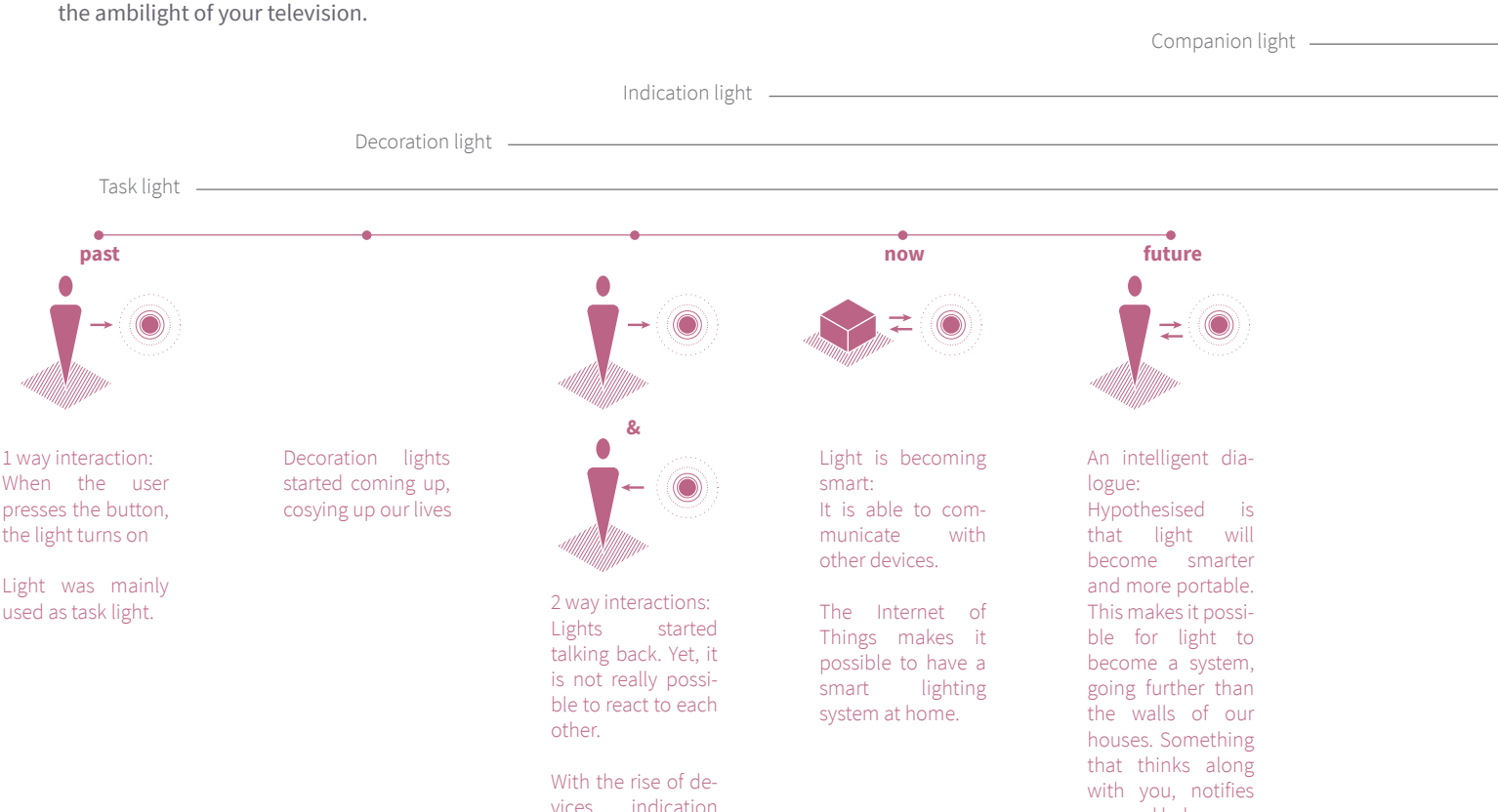


figure 27: the development of light and the envisioned future interaction

The light entity

Light as one living entity. Accompanying our lives wherever we go as a friendly companion to have a dialogue with; understanding our needs and moods and reacting on it.

figure 28: the future vision of light

Aesthetics of light

Light is a visual phenomenon. This is why we cannot ignore the aesthetical part of it. An aesthetical study will show interesting opportunities and possibilities for light as decoration light, one of the three usages of light mentioned above.

Gathering

Throughout the project a visual database has been built, including everything that sparked inspiration. Not all pictures involve light, some have been added to the collection because of their potential to involve light. This can be just as inspiring and can result in novel lighting solutions. The gathering was done intuitively, on any random moment and based on different inspiration focal points.

Clustering

There is a reason for every spark of intuition, so in order to make these sources of inspiration more tangible, they were clustered. Pictures with the same inspirational focal point were put together. This formed the groups shown in figure 29.

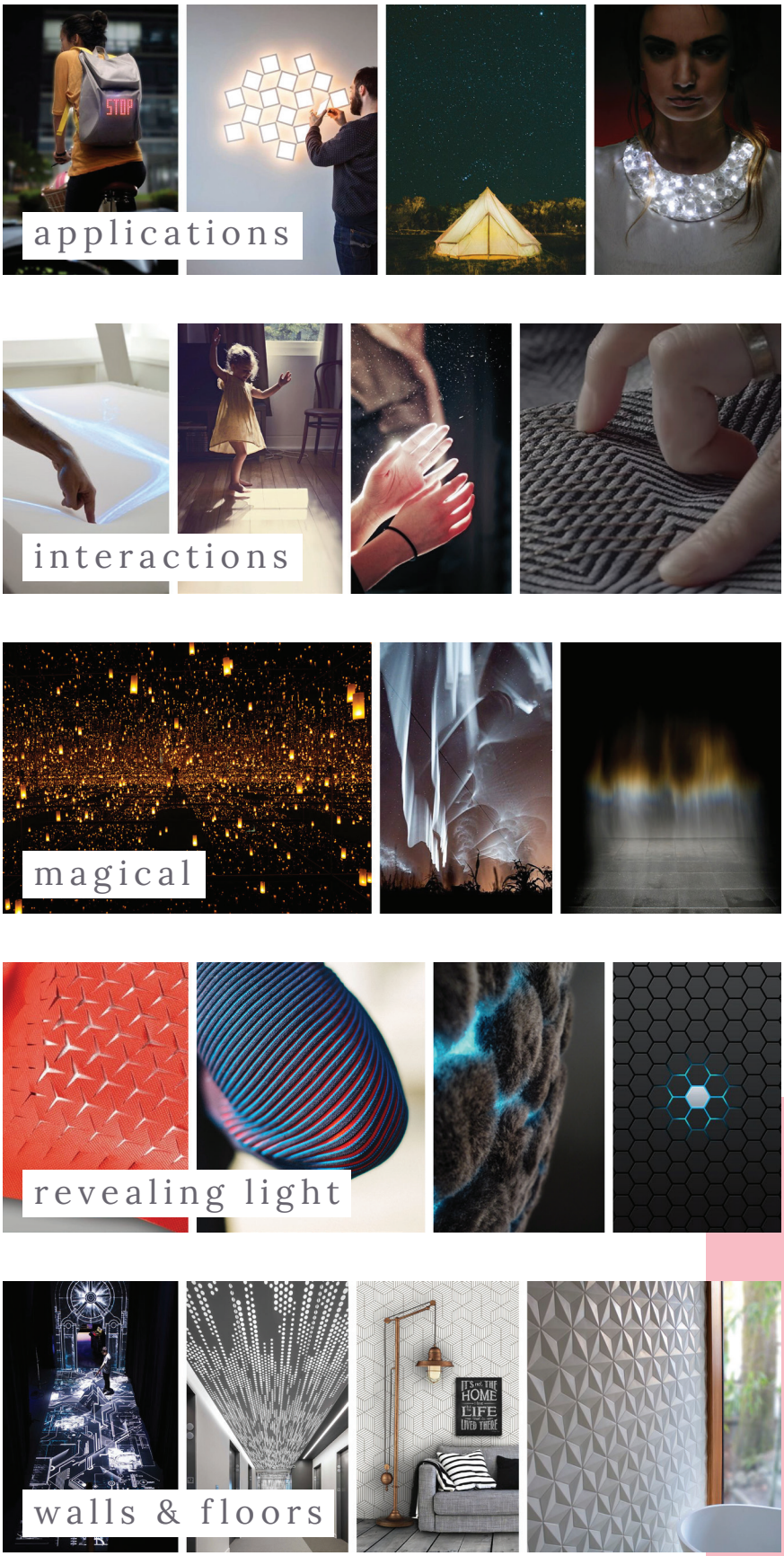
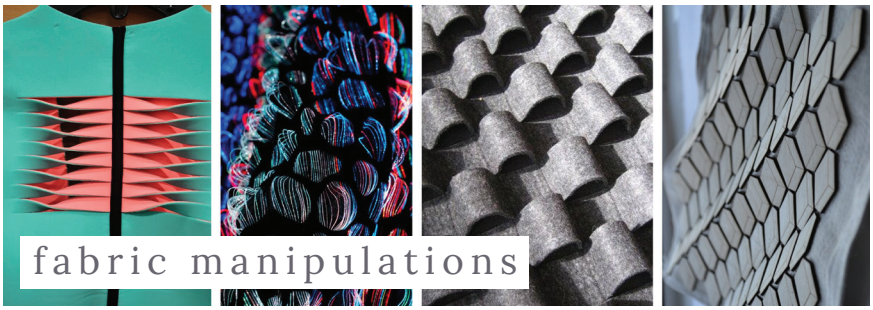
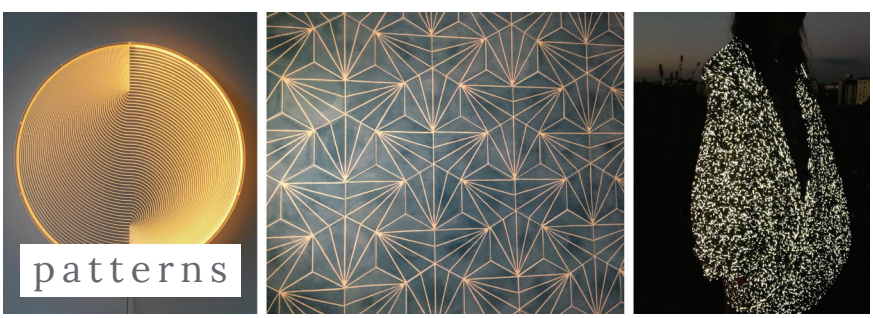


figure 29: clusters of light as an aesthetical phenomenon





Utilising the clusters

These clusters and the light vision formed an inspiration catalogue which was used in different stages of the process. In the analysing phase it sparked ideas on an explorative level. Some of the clusters above brought up many questions and therefore helped choosing which material thinkering test would be interesting. In the ideation phase the clusters brought up new ideas on an application level. While in the conceptualisation phase it served as an inspiration on an aesthetical level.

SOCIETY

The third context analysed, next to the context of light and that of the technology, is our society. To fully discover the potential of EL, it is not only important to analyse the context of light, but also to analyse our current society. This analysis will help to identify the desires of potential future customers of an EL product. Of course our society is a very broad topic, so in order to find an application for EL, steps will be taken to narrow down the scope from a world vision to a concept (see figure 30). This chapter discusses the first step in this process of scaling down; making a vision statement.

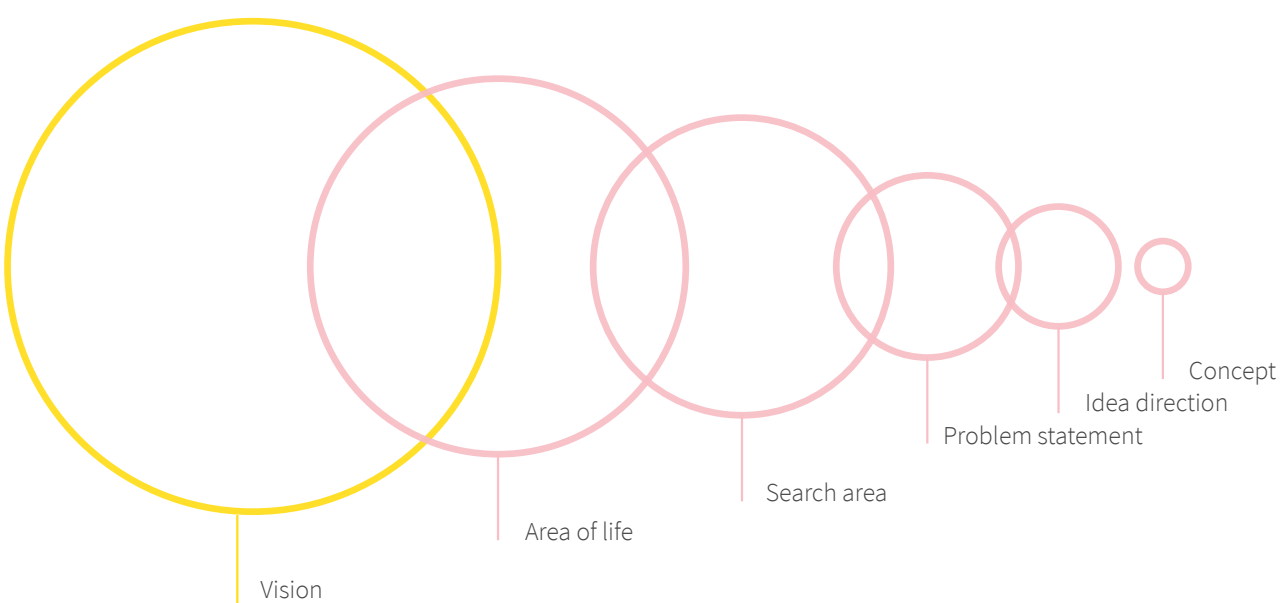


figure 30: the steps taken to narrow down from a societal point of view, to a concept. Highlighted is the focus of this chapter.

figure 31: The factorclustor 'Hygge'

Principles, states, developments, trends

A way to classify context factors, is by thinking of them in the following categories: principles, states, developments and trends (Lloyd, Hekkert & van Dijk, 2006). These four categories go from unchanging to fast changing respectively. Looking at the present (the principles and states) as well as the future (developments and trends) helps to create a broad overview of how the context is evolving. 150 trends, developments, principles and states were found focused either very broadly (human needs) or quite specifically (new ways of shopping) (see appendix 3). These factors were clustered into factorclusters to form a comprehensive yet clear image of our context. An example of a factorcluster and the aspects it consists of can be seen in figure 31.

Vision

Explaining these factorclusters (see appendix 4) eventually turned into a general understanding of what is happening in the world around us; the dilemma we are facing nowadays and my vision for the future. It also resulted in a theory about present-day desires.

> Our modern world is a fast changing one, especially in the technological and digital field. We are all trying to figure out how to deal and react to all the smart objects and social media around us. The everyday supply of new content and new products seems endless. On the one hand we are embracing all these new technologies because of the opportunities it provides us. It is almost impossible to imagine life without these technologies. But on the other hand we also try to detach ourselves from these technologies, trying to find the authentic things, people and experiences again. We are walking on a thin line between these two sides: the authentic and 'real' world and the digital world. This is something we as designers should find a balance in, looking for smart technologies that still give the user the feeling of authenticity. Either through the experience that it uncovers or by the possibilities it enables. The question is really; How to make things real in a digital world?

So for this project I will be focusing on the following vision:

"I want to use technology to connect us to our environment, instead of distracting us from it."

figure 32: the digital world VS the physical world

This division between the digital world and the physical world (see figure 32) results in a division of desires. It is important to note that the desires from both sides are present in almost all of us.

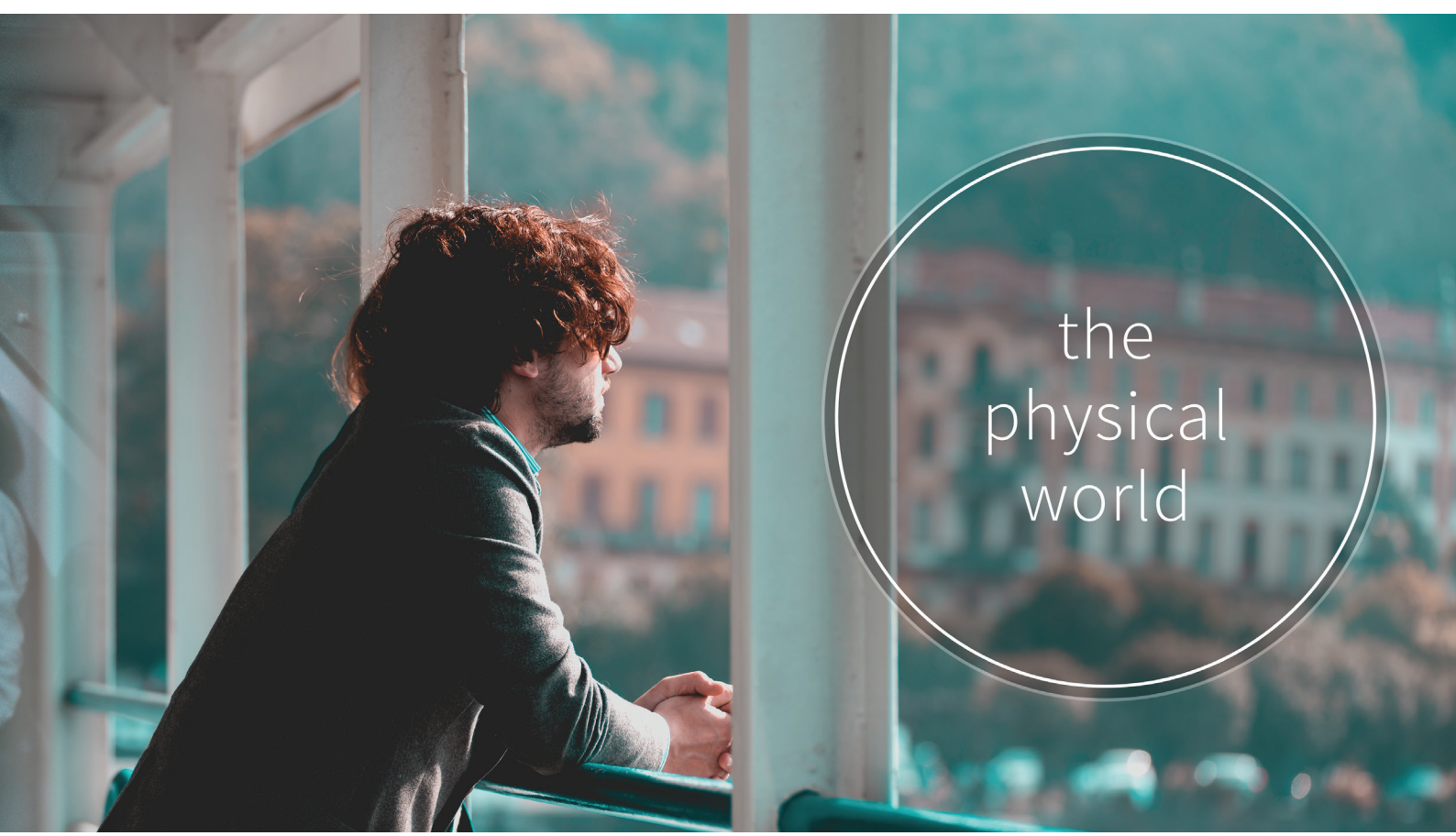
The desires that are triggered by social media because there is an abundance of it online:

- *The desire for aesthetical quality*
- *The desire for freedom to express ourselves*
- *The desire to be and feel unique*
- *The desire to belong to a group*

On the other hand there are desires that are a reaction to social media. People are starting to see the media as a negative influence and new research is being done about the effect of this online living on our health. The following desires are triggered by social media because there is a lack of these qualities online:

- *The desire for authentic quality*
- *The desire for authenticity*
- *The desire for simplicity*
- *The desire for experiences instead of stuff*

These desires can help with the evaluation of ideas and concepts and they can be used as inspiration materialisation phase.



PART 2
CREATION

With the two visions of the previous chapter (the vision regarding society and the future vision of light) and the knowledge about the opportunities and limitations of the product, we can now start to narrow down the scope. In this part, all the previous knowledge, including the brief of this project, will determine a suitable Area of life (see figure 33).

AREA OF LIFE

The concept of an area of life is not a regular designing concept,. In fact, it was made up for this assignment. Because of the vast dimension of the context of society, it was hard to immediately narrow it down to a search area. A search area describes already a group of users in a broad sense, a lifestyle so to say, and the activity that is important with it. Our Area of life is a bit broader, it does not rule out people, it rather describes a bundle of desires in life which a lot, if not all, people have.

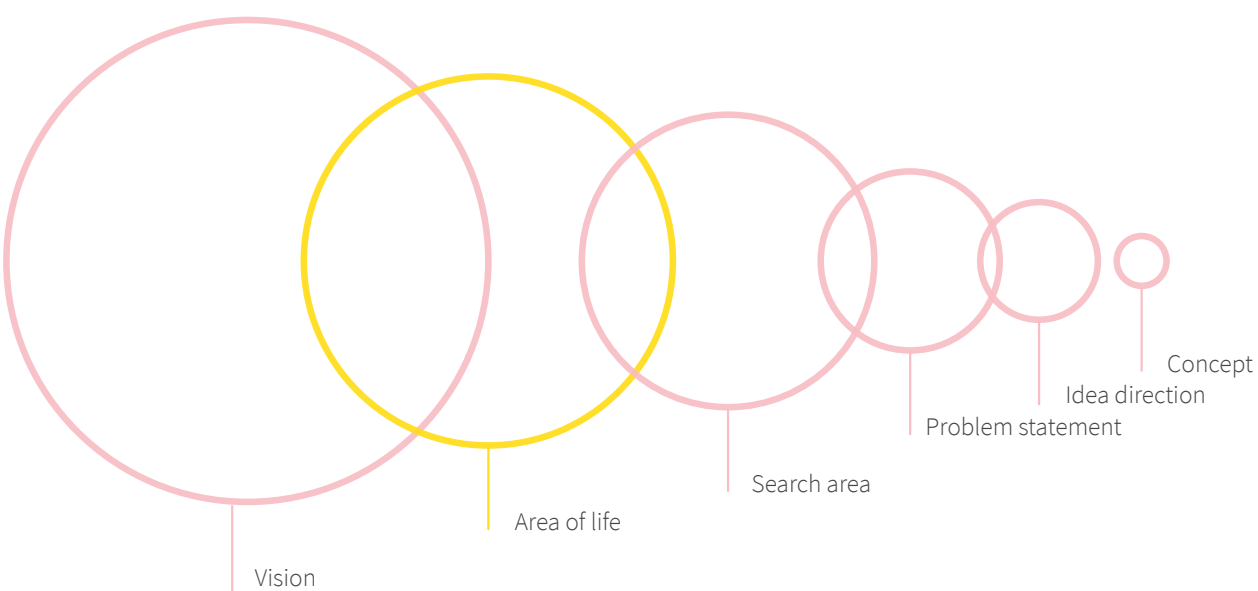


figure 33: the steps taken to narrow down from a societal point of view, to a concept. Highlighted is the focus of this chapter.

Areas of Life

The trendclusters (see appendix 4) all tell their own story, but a very narrow one. It became apparent that some of these clusters could be combined to create interesting domains. By merging the clusters together, more complete stories were formed, encompassing a certain Area of Life. In total, 9 of these areas emerged:

1. **Publically private:**
   From trendclusters: Small living in big cities + Sharing is caring + versatile working

2. **The new working space**
   From trendclusters: Versatile working + Awareness for the health of body and mind

3. **The living living space**
   From trendclusters: 'Living' living space + Hygge + Enabling authenticity

4. **Instaproof advertising**
   From trendclusters: Social media as ad tool + always online + instagram worthy

5. **Let's go outside**
   From trendclusters: Awareness for the health of body and mind + fashionably healthy + experience as the new luxury

6. **Take care: a healthy body & a healthy soul**
   From trendclusters: Awareness for the health of body and mind + not-mass produced + fashionably healthy

7. **Be the change**
   From trendclusters: Take a stand + personal sustainable liability + sharing with strangers makes us feel united

8. **The real things matter**
   From trendclusters: Not-mass-produced + quantity VS quality experiences + assisted quality

9. **EL as a measuring device**
   From trendcluster: Complex math as a solution space

Together with the strengths and weaknesses formed in the previous chapter, product examples were devised for these areas of life (see appendix 5). By combining the two it became clear that 5 out of the 9 areas were less fitting with the project. They contained the least amount product ideas. This is undesirable for the next phase, the ideation, since quantity in ideas eventually brings quality. The four areas which did contain a decent amount of product ideas are: The living living space, the new working spaces, publicly private and take care: a healthy body & healthy soul.

The living living space

The Internet of Things is on the rise and with it a whole scala of 'smart' products. The home area is slowly transforming into an entity that serves its residents. Things as temperature and light now have an app and can think for themselves to suit the needs of their owners. The first step in this transformation are the products already connected to a powersource, but this will soon expand to products that not yet fall into this scope (a smart couch, anyone?).

figure 34: visual representation of the 'living living space', where every piece of furniture could be connected

The new working spaces

There are two main shifts going on in this area. On the one hand we have the shifting view of wellbeing for employees. Mental illness, like stress and burnouts are now accepted as legitimate. And with the high pressure people put on themselves nowadays it is even occupational illness number 1 (de Volkskrant, 2013). Prevention methods are applied in some extend to counteract this trend.

And on the other hand we have the flexibility in work playing up. Since it is harder to get a permanent contract or a full time job, people are shifting towards flex working and freelancing. This calls for whole new design of workspaces. Do we still need offices or are we going to work from the road?

figure 35: visual representation of the flexworking generation in the 'new working spaces'.

figure 36: visual representation of the sharing community of the 'publicly private' area of life.

Publicly private

We are more and more turning into a sharing community. Content is heavily shared online, we share our personal stories and pictures with strangers everyday. But also in the physical world we are starting to appreciate this sharing trend. Platforms like Uber, Peerby and Airbnb let us share our personal possessions with others, from houses to cars. And as the cities become more crowded and our living space much smaller, the need for properly designed public spaces becomes more important. How can we design for a world where the boundary between private and public is blurred?

Take care: a healthy body & a healthy soul

Being healthy is trendy. Eating super-foods and becoming vegan has shifted from a hippie thing to a hipster thing. We are becoming more and more aware what our body needs and we are willing to put effort in it. Also the mental side of health is getting more attention. Where earlier on someone would be considered weak because they can't deal with the stresses of life anymore, it is now seen as a legitimate reason to call in sick because you are overworked. Mental illnesses and disorders like ADD, depression, autism and burnouts are accepted as real. As well as that more and more people believe alternative treatments have a positive effect on one's health. The rise of the 'quantified self', where we collect all kinds of data about ourselves, is helping us learn and react to our bodies' needs.

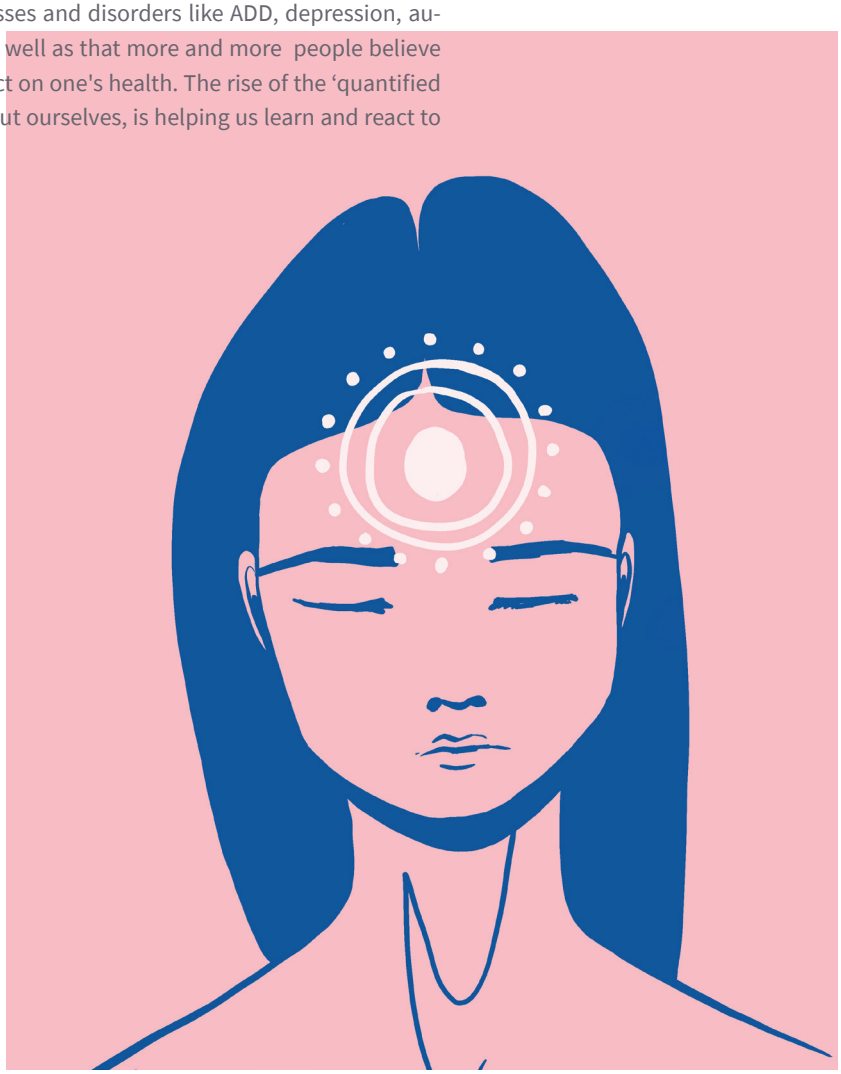


figure 37: visual representation of the area of life 'Take care'

Choice of Area

Coming up with product ideas already showed us that all four search areas contain enough solution space for an EL based product. The choice for one of these is therefore not made on this ground, but by testing it with the global assignment:

"A meaningful product with electroluminescence as the core component, which preferably can't be done with other forms of light."

Two main goals become apparent in this assignment: it should become a meaningful product and it should become a product that can only be done with EL. The Areas of Life were laid out on these two components, as can be seen in the matrix of figure 38. The ideal area would be in the upper right corner: very meaningful and very fitting with EL. Yet, because these Areas of Life are still so broad, it is hard to place them on the 'fit with EL' axis. It is very dependent on the topic and execution of this within the area that would be addressed. For the 'meaningful' axis, the placement is less vague because it is only dependent on the variation of topics, and not dependent on the execution. As we can see, especially the area 'a healthy body & healthy mind' scores high on this axis.

Because, as said above, the vertical axis is very dependent on the execution, 'a healthy body & a healthy mind' could, through ideation, shift along this line. It is, due to its place on the horizontal axis, the most promising field for this assignment.

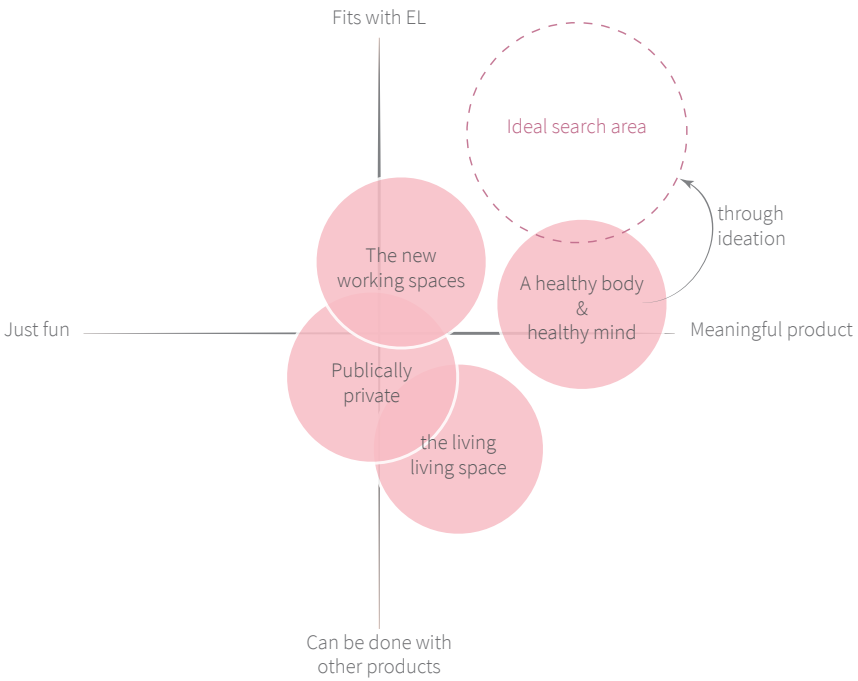


figure 38: all four areas of life plotted on the matrix. The axis were chosen to represent the brief of this project

Conclusion

Considering the brief for this project and the amount of promising ideas, the Area of Life 'A healthy body & healthy mind' is the most fitting area for this assignment and will be taken further into the next phases together. The topic is the most meaningful of the four and can, through ideation, be made uniqiue for EL.

INSIGHTS BOOK 1

Technology

Strengths

- *Shape freedom*
- *Can be printed on a lot of materials*
- *Immidiate interaction effect in different ways*
- *Very high flexibility*
- *2-sided illumination*
- *Transparent*
- *Low weight*
- *Thin*
- *Hufterproof*
- *Portable*
- *tays cool*
- *Homogenous light*

Weaknesses

- *Degrades faster in sunlight*
- *Illuminance value*
- *Power consumption*
- *Lifetime*
- *Cost*
- *Limited colours*

Light

Three key usages for light have been found; task light, indication light and decoration light. Because of the low illuminance value of electroluminescence, task light is not a feasible option. The final application of the EL material will therefore fall in either the indication light or the decoration light domain, or in both. When looking at the developments regarding light, it is visionised that as we are less and less limited to outlets due to the developments in portable batteries, light will be set loose from its boundaries and bulkiness. It will be invisibly incorporated in our lives.

Future vision

"Light as one living entity. Accompanying our lives wherever we go as a friendly companion to have a dialogue with; understanding our needs and moods and reacting on it."

Society

Our modern world is a fast changing one, especially in the technological and digital field. We are all trying to figure out how to deal and react to all the smart things and social media around us. The everyday supply of new content and new products seems endless. On the one hand we are embracing all these new technologies because of the opportunities it provides us. It is almost impossible to imagine life without these technologies. But on the other hand we also try to detach ourselves from these technologies, trying to find the authentic things, people and experiences again. We are walking on a thin line between these two sides: the authentic and 'real' world and the digital world. This is something we as designers should find a balance in, looking for smart technologies that still give the user the feeling of authenticity. Either through the experience that it uncovers or by the possibilities it enables. The question is really; How to make things real in a digital world?

Future vision

"I want to technology to connect us to our environment, instead of distracting us from it."

Area of life

Considering the brief for this project and the amount of promising ideas, the Area of Life 'A healthy body & healthy mind' is the most fitting area for this assignment and will be taken further into the next phases together.

BOOK 2
PERSONALISATION

PART 1
ANALYSIS

In book 1 the context was narrowed down from a world view to the area of life; a healthy body and a healthy mind. This area of life is still very broad and can contain several different ideas and idea directions, making the group of users massively varied as well. The area of life needs to be narrowed down to more defined user groups. These groups can then be studied, mapped out and designed for. In this part, the all-embracing area of life will be scoped down to a user group.

EXPLORATIVE IDEATION

To make a well-considered choice, a lot options have to be considered. For design projects, especially of this scale, it is not possible to map out all options, but quantity is still very important. The generation of ideas was done in several sessions, all with a different focus, to ensure this high quantity in ideas. A grasp from these ideas can be seen on the next pages (figure 40). For the full explanation and method of the creative sessions that generated these ideas, please read appendix 6.

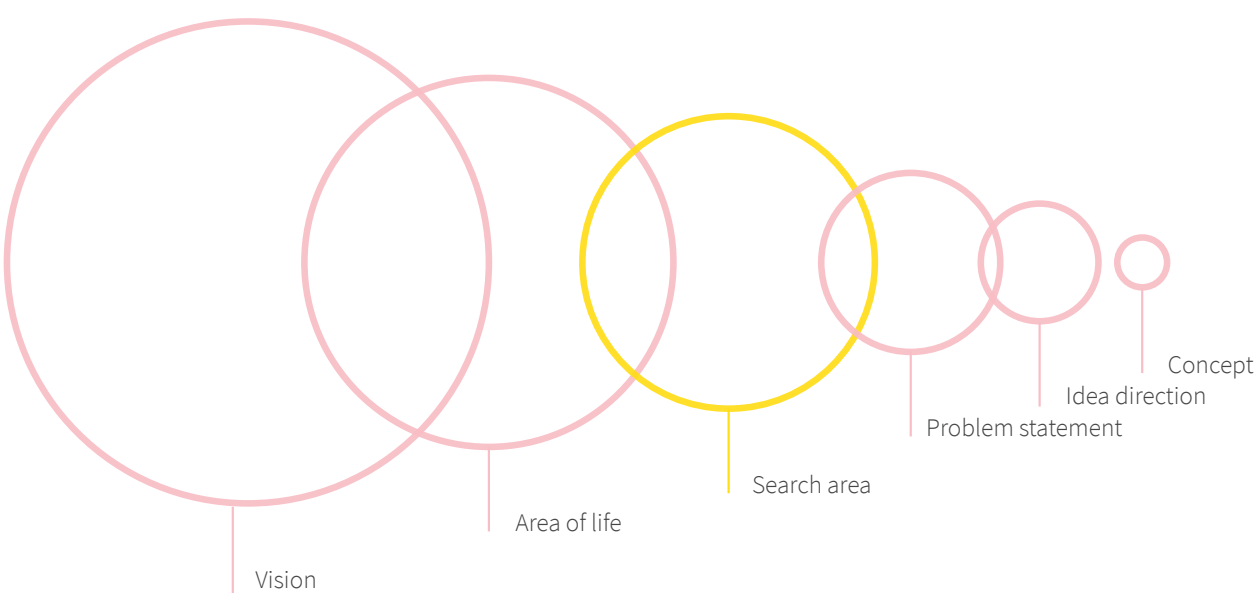


figure 39: the steps taken to narrow down from a societal point of view, to a concept. Highlighted is the focus of this chapter.

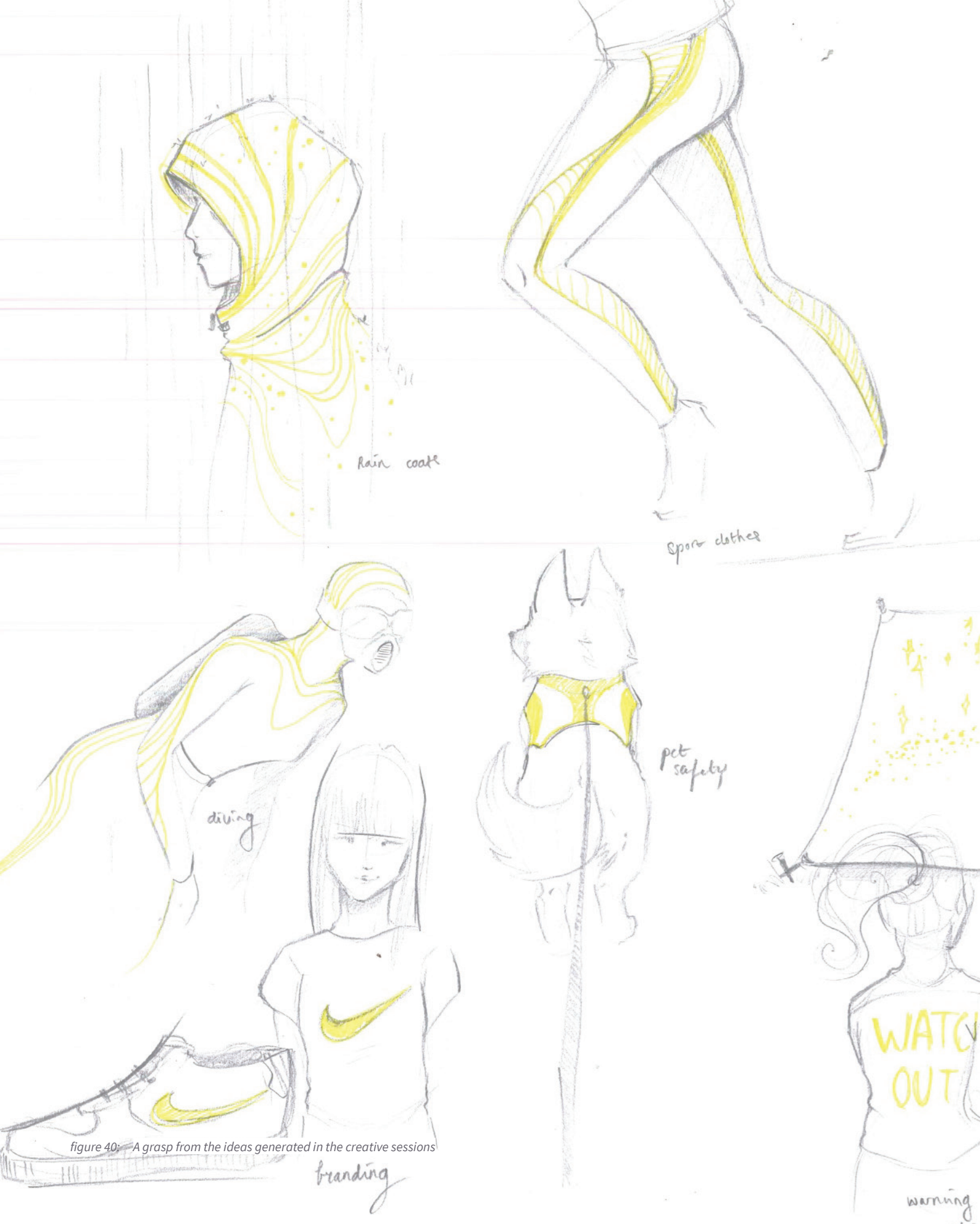
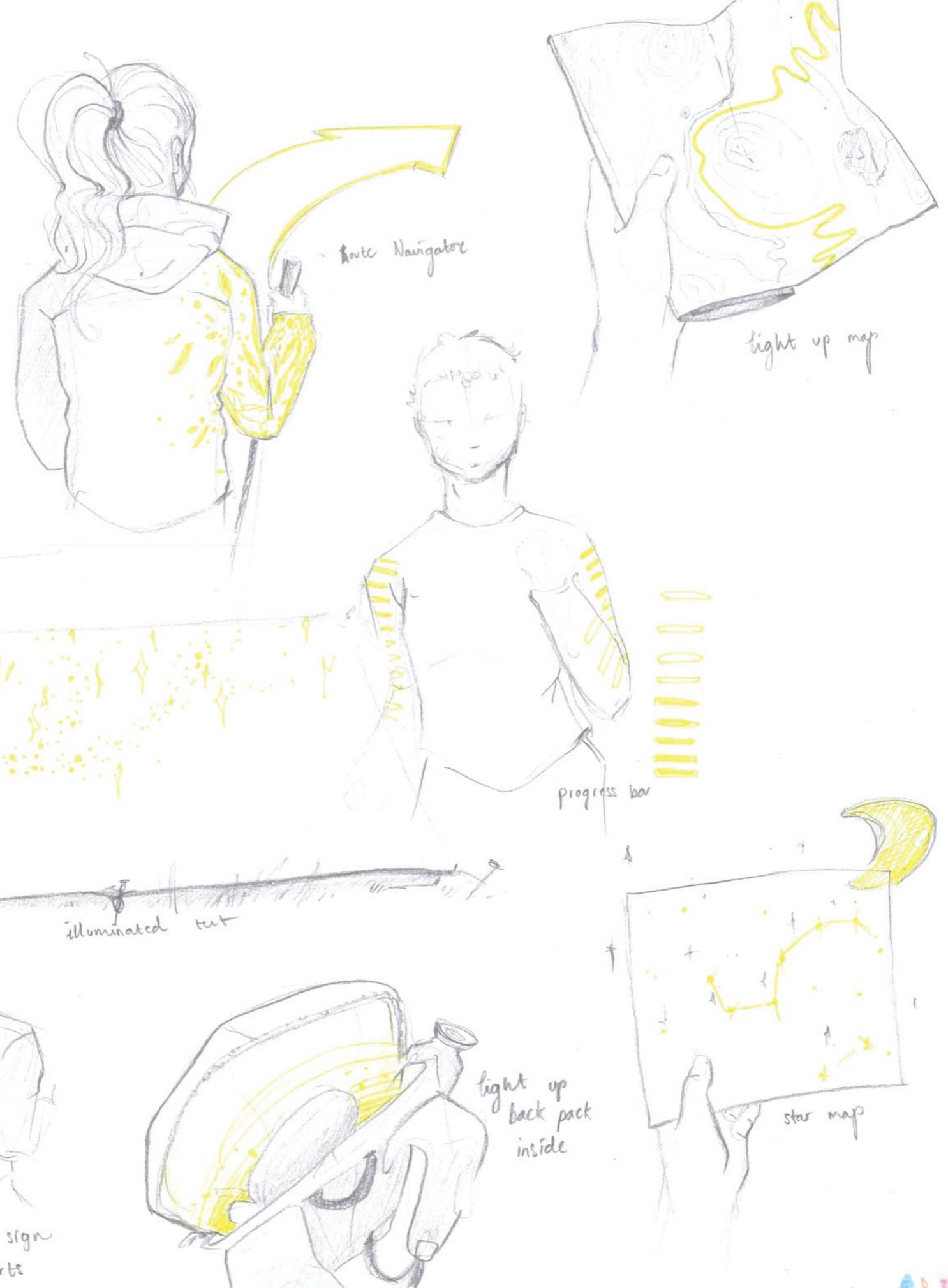


figure 40: A grasp from the ideas generated in the creative sessions


Route Navigator
light up map
progress bar
illuminated text
light up back pack inside
star map

Results

All ideas generated in the creative session were plotted on the same matrix which was used in the Area of life chapter (see figure 42). This matrix captures the graduation assignment in a more quantifiable model, which helps to compare and evaluate ideas. However, 'meaningfulness' is still a vague concept so conclusions should be drawn carefully. This is why, for evaluating the ideas, the matrix was seen as a four boxed model rather than axis with increasing scale. Each idea fell in either one of the four boxes and all ideas in the same box have the same potential. An idea was either meaningful, or not. And it was an unique application for EL, or not. Eliminating the scale of the matrix helped quantify the concept 'meaningfulness' a bit more without making it too prone to personal opinions. The sweet spot in this matrix is the box of unique with EL and meaningful, which is the top right corner of figure 42. Ideas in this domain all fit the brief.

A recurring theme in this top right corner, the sweet spot, was the integration of EL on (sports-)clothing. These ideas within this theme were inspired by two things:

1. The creative facilitation session, where a lot of attention was given to the subject 'the quantified self' (see appendix 6). The term is used to describe the phenomenon of people using modern tools to collect data about themselves and their bodies. This trend is rapidly growing with the rise of small sensors and the Internet of Things. Tools frequently used for this objective are mobile applications and smart wearables like smart watches. This enhancement of the users' physique makes the application meaningful.

2. Tinkering session 1. Light on clothing is still a novel application area in which EL could have an competitive advantages due to its properties; the minimal thickness, the high flexibility and its freedom of form. The tinkering session proved that printing EL on fabrics is possible (see appendix 2), making it a unique application for our material.

This quantified self scope is a promising direction because it fits the conclusions of our three context analyses. A schematic representation of these contexts and the conclusions can be seen in figure 41 and can be read about in the previous book. Here is why the quantified self is promising:

1. It fits the brief, by being a meaningful as well as a unique application with EL.
2. It fits the Area of Life, as the collected data is used to enhance ones' health.
3. It fits the visions, as it connects the users with their environment: their body.

figure 41: a schematic representation of the three contexts and how their conclusion form a base for the search area choice.

figure 42: all 50 ideas were plotted on the matrix

Conclusion

This ideation phase helped narrowing down our area of life to a smaller domain. Investigating the potential of the Area of Life by coming up with as many ideas as possible gave a clear overview of the possibilities. The Quantified self search area is one of these possibilities with a lot of potential for this project. It is, of course, not the only direction suitable for this brief. The brief is so broad that many roads can be wandered. Yet its high potential cannot be ignored.

Therefore we will be focusing further research on this search area: the quantified self.

THE QUANTIFIED SELF & THE SMART WEARABLE

Before we can start designing, we need to know a bit more about the search area. In this chapter, the search area is analysed, in numbers, facts and competitors. But most importantly, the users' needs, problems and desires are mapped. The end of this chapter will conclude in a theory describing the essence of the quantified self movement.

The domain

The 'Quantified Self' is a term that indicates the collection of personal data through technology. It was first used in 2007 to name a local collaboration between users and technology tool makers, all interested in the automation of data collection (Lee, 2013). The movement has been growing in popularity ever since, helped by the quickly developing technology industry of the mid 2000s. The decrease in battery- and sensor sizes and the popularity of the smartphones were all key in making the quantified self an attractive market. According to Statista, the smart wearable market will grow annually around 4.4%, at least until 2022. This will result in a market volume of 16,062 million dollar at that time (Statista, 2018).

The collection of data in this domain, is always done with the use of a 'smart' tool. A well-known example is the smart watch, tracking the activity of their wearers (see figure 43). But there are also a large amount of mobile apps available that collect data. Sleep trackers, step counters, food trackers, they all fall in the field of the quantified self, and there are many more. Any application or tool that is used to collect personal, quantifiable data, is a tool for the quantified self.

A relatively new tool and one that is extra interesting to us, is smart clothing. It is a market that still has to go mainstream, but it is in the rise. Companies are developing products like heart rate monitoring bras (see figure 44) and jackets that can control your mobile phone. The developments in the e-textiles industry go hand in hand with this market, and electroluminescence could play a part in it. In tinkering session 1 it was found that EL can in fact be printed on fabric. Adding the dimension of light to fabrics gives new opportunities for smart wearable, both aesthetical and applicational. At the moment, light-up e-textiles are available but it did not trigger a massive run for it. Two forms of light are currently used; LED and optical fibres.

The problem with LED is its thickness and the fact that it is point source. The thickness can be uncomfortable or even annoying. And the point source limits the aesthetical freedom. One is always limited to a pixelated pattern. A more comfortable option is optic fibre, which is seamlessly woven into the fabric. There are some aesthetically pleasing examples available, like Sara & Sarah (see figure 45). The problem however is that the aesthetics are still limited due to the line-like fibre structure of the material.

EL could be the solution to both the comfort problems of LED and the aesthetical limitation of optic fibres. The low thickness, planar illumination and high form freedom of EL can be a welcome innovation in the smart textile industry. And aesthetics should not be underestimated in the clothing industry; there is a fine line between a nerdy gadget and a trendy device when it comes to wearables.

figure 43: the Apple watchis a well known example of a smart wearable.

figure 44: the Supa sportsbra has an heart rate integrated
Image by Supa (2018)

figure 45: the optic fibre illuminated fabric designed by Sara & Sarah
Image by RCA (n.d.)

Defining the user group

As we can see, this domain is very broad due to its big range of metrics to track and the even bigger amount of tools to do this. This makes the user group also very broad, too broad to investigate in the amount of time given in this project. Statista shows that in 2017, 29.1% of the user group is between 18 and 24 years old see figure 46. The group is evenly divided in men and women. Also, 46.1% percent of the users falls in the high income scale (Statista, 2018).

Interviews were conducted (see appendix 7) to get a better understanding of the user group, but only with a sample of the total group of users that would buy a quantified self product. It was chosen to do these interviews with people in the age of early- and mid twenties. This is not the largest age group in the smart wearable industry but the group is chosen for another reason; because we will be designing a smart wearable, probably a smart garment, we need to look at the fashion industry. For a trend to catch on, it needs to be accepted by the early adopters.

In fashion, the young are more likely to wear a trend than older people, wanting to be perceived as 'cool'. Fashion and personal style is a delicate subject since it plays an, underlyingly, large role in our lives. Everyone wants to be accepted and therefore you can not fall out of line with your peers. So for our smart clothing product to become a succes, we need to turn to the group that is most likely to accept the product: users between 18 and 24. Since they are more prone to follow fashion trends than the other age groups. This might not be the largest group of users in the smart wearable industry, but the difference is little. Getting to know this group is a key to creating smart clothing that will be accepted. Once the early adopters wear the item, the rest will follow slowly, but automatically.

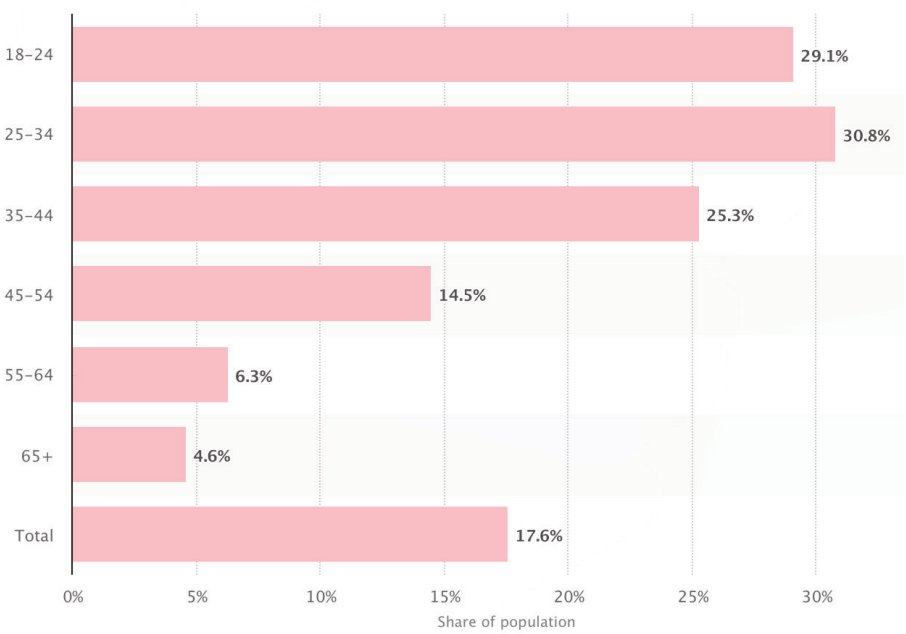


figure 46: the age distribution of the users of wearables. Image by Statista (2018)

So what is happening here?

The following insights were derived from these interviews, a personal indulgence in the world of the quantified self and by seeing a documentary about our lives with smartphones. The complete set of notes and quotes from these explorations can be found in appendix 7.

Goals

Everyone in the quantified self movement has a different goal, but it all comes down to learning from yourself and improving. The tool for these people to get to that goal is a quantified self tool. The main goal, always focused on getting mentally or physically healthier, is a long term target. It can take months or even years for them to get there. Because of this slow progress, people can lose motivation. Through the quantified self data, small changes become visible, which keeps people motivated. Even though it seems like you are not showing progress, the data shows you otherwise. These smart wearables divide the main goal into smaller daily or weekly goals, making them more manageable. Reaching a (daily) target triggers the human reward system, keeping the users motivated. The adding of gamification to these tools, like earning badges, collecting points and having a leader board, is also a way to enhance motivation. Quantifying and visualising a goal in a graphic, makes it easier for the user, they either reached it or not, they don't need to think about it anymore.

Data

Every tool, whether it is an app or smartwatch, collects data of one or multiple metrics. This data is the basis of the quantified self movement. The raw data itself, is not that interesting. It only gets interesting when it is put in relation to something; either to your past self, your peers or the healthy norm. The data enables the user to see even the smallest changes in progress, making it so valuable. This is why if a data set is missing, people feel like 'they have done something for nothing', because now the progress is not tracked realistically. When data is tracked to gain knowledge about a certain behaviour, the quantified self tool will eventually become redundant if the user knows all there is to know ("how much hours of sleep do I need?"). When the data is used during a certain behaviour, it will stay of necessity ("what is my running pace?").

Behaviour change

These applications and tools help in the change of behaviour because the user becomes aware of their behaviour. This gain in awareness is a very important aspect of the quantified self movement. The data and the rhythm of the daily goals confronts the user with facts about their goal and their progress. Because the user makes an agreement with themselves to change a behaviour (with the use of a smart wearable) it feels like they have made an agreement with the smart wearable itself. Just the fact that the user has this agreement with something other than itself, can serve as a nudge to keep working towards a goal.

Negative pointers

But even though smart wearables help in the change of behaviour, it does have some negative pointers. The constant comparison for instance, especially with other people, can give an extra layer of pressure to people in their already stressed lives. Also, when the data is not interpreted correctly, people can draw the wrong conclusions. This is especially true for raw data. People can for instance start dieting even more if they notice they have not lost enough weight. While in fact the weight gain can originate from a healthy muscle gain. Another negative aspect of these tools is the lack of human empathy in them. Daily goals are ruthless, they are set once for a longer period of time and they do not change to fit a personal schedule, a sickness or a stressful day.

Results

These insights were valuable for the deeper understanding of the quantified self movement. The framework of figure 47 summarizes these insights.

What we learned from all the insights is that the main reason people use smart wearables or quantified self applications is because they want to change something about themselves. They have a goal. The users want to change the state they are being in right now, into another state. For instance, losing ten kilograms or being able to run a marathon. To achieve this and to maintain this goal state, a behavioural change has to happen. So actually, the technology should not only help them achieve a certain state, but should do this by changing their behaviour. Because eventually it is not the state that matters, it is the lifestyle change: this will keep you in the state. The framework of figure 47 shows that long term change in behaviour is the result of the following five aspects: awareness, motivation, action, rhythm and lifestyle.

Awareness, a short moment in time
A person becomes aware of his or her behaviour. Being aware is very energy consuming state. This, is why it is almost always a short moment in time. But it is a very important one because the direct consequence of awareness is motivation.

Motivation, a longer moment
When a person is motivated to change something or to do something, it will result in an activity. This state stays some time but will end shortly if it is not turned into action.

Action, a longer moment
Motivation ultimately leads to action. This is where to good stuff happens, this is the moment where the actual steps are being made towards the ultimate goal.

Rhythm, a very long moment
When a person constantly decides to do a certain action it becomes a rhythm. This is however not set in stone, rhythms change. By constantly going through the cycle of awareness, motivation and action, a rhythm will sustain and the cycle will become easier.

Lifestyle change, forever
If a rhythm is being set and continued, eventually a lifestyle change will happen.

Conclusion

The user group in the quantified self movement all have a specific reason to use these tools and a target to achieve. The ultimate goal is the change of a certain behaviour. Through the gathering of data through smart wearables, constant awareness is created for this goal. It is the first of 5 steps in the actual change: awareness, motivation, action, rhythm and lifestyle change.

"The essence of the quantified self is changing behaviour by gaining awareness."

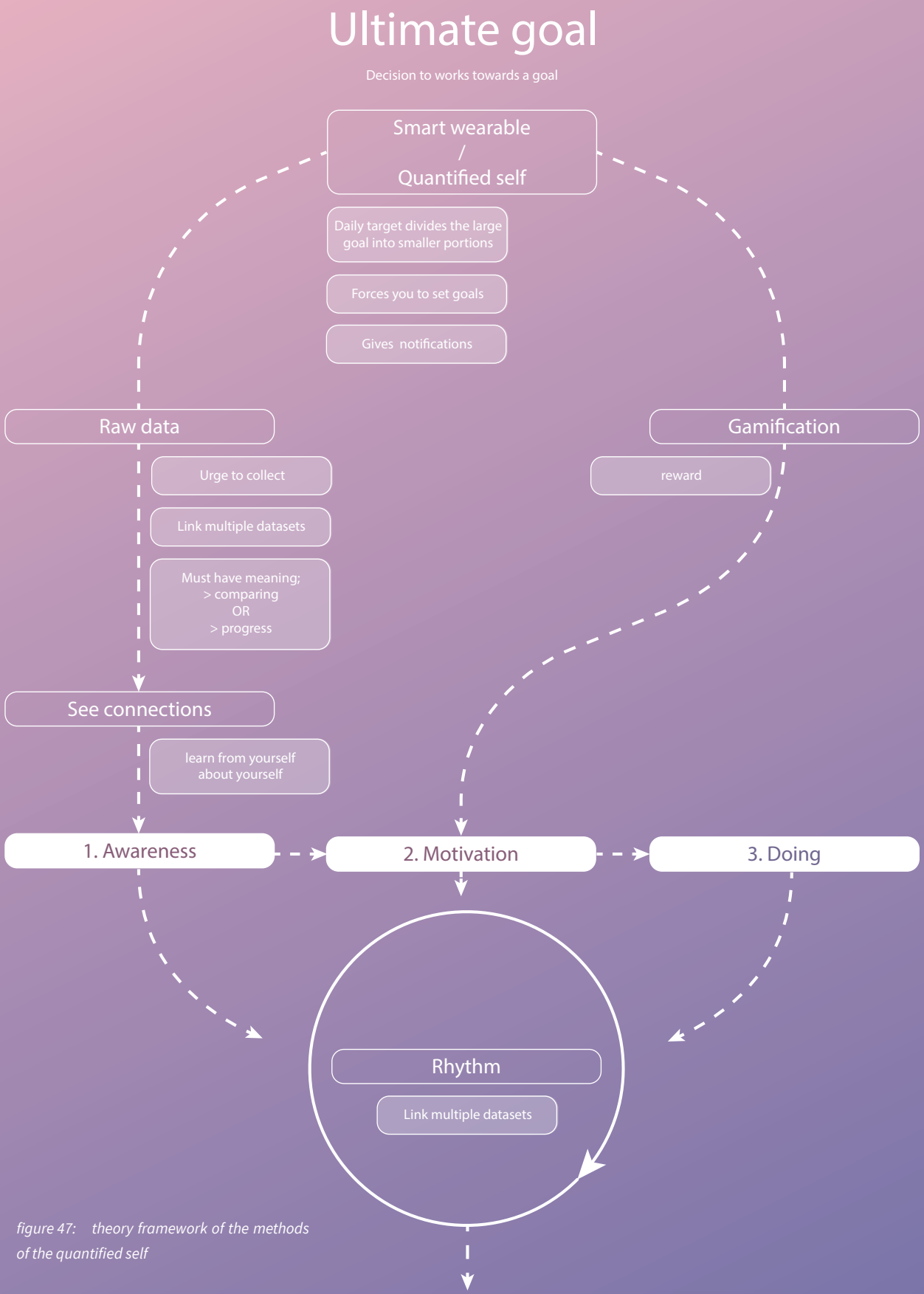


figure 47: theory framework of the methods of the quantified self

PART 2
CREATION

Now that we have a more general understanding of the quantified self movement and understand the methods of the smart wearable tools and the objectives of the user group, it is time to start designing. First, a design goal has been formulated, out of which inspiration was drawn, but which also helped to narrow down the domain to a clear and achievable goal. After that, concepts were drawn up. This part will conclude with a concept direction that meets the design goal. In figure 48 these steps are highlighted.

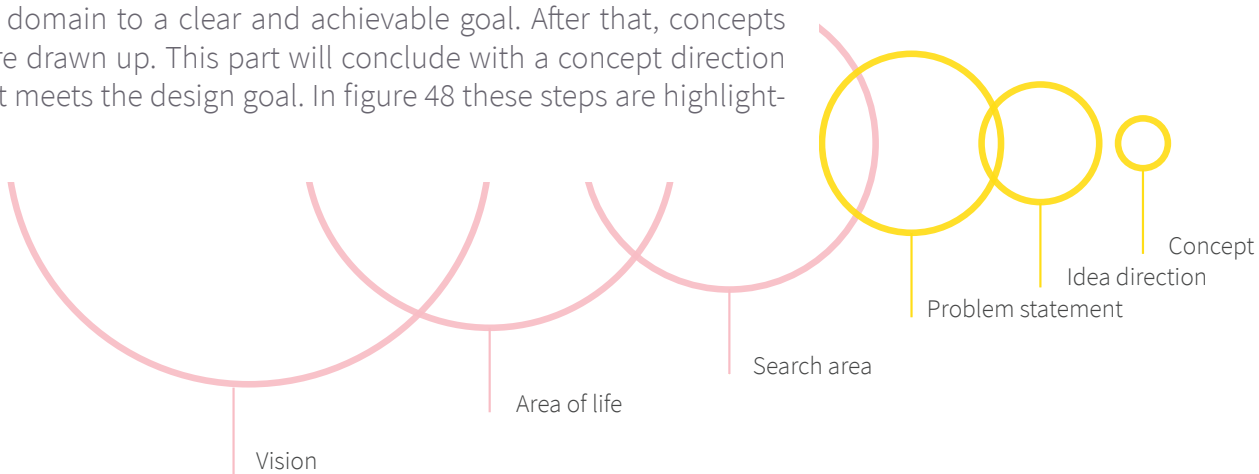


figure 48: the steps taken to narrow down from a societal point of view, to a concept. Highlighted is the focus of this chapter.

DESIGN GOAL

The insights of the quantified self movement analysis led to the design goal formulated on the following page. In this chapter, the different aspects of this goal will be explained briefly.

"I want to facilitate the process of behaviour change for people who want to increase their overall activity, by making them aware of their current behaviour with the use of electroluminescence."

So what does that mean? Four important aspects of this goal will be elaborated on below.

"I want to facilitate the process of behaviour change for people who want to increase their overall activity, by making them aware of their current behaviour with the use of electroluminescence."

1. BEHAVIOUR CHANGE

The reason for people to buy or use quantified self tools always has something to do with change. The users want to change something about themselves, like being able to run a marathon or to feel more energised, and hope the wearable will help them with this. This change in state will only be lasting if a change in behaviour also occurs.

2. INCREASE THEIR OVERALL ACTIVITY

This change that the user group wanted to achieve was different from person to person, but the main topic always involved health. The design goal will however not focus on a specific physical goal, like losing weight, because of the following:

"Having 'adjacent' goals such as healthy eating and quitting smoking decreased Fitbit use, when compared to 'central' goals such as increasing activity."

- Storni, Cristiano (2018)

Because we are designing for behavioural change, we need to make sure the users keep using the product. Therefore, the design goal focuses on 'increasing the overall activity' because people who have a central goal are less likely to quit.

3. BY MAKING THEM AWARE

Awareness is the first step to behaviour change and is therefore a very important aspect of it. It is also an aspect we can influence in multiple ways, as will be discussed in the next chapter.

conclusion

This design goal is restrictive enough to steer the concepts in a promising direction. But also leaves enough room for innovation. Especially in the subject of awareness, which will be a leading subject in the concept ideation.

4. WITH THE USE OF EL

For this graduation assignment, an application had to be found for electroluminescence. It makes sense to use this now, not only to fulfill the brief, but also because light can indicate something (see the chapter Light). Making the user aware of something. It is also an unique material for smart clothing because of its thin and aesthetical properties.

CONCEPTS

The first question that comes to mind when reading the above formulated design goal is the following: “How can we gain awareness?” This question has been tackled in a brainstorm, which can be read about in appendix 8, and led to five concepts, each tackling another form of awareness.

Evaluation

The five concepts were evaluated on how well they could achieve our design goal:

"I want to facilitate the process of behaviour change for people who want to increase their overall activity, by making them aware of their current behaviour with the use of electroluminescence."

Our main goal, and the main goal of the Quantified Self is behaviour change. But it can be a hard process. In the previous research about smart wearables, a few qualities were found in these products which helped to motivate the user just that little bit more. These qualities could be the difference between a succes or a failure.

Qualities

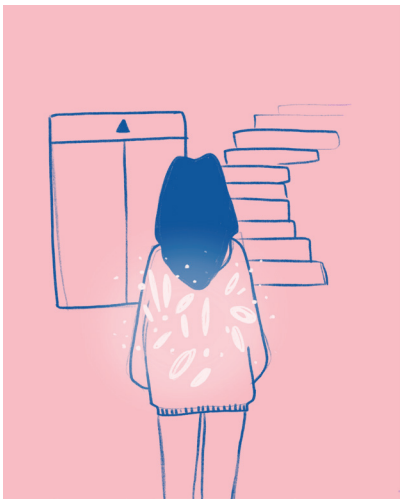
The five generated concepts will be evaluated based on these qualities.

- *Goals are an important part of the quantified self. Having a daily goal helps to break up the large process of behaviour change into more manageable pieces.*

- *Constant reflection, not just at short moments increase awareness. A short moment can easily be ignored.*

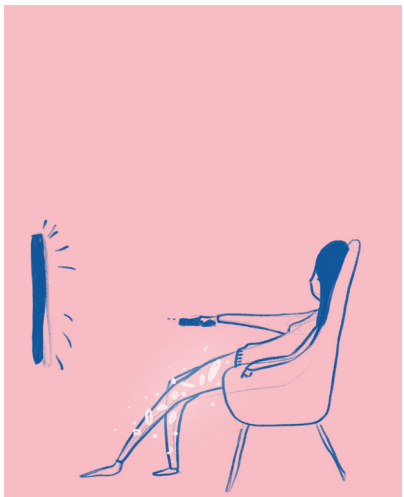
- *The awareness should be focused on a positive trigger, how well one is doing. And not a trigger when the user is doing something wrong, giving them a negative association with the product.*

- *Through everyday reflection on a daily goal, awareness enhances even more. Also it leaves opportunity for people to change their daily goal according to everyday life, making the product more forgiving.*



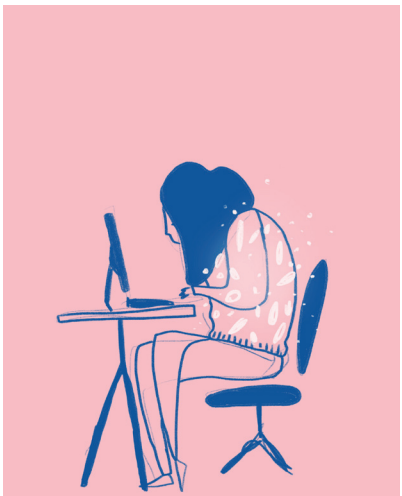
Awareness of the location

Through pointing out the easy wins in life, like taking the stairs instead of the elevator, small changes can be made with a large effect. The wearable will notify the user when it is in a specific location where a healthy choice can be made.



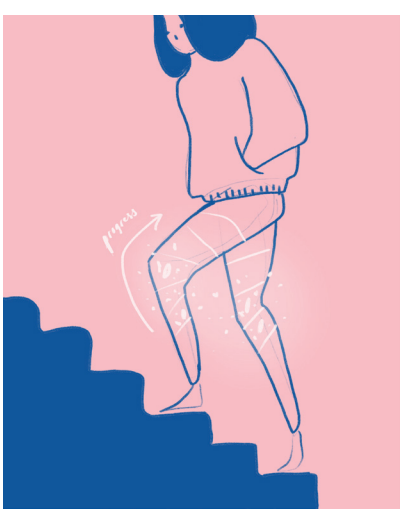
Awareness of time

Through pointing out how one spends one's time, the user can be made aware of their time management. The smart wearable recognises empty moments, like watching a show when waiting for something, so a more healthy and satisfying activity can be done in this moment.



Awareness of inactivity

Through reflection on activities that have been going on for a long time, the user is made aware of how much time they spend on certain activities. The smart wearable will start to glow if a person has not moved, or stood up, in a long period of time



Awareness of the goal

Through constant reflection on the progress, the user is made aware of their daily and overall goal. The daily goal will be set by the user and the smart wearable will show their progress.

Awareness of the effect

Through the degradation of another object, the effect of inactivity is symbolised. The user is made aware that if you don't take care of yourself, you also degrade. The light in the smart wearable will slowly fade when the user has been inactive for a long time.

Conclusion

The choice has been made to continue with the concept direction of 'Awareness of the goal'. This concept direction incorporated most of the qualities which help to change behaviour, and is therefore most likely to achieve our design goal. It incorperates goals, which are constantly reflected. The awareness focuses on how well the user is doing, so it is a positive association. And last, the relfection is daily.

INSIGHTS BOOK 2

Ideation

This ideation phase helped narrowing down our area of life to a smaller domain. Investigating the potential of the Area of Life by coming up with as much ideas as possible gave a clear overview of the possibilities. The Quantified self search area is one of these possibilities with a lot of potential for this project. It is, of course not the only direction suitable for this brief. The brief is so broad that many roads can be wandered. Yet its high potential cannot be ignored.

Therefore we will be focusing further research on this search area: the quantified self.

1. It fits the brief, by being a meaningful as well as unique application with EL.
2. It fits the Area of Life, as the collected data is used to enhance ones health.
3. It fits the vision, as it connects the users with their environment: their body.

Quantified self

The user group in the quantified self movement all have a specific reason to use these tools and a target to achieve. The ultimate goal is the change of a certain behaviour. Through the gathering of data through smart wearables, constant awareness is created for this goal. It is the first of five steps in the actual change: awareness, motivation, action, rhythm and lifestyle change.

"The essence of the quantified self is changing behaviour by gaining awareness."

Design Goal

"I want to facilitate the process of behaviour change for people who want to increase their overall activity, by making them aware of their current behaviour with the use of electroluminescence."

Concept

Awareness of the goal
Through constant reflection on the progress, the user is made aware of their daily and overall goal. The daily goal will be set by the user and the smart wearable will show their progress.

BOOK 3
MATERIALISATION

PART 1
CREATION

With the concept direction of “awareness for the goal” a final design was formed, keeping in mind all the aspects of the design goal and incorporating small ideas from the concept ideation of appendix 8. In this part the final design will be explained, not only the ‘what’ and the ‘how’ of the product, but also and especially the ‘why’ of certain design choices.

AWAREABLE;

a wearable enabling awareness

In our busy lives filled with content, content, content it is hard to keep track of what is important. The Millennials are overworked and is not strange why; The rise of the digital age brings new dilemmas and stress factors, demanding attention but also demanding quality. Aesthetics and a perfect life is what we strive for. The impact of digitalisation is undeniable, and these products are here to stay. This is why more 'human' designs are needed; products that help us pursue activities that are actually important, instead of pressurising us further into living fake and perfect lives. Linking digital products to the physical world is a great way to connect us again with the real.

figure 49: the digital age

One aspect of life often, and sometimes purposely, forgotten is physical activity. Even though it makes us less stressed and more energised, something much needed in a life as busy as we are living today, it is often one of the first activities to go out the door when a busy schedule or a stressful period is coming up. It is hard for people to maintain a rhythm, especially the younger people in college, still figuring out how to handle new responsibilities. Yet it is this rhythm that can help with maintaining a healthy physical lifestyle. What if our connected objects would help us remain active? And not by demanding even more of us, but just by keeping us up to date with ourselves, helping us gain awareness on our movements and connecting us again with our bodies. A wearable accompanying our lives wherever we go as a friendly companion to have a dialogue with; helping us achieve our goals without neglecting the fact that we are humans, and we are busy.

Well, meet Awareable.

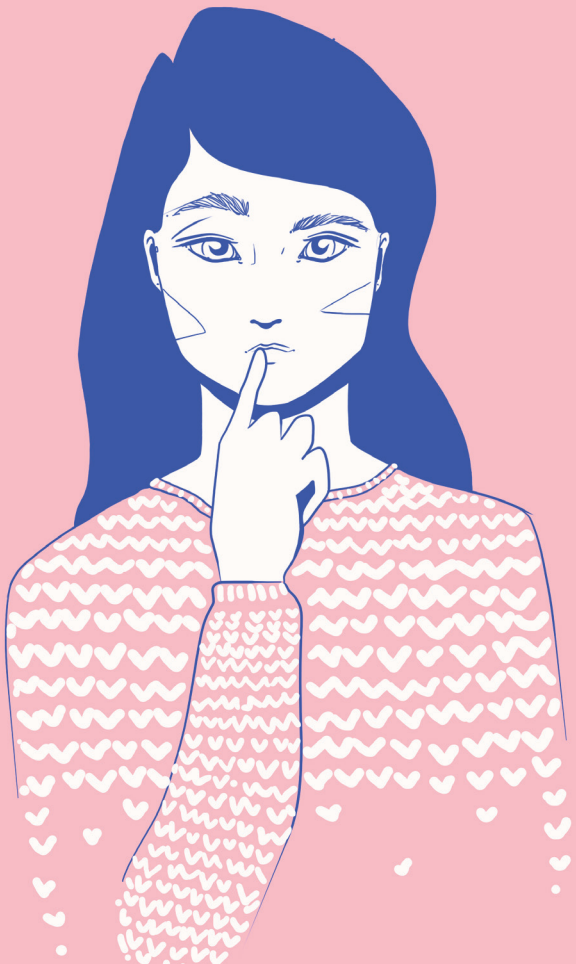
figure 50: The Awareable

The scenario

Awareable is a wearable that is designed for behavioural change, focused on physical health in a general sense of the word. It wants to help user become more active, without being insensitive. It tries to change the lifestyle of its user slowly, but steadily, by making them aware of their daily activities. It does so by letting them reflect on their days and choose a reasonable activity goal for that day. The process of this goal is then shown graphically on the wearable. The user is literally wearing a reminder, everywhere they go. The closer the user is to the goal, the more beautiful the wearable gets, rewarding them for their effort. In figure 51.1 to figure 51.10 the scenario is visualized to explain the full interaction.

figure 51: steps 1 to 10 of the scenario

2: evaluate day

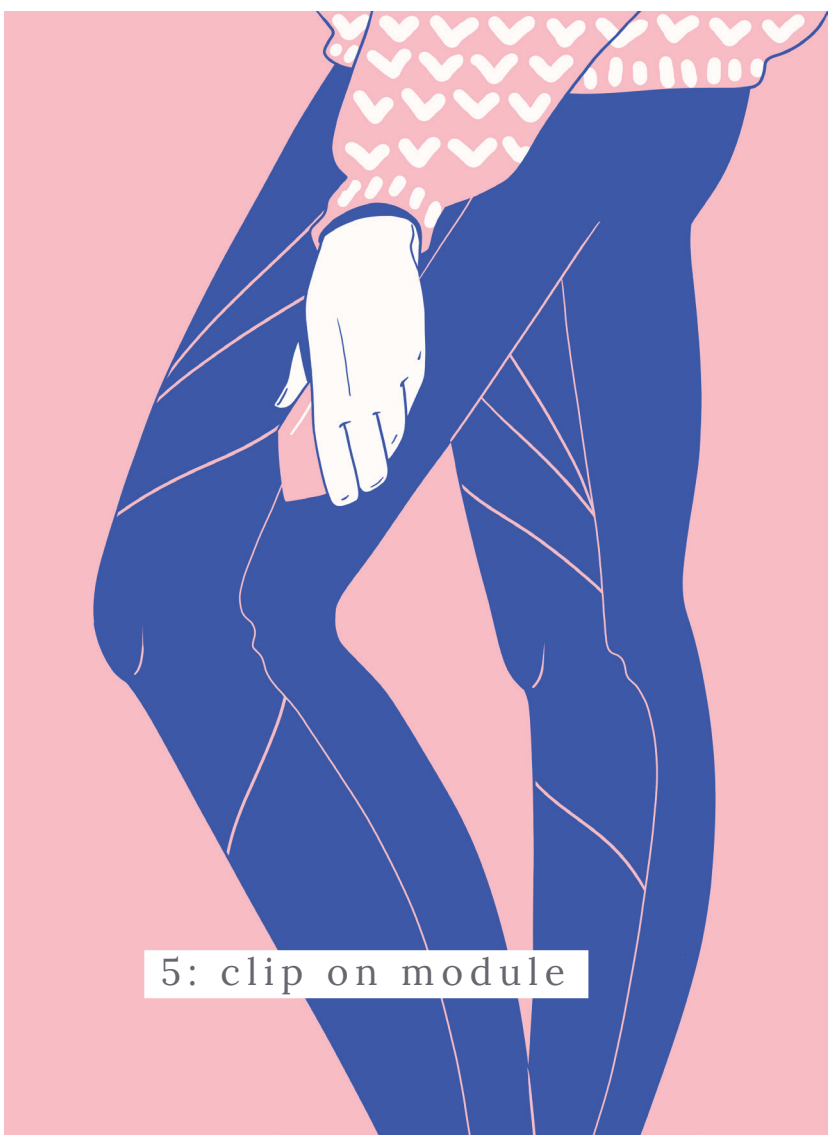


3: fill in daily target

1 to 3
Every day, a short moment after the alarm has gone of, the synced application asked the user a few questions about their day to make them aware of their affairs and mood and to let them set an activity goal they think is reasonable for that day. For more in depth explanation about the application and these questions go to page 98.

4
The wearable is put on and the goal is synced with it.

5 and 6
During the day, the wearable keeps track of the progress and shows it to the users in a live progress bar: the more sections of light are shining, the closer you are to your goal. A smartphone is not needed because the wearable itself has enough sensors to measure general activity.



6: progress is reflected on the wearable

7 and 8
When active, the nearest section to become full will start glowing: signaling the user that they are working towards their goal and motivating them to push on.

9: final push to finish goal

10: app registers when goal is completed

9 and 10
When the goal is reached, all sections are glowing and an alert is sent to the app. In an overview the progress of each day is visible. Having visual feedback of an achieved goal triggers the reward system (see appendix 7, interview 1).

The garment

The basics of this product to not differ from clothing piece to clothing piece; a t-shirt would have the same scenario as a pair of pants. However, for the final design a pair of leggings is chosen. Focusing on only one piece lays gives the opportunity do dig deeper into the aesthetics of it, laying out ground rules for other pieces. It also communicates more easily to talk about one product instead of about a line of clothing. Like a concept car in the automotive industry this design will be the leading source for inspiration for further apparel.

A legging was deliberately chosen for its limitations: the fabric is highly stretchable and worn very tightly to the skin. Incorporating light in an non obtrusive way in this garment is way harder than it would be in a loose piece of clothing. So for a proof of concept, a legging is the most logical choice. This immediately links us to women; who are still the majority in wearing leggings as a daily outfit.

The psychology

The strength of a piece of clothing in this design is the fact that it is worn close to the body, throughout the whole day. It is a direct link to the physical body, even though we are wearing technology, which helps to keep us grounded. A lot of application and non-clothing smart wearables focus our attention to digital information. Even though this is information about the body, it feels disconnected from it by reading it from a screen. By having the information worn on your body, the information becomes less digital, but instead is brought to the real world and our real physique. This increases the impact of the information, and so increases awareness. The information, which for the case of Awareable is only percentages, doesn't need to be complicated anymore this way.

The fact that a piece of clothing is worn all day long, also increases the awareness effect. You cannot really forget it, it cannot be left in your side pocket and it cannot be ignored. It should however not become embarrassing. This is why the wearable only gets more aesthetically pleasing as the goal progresses, and not less.

The aesthetics

Because clothing is such an important aspect of our everyday appearance, it is important that the product enhances this aesthetic or at least does not downgrade it. The light on the wearable is obviously attracting a lot of attention, which gives an opportunity to enhance certain traits of the body. Different shapes and angles can accentuate different body shapes. In figure 52 a study of the effect of the light sections on perceived body shapes can be seen. We can see that the upward graphics are most flattering for women (1, 2, 5, 7, 11, 12), they enhance the shape of the hips and add length to the legs. It also implies an illusion of speed, while the downward motion (3, 6, 10) on the other hand seems to slow down. The straight graphic designs (4, 8, 9) does add length to the legs but does nothing more for the shape of the body. What we can also see is that curved lines (2, 5, 110, rather than straight lines, are more flattering for the curves of the body. The light sections flow around our natural lines this way rather than that cut them off.

This study led to the following design guidelines:

1. The general sections of light should be going upwards.
2. They should not be perpendicular to the body.
3. The lines of these sections should be curved, flowing with the natural lines of the body

Which together with a study on the effect of patterns on the aesthetics (see appendix 9) eventually resulted in the final design.

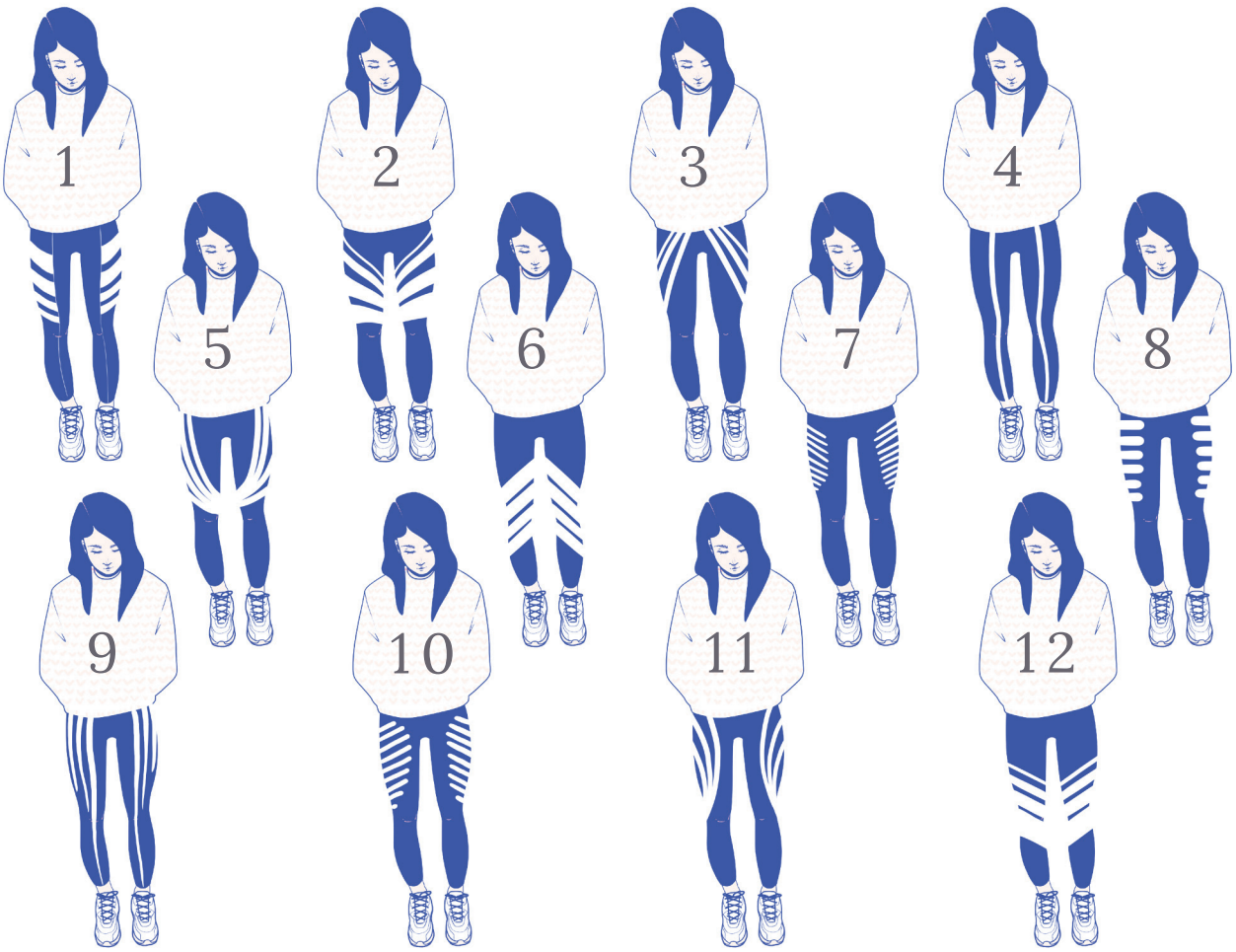


figure 52: study on the effect of different lines on the perceived body shape

The 4 sections

The communication of the progress of the goal is done through four sections of light. Each representing a fourth of the goal (see figure 53). If none of the sections is lit, then the progress is between 0 - 25%. If one section is lit, the progress is between 25 - 50%, and so on. When all four sections are shining, the goal is reached. During activity, the next section to light up will start glowing. This communicates to the user he/she is doing a good job, but also shows that the garment is registering the movement.

figure 53: explanation of the sections and interaction with the light original image by Nike (2018)

Progress:

75-100%

50-75%

25-50%

0-25%

THE ACCEPTATION

A piece of clothing is a very personal thing, reflecting who we are or who we want to be to the outside world, which is why it is very important to think about the acceptation of the Awareable. We carefully select the items in our wardrobe, we all tell a story. Some do not want to be noticed while others want exactly that. Some want to be seen as a romantic person and others want to be cool. But we all want to fit in within a certain social group. In our product, the light on the garment attracts a lot of attention, which is not a wanted trait for some people. Especially in the implementation phase of the product, when the Awareable is still a novel sight, people might feel awkward wearing it. It is a piece of clothing that, because of the light, falls outside of the norm, which is a scary place for a lot of people when it comes to fashion. In order for the Awareable to be a success, it needs to be accepted and normalised.

The user group

The acceptation of the product will lie in the hands of the early adopters. Which, in the case of the fashion industry, is on the break line of teens and young adults (Saravanan, Nithyaprakash, 2015). So it is important that we make the Awareable attractive for this age group. It needs to be seen as a trendy and a must-have item. When this group has accepted the product, and light up apparel is seen on the streets, more user groups will start to accept it and eventually even wear it: illuminated clothing is normalised.

So, who are these early adopters we are designing for? To create a clearer image of these individuals, two personas were made (see figure 54):

The adopters are the children of the online world. They grew up with the Internet and social media is their playground. This brings a lot of new opportunities but also problems. A strive for a 'perfect life' and the constant feeling that they need to do more, more, MORE lays pressure on them and their daily lives. Making it hard to focus on the important things. They are busy people, keeping in contact on- and offline and do not want to miss anything. They want to look good and try to keep up with trends (they need to look good on their Instagram selfies), and follow online influencers for inspiration.

Due to the busy lives they lead, doing sports sometimes gets lost in their other activities. Although they want to stay fit and lean, it is not something their schedules allow time for. Staying active during the day and being reminded about their daily goals can help accompany them in staying fit, without getting overwhelmed with another point on their to do list.

figure 54: the persona's of the early adopters

Nike

Yet, it is not enough for a smart wearable to only be novel to get the early adopters to buy the product. The garment needs to be have a trendy vibe in order for them to wear it. This is where Nike, fictively, comes in. If Nike would publish this garment the chances of it catching on would be much higher in comparison to a novel start up. But it is not only beneficial for the acceptation of our EL product, it is also fitting with the brand. This link with Nike serves to show how we could implement the Awareable in such a way that it would be accepted by the target group.

Linking Nike to our smart wearable product is logical for several reasons:

1. Nike is a highly influential player in the fashion industry. Nowadays it is far more than only active wear, it is a leading brand in the streetwear industry. Not strange then to see that Nike has the second largest amount of followers on Instagram in comparison to other brands (Statista, 2017)
2. Nike is already involved in the smart wearable industry. They have coupled up with the Apple Watch to promote their own running app Nike NRC even more. An application already downloaded by 723.843 users (Google play, n.d.), and these are only Android users.
3. Nike is doing a lot to innovate their clothing. They are using the latest fabrics and are developing their own to stay ahead of the pack. Even though they have not brought out any smart garments yet, it would not look odd in their product portfolio.

The link with Nike has influence on the aesthetics of the product, but it is a small one. Their portfolio of leggings is a widely varied one, so ours would not misstand. A logo however, should be added in the final design. See figure 55 and figure 56.

figure 55: visualization of a Nike garment implemented with EL original image by Nike (2018)

figure 56: visualization of a Nike garment implemented with EL
original image by Nike (2018)

figure 57: a representation of what the clothing line could look like original images by Nike (2018)

Clothing line

Although the legging would be the flagship garment, communicating the possibilities of EL on fabric the best, it is smarter to bring out a whole clothing line in the long run. The concept of daily awareness about your goals only works when the concept is carried around daily. This is ofcourse not hygienic nor desirable, so multiple garments need to be available. This way the users can wear an Awareable and keep track of their progress every day. It also allows for a more personal outing of one's style. As said before, fashion is a very personal subject. Having only one Awareable (especially a legging, which is still dominantly worn by women), would not go in line with this. A lot of potential users would not buy the product, only because it does not fit their appearance.

An example of this clothing line is shown in figure 57. Shirt, trousers and sneakers alike can be 'upgraded' with the Awareable technology. Because the printing process of EL is relatively simple, it is easy to implement it on different garments.

There is a connection needed between the different products to make the concept work, so daily goals and progress is shared among the garments. This will be done through the mobile application. Data is synced from the garment to the phone to the new garment.

Conclusion

In order for the Awareable to be accepted by the masses a select group of people, the early adopters, first need to start wearing the product. These young adults follow trends and start them. An important apparel company for this group is Nike, and due to its link to the sporting culture and their will to innovate, this is a perfect brand to take on the challenge. A clothing line needs to be created which implements the Awareable technology, so the busy young adults of today can wear the illuminated clothing everyday, slowly changing their own lifestyle and influencing others to do the same.

figure 58: visualization of a Nike garment implemented with EL
original image by Nike (2018)

THE DETAILS

To make this whole interaction work, three aspects need to work together: the electroluminescent sections on the garment, the application and the driver module containing the energy supply and the sensors. In this chapter each of these aspects will be explained individually and how they link to each other.

EL on fabric

The first aspect, and also the most obvious one, are the electroluminescent sections. They are the base of the product. Four panels have to be incorporated and connected to the main power supply module. The use of wires can decrease the aesthetics of the garment and should therefore be hidden. A way to do this elegantly is by placing them in the seams of the legging (see figure 59). The seams should be directly next to the electroluminescent panels, so no excess wire is showing.

Because EL can be screen printed, it is easy to showcase different patterns. It is an advantage point of the use of EL, no other light source is able to display such intricate patterns on fabric, and should therefore be celebrated. In figure 59 and figure 60 some designs are shown as a source for inspiration regarding the patterns.

For mass production, the regular screen printing technique does not suffice since it a time consuming process. In the fabric industry, the technique of roller screen printing is used to print rapidly on fabrics. Although it is not tested with EL yet, it has great similarities with the regular technique and therefore seems promising.

figure 59: visualization of the difference in patterns the EL sections can be printed in and the placement of the wires original image by Nike (2018)

figure 60: visualization of the difference in patterns the EL sections can be printed in. original image by Nike (2018)

The application

The application is the communicating factor. The garment itself collects the data through sensors, but it cannot communicate it with the user more extensively than showing the progress on the sections. A smarter device is needed: in comes the smartphone. It is not desired that the application becomes the main focus of Awareable so the interaction with it is very concise. The application is made as simple as possible, it only has a few features necessary to make the whole concept work. These features are:

1. **The daily filling in of a specific goal**
   Every day after the alarm goes off, the user is asked to fill in the following blanks:

   - *Today I feel [...]*
   - *My day is [...]*
   - *So my daily goal will be [...]*

   Daily reflection like this can help users to learn about themselves and set realistic goals. This last bit is important, as realistic goals are more likely to be met which triggers the reward system; eventually this will help in the long run with keeping up with their overall goal of a change in behaviour. The visual of figure 61 shows the questions screen. The user can choose from a few preset goal types which are working together with the sensors of the Awareable like a step goal, a minute goal, a calorie goal or a distance goal. More of these presets can be added in the future once the sensors develop and activities can be tracked more accurately.

2. **The real time progress in a more accurate way:**
   The EL panels show approximately how far one is along their goal, but it is not very accurate. Sometimes the user does want to know this, for instance if they are contemplating if the goal is still within reach for this day. The application will be able to show them. And if it is not a realistic goal anymore, the user can change it. See figure 63.

3. **Data from past days and months. Showing the progress of the user:**
   People like to see their progress. It helps them to learn but also makes them feel good about themselves. It is triggers another layer of awareness: awareness about their overall progress. See figure 62.

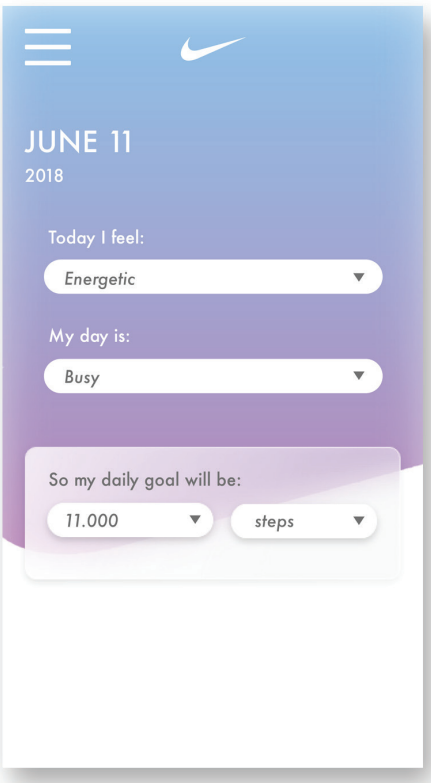


figure 61: application screen of questions

figure 62: application screen of the monthly overview

figure 63: application screen of progress

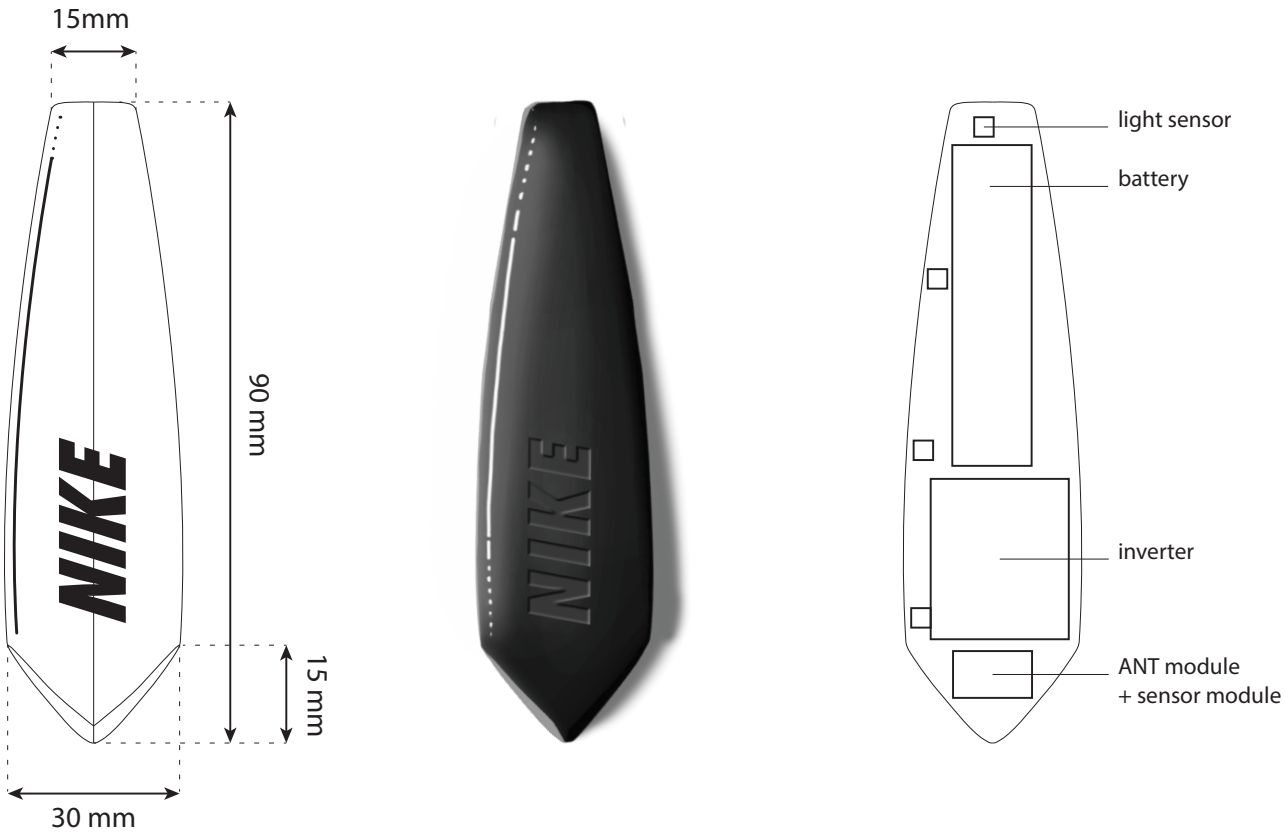


figure 64: the measurements of the module with the configuration of the components

The module

In order for this to all work a few things are needed: 1. The EL fabric has to be powered with an alternating current 2. information about the movements and whereabouts of the user needs to be tracked, 3. all this information has to be turned into visible data in the form of light and 4. it needs to be shared with the mobile device of the user. It also needs to be portable and wearable, which means they all have to fit within a small module, attached to the wearable. This module and its relative size is shown in figure 65. Its shape is derived from a little shape study, which can be found in appendix 10.

The module is detachable, so it can be charged and it will not be damaged when the garment is washed. But another reason for this is because it is interchangeable with other garments. If the user owns more than one piece of Awareable, only one module is needed this way. This saves money and resources.

The configuration inside the complete module can be seen in figure 64. The components are explained on the right. On page 103 a more elaborate explanation of the used sensors and the reasoning behind them is given.

Battery
We will be using a 18650 rechargeable battery (3.7 V Li-ion 3400 mAh Panasonic NCR18650B) (Conrad, n.d.). This battery is able to illuminate two A4 sized EL panels for up to 19,5 hours, enough to last through the day. If the battery does get almost empty, the garment will blink to notify the user.

Inverter
The inverter is needed to turn the direct current coming from the battery into alternating current. Everytime the current shifts, the EL panel will release a photon, which is why a direct current won't work. The current the battery supplies determines the kind of inverter. In our case the inverter should turn a 3,7 V AC current into a 120 V DC current.

ANT module
This module is widely used in other sport wearables. It contains a transmitting module, so the data can be sent to the accompanied smart-phone (Søderholm, 2016).

Light sensors
The light sensors serve as a button. Swiping down the module will turn off the EL panels (for when the user is in a cinema for instance). Swiping up turns them back on.

figure 65: the module attached to the Awareable original image by Nike (2018)

Sensors

The sensors incorperated in the Awareable are chosen to measure the activity of the user accurately. The choice is based on the sensors the current wearable industry uses regularely, which are the following (Henriksen et al, 2018):

- *Accelerometer: this sensors measures the acceleration in three directions*
- *Magnetometer: this sensor is a digital compass and can detect the orientation of the device. Together with the accelerometer these sensors count steps, calculate energy consumption and estimate the type of movement the user is doing.*
- *GPS: this sensor can give an accurate estimation of the speed and location of the user as well as the gain or loss in altitude.*

Together, these three sensors will be sufficient in estimating the type of activity the user is performing. Consequently these sensors give an accurate representation of the progress the daily goal.

The sensors used in the Awareable are not different from those implemented in a smartphone. So why not only use the smartphone then? Well simply put, a smartphone isn't a wearable. This means that during the day, it is not alway close or attached to the body. The phone can be left in a purse, jacket pocket or at the desk when someone is going for a walk. The user will miss out on a lot of data this way, giving it an inaccurate representation of their goal. This is why wearables are much more accurate and still have an advantage over smartphones.

Costs

Now that it is clear which components and materials are needed to make this product, an estimation can be made about the cost. This estimation can be found in appendix 11. The final production costs of the Awareable would be 37,26 Euro's; 12,26 for the module and 25,- for the legging with EL panels.

Nike shoes sell for 3,57 times their cost price (American City Business Journals, 2014). We will use this number to calculate the retail price of Awareable. For the whole product including the module this would arrive at 133,02 Euro's. This might seem a lot for a pair of leggings, but Nike is already selling leggings at a price of €130,-. And these legging do not come with a smart system. We could go even higher than this because of the added advantage of the Awareable. The prices could be something like this:

Legging with EL	€140,-
Module	€40,-
Total	€180,-

Because the module is interchangeable between garments, the user only needs to buy it once. It is therefore better to sell the two apart from each other.

figure 66: visualization of the difference in patterns the EL sections can be printed in. original image by Nike (2018)

THE IMPLEMENTATION

In this chapter, a roadmap will be presented for the implementation of the product from now until 2035. In a previous chapter the acceptation plan of the product has been discussed. The acceptation plan influenced which target group to tackle for the final design and how to make sure the product would get its place on the market. This is all very short term, it only focuses on the initial design until a few years after the release of the Awareable. This focus is good as it makes the current design as good as it can be for its first release. However, it is also interesting to look a bit further in the future. This can show promising developments and inspire what the product can become.

Technology roadmap

The roadmap, as can be seen in figure 67, shows presumed future developments until the year 2035. These developments will be discussed per date.

2020

The first Awareable will come to the market: illuminated shoes. Because of the sturdiness of the shoes EL panels will suffice. Later on this will be replaced with EL fabric, to open up new possibilities. Yet the EL fabric still needs to be developed regarding safety, wash-ability and degradation.

2022

The EL fabric is now ready for the market and the first Awareable activewear will be sold. The earlier implementation of the shoes help with the acceptance of illuminated clothing, but the first batch will probably be sold to the early adopters. At the same time, EL is being further developed to enhance its lifetime, light output and recyclability.

2025

Due to the developments in the battery industry and the rise of smaller and cheaper touchscreens the mobile application will become obsolete. The module attached to the garment will be able to execute the whole interaction.

2027

By now illuminated garments are totally normalized in society and also formal wear is implementing the technology. This does not mean everybody will use it, but it will not raise questions anymore. At the same time the sensors are becoming more and more complex yet flexible so new and more complex physical data can be obtained.

2035

Sensors are now able to sense moods and human emotion. The Awareable is now able to react on the mood of its user without the need for a physical interaction. The garment is due to these sensors and the movement recharging batteries completely self regulating. It is a smart, everyday companion to help us keep focus on what we find important.

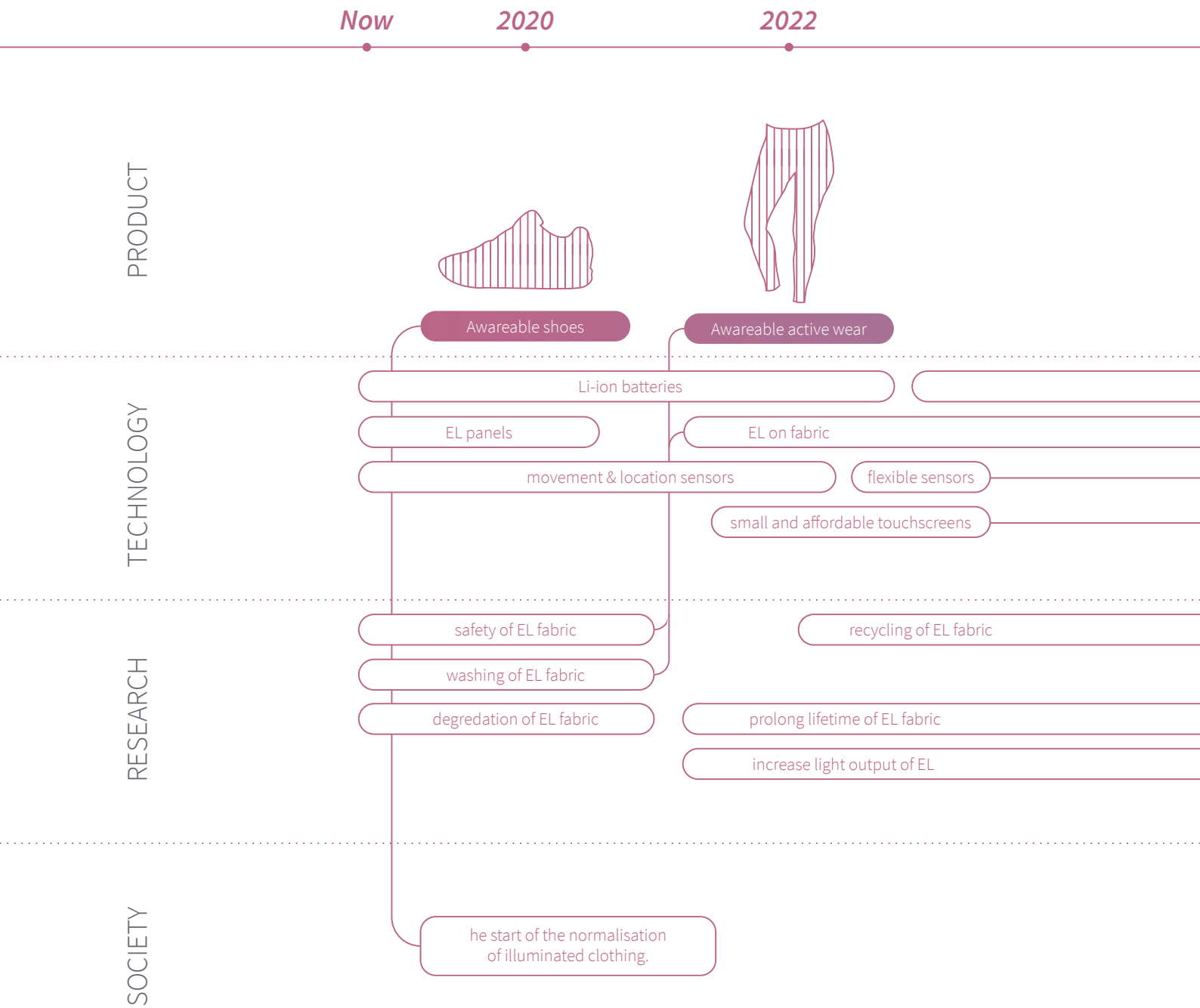
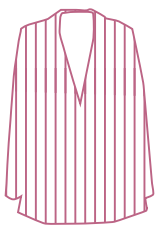


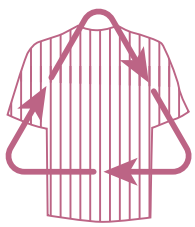
figure 67: the roadmap of the technology of EL on fabric

2025

2027

2035





no mobile application needed

regular and formal Awareables

self-regulating smart garments

batteries get smaller, and more powerful

movement charging batteries

sensors for calories and more complex activities

sensors for moods

Illuminated clothing is now completely normalised.

Our clothing will start to understand our moods and needs and will be able to react to it. A smart dialogue between man and product

PART 2
VERIFICATION

A full research of the effect of our design on the intended user is for this project too extensive. It would require a fully functional prototype worn throughout the whole day, or even longer. But it is good to check design assumptions, so in this chapter two less elaborate but still useful tests have been conducted. The first will test the design on a more emotional level, looking at how participants feel about gaining awareness and setting goals. The other test is more a proof of concept; can an EL garment actually be made? In this test a working prototype will be tried to make, to show the reachability of the idea.

AWARENESS TEST

The awareness test was done to check a few key assumptions made in the design. The first touch point of the users (see the scenario) will be with the application when the user is asked to fill in some questions. These questions were based on the interviews with smart wearable users and personal reflection (see appendix 7) and served as a tool to make the user more aware about their goals and their day but also to make the wearable more humane. By setting a goal daily, the wearable becomes more understanding. While permanent goals for the rest of the month can sometimes feel overwhelming and insensitive, for instance when one becomes ill. This is however still an assumption and this test will look at the effect of the daily questions on people. I will validate the design choices made in regard to these assumptions.

The set up

Four people (2 male and 2 female) who primarily work out according to their own planning were asked to participate. They themselves plan their activity, workouts and motivate themselves, not third parties like trainings schedules or the gym or a club. The Awareable also focuses on people that plan their own physical activities, so this is an important aspect because it influences the use and usefulness of our design. The full test set up and complete set of insights can be found in appendix 12.

The participants were asked the same questions the application would, (see page 98) every morning for five days.

With this test, the following questions were tried to be answered:

1. Do people gain awareness about their sports activity with these questions?
2. How did the people react to the questions?
3. Would people like to use the product/do they see the potential in it?
4. What would they like to change about it?

Results

In the test a few topics became apparent to be important. Important quotes were highlighted from the transcript (see appendix 12) and merging these quotes together formed the following answer to the research questions:

1. Do people gain awareness about their sports activity with these questions?

Yes they did. Especially about the influence and importance of general movement. The participants thought it was a good thing when one is made aware of their natural activity behaviour. When talking about how active a person is, people immediately think about big sport activities like hitting the gym or going for a run. They tend to forget how active they are generally.

"I noticed due to this test that I am really unaware of my other moments of movement, my general activity level. I immediately looked up a hiking schedule after this."

They liked that, because they received the questions everyday, they could easily reflect and adjust during the week. But they might have liked a little reflection reminder like 'How did it go yesterday?'.

2. How did the people react to the questions?

The participants liked that even the littlest activities could be included, instead of only the big sport activities. They felt more satisfied due to the inclusion of these smaller activities. They would however like to get the questions right after they wake up and have preset answers. Like smiley's for the 'how are you feeling' question and preset activities for the 'activity goal of the day' question.

The participants think that you would learn more and more about yourself the longer you use the product. This helps to set more realistic and reasonable goals, something they now found a bit hard.

3. Would people like to use the product/do they see the potential in it?

Planning activities and tracking them is not for everyone. The person who had a lot of intrinsic motivation to be active did not like it at all. While the people who needed more extrinsic motivation to be active did feel like planning and tracking their activities could work for them.

Also, the participants really missed the progression feedback and the reward if they actually did something. In this test they did not wear the Awareable or any other tracking device, which is designed to make people aware of their activity and progress. Wearing the Awareable could already be enough of a reflection moment. They thought the light could be a nice reminder and reward.

4. What would they like to change about it?

They liked to have the daily questions more quantifiable, with presets answers like said before. Not only because this is easier to fill in, but also allows the users to see the progress more easily.

"After a while, after two months or something, you can start to see the effect of being more active. When you for instance see that you feel better in the morning. They have a long term, these questions."

They did also specifically state the importance of the naming and marketing of the product. Marketing it as an activity tracker can turn into something obsessive and too goal oriented. The bad thing about a reward, is that when a goal is not reached, it immediately feels like a punishment. While calling it a wearable to gain awareness about one's daily activities would give it another, more friendly meaning. When people focus more on the 'making aware of their activity' part, they could have a more positive mindset towards the product, set more realistic goals and use the product for a longer and more pleasant time.

The participants liked the idea of a ‘sport-mode’ and ‘live-mode’. The live mode would track the general activity during the day and show the daily goal, including things like cycling and even the smallest of walks. In the sport mode the user could assign a metric and a goal to the light bars, and just start their activity. The lights could show a distance goal, time goal or calorie goal for that certain activity. The person who at first said they would not use the product, because he already is intrinsically motivated to be active, said that he would like to use the sport-mode. While the people who were extrinsically motivated would like to use the live-mode.

To conclude

We have learned from this test that the questions of the mobile application do have a positive effect on the user regarding awareness about their activity level. This is a promising insight, that only these daily questions already have an impact. When the Awareable garment is added, this can form a complete system in gaining awareness, making the behaviour change even more probable.

The Awareable is not for everyone though, intrinsically motivated people are not in need of it. But it can be rather helpful for people who do not have this motivation. For them, this gain in awareness can be they key in staying motivated to be active.

It is also important that we market the Awareable in a suitable way. Focused should be on 'gaining awareness' and not 'tracking goals'. Laying too much focus on goals can put extra pressure on people which can turn into negative associations with the product or obsessive behaviour.

PHYSICAL PROTOTYPE

The physical prototype serves as a proof of concept; with limited time and means a believable product will be made to show the feasibility of the concept. The final production will eventually be done on mass scale and with more precise devices, so the prototype does not need to be perfect. In this chapter the focus of the prototype will be explained, the making of this prototype will be elaborated on slightly, as well as the (design) choices that have been made to create a functioning mock up.

What is the concept?

Before we can prove the validity of a concept, we need to know what this concept entails. Of course, this whole book tries to explain the Awareable, but we are looking for its core essence. This project started out with the following assignment:

"... design a meaningful product with electroluminescence as the core component..."

Even though this assignment was a search for an application with the EL material, the concept of the Awareable is not the technical application of EL on fabric. As said in the assignment, EL is the core component, part of a bigger product. The actual core lies in the other focus of the assignment, namely the focus on a meaningful product. The meaningfulness of the Awareable comes from its interaction with the user, making the user aware of their behaviour so it can be changed. It is this interaction that makes the Awareable unique and it is this interaction that is the core essence of this concept.

For this prototype the focus was laid on this essence as well. The goal of this prototype is to proof that the design can indeed make people aware. All design choices for the prototype were made to recreate the intended interaction, or a simplification of it depending on the difficulty of the interaction.

Demands and boundaries

The prototype will not be exactly the same as the final product would be, but how far off is still good enough for a proof of concept? Some boundaries and demands were formed as directives for the making of the prototype. Since the focus is on the interaction of the prototype, the demands and boundaries focus on these things as well. This entails that the prototype should be able to fit on a body as well.

Demands:

1. The prototype needs to have 4 sections of EL, each representing 25% of the activity goal.
2. The 4 EL sections can be lit individually.
3. The garment will be a legging. It has to fit skintight to the legs and be stretchable.
4. The prototype will be wearable, meaning that it is life size, fits nicely on a body without looking awkward and does not hurt or electrocute the wearer.

Boundaries:

1. The EL does not need to react to sensors. Programming it on forehand is fine.
2. The electronics (battery, Arduino, etc.) can be bulky, but have to be hidden somewhere.
3. The prototype does not need to be vandal-proof, it should be handled with care.
4. The EL does not need to have intricate patterns, regular planes work well enough to show the use.
5. The garment does not need to be comfortable, some parts will be bulkier than in the final product and will therefore stick out or feel annoying.

figure 68: the design of the prototype

Prototype design

A lot of choices had to be made in order to make a prototype that meets the demands. These choices can be read about in appendix 13 and led to the prototype design which can be seen in figure 68. It is a simplification of the final design of the Awareable concerning design, but that should not be of influence on the interaction.

The creation

figure 69 to figure 77 show a visual representation of the production of the prototype. For a more technical description, please read appendix 13.

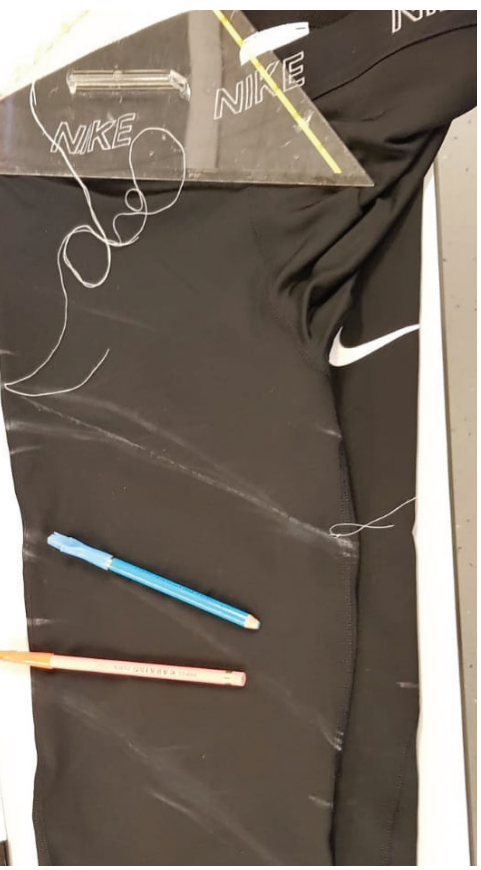


figure 69: drawing the guidelines for the EL strips.

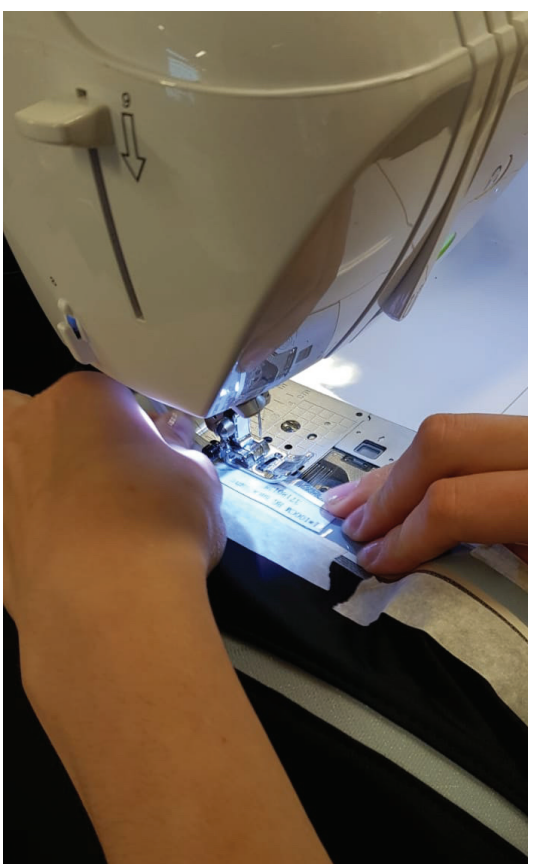


figure 70: Sewing in the EL strips.

figure 71: Cutting away excess fabric.

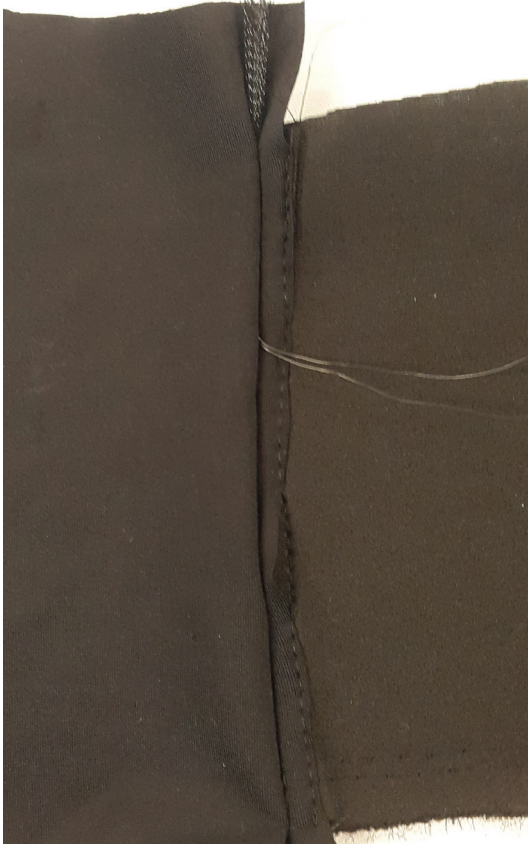


figure 72: Sewing test for hiding the wires in the seam.

figure 73: The EL strips were labeled, according to the lengths of the wires attached to them.

figure 74: Testing the EL strips, they still work after being sewed in.

figure 75: Sewing test to see how the EL strips will fall in the seam.

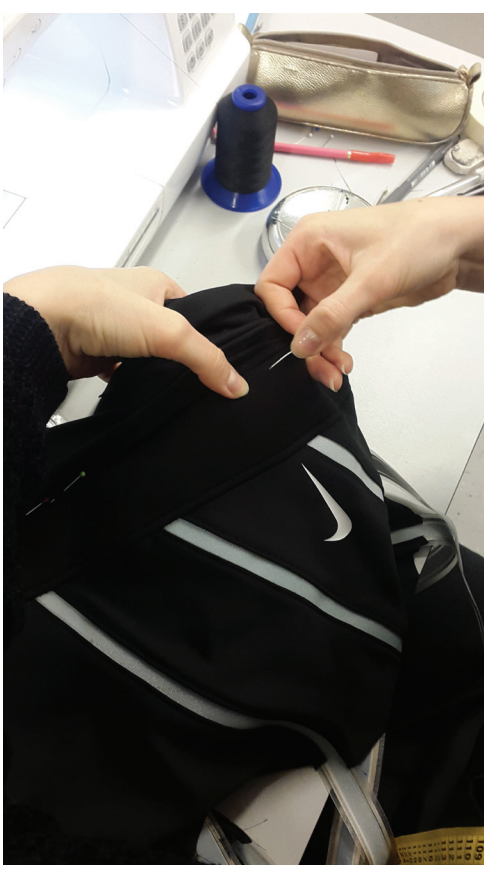


figure 76: Closing up the legging again

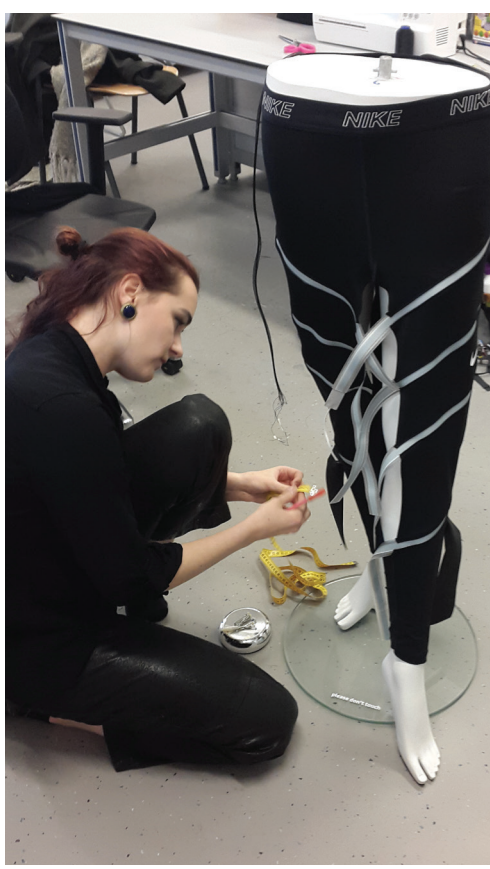


figure 77: Fitting the legging.

Validation

The prototype was tested on the basis of several scenarios:

1. How it is perceived standing up from the perspective of someone else.

2. How the Awareable is perceived standing up, from the users' perspective.

3. How the Awareable is perceived by the user when he/she is sitting on a couch.

4. How it is perceived by the user, walking the stairs.

5. How it is perceived sitting down at a desk, from the users' perspective.

Photos have been taken from all of these scenarios, see figure 78 to figure 85. Positive and negative remarks were formed to evaluate the design of the Awareable. The focus of the remarks are aimed at the specific interactions that are important in the different scenarios.

Standing up from the perspective of someone else

The interaction with other people is mostly based on aesthetics. The garment should be perceived as something attractive and it should be complementing to the body.

Positive remarks:

Looking at figure 78 we can see that the intended effect of the aesthetics (elongating the legs and accentuating the curves, see appendix 9) is working out. By using almost the full length of the leggings, the eye is drawn upwards, which gives the impression of length. Also, even though the EL strips in the prototype are straight, they appear to be curved due to the shape of the body. Because the lights are following the natural lines, the leg seems more curved.

Points of improvement:

The light output of the EL strips is visible here, but would be questionable in a more lit up room. The light output is Photoshopped in this picture, so the real effect might differ from this representation.

figure 78: the Awareable perceived standing up from the perspective of someone else

figure 79: the Awareable perceived standing up from the users' perspective, one knee bended.

figure 80: the Awareable perceived standing up from the users' perspective, straight legs

Standing up, from the users' perspective
The main interaction focus in this scenario is on communication. The Awareable should be able to show the user his or her progress towards the daily goal.

Positive remarks:
All four light strips are visible when standing up (see figure 80), although the bottom strip only slightly. This means that the total progressed can be seen from this standpoint.

Points of improvement:
When the user bends their knee, the bottom strip disappears from sight (seefigure 79). However, standing up with two bended knees is not very comfortable. One leg is normally straight, so one of the bottom strips will always be visible.

figure 81: the Awareable, perceived by the user when he/she is sitting on a couch

figure 82: the Awareable perceived by the user, walking the stairs.

Sitting on a couch
In this scenario, the Awareable should be able to show the progress to the user.

Positive remarks:
The three upper EL panels are really well visible (see figure 81).

Points of improvement:
The bottom EL panel however, is not. In the original design of the Awareable, this would even be two panels (see figure 53) When the progress of the goal would be below the 50%, the user would not be able to see the light in this scenario, which is not convenient.

Walking the stairs (or any activity)
During the the scenario of walking the stairs, or doing other activities like walking or running, the Awareable should show the user that he/she is working towards the goal. This is done with an glowing animation effect on the garment. The progress of the user should also be visible.

Positive remarks:
Al four strips are visible (see figure 82), though the bottom strip is again hard to see. The animation effect will probably be noticeable, telling from the glow that comes from the strips in the picture above. The difference between a non-glowing panel (the most upper strip) and a glowing panel (the strips below) is visible.

Points of improvement:
The most bottom panel is not very easy to see.

Sitting at a desk

This is a very important scenario. The Awareable is designed to make people aware of their activity level, to trigger the user to be more active. This means that in inactive situations, like working at a desk, the user should be able to notice the garment properly else the user will not become aware.

Positive remarks:

The desktop was obviously going to be a viewblocker, but despite of it, the panels are still visible (see figure 83 to figure 85). We can see that even though the legs are tucked away under the desk completely, a small part of the Awareable is still visible. The two pictures on the next page show the Awareable in an lit and unlit state. The lit state is a lot more noticeable.

figure 83: the view on the Awareable when one is relaxing at the desk

Points of improvement:

The most upper panel might be visible, but the others are not. The last panel only lights up when the goal is reached completely, so before this time, the user knows nothing about their progress. To make the user aware of this progress, he/she needs to shift posture, like shown in figure 83. But they need to be made aware of this first. A little light notification in the form of a glow could work, since the upper panel is visible, after it senses a period of inactivity.

Conclusion

The prototype proves that in most of the scenarios the intended interactions can take place. Small alterations are needed regarding the most bottom panel, which is not always visible in every posture. In the original design of the Awareable, two panels are placed on the lower leg. This needs to be revised.

However in the situation where the user is sitting at a desk, extra interactions are needed. Most of the panels are not visible in this case, so the most upper panel needs to notify the user solely on its own.

We can conclude that the Awareable will, with some minor alterations, can deliver its intended interactions.

figure 84: the view on the Awareable when one is working at the desk, without light

figure 85: the view on the Awareable when one is relaxing at the desk, with light.

RECOMMENDATIONS

The awareness test and the prototype generated valuable insights in the design as it is now, and how it can be improved. Since the scope of this project is limited, these insights will not be implemented in a redesign anymore. They will in this chapter be noted in the form of recommendations. These pointers are divided in either recommendations for the design itself, and in further research that can be valuable .

Recommendations for the design and implementation:

- Implement preset answers to the questions asked in the app. This makes it easier to fill in for the participants (and less tedious), but it also makes the answers more quantifiable. By making it measurable, the effect of the Awareable is easier to measure on the long run this way. This gives the users the opportunity to learn even more about themselves.
- A little reflection moment should be added in the morning. Like 'How did it go yesterday?'.
- The questions should pop up in the morning, right after the alarm has gone off. If the user already has started their day, the questions are perceived as annoying.
- The marketing of the product is very important. It should not be marketed as an activity tracker, which can increase obsessive behaviour and negative feeling towards the product if goals are not met. It should rather be marketed as a product that makes you aware of your activity.
- The product and the marketing of it should be focused on people who are not intrinsically motivated to practice sports. Some people do have this intern motivation, and they are not in need of this product, they are already naturally aware of their activity.
- In a while, a more appropriate garment should be designed for working people. This is a target group which could also benefit a lot from the Awareable, since they are not naturally active during the day due to their jobs. A legging is however not appropriate everywhere so a more decent piece should be designed.

- The sensor industry is growing fast with the rise of the smart wearable. It is recommended to keep updating the sensors of the Awareable as new ones are coming on the market. The more activities the Awareable is able to capture, the more valuable it will become. But for now, the design is only using sensors which are tested and proved to work well for tracking activity.

- There should be a beginner mode in the application: splitting the daily goal into smaller sections. People tend to overestimate themselves a lot which can be disappointing and increase negative feelings towards the product. When the goal is split up, it is easier to recognise if something is not feasible. The beginner mode will have more evaluation moments during the day so people can adjust their goal according to their miscalculations. It is hypothesised that after a little while, the user will start to understand themself and only one daily goal is needed form then on.

- A sport-mode should be developed and implemented in the application. The live-mode will be the regular mode, which we focused on in this design, it tracks and communicates the progress of all forms of activity during the day like walking, cycling and taking the stairs. But the sport-mode can be turned on when a larger sporting activity is being done, for instance when the user is going for a run. The light could in this mode communicate other subgoals which are relevant for the type of activity. In the case of a run this could be a time goal, a distance goal, or maybe even a speed goal. This is something that has not been worked out yet in the current design but can add a lot more depth to the product.

- The most bottom two EL panels should be made more visible. One of them could shift to the upper leg (like in the prototype). The other one could be linked more to the upper leg; it could extend on the side of the leg upwards.

- A notification should be added when the user is inactive for a longer period of time. When sitting at a desk, the Awareable is not visible so the effect of gaining awareness is cancelled. The notification should not be perceived as annoying however, so user tests should be done about this interaction.

Recommendations for further research

- The time frame of this project did not allow for a user test. But it will be very relevant to test the effect of the awareness caused by the light with real users with a working prototype. Especially focused on the motivation gain of the users. In a previous chapter a framework was presented which stated that awareness about a behaviour can turn into motivation to do something about the behaviour. It will be interesting to see the real impact of the effect of the awareness gain on the motivation level.

- EL on fabric is a fairly new concept, and not used in large quantity commercial products yet. And there is a reason for it: some aspects still need to be researched and developed before EL is ready to be implemented in the wearable market. These aspects are:

1. Stretchability: EL is, as it is now, not able to withstand stretch. This is quite problematic in highly stretchable pieces of clothing. Like shown in the prototype in the previous chapter, it is still possible to use EL in these kind of garments, but adjustments in the design had to be made. For full design freedom, the EL principle should be designed to be stretchable.
2. Waterproofness: Phosphor degrades when it gets in contact with water, which is of course undesirable. A coating or some sort of protection needs to be applied to keep the water away from the phosphor.
3. Safety: The sample made in tinkering session 1 gave shocks when it was touched. Any open connection should be insulated and the upper conductor should be coated.
4. Washing machine: Clothing needs to be washed, which is a whole new challenge. The phosphor layer should be protected, as said before. But all the layers of the EL should also be able to withstand soap and heat. Next to this the wires and connections should also be sealed.

INSIGHTS BOOK 3

The product

This smart system makes its user aware of their daily physical activity. The progress of a daily set goal is reflected through the day on their wearable; the further the progress, the more electroluminescent sections will light up and the more appealing the garment becomes. This constant reflection enhances awareness which eventually can lead to the wanted behaviour change of being more active.

Acceptation

Clothing is a very personal subject, for a clothing trend to catch on, the right target group should be addressed. Light on clothing is a very novel concept, and a very blatant one. The wearers should feel comfortable in it, which is why a younger target group was chosen for the first line of Awareables. Younger people are more eager to adopt new styles of clothing and lay more importance in being found 'cool'. Linking the Awareable to a popular brand, like Nike, raises the changes for the Awareable to be accepted by the early adopters.

Details

The Awareable exists of three main components:

1. The garment
   The garment is the main component. It is where the electroluminescent material is added and which has the main interaction points with the user.

2. The application
   The application is the component which translates the raw data into numbers and which communicates the user input with the garment.

3. The module
   The module is the backbone of the design, it contains all the electronics. The battery and inverter drive the EL panels. The sensors collect the data and the ANT module communicates this with the mobile application.

Implementation

The Awareable is not yet ready to be sold. Several aspects of the EL material still need to be researched and developed. The first step of illuminated clothing will be a line a shoes, these are easiest to produce as it does not need stretchable EL panels.

We hypothesize that by 2025 illuminated clothing will be fully accepted and by 2035 our clothing will be able to sense our moods and emotions.

Verification

In the verification part, two tests were done. One was an interview session with 4 participants who were asked the questions the application would ask for five days. Although the participants had some remarks on how to improve the design, three said they would see themselves use the Awareable. These people had trouble to motivate themselves to practice sports. The other participant was already intrinsically motivated. Which is a logical finding; the person already aware of its activity level does not need to gain extra awareness.

The other test was the making of a prototype. Even though premade EL strips were used, which are not flexible, the garment was wearable and the strips were visible for the wearer on most occasions. A few minor alterations are needed to optimise the design. This prototype proofs that the interactions of the scenario described on page 80 to 85 are possible.

CONCLUSION AND LIMITATIONS

Conclusion

The goal stated to the right was the starting point of this project. It contains two aspects which will be evaluated in this chapter: 1. a meaningful product and 2. electroluminescence as the core component.

> *"The aim of this project is to design a meaningful product with electroluminescence as the core component, which preferably can't be done with other forms of light."*

A meaningful product

This is, and in the project always was, a vague term. Yet, that did not obstruct the process in any way. The addition of the word 'meaningful' was a personal choice. As a designer I felt the need to look for a product that would make sense in the current world. I did not want to design a regular product, I wanted it to be meaningful to people. And because this was a personal addition to the assignment, it was easy to make choices. Whenever the project got stuck on this point I could go back and ask myself 'do I find this meaningful?' If it was, I was satisfied.

This personal and introspective approach made it easy to make choices, but makes it hard to evaluate the project objectively. Nevertheless, this personal gut feeling can be put into words. There are some points which were key aspects throughout the project which showed me that the Awareable is indeed a meaningful product:

- The design focuses on increasing the health of people. It is focused on getting people more active, and therefore more healthy. Especially aimed at people who are not intrinsically active.
- The Awareable tries to be as friendly as possible. Negative associations found with smart wearables were redesigned into more positive and humane touch points.
- The Awareable focuses on the change of behaviour, but in a way that is, hopefully, lasting. It tries to turn good behaviour into habits.

Electroluminescence as the core component

Even though the whole Awareable system consists of three main components (the garment, the application and the module), the EL panels are still the most important. They entail the core interactions with the user.

Looking at the goal and the design of the Awareable, with the knowledge we have now, we can say that the brief is met.

Limitations

There have been and still are some limitations to this project, they will be stated here per book.

Book 1: Exploration
Because of the openness of the assignment, the possibilities were endless. Of course, there is no such thing as endless time so concession have been made about what to dive deeper into, and what not. To the best of my ability I have tried to map out options for potential search areas, but not all possibilities have been explored.

Book 2: Personalisation
The interviews for the quantified self research were done with only five students from a particular target group; people between 18 and 24 years old. This target group was chosen because of its high potential to accept a smart clothing product. However, it would be interesting and valuable to speak to other target groups, it could enhance the design of the Awareable, making it more inclusive. Or another product line could be added. For now, the Awareable is focused on this same target group, but people who are working desk jobs could also benefit from the use of this product.

Book 3: Materialisation
In this book a lot of the components which make up the Awareable are being explained. Although a lot of thought and research have gone into these components, they are not done, nor perfect. As an interaction designers I tried to focus on the aspects that are of most influence for this, but that still entails a lot. The embodiment needs to be looked at and improved. Also, a lot of crucial aspects about the EL material still need to be optimised through research. The material as it is now cannot be used in a smart wearable application for consumer use. It is not washer friendly, stretchable and durable enough.

The verification of the product has been done as well as the time frame allowed, but this still leaves some questions to be answered. A full user test with a working prototype should be done in future research.

REFLECTION

The question that started this graduation project was a simple one; we have a unique material at hand, electroluminescent light, what can we do with it? But in its simplicity, it was a hard nut to crack. The freedom of the assignment gave so many options that it sometimes seemed impossible to research in the timespan given.

But now we are here and apparently it was possible through trial and error. Starting with a solution is hard, although it might not sound like it. And this is how every material driven design project starts out. You get a solution, but not a problem. It is like getting an answer without knowing the question, millions of questions could be possible. Making a choice, and especially a grounded choice, is hard. But just like the fact that there are no stupid questions, there are no stupid problems. So eventually any choice will do. Yet, to give myself a bit more of a direction I added 'meaningful' to the application, and this was very helpful in ruling out product ideas that seemed very appealing, but were only based on aesthetics.

The project, as described in this report, seemed logical. But the actual process was not. Many phases blended together and were done simultaneously. A lot of times it felt like it would never come together. It was hard to foresee the process. Yes, a planning was made and the general steps were in there, but it never goes completely according to plan.

The times at which I struggled the most were the decision making moments. I have never been strong in this, not in my personal life nor in my projects. But a deadline helps. This project taught me a lot on the subject and simplifying is the key. I always tried to solve all problems at once but sometimes it is just better to focus, choose one, and excel in it.

I also learned how to handle such an open brief. This project does not only answer the question how to implement EL in a meaningful way, but is also a way how more material driven design projects might find a meaningful solution. By moving back and forth between the material and the context, going from very zoomed in to very zoomed out was hard because it felt like the two would never come together. But it created a very comprehensive knowledge about both fields, which made it eventually easy to find a solution. And I believe it made the solution stronger and more meaningful.

During the project I kept a list of notes for myself, so here we go:

- If you can't decide, try to figure out why you can't decide. Is the other information too important to let go? Do you know too little?
- A question is never stupid if you yourself have already given the questions some thought.

- Eventually you just have to start doing. It will bring you so much more information than just theory.

- Your intuition is probably right. Find out where it is pointing towards and find out why.

- Your team not only assesses you. It is also your team.

I would probably try to do it differently next time, but I cannot say I am not proud of where the project ended up.

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