

The background is a black field filled with a grid of squares. Some squares are red and some are blue, creating a pattern that resembles a reflection or a digital mosaic. The squares are arranged in a way that they seem to be floating or reflecting off each other.

Selective Reflections

Master thesis

Bas Ammerlaan

Colophon

Author

Bas Ammerlaan

Master Thesis

Msc. Design for Interaction
Faculty of Industrial Design Engineering
Delft University of Technology

Graduation committee

Chair Prof. Dr. Ir. S.C. Pont
Human Information Communication Design

Mentor C.R.G. Smit MSc PDeng
Human Information Communication Design

Second mentor Ir. S.J.W. Aerts
TU Delft Science Centre

Client

Highlight Delft

Date

January 2024

Preface

I would like start with expressing my gratitude to my supervisory team, consisting of Sylvia Pont, Charl Smit and Simon Aerts. Everyone's expertise is highly appreciated and it helped me to obtain a lot of knowledge and experience about the context of the project.

The motivation for doing a graduation project derived from the elective course Lighting Design at the Industrial Design Engineering faculty. The course assignment to deliver a multi sensory experience, sparked a lot of joy and interest in the field of lighting design. The scope for this project originally started with a conversation with Simon about Highlight Delft and the next festivals' theme which was perception. In addition, after the lighting design course, Sylvia and Charl expressed that they would be available to supervise my graduation project. After an explorative meeting with Sylvia and Charl, the scope of the project was defined. Creating an interactive light and sound installation with holographic projection and spectral tuning which communicates a certain perceptual phenomenon to the visitors of Highlight Delft. This scope changed over the course of the project to come to a final design that has more focus and is better tailored to the audience.

The installation will be made for Highlight Delft, an innovative art and technology route through Delft. Since the beginning, Highlight wants to present innovative ideas of the future. They showcase work by artists, designers, researchers and companies. The organisation strives to display the art at unique locations in the city of Delft. While the installation is made for Highlight, it does not function as a typical client. Highlight will not directly be involved in the graduation project. This means that there is creative freedom without the interference of the organisation. During the graduation project, Highlight always had the option to not include the installation that would originate from the project.

Summary

The project originated with the goal of creating an interactive light and sound installation for Highlight Delft, an innovative art and technology route. This involved incorporating holographic projection and spectral tuning to convey a specific perceptual phenomenon. The initial phase included extensive research into holographic projection, spectral tuning, and a broad literature review on perception. Experimentation with acquired knowledge informed the practical application, distinguishing effective principles and guiding the design process.

From the experimentation phase, three design directions emerged, with the idea of projecting coloured visuals on multiple layers of semi-transparent textile standing out. Tuning the projection in terms of colour and timing allowed visuals to move between the textile layers. By integrating storytelling into the concept a design brief emerged. However, during the development of the first concept, the design brief missed focus, leading to more complex ideas. Emphasizing communication, the focus shifted to conveying how spectral tuning can influence depth perception in the current setup. This resulted in the emergence of concept 2 with a simplified design involving two layers of textile and a projector.

A preliminary test of concept 2 revealed a need for additional information to enhance understanding and appreciation. The addition of an illustrative introduction before experiencing the installation, significantly improved attributes such as perceived depth, beauty, immersion, engagement, and coherence. These insights guided refinements in the final design, including a shortened visual narrative, added audio for increased engagement, and an elaborate exhibition space design. Attention was consistently committed to communication at various levels.

A final validation test produced varied results but consistently high scores on every attribute. Feedback and recommendations from the test were well-received, eliminating ambiguities. Even individuals outside the test expressed enjoyment of the experience. Despite the project's initially broad scope, a focused approach, particularly in communication, developed in a final design that communicates clearly and evokes joy and interest in viewers.

List of definitions

Absorption

Absorption refers to the process by which a material assimilates incident light rays, leading to a reduction in light intensity.

Transmission

Transmission is the passage of light through a material without being absorbed or scattered.

Reflection

Reflection occurs when light bounces off a surface, following the law of reflection, which states that the angle of incidence equals the angle of reflection.

Scattering

Scattering involves the random redirection of light in all directions when it interacts with small particles or irregularities in a medium.

Refraction

Refraction is the bending of light as it passes from one medium into another with a different optical density.

Diffuse

Diffuse lighting refers to uniform and evenly distributed light across a surface, minimizing shadows and reducing glare.

Uniform

Uniform lighting, similar to diffuse lighting, provides consistent and even illumination over a given area or surface.

Distribution

Lighting distribution refers to the pattern or arrangement of light intensity across an illuminated area.

Incident angle

The incident angle is the angle at which light or a ray of light strikes a surface. It is measured relative to the normal (perpendicular line).

Diffraction grating

A diffraction grating is a device with a precise pattern of closely spaced slits or grooves. It disperses light into its component wavelengths, producing a spectrum.

Colour temperature

Colour temperature is a characteristic of light sources, describing the perceived warmth or coolness of their emitted light. It is measured in Kelvin.

Hue

Hue refers to the attribute of colour that distinguishes one colour from another on the colour wheel. It is the quality that allows to describe colours.

Saturation

Saturation, also known as chroma, represents the intensity or vividness of a colour. Highly saturated colours appear pure and vibrant, while desaturated colours tend to be more muted or pastel.

Luminosity

Luminosity is the perceived brightness of an object or colour, irrespective of its hue or saturation. It is associated with the overall lightness or darkness of an area and is often quantified in the CIELAB colour space.

Luminance

Luminance is a measure of the amount of light emitted or reflected from a surface.

RGB

RGB stands for red, green, blue, and it is a colour model that represents colours by mixing these three primary additive colours.

CMYK

CMYK is a subtractive colour model used in colour printing, where colours are created by subtracting varying amounts of Cyan (C), Magenta (M), Yellow (Y), and Key (K, black) ink from a white background.

Table of contents

1 | Research

1.1 Holographic projection	8
1.2 Spectral tuning	10
1.3 Perception	11
1.4 Perceptual phenomena	13
1.5 Perception in light art	16

2 | Explorations

2.1 Experiments	19
2.2 Direction development	20
2.3 Direction iterations	21
2.4 Design brief	22

3 | Concept development

3.1 Concept 1	24
3.2 Concept 1 insights	25
3.3 Concept 2	26
3.4 Objective development	27

4 | Test

4.1 Test setup	29
4.2 Method	30
4.3 Results	32
4.4 Conclusion	35
4.5 Discussion	36

5 | Final design

5.1 Visual narrative	38
5.2 Audio	43
5.3 Textile	44
5.4 Frame	46
5.5 Exhibition space	50
5.6 Communication	52

6 | Validation

6.1 Test setup	54
6.2 Method	55
6.3 Results	56
6.4 Conclusion	59
6.5 Discussion	60

| References

61

| Appendix

65

1 Research

This chapter functions as a wide-ranging exploration in the context of the project. As the project is only defined by the two technologies spectral tuning and holographic projection, and a to be communicated perceptual phenomenon, research is necessary to achieve a greater understanding of the technologies and perception. A general understanding of perception is achieved to subsequently explore the perceptual phenomena and its use in light art. After the research phase, enough knowledge is acquired to do the experiments to explore how gained knowledge functions in practice. Researching was a continuous process during the project and it was therefore continuously relied upon during the experimenting and defining phase as well.

1.1 Holographic projection

Optics

As holographic projection, spectral tuning and visual perception cover the behaviour of light and how it interacts with matter, it is important to cover optics, as it forms the fundamental framework for these interactions. Optics concerns describing the behaviour of light, mostly the electromagnetic radiation around the part of the electromagnetic spectrum visible to the human eye. Optics can be divided into three categories to describe light: physical optics, geometrical optics and quantum optics. This report only considers physical optics and geometrical optics as quantum optics is focussed on describing photons and how it interacts with atoms and molecules, which is not relevant for the context of this project.

Physical optics studies the nature of light and how it interacts with matter (Katz, 2002).

Physical optics examines interference, diffraction, polarisation, and other phenomena where geometric optics is not comprehensive enough to make approximations with rays. Physical optics can be seen as a method which is in between geometric optics and exact physical theory, because it uses waves in comparison with geometric optics, but does not use the exact theory to do this (Wikipedia contributors, 2023a).

Geometrical optics is a branch of optics that deals with how light is propagated, reflected and refracted (Katz, 2002). It concerns the behaviour of light as it interacts with optical systems, such as lenses and mirrors, but it simplifies the study of light by treating it as rays rather than waves. This simplification is valid when the wavelength of light is much smaller than the size of the objects and apertures involved, which is typically the case for visible light. Light is represented as a ray which is a straight line that indicates the path along which light travels (Toal, 2023). This simplification makes it easier to analyse the behaviour of light as it interacts with optical elements.

Holographic projection

Holographic projection is a holographic technique that projects 2D imagery of 3D scenes in such a way that it appears like a spatial 3D scene. While holograms recorded with a photographic film, are static 3D images that require specific viewing conditions, holographic projection involves real-time creation of dynamic 3D images that can be projected into space or onto surfaces. These differences make holographic projection suitable for applications such as presentations, entertainment, and interactive displays, while holograms on photographic film are typically used for static 3D imaging. There are several different methods and technologies used for holographic projection. Often technologies are combined to strive for high quality projections with wide viewing angles. A list of several holographic projection techniques are listed below.

Pepper's ghost

Pepper's ghost is an optical illusion technique where an object or image is reflected on a transparent surface (Gentet & Lee, 2022). The viewer will see the reflected object or image which has depth blended in a real environment. A setup of the technique can be seen in figure 1.1. This technique is often used in theatrical performances, museums, and theme park attractions. The technique is not holographic, but shows aspects from it in a budget-friendly, effective way. Figure 1.2 shows an artwork where the pepper's ghost technique is applied on three separate layers combined with real objects positioned between the layers. Such a setup could be interesting in the context of this project, by applying spectral tuning on the real objects in between the layers.

PepperScrim

PepperScrim is a variation of the pepper's ghost technique and uses a highly transparent metallic, mesh fabric to reflect projections. In comparison with pepper's ghost, it is not needed to have the reflective surface in an angle of 45 degrees and the fabric can have front and rear projection (Showtex, n.d.)

Light field displays

Despite the fact that light field displays are not based on the same principles of holographic projection, the technique still aims to create three-dimensional imagery. Light field displays capture and project light rays from different angles, creating a realistic 3D effect.

Light field displays work by capturing and projecting a multitude of different views of a 3D scene simultaneously. Traditional 2D displays show a single perspective of an object, but light field displays capture and reproduce the various perspectives and viewpoints of an object or scene.

For the continuation of this project, it is important to provide an overview on the characteristics of holographic projection (HP). This could be of value when experiments or ideas need to be evaluated, but do not form a strict requirement during evaluation. The characteristics are based on the different projection techniques and holography aspects described previously.

1. Three-dimensional: HP creates representations of objects or scenes that appear to be three-dimensional, allowing viewers to perceive depth and spatial relationships between objects.
2. Parallax: HP exhibits parallax, meaning that the image appears differently when viewed from different angles, providing a sense of depth.
3. Perceived depth: HP creates a convincing illusion of depth, with objects appearing to have volume and occupying three-dimensional space.
4. Viewing angle: Viewers can often interact with projections by changing their perspective, moving around, and observing the image from different angles to explore the 3D content.
5. Dynamic content: Some holographic projection methods allow for the creation of dynamic, real-time holographic images that can change or be interactive.

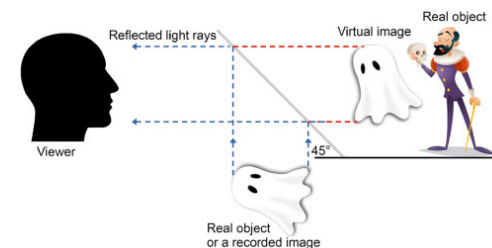


Figure 1.1: Pepper's ghost (Gentet & Lee, 2022)

Figure 1.2: Three pepper's ghost layers



1.2 Spectral tuning

Spectral tuning is our capacity to regulate light at different wavelengths via engineering and product development (Eaton, n.d.). By making deliberate adjustments or modifications of the spectral composition of light emitted by a light source, specific lighting objectives or desired effects can be achieved. The spectral composition of light refers to the distribution of wavelengths or colours within the visible spectrum. The continuous development of light sources and the continuous research on the effects of light on matter, facilitates a shift in considering light more in terms of their applicability. Below, the key aspects of spectral tuning can be found to provide a clear overview of what it consists of.

Manipulating wavelengths

Spectral tuning involves changing the relative intensities of different wavelengths of light emitted by a light source. This can be done through various methods and technologies like optical filters, diffraction gratings, LEDs and photonic crystals. Each technology offers its own advantages per application or context.

Colour temperature control

One common application of spectral tuning is the control of colour temperature. Studies show the importance of colour temperature on human performance. Research by Rautkylä et al. (2010) shows how a 17,000K light source maintains higher alertness levels in lecture halls in comparison with 4,000K light. Besides having effect on our alertness, colour temperature can also influence the perception on our thermal sensation and comfort (Brambilla et al., 2020). Controlling the colour temperature can have a great influence on how we perceive our surroundings.

Circadian Lighting

Circadian lighting is lighting intended to have a biological effect on the human circadian system. Spectral tuning plays a crucial role in circadian lighting, which is designed to mimic the changing spectrum of natural daylight throughout the day (Bios, n.d.). This can help regulate our circadian rhythms, improve alertness during the day and promote better sleep at night.

Colour Rendering

One of the most important aspects which can be controlled by spectral tuning is colour rendering. It refers to how accurately a light source renders the colours of objects in comparison to natural daylight. In some case, spectral tuning can be used to adjust the colour rendering to enhance or diminish certain colour properties. For example, by spectrally tuning a light source, the colours of the surrounding objects can be enhanced in terms of vibrancy and saturation. The colour rendering can have a great effect on the colour discrimination, which is the ability to distinguish colours (Kruisselbrink et al., 2018).

Applications

Spectral tuning has a wide range of applications across various industries and settings due to its ability to customize the spectral composition of light to achieve specific goals. There is a rise in human-centric lighting that support human well-being and circadian rhythms (Houser et al., 2020). This is particularly valuable in healthcare settings, offices, and residential environments. The applications above can already be achieved with a small amount of LEDs. The example in figure 1.3 and 1.4 shows a situation where multiple LEDs are used to influence the colour discrimination. Multiple LEDs facilitate even more control when tuning the light spectrum. In white light the skull of the triceratops clearly shows that it consists out of two different materials, perceiving two different colours. By spectrally tuning the environment shown in figure 1.4, the two different materials almost appear to have the same colour. The ability to distinguish colour is counteracted by the light, resulting in a skull which appears to be one whole.



Figure 1.3: Triceratops in white light (DyViTo, n.d.)

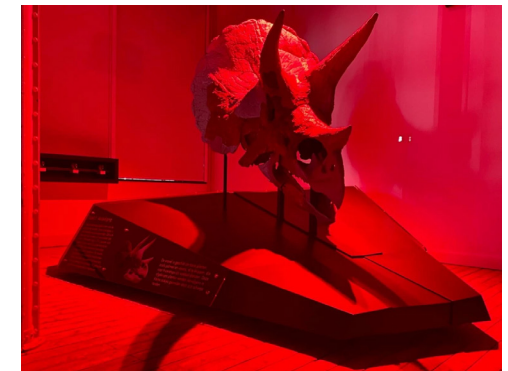


Figure 1.4: Triceratops spectrally tuned (DyViTo, n.d.)

1.3 Perception

The three stages of perception

Perception is a complex cognitive process through which individuals interpret and make sense of sensory information from their environment. It involves gathering, organizing, and interpreting sensory data to create a coherent and meaningful understanding of the world around us. According to research from Ou (2017) the process of perception can be divided into three stages: selection, organization and interpretation. Each stages will be briefly explained to give a clear view on how perception can be structured. It is important to note that there are multiple approaches to structure perceptual processes, but for now the research by Ou (2017) is chosen as base and complemented with matching research. The research by Ou is chosen, as it clearly categorized the stages of perception and provided real life examples to make the theory more understandable and easy to interpret.

Selection

The selection stage begins with the reception of sensory input from our environment through our sensory organs. Our environment is full of different stimuli and these stimuli are simultaneously being presented to our body waiting to be processed. But in reality, individuals cannot process everything they receive. People must filter out key aspects to prevent sensory overload (Middleman & Goldberg Wood, 1991). As a result, we selectively perceive just a small amount of the information in our surroundings. Therefore, not all sensory input is processed equally. Our attention is directed towards certain elements or features in our environment based on factors like novelty, intensity, personal relevance or expectations. These factors influence what we choose to pay attention to and perceive. The formation of such a subjective percept occurs by making the most accurate understanding of sensory inputs based on a series of hypotheses and constraints generated from past knowledge and experiences (Gilbert & Sigman, 2007). This is an example of top-down processing which influences our bottom-up processing.

Organization

During this stage, the brain processes and structures the selected sensory data in a systematic manner, leading to the recognition of meaningful patterns and the creation of a coherent perceptual experience. In the organization stage, our brain excels at identifying patterns and regularities in the sensory information received. As more than 70% of our information is collected by vision (Mandal, 2003), perceptual grouping forms a key component in the organization stage. It involves the brain's ability to group individual sensory elements into coherent wholes. For example, the ability to gather visual components that belong to one item and separate them from other objects (Roelfsema, 2006). This is also the stage where cross-modal integration occurs, which involves integrating sensory information from different senses to form a comprehensive perceptual experience.

Interpretation

After categorising the selected inputs into organised and stable patterns, we attempt to make sense of these patterns by assigning meaning to them. In the interpretation stage, we consider the broader context in which the selected sensory information exists. This context can include our knowledge, memories, beliefs, and the specific situation in which the perception occurs. We attribute meaning to the sensory input by connecting it to our existing knowledge and experiences. This involves drawing on our mental schema, which are cognitive frameworks that help us make sense of the world. The sensory input often consists of a lot ambiguities. As a result, its interpretation becomes an undetermined problem with a whole set of solutions. This makes the sensory input non-veridical and idiosyncratic. Our brain often engages in pattern completion during interpretation. This means that even when we receive incomplete or fragmented sensory data, our brain fills in the gaps using our previous experiences and knowledge. Our expectations and prior beliefs heavily influence the interpretation process. We often interpret sensory information in ways that confirm our existing beliefs or expectations. This phenomenon is known as confirmation bias. This stage is heavily influenced by cultural differences. People with various experiences and backgrounds will attribute different interpretations to the same input, resulting in perceptual variety Ou (2017).

Useful principles of perception

After researching the general stages of perception, visual perception and other aspects which are not described in this chapter, some principles of perception stand out. This means that some perceptual principles, could be useful in the later stages of the process, enhancing the total experience of the installation.

Top-down and bottom-up processing

Bottom-up processing starts with the raw sensory data and builds up to higher-level interpretations. Top-down processing, on the other hand, involves using prior knowledge and expectations to guide perception. As described on the previous page, perception involves a dynamic interplay between bottom-up and top-down processing. It would be interesting to influence these processes in such a way that users become aware of this phenomenon.

Multi sensory integration

Our brains integrate information from multiple senses to create a unified perception of the world. For example, when watching a movie, we combine visual and auditory cues to perceive a coherent storyline. Multi sensory integration could be used to enhance the phenomenon which needs to be communicated, creating a multi sensory experience.

Perceptual constancies

We tend to perceive objects as stable and unchanging despite variations in sensory input. This includes for example colour constancy and size constancy. Playing with these constancies could make users aware of the fact that the perception of our environment is indeed non-veridical and idiosyncratic.

Depth and spatial perception

Our ability to perceive depth, distance, and spatial relationships is an important aspect of perception. This is achieved through cues such as binocular vision, monocular cues and motion parallax. The installation could trigger these cues to play with depth perception and letting users control these cues to indirectly control their own perception. This fits to the theme of the festival 'Do you see what I see?'.

Individual differences

Perception can vary among individuals due to factors like genetics, past experiences, and sensory acuity. What one person perceives may not be identical to what another person perceives in the same situation. These differences can be exposed to make users aware of it and creating a better understanding of the people around us. This also connects with the theme of the festival.

1.4 Perceptual phenomena

After exploring multiple phenomena, a selection of five phenomena is made to use in the experimentation phase. These phenomena can be found below with an explanation and an image, illustrating the phenomenon as clear as possible.

Gestalt Principles

The Gestalt principles attempt to define the regularities that drive the organisation of perceptual information into unitary forms, often known as groups or Gestalten (Todorović, 2008). The gestalt principles can form a steady foundation for structuring the content of the projections. Artists use principles like proximity, similarity, closure, continuity, and figure-ground to create compositions that guide viewers' attention and create harmonious or intriguing arrangements of visual elements (figure 1.5).

Visual flow

Artists employ repetition, pattern, and rhythm in their compositions to guide viewers' eyes and create a feeling of movement and fluidity within the artwork. In art, flow relates primarily to the visual flow of the artwork. *Starry Night* by Vincent van Gogh is a perfect example of a painting which guides the eyes of the viewer with his brush strokes, movement and colour use. In figure 1.6 and 1.7, the artist Sougwen Chung created illustrations which already embody a lot of movement, but by using different lighting patterns the visual flow is enhanced. Therefore, this artwork matches the context of the current project.

Moiré Patterns

Moiré patterns are interference patterns created by overlaying grids or lines, producing dynamic visual effects that change as the pattern or viewer moves. Figure 1.8 shows a moiré sculpture where the moiré pattern is defined by the movement of the people walking by, facilitating a unique and dynamic pattern each time. Figure 1.9 shows a more conventional moiré pattern created with sheets of graphene.

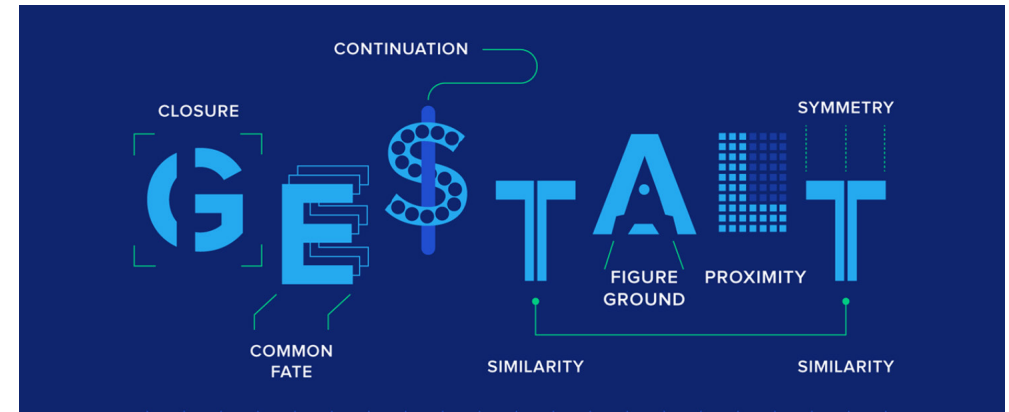


Figure 1.5: Gestalt principles (Priya, 2023)

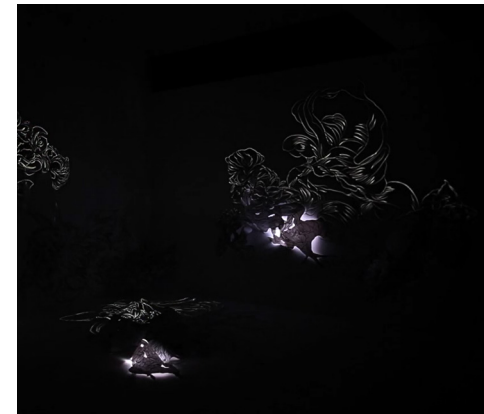


Figure 1.6: Chiaroscuro (Chung, 2013)

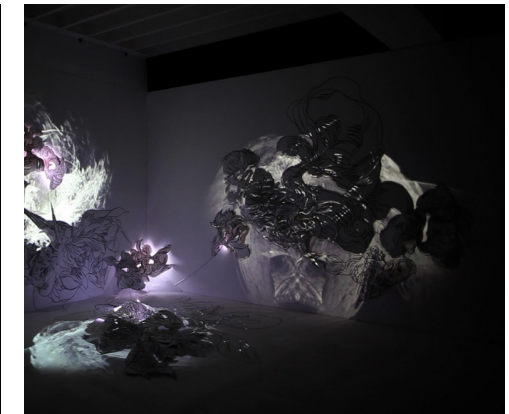


Figure 1.7: Chiaroscuro (Chung, 2013)



Figure 1.8: Moiré sculpture (Hypersonic, 2016)

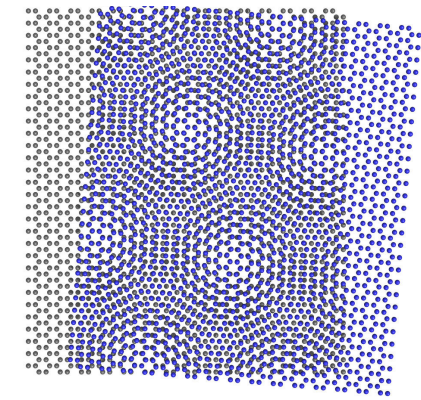


Figure 1.9: Moiré sculpture (NIST, 2010)

Optical illusions

Optical illusions are a result of our brain making sense of incomplete information. Through assumptions, our brain tries to solve the under-determined problem. This is caused by the brain being capable of making sense of input which is ambiguous, causing perceptual errors like illusions (Fraser & Lueck, 2021). Optical illusions are often created through the manipulation of shapes, colours, patterns, or visual stimuli. They showcase how our visual system can misinterpret information, leading to intriguing and counter-intuitive perceptions. The illusory expansion experienced in figure 1.10 is caused by our pupils adjusting to the darkened area in the centre (Laeng et al., 2022). When looking at the black hole, the pupils adapt to the motion illusion to prepare for a change in luminance. The Ebbinghaus illusion in figure 1.12 shows relative size perception. The illusion is caused by the size of the purple circles and their distance to the yellow circle. The brain's visual perception system distorts the relative size of the yellow circle as a result of these modifications (brainHQ, n.d.). Figure 1.11 shows the Café wall illusion which is caused by irradiation illusion, where white areas are perceived larger in size than black areas. This version strengthens the effect by adding small diamonds at each intersection (Borkhataria, 2017).

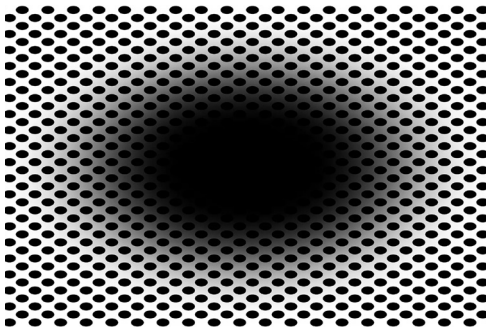


Figure 1.10: Illusory expansion (Laeng et al., 2022)

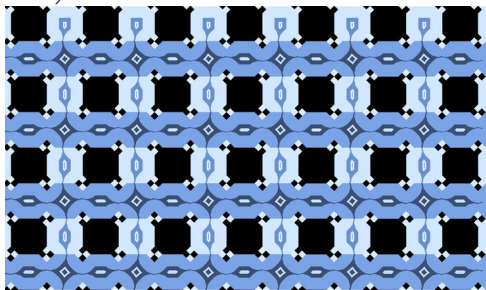


Figure 1.11: Café Wall Illusion (Skye,n.d.)

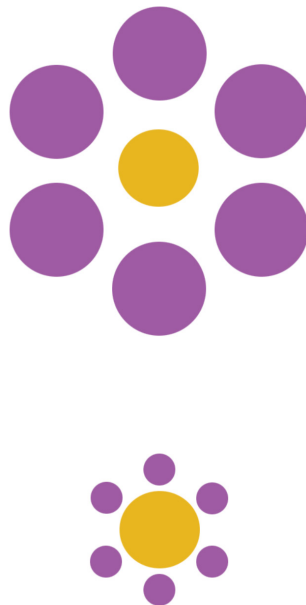


Figure 1.12: Ebbinghaus illusion (brainHQ,n.d.)

Simultaneous colour contrast

When two surfaces with the same spectral composition are set against distinct chromatic backdrops, they appear to have a different colour (Soranzo, 2016). This is known as simultaneous colour contrast. The appearance of a colour is influenced or altered by the presence of surrounding colours. This effect occurs when our visual system processes colours in relation to their context. Simultaneous colour contrast demonstrates that the perception of a colour is not solely determined by the physical properties of the light hitting our eyes but is also influenced by the colours surrounding it. As the explanation of the phenomenon changed over the years, the phenomenon is now interpreted based on the fundamentals of perceptual organisation. A surface's apparent colour is essentially influenced by the global contrast between the surface and the colour of the surfaces to which it perceptually belongs. The examples in figure 1.13 shows the perceptual phenomenon by altering the hue, luminosity and saturation of the backdrops, changing the appearance of a single colour. Figure 1.14 shows examples of adjusting the backdrops in such a way that the colours in the centre appear as the same, but are different when placed out of the context.

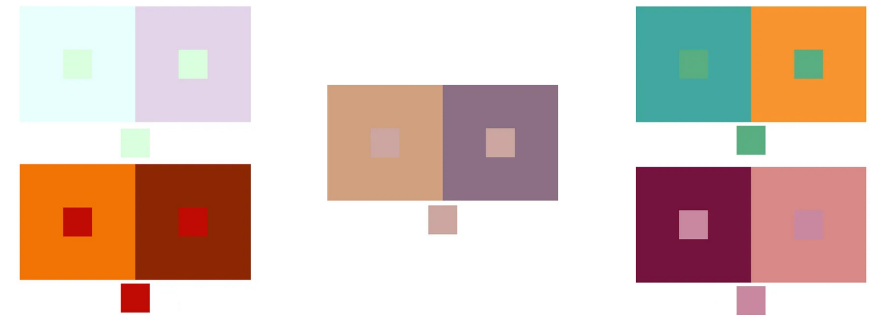


Figure 1.13: Altering hue, luminosity and saturation of a single colour (Dutt, 2021)



Figure 1.14: Two different colours appearing as one (Dutt, 2021)

Chromostereopsis

Chromostereopsis is a perceptual phenomenon where the colours on a two-dimensional surface appear to have different planes of depth (Thompson et al., 1993). This phenomenon is particularly strong when red and blue are used next to each other. Other colour combinations can also be used like red and green. Figure 1.15 shows a figure with multiple clear example of the chromostereopsis effect. Looking at the numbers, the red blocks with numbers are clearly perceived in front of the blue blocks with numbers. The lower part of the figure shows how different shades of green are all perceived to be on a different plane of depth. This effect is often utilized in art, design, and advertising to create a sense of depth or to make certain objects stand out.

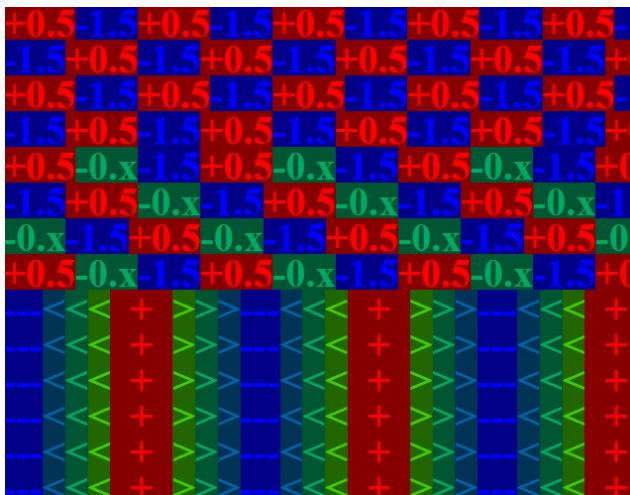


Figure 1.15: Chromostereopsis (Wikipedia, n.d.)

Coloured shadows

While coloured shadows are not a perceptual phenomenon, but falls into the domain of optics, it is still worth describing the effect as it can be interesting to use in later stages of the process. Coloured shadows are often demonstrated using a light source or multiple light sources which are able to illuminate RGB colours and by having a certain distance between the illuminated colours. By illuminating an object with RGB colours the shadows will have CMY colours and vice versa. The effect can be seen in figure 1.16, creating a CMY shadow with RGB light. Coloured shadows can be seen as a perceptual phenomenon that challenges our conventional understanding of light and colour. It especially triggers the preconception that shadows are always black. The phenomenon works based on subtractive colour mixing which creates new colours when other wavelengths of light are removed (Hanover College, n.d.). Looking at the figure, the shadow of blue light is yellow, because the wavelengths that make up blue are blocked.



Figure 1.16: Coloured shadows (Craven, 2021)

Colour perception

When light hits a surface, a part of the light spectrum is absorbed and the remainder is reflected. Thus, the colours we observe are not inherent in objects. Colours only exist in our mind. Colour is a perceptual response to rays of light entering the eye either directly from light sources or indirectly from light reflected by illuminated objects (Xin, 2006). Colour vision is the process by which the human visual system interprets different spectra of light as distinct colours. This intricate ability relies on the eye's specialized photoreceptor cells, namely cones, which are sensitive to specific ranges of wavelengths. The cones contain pigments that absorb light, signalling the brain about the presence of particular colours. The perception of colour depends on a lot of factors. For example the lighting, the surrounding colours as described on the previous page and the state of adaptation of the eye. It is important to consider these factors when analysing the perception of colour and work with colour perception in general.

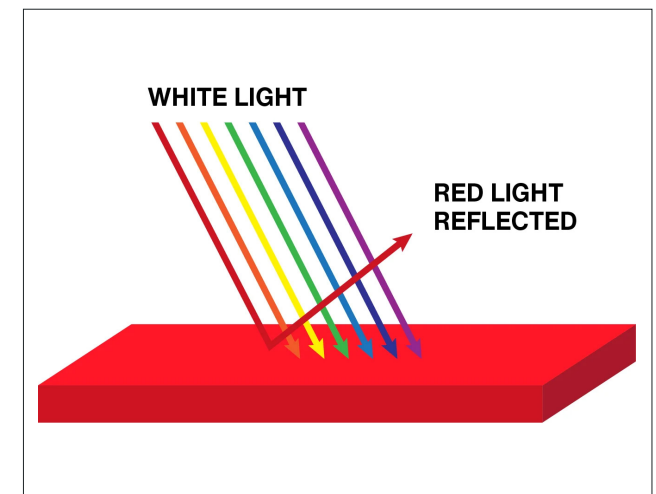


Figure 1.17: Perceiving reflected colours (Pantone, n.d.)

1.5 Perception in light art

By analysing the work of renowned artists working with light and perception, it becomes clear how they communicate perceptual phenomena to audiences at a high quality.

Olafur Eliasson believes in creating experiences where the people become aware of their body making sense of their surroundings, consequently leading to enhanced self-reflection which results in a more thoughtful attitude towards the outside world (Walker, 2022). The installation *Beauty* in figure 1.19 consists of a dark room with a hose pipe creating mist and a single light source illuminating the installation. From some angles a rainbow can be seen through the mist, intrinsically motivating the visitors to explore the angles which provides that extra visual effect. The sketch in figure 1.18 shows the setup of the installation. While the real installation seems dark, all the elements from the setup are visible to the public. In contrast with Turrell, Eliasson shows the elements which triggers the senses of the visitors. He calls it seeing yourself sensing (Tate, n.d.). Visitors will become aware of how the setup works and how it subsequently plays with the senses. The artworks of Olafur Eliasson are further explored on the bottom of the next page.

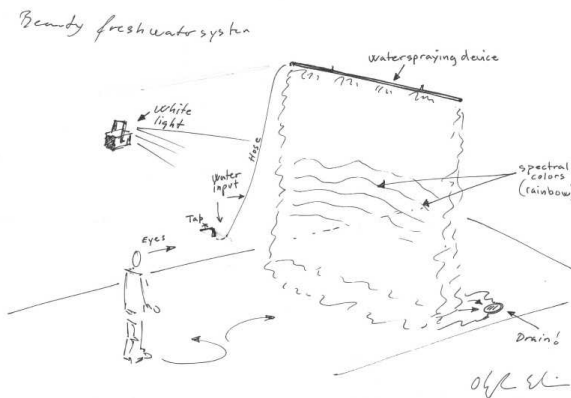


Figure 1.18: Sketch for *Beauty*, Olafur Eliasson (Tate, n.d.)

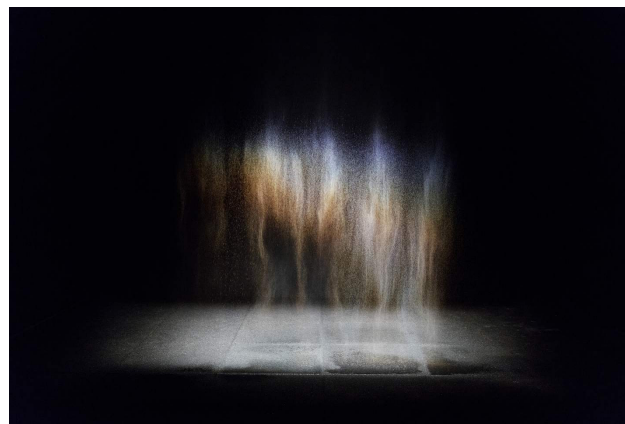


Figure 1.19: *Beauty*, Olafur Eliasson (Berg, 1993)

James Turrell describes most of his work as having no object, image or focus. This facilitates a situation where you are looking at you looking, trying to create an experience without words circulating through your thoughts (Herd, n.d.). Despite the fact that *The Light Inside* in figure 1.21 functions as tunnel between two spaces of a museum, it provides the visitors with a transition which triggers their spatial perception. By illuminating the sides with a uniform field of colour where the edges can hardly be seen, Turrell is creating a Ganzfeld. The *Skyspace* in figure 1.20 shows an example where a Ganzfeld effect with artificial light is combined with natural light. The interaction of natural and artificial light challenges the perception of the light intensity from each source (Rahimi & Steen, 2020). As clouds come and go, the perception of depth is challenged. Clouds facilitate depth cues and a blue sky facilitates a visual field where it is hard to grasp the perception of depth. The slowly changing colours on the ceiling create a continuous interplay of colour interaction. Turrell chooses to hide light fixtures and does not obstruct the sky with glass windows to strengthen the feeling of having no objects to focus on and subsequently strengthen the experienced perception.

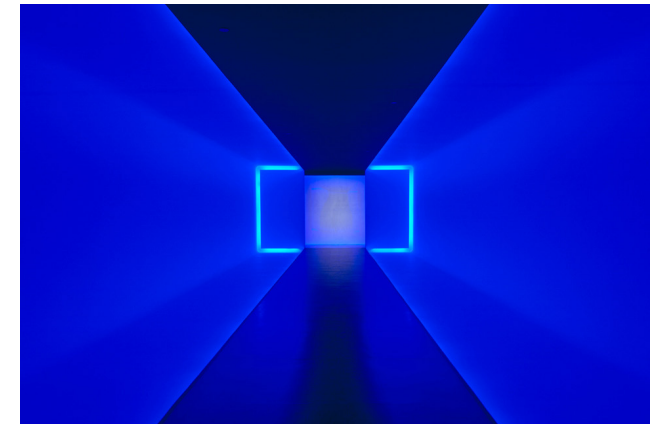


Figure 1.21: *The Light Inside*, James Turrell (Herd, n.d.)

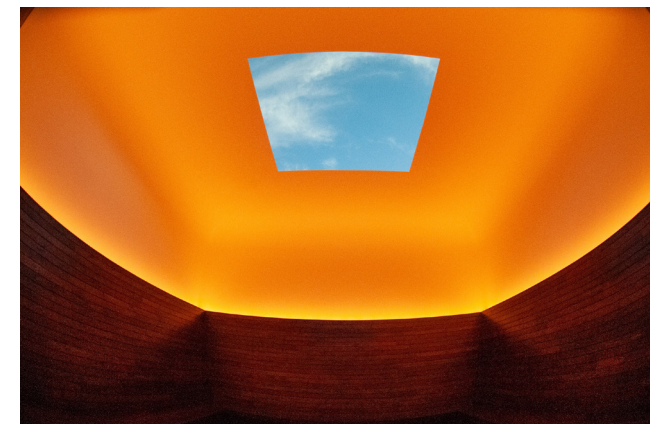


Figure 1.20: *Skyspace*, James Turrell (Lauer, 2022)

Anthony McCall is known for his innovative work in the field of contemporary art, including the exploration of light, space and perception. A great example of his style can be seen in figure 1.25. The installation consists of more-or-less conical forms created with projected light, which slowly change over time. The form seems as one whole, but actually consists of two forms being brought together by a wipe, which is a transition technique used in cinema (Ellard & Johnstone, 2006). The wipe is a slow transition where the new scene slowly covers the old scene, creating a unique overlapping visual. Figure 1.24 shows the stills that are made of the projected shapes with an interval of two-minutes. McCall's works often explore the fundamental properties of light and its relationship to human perception. His interest in the phenomenological experience of art is evident in the way he plays with the viewers' perception and their role in shaping the artwork through their movements and engagement with the projected light. With his light projections, he sparks the intrinsic motivation to interact with the ray of light, move the body and see how we can influence the light (Novikova, n.d.).

Figure 1.22 shows a labyrinth designed by Olafur Eliasson. The labyrinth consists of coloured plastic sheets in cyan, magenta and yellow. By walking through the maze new colours appear when sheets overlap each other. The maze creates spontaneous compositions that continuously shift by the movement of the viewer through the area (Eliasson, n.d.). It is interesting to note that multiple artworks described in this section, subconsciously motivate the viewers to explore and see how they can interact with the work. Most artworks also provide continuous cues to keep exploring like being motivated to find new colour mixtures in the maze. Figure 1.23 presents an installation consisting of rotating lenses, mirrors, prisms and colour filters which are illuminated by five spotlights. The light is reflected and refracted by the optical devices, creating a unique sequences on a curved black screen. Each optical device rotates at a different speed, providing constantly new sequences (Tanya Bonakdar Gallery, n.d.).



Figure 1.22: Seu corpo da obra, Olafur Eliasson (Strasnick, n.d.)

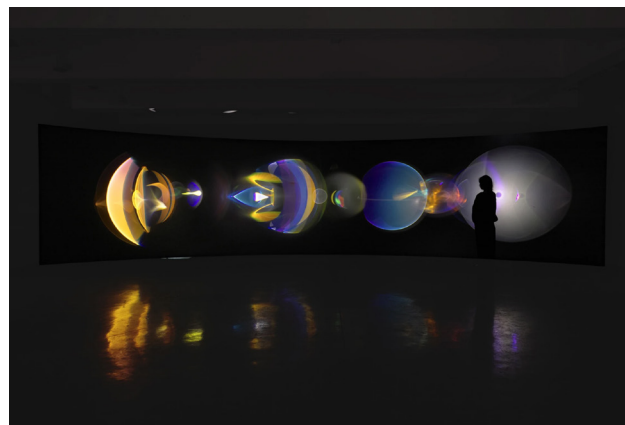


Figure 1.23: Your ocular relief, Olafur Eliasson (Tom Powel, n.d.)



Figure 1.25: Between You and I, Anthony McCall (Glendenning, 2006)

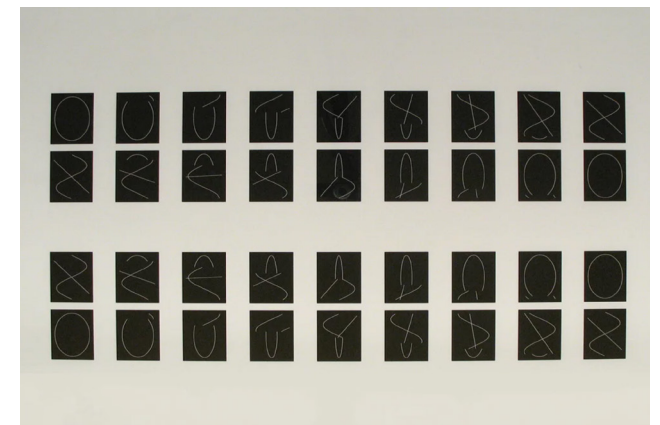


Figure 1.24: Between You and I, Anthony McCall (i8, n.d.)

2 Explorations

This chapter combines the experimentation phase and the define phase. The experimentation phase was used to experiment with the gained knowledge from the research phase and to see how theories would work in a practical sense. The define phase was used to convert the experiments that showed interesting effects into multiple explorative directions. These directions were subsequently combined with perceptual misconceptions. The chosen direction is finally combined with a larger story. The define phase was concluded with a design brief. This chapter summarizes both phases, to provide enough information towards the concept phase.

2.1 Experiments

All the conducted experiments with explanation and an analysis can be found in appendix 2 and 3. This page shows the main conclusions of the experiment phase.

Spectral tuning

The experiment phase directly started with multiple experiments using spectral tuning. At first, knowledge was obtained on how the different tuning settings of the Ledmotive setup would influence the appearance of the printed colours. A simple, but effective illustration is shown in figure 2.1 and 2.2, where the centre eye completely disappears with red light. Precisely tuning the spectrum of light on coloured moiré patterns, resulted in interesting movement and small changes in depth. After analysing the conducted experiments, the spectral tuning experiments showed a profound exploration on perception, while also relying heavily on technology.

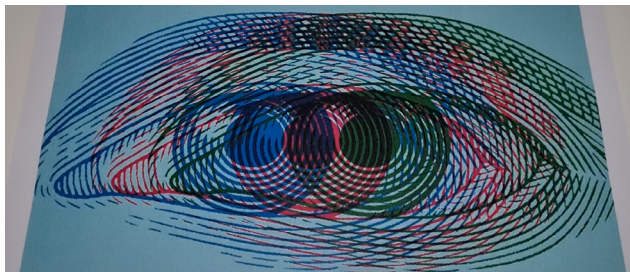


Figure 2.1: Moiré pattern with all light channels on 50%



Figure 2.2: Moiré pattern illuminated with red light

Organza projections

As it was the goal to combine spectral tuning and holographic projection, multiple experiments were conducted in that specific direction. Especially, the pepper's ghost illusion was experimented with in multiple set-ups. Combining both techniques did not lead to strong visual effects, nor did it showcase parts of perceptual phenomena that were researched. In contrast, the experiments with projecting on organza led to strong visual effects. Putting multiple layers of organza behind each other and projecting on it, resulted in a great 3D effect. Figure 2.3 and especially figure 2.4 showcases how the light is reflected on multiple layers of organza creating a 3D object in the air, thus showcasing similar specification as holographic projection. Multiple explorations were done on the organza and these experiments showcased how a simple technique can create strong visuals that already touched upon multiple perceptual phenomena. After analysing the experiments, the organza projections scored high on profound exploration of perception, while it was lightly relying on technology.

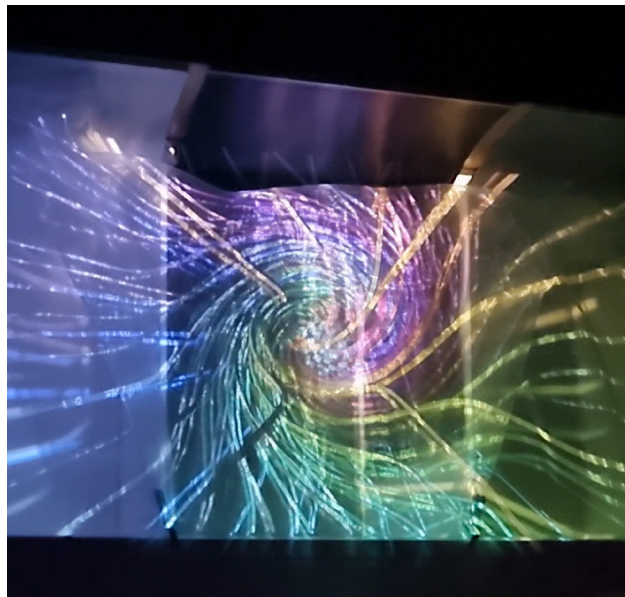


Figure 2.3: Two layers of organza with projected spinor + strings

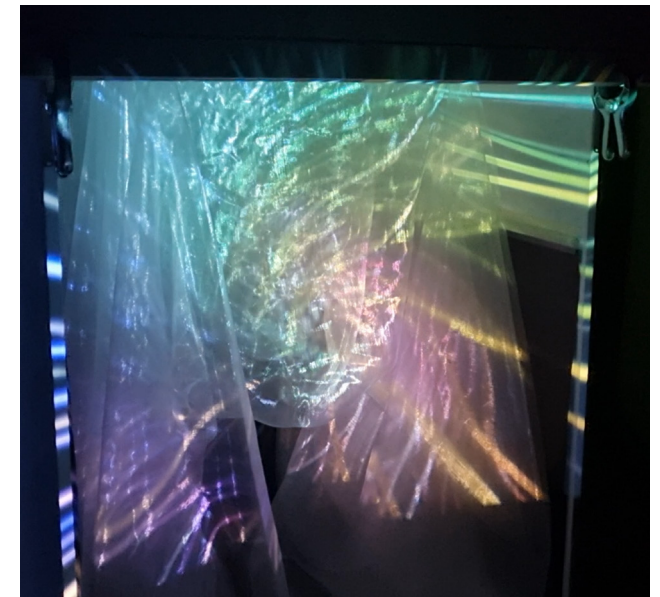


Figure 2.4: Five layers of organza with projected spinor + strings

2.2 Direction development

After the experiment phase, more time was spend on combining the experiment knowledge and research knowledge into a story. Connecting a story can help in making difficult things more accessible and easier to engage with. By coming up with a story that people can relate to, the threshold to link with the complicated scientific phenomena can be made lower. During the direction development, the idea arose to link certain misconceptions about perception with the gained knowledge of the experiments and research. This resulted in a list of misconceptions that were directly linked to the found perceptual phenomena. Three of these links were developed further. This can be seen on the right side of this page. The overview information is not modified since these directions arose.

Phenomenon
Chromostereopsis

Misconception
Senses provide consistent information

Overview
Chromostereopsis can showcase how our senses can be deceived by challenging the impression of depth created on the organza layers.



Figure 2.5: Chromostereopsis video projected on red and blue organza

Phenomenon
Coloured shadows

Misconception
Misconception of bias

Overview
Coloured shadows on coloured organza layers together with dynamic RGB light has the potential to let the shadow 'move' through the organza layers.



Figure 2.6: Pen illuminated with RGB light, creating different CMY shadows

Phenomenon
Colour perception

Misconception
Perceiving intrinsic colours

Overview
Through the interplay of coloured organza and tuned projections, visitors can discover how colour perception works and how the interaction of it can create a sense of depth and movement.

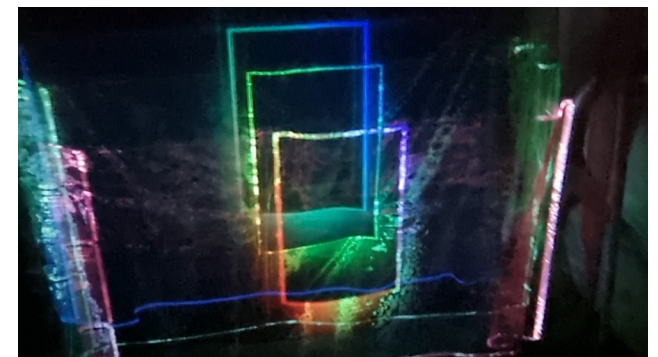


Figure 2.7: Black rectangle with glowing and changing gradient edge being projected on red, green and blue organza

2.3 Direction iterations

After experimenting with the directions, the chromostereopsis and colour perception direction showcased the strongest expression of their perceptual phenomenon. This is also due to the fact that coloured shadows are not a perceptual phenomena, but is about optics.

Figure 2.8 shows an image of the chromostereopsis version of *The Starry Night* by Vincent van Gogh being projected on red, green and blue organza. This experiment was conducted to explore the visual effects of a landscape being projected on three layers of organza. The colours of this version were very suitable for this setup. The experiment resulted in interesting 3D effects, as each colour was reflected the most on its own layer. On the other hand, chromostereopsis is about the perceived depth in a 2D image. Therefore this setup lacks the ability to communicate the phenomenon in its true form. As the phenomenon could not be communicated in its true form, it was chosen to only continue with the colour perception direction.



Figure 2.8: Chromostereopsis version of *The Starry Night* on red, green and blue organza

Figure 2.9 presents an iteration on the colour perception direction. By precisely tuning and timing the projections, the visuals would appear on the different layers, which resulted in changes in depth. This direction showcased that it could communicate two perceptual phenomena. Colour perception and subsequently depth perception. Therefore this direction is chosen to continue with. To make the phenomena more accessible to connect with a story about polarisation is added next to the already connected misconception. The polarisation story connects with the phenomenon of colour perception and is meant to connect elements of everyday life to elements of colour perception. Hopefully this story can help in making a scientific phenomenon more approachable.



Figure 2.9: Black rectangle with red coloured edge projected on red, green and blue organza

Polarisation story

As the polarisation in the society is increasing, it would be interesting to address the societal challenge of growing us-versus-them thinking and the need for understanding and dialogue.

The projections can resemble the society divided by contrasts and separation of colours. The symbolism should be clear, where the “us” and the “them” is separated and communication is disrupted. The perceptual phenomenon, colour perception, functions as a metaphor for how we perceive others.

Visitors can engage with the installation by tuning the colours and shifting the visual representation towards harmony and unity. This experience challenges the misconception that societal separation is intrinsic and unchanging. By understanding and empathizing with different perspectives, visitors can bridge these separations and work on a more harmonious society.

Adjusting the colour of the projections and observing the interaction with the organza layers symbolizes the need for dialogue in a diverse and multi-layered world.

This story aligns with the festival’s theme, “Do you see what I see?” by encouraging visitors to reflect on how they perceive others and the society. It serves as a reminder that societal polarization is not inevitable and that, like the perception of colour, it can be influenced and transformed.

2.4 Design brief

After having a clear direction on the to be communicated perceptual phenomenon and the story to connect with it, a design brief was drafted. Below the goals, objectives and the aspects that are out of scope from the design brief are shown. These goals and objectives will be used at the start of the concept development.

Goals

1. Educational awareness: increase awareness and understanding of the basic principles of colour perception.
2. Social reflection: encourage visitors to reflect on societal polarization and the need for dialogue and empathy.
3. User engagement: engage visitors through an interactive experience that challenge their preconceptions.

Objectives

Educational objectives

1. Demonstrate colour interactions: create a visual demonstration that showcases how coloured organza layers interact with spectrally tunable projections to influence colour perception.
2. Provide explanatory content: develop accompanying explanatory content to help visitors understand the science behind colour perception and how it relates to the installation.
3. Incorporate interactive learning: implement interactive elements within the installation that allow visitors to actively engage with and experiment with colour perception.

Narrative objectives

1. Visual symbolism: design a clear visual representation of societal polarization and unity within the installation.
2. Narrative development: create a compelling narrative that aligns with the festival's theme "Do you see what I see?" and reinforce the message of overcoming societal divisions through perception and understanding.

User engagement objectives

1. Envisioned interaction: develop an intuitive and user-friendly interface that enables visitors to adjust colours and view the visual effects representing the narrative.
2. User guidance: provide clear instructions and guidance to ensure that visitors can easily interact with and understand the installation.

Out of scope

- In-depth societal solutions: while the project addresses societal polarization, it does not aim to provide comprehensive solutions to this issue.
- Comprehensive colour theory: the project will focus on the interactions of colours, light and materials but will not delve into advanced colour theory.
- Inclusiveness: no additional design steps will be taken to make the installation inclusive for visually impaired people and deaf people. Meaning that the visually impaired people can still experience the sounds and deaf people can still experience the visuals. No additional design steps will be taken to bridge their specific impairment.

Notes

The focus will be on producing an interactive light installation. Sound will be implemented if there is enough time to implement it in a qualitative way. The goal will be to achieve both aspects, because sound can contribute to the experience in a great way. The installation will not take any political or societal position.

3

Concept

development

This chapter will explain the development of the concepts. This consists of concept 1, the insights from concept 1, concept 2 and an update of the objectives. The objectives changed during the whole project. The choice has been made to only show the adjustments between the objectives made in the define phase and after the concept phase. This will provide a more clear overview than constantly showing the small adjustments made to the objectives.

3.1 Concept 1

Progression

Concept 1 developed from a textual polarisation story to a full visual polarisation story with according interactions. Figure 3.1 shows the main steps taken in concept 1. From the beginning, the main goal was to translate elements of polarisation to visual effects with according interactions. An example of an element could be the social interaction between people, ranging from segregation to integration. This is then converted to a fitting visual representation like layer interaction, that ranges from minimal interaction to layer blending. This process resulted in six different visual representations that the visitors could influence by interacting with the installation. The societal polarisation is being represented by shapes inspired by the kiki and bouba effect. Figure 3.2 shows one of the visual scenes developed during the process, where kiki's and bouba's bounce off each other to showcase their indifferences. The goal for the visitors is to tune the six different parameters in such a way that the total visual representation shifts from visual polarisation to visual unity. Visual unity is being represented by a portal shown in figure 3.3. The circles of the portal smoothly blend between the layers, resembling a society that connects with each other again. A full overview of the visual story can be seen in appendix 4. During the development of the concept, a wide range of visual effects was tested to see what animations would achieve a clean movement through the layers. Concept 1 ended in a fair amount of insights about the visual effects and the communicative part.

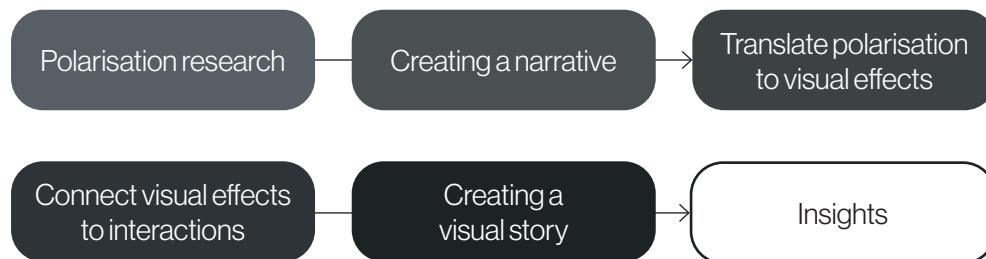


Figure 3.1: Main steps taken in concept 1

Decision to discontinue

As concept 1 developed, the visual effects and the connected interactions became increasingly complicated. Despite the fact that the last step in this concept, the visual story, provided a structured build-up of the polarisation story and its visual effects, it slowly became clear that this concept was losing focus. The visual story and the accompanying interactions took the focus away from the perceptual phenomena that were meant to be communicated. Additionally, the green coloured projections that were meant for the green organza layer, also showed strong reflections on the red and blue organza layer. This effect is shown in figure 3.4, where green with an RGB value of 0,255,0 is projected on the three organza layers. Besides, the red and blue shapes were also being reflected considerably by the green organza layer. These effects made the story even more distracting, as it was not clear enough on which layer the visual elements were located. The intended effect of shapes 'moving' through the layers could therefore not be achieved properly. The arguments described above gave enough reason to shift to a different concept direction.

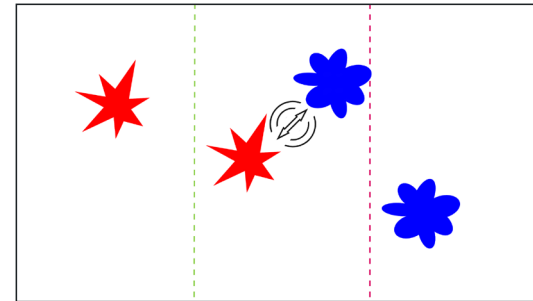


Figure 3.2: Visual scene of polarisation story

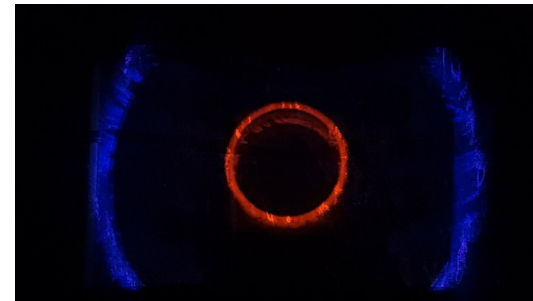


Figure 3.3: One of the portal explorations

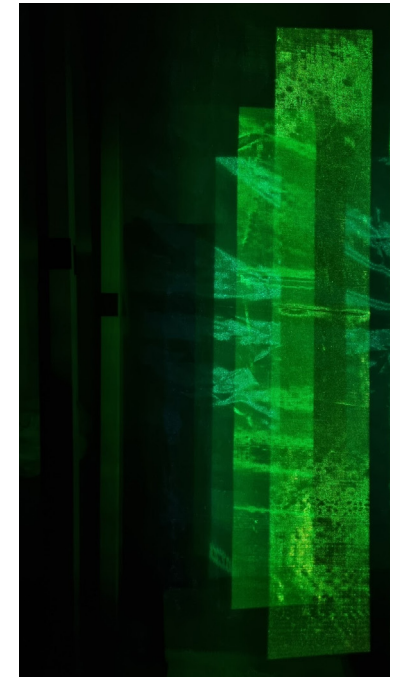


Figure 3.4: Green projected on the organza layers

3.2 Concept 1 insights

Communication

Despite the fact that concept 1 did not produce the desired results, it still produced valuable insights and knowledge that could be used in the development of concept 2. This transition from concept 1 to concept 2 started with the shapes projected in figure 3.5. It consists of a simple, static projection of a red, green and blue circle on top of each other. This combination effectively showcased how spectral tuning influences the absorption and reflection of light by the different layers and how this will subsequently create differences in depth. This is the core message that was missing in concept 1. This insight also showed that the core message should be the story which needs to be told directly and not the story about polarisation. By directly creating visual effects based on the core message, there is less chance that visitors get distracted by elements that do not add value and more chance that they will understand what the installation is about. These insights led to more focus on what needs to be communicated to the visitors.

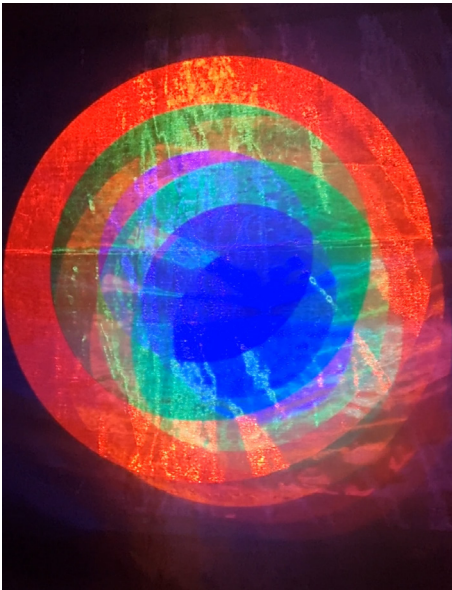


Figure 3.5: Projection of red, green and blue



Figure 3.6: Change in organza layers

Design and visual elements

Next to the main insight on communication, there were more insights based on the design and visual elements of concept 1. These insights are listed below.

Green

Something that is already mentioned in the previous subsection and shown in figure 3.4, is the negative effect of projecting green and the influence of the green organza layer on red and blue elements. To eliminate these undesirable effects, concept 2 will continue with a red and blue layer only (figure 3.6).

Motion parallax

Figure 3.7 shows an exploration of different colours of green being projected on the three layers. This exploration unconsciously showed motion parallax when the viewer changes perspective. Once again a simple static image communicates an essential cue that influences depth perception.

Portal

The portal in concept 1 was the only element that directly showcased a play with depth perception. While the exploration during concept 1 was minimal, the portal showcased a high communicative value and is therefore being further explored in concept 2. Another important insight during the exploration of the portals, was the flickering effect. The circles went from a high light intensity to no light intensity which caused a flickering effect. This effect could exclude a large group of people to watch the installation, which is undesirable.

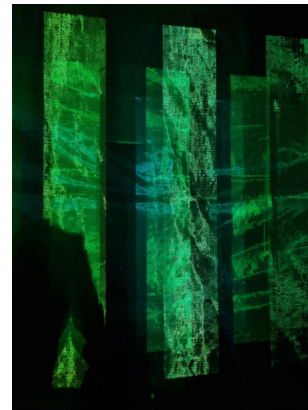
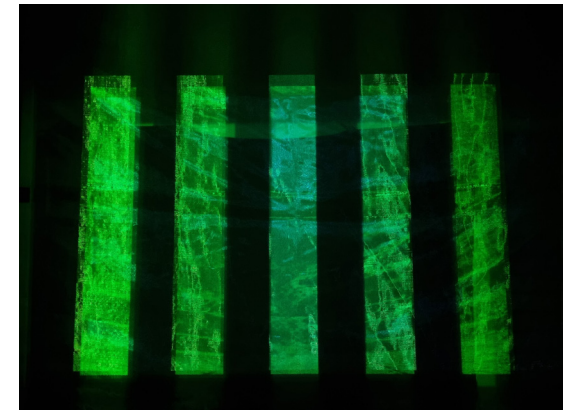


Figure 3.7: Green rectangles creating motion parallax



3.3 Concept 2

Development

With the knowledge and insights gained from concept 1, concept 2 started with a quick exploration phase. The goal of the exploration phase was to quickly find out which visual effects would work on the new setup with the red and blue layer, while keeping slow transitions in mind. The exploration started with simple visuals shown in figure 3.8, where the red circle is clearly in front of the blue circle. These explorations were further expanded to animated rings creating a ripple effect shown in figure 3.9. By combining static, slowly fading shapes with dynamic, precisely timed fades, a visual build-up slowly occurred.

Communication

During the development of concept 2, the communicative part became increasingly more focused. Figure 3.10 shows a schematic overview of the communicative development of the installation. Since the beginning of the concept phase, it was the goal to showcase the basic principles of colour perception and play with the perception of depth of the visitors. However, the intended principles fall short in describing colour perception. The absorption and reflection of light belongs in the field of optics, and the angle of incidence and perspective relative to a reflective surface is not enough to describe colour perception. The principles of depth perception are incorporated in the visual effects, but are quite scientific to directly communicate to the visitors. By zooming out on the perceptual phenomena, the accompanying principles and the technology spectral tuning, the communicative part became clear. The lower part of the scheme shows the narrative in three blocks. By using spectral tuning, the absorption and reflection of light can be adjusted to influence the perception of depth. The concept still shows some principles of colour perception, but this will not be part of the core message.

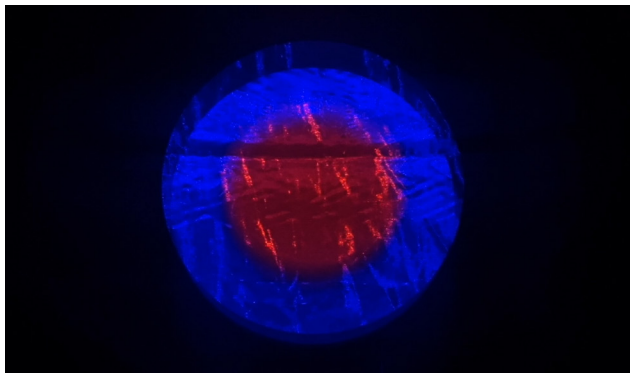


Figure 3.8: First red and blue circle exploration

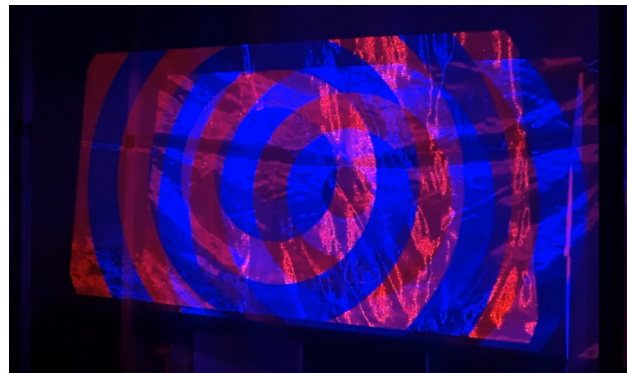


Figure 3.9: Multiple rings creating a ripple effect

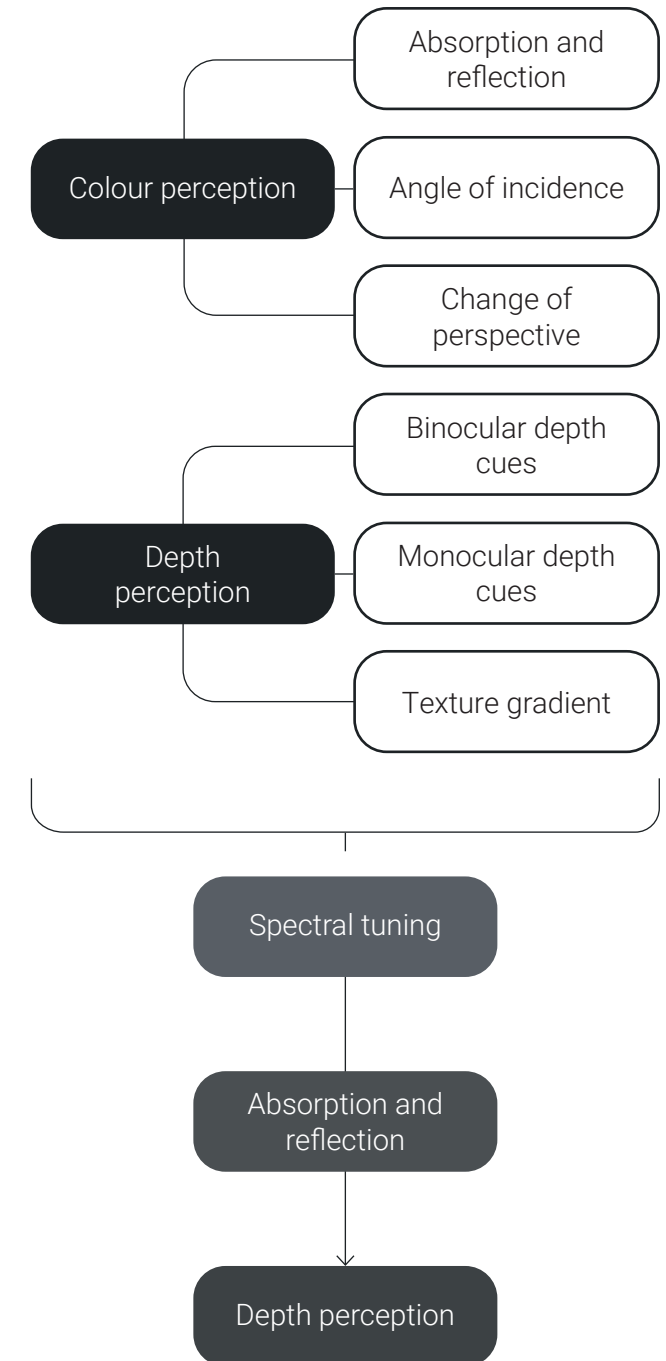


Figure 3.10: Development of the communicative part

3.4 Objective development

After going through the concept was, it became clear that the previously stated goals and objectives of the design brief were no longer relevant. Colour perception is no longer the communicated phenomenon, the polarisation story is discontinued and the last concept does not focussed on interactivity. Therefore, the three previously stated goals below are converted to a new goal.

Goals

1. Educational awareness: increase awareness and understanding of the basic principles of colour perception.
2. Social reflection: encourage visitors to reflect on societal polarization and the need for dialogue and empathy.
3. User engagement: engage visitors through an interactive experience that challenge their preconceptions.



Goal

1. Showcase how the technology spectral tuning can influence depth perception.

Subsequently, the goal is split in multiple objectives. The objectives are categorised in a communicative and experience category. The objectives of the communication category is focussed on transferring the communicative part of the installation to the visitors. The objectives in the experience category are focussed on the attributes that facilitate a qualitative experience for the visitors.

Objectives

Communicative objectives

1. The installation showcases how spectral tuning influences the absorption and reflection of light by material.
2. The installation showcases how the textile layers and tuned projections can facilitate differences in depth perception.

Experience objectives

1. The installation showcases the effect of spectral tuning in an experiential manner.
2. The visuals should immerse the visitors in the narrative
3. The narrative keeps the visitors engaged
4. The visuals are appealing to look at
5. The total experience of the installation is coherent

4 Test

This chapter functions as an in-between validation moment for the final prototype. This test will validate if the current concept is meeting the objectives. This chapter will describe how the research on the final prototype is conducted and which results it has brought. The chapter will be concluded with a conclusion, discussion and recommendations for the final design.

4.1 Test setup

Research aim

The aim of this research is to test if the current design is meeting the objectives which were defined in an earlier stage of the design process. As there are multiple objectives which need to be met, it is not possible to state a research question which covers all the objectives. The objectives are once again stated below:

Communicative objectives

1. The installation showcases how spectral tuning influences the absorption and reflection of light by material.
2. The installation showcases how the textile layers and tuned projections can facilitate differences in depth perception.

Experience objectives

1. The installation showcases the effect of spectral tuning in an experiential manner.
2. The visuals should immerse the visitors in the narrative
3. The narrative keeps the visitors engaged
4. The visuals are appealing to look at
5. The total experience of the installation is coherent

Most of the objectives were directly converted to Likert scale questions, as they are directly measurable. At first, the test would consist of only one test condition. In this condition, the participants (n=10) had the opportunity to read the installation sign with a title and QR-code that was placed next to the door of the test environment. This test showed that the first communicative objective was not met. After the first test, multiple participants stated that they would have liked the experience better and would have been more engaged if they know what they were looking at. Therefore, a second test was conducted where the participants (n=4) were pointed to the installation sign that had a subtitle and illustrative introduction next to the title and QR-code. The results of both test conditions are showed separately and in comparison with each other

For this test, I will mimic the characteristics of the envisioned final design and environment in which the final design will be presented. The final design will be presented in one of the rooms of The Social Hub in Delft.

Participants

The users of the installation will be the visitors of the art and technology festival called Highlight. The users consist of a wide variety of people in terms of age, cultural background, educational level and profession. To recruit such a wide variety of people would take too much time away from the graduation project. Besides, all participants should be available and willing to do the test at the faculty, as the test setup is not easily transportable. Therefore, the choice was made to recruit master students from the Industrial Design Engineering faculty. This will speed up the research process, while still providing enough research input to obtain valuable insights.

4.2 Method

Tools and equipment

The test setup consisted of the following tools and equipment:

- A frame with two organza layers (red and blue) and an absorption cloth
- Small, white cardboard screen
- Two projectors
- Information sign (one with title and one with added illustration)
- Laptop
- HDMI splitter
- A dark environment
- An illuminated environment

The test will be conducted in the audio lab of the Industrial Design faculty. The lab provides enough space for participants to walk around and it offers a separate cabin for filling in the consent form and survey. A simplified top-view of the setup can be seen in figure 4.1, where P is the participant and R the researcher. The white cube shows the enclosed cabin that can be illuminated. Besides, there is a desk and chair inside (figure 4.4). Figure 4.2 shows a large part of the test setup and how the cables of the mini projector are taped onto the floor to prevent participants from falling over. Normally, this area will be continuously be darkened to mimic the final environment in which the installation will be presented. The information sign is placed outside the audio lab as this will also be the position at the final environment (figure 4.3).

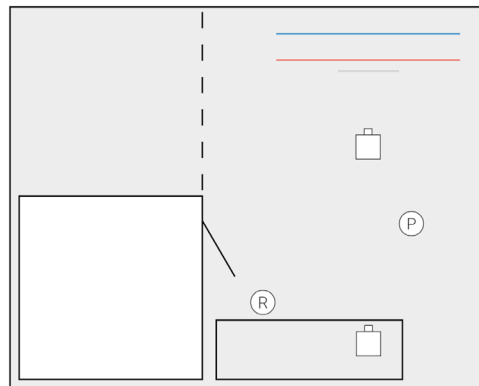


Figure 4.1: Simplified top-view of setup



Figure 4.2: Test setup seen from the researcher position

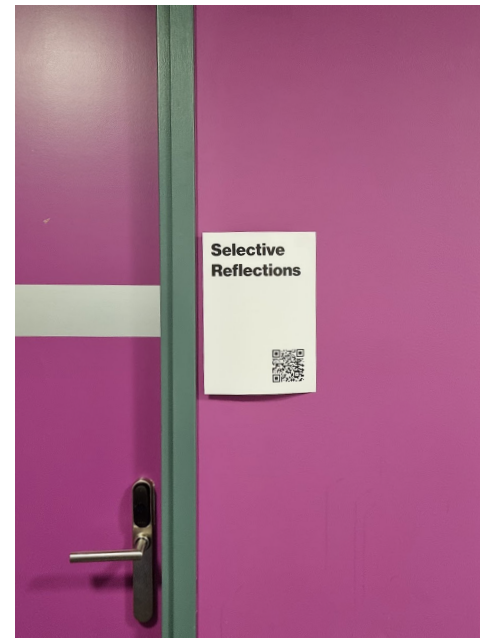


Figure 4.3: Information sign



Figure 4.4: Illuminated survey space

Procedure

This experiment was approved by the HREC, TU Delft. When a participant entered the dark audio lab, they were directly guided to the illuminated cabin. After introducing the purpose of the research, the participant had time to go through the informed consent form (appendix 5). Subsequently, the procedure of the test is explained to the participant. At first, the participant will experience the installation through the full visual sequence – to provide the full experience and let them set their internal frame of reference for the ratings. After that, they went through four rounds where for each round a separate part of the sequence is displayed (figure 4.5). After each round a shorty survey needs to be filled in, in the illuminated cabin. After going through the four rounds, the participant will be asked to fill in post-test questions. The full survey can be found in appendix 6. During the test, the researcher will observe the actions of the participant and score (yes/no) if three specific ones were executed. A scheme of the participants with the order of the visual sequence, together with the action observation sheet can be found in appendix 7. At sequence 0 the participants are expected to only rate the projections on the cardboard and at sequence 1, 2 and 3, the participants are expected to only rate the projections on the organza. Between the test groups there is one difference. The first group had the possibility to check the information sign at the door of the lab and the second group was explicitly told to look at the illustrative introduction after the test procedure was explained (figure 4.6 and 4.7).

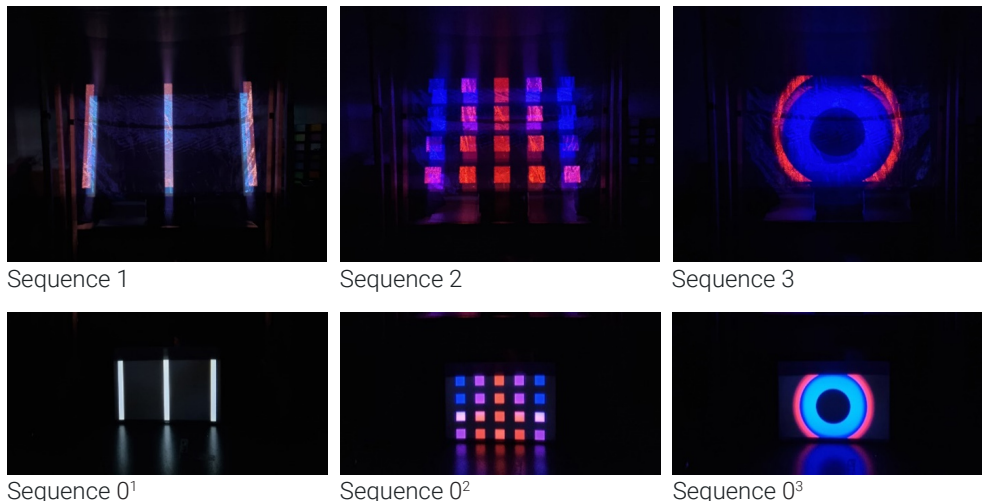


Figure 4.5: The different sequences on organza and on cardboard

Figure 4.6: Information sign with added quote and illustrative introduction of the installation hanging above the desk in the cabin



Selective Reflections

How to select reflections?
Spectral tuning!

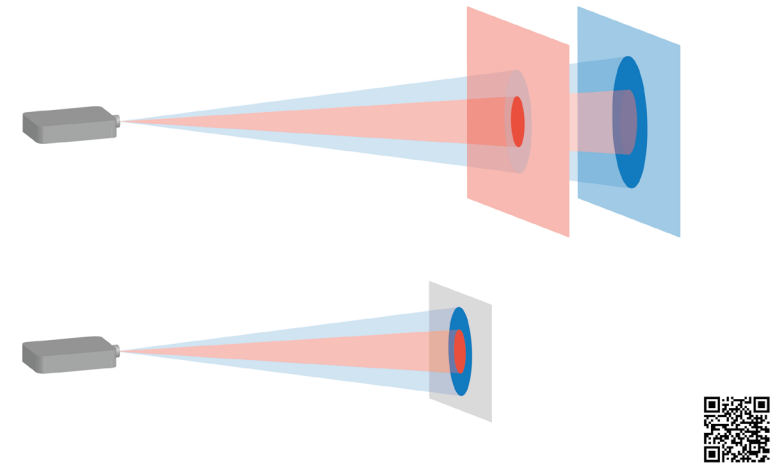


Figure 4.7: Information sign with added quote and illustrative introduction of the installation. A larger version can be found in appendix 8.

Data processing

During the test, the data will be obtained on paper. After all the tests are completed, the data on the paper will be transferred to the laptop of the researcher. Subsequently, the rating data will be transferred to excel to visualize the data. The ratings for the projections on cardboard function as a baseline when comparing it to those for the projections on organza. The Likert scale questions and open question after the test can be used to validate the overall experience of the installation. The actions can be used to validate if certain actions were performed.

4.3 Results

The quantitative data is converted to different bar charts. The quantitative data is split in within group results and between group results. This subsection is finalized by a summary of the qualitative data.

Within group

Figure 4.8 shows a bar chart with the results of the attribute ratings of the group that did not receive an illustrative introduction before watching the visual sequences. The y-axis shows the rating score and the x-axis is divided into the attributes depth, beauty and immersion, and the sequences ranging from 1 to 3 for each attribute. The bars represent the means of the attribute ratings, while the error bars show the standard error.

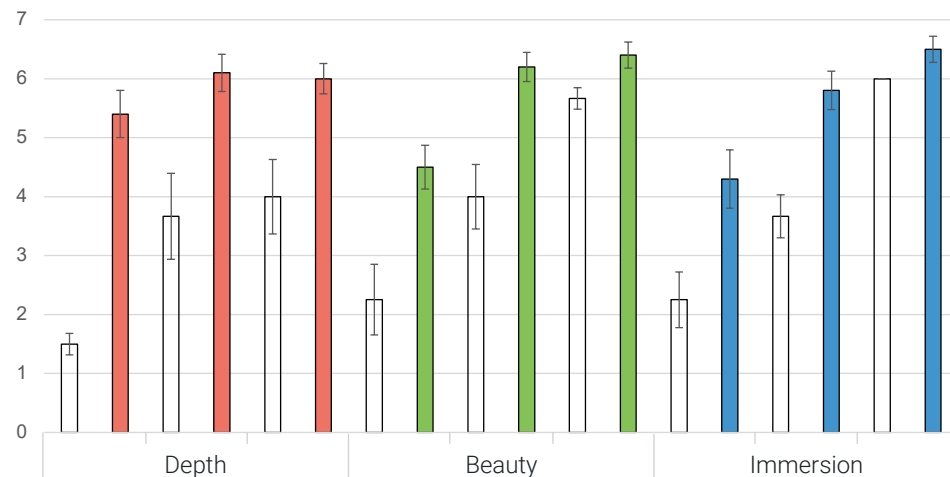
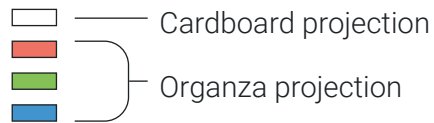


Figure 4.8: Organza and cardboard projections rated per attribute without illustrative

The chart in figure 4.8 shows that nearly every attribute score is increasing per sequence. This applies to the cardboard projection and the organza projection. Only the depth attribute for the organza projection is not completely increasing. Additionally, the cardboard projection has a lower score on each attribute and sequence when comparing it to the organza projection.

Figure 4.9 shows a bar chart with the results of the attribute ratings of the group that received an illustrative introduction before watching the visual sequences. The attribute score per sequence is not increasing so consistently as the scores in figure 6.8. The depth attribute on the cardboard projection and the beauty attribute on the organza projection is not increasing over time. This chart shows similar differences between the attribute scores of the cardboard and organza projections. Only the beauty attribute in the third sequence of the cardboard projections shows a deviation. Additionally, the chart shows great differences between the standard error values. These value differences are greater than the standard error values in figure 4.8.

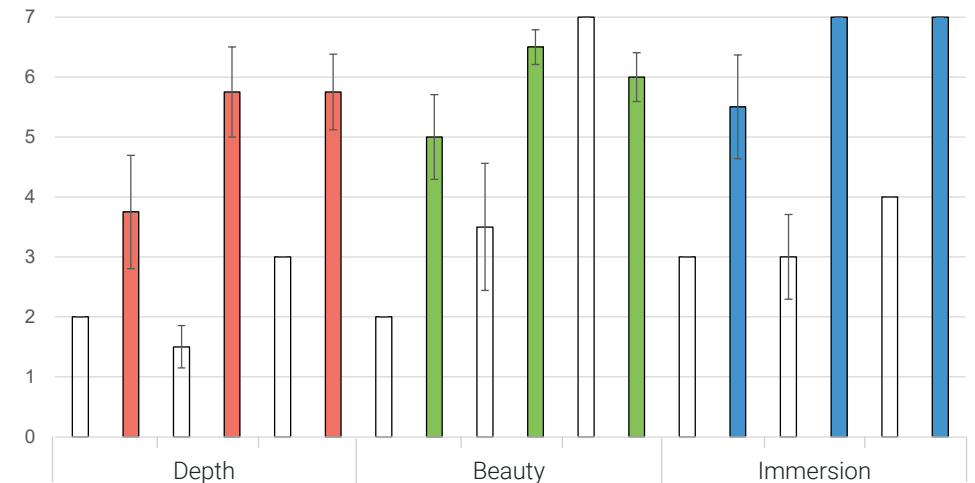


Figure 4.9: Organza and cardboard projections rated per attribute with illustrative introduction

Figure 4.10 shows the results of the observed actions during the test. The observed actions were noted with a yes or no per participant and this is subsequently converted to a stacked bar chart. In the group without the illustrative introduction, 80% of the participants walked around to vary their viewing angle and only 40% of the participants read the title on the installation sign. In the group with the illustrative introduction, every participant walked around to change viewing angle. All participants read the title, as it was introduced on the illustrative introduction. None of the participants in both groups took their time to scan the QR-code.



Figure 4.10: Observed actions during the test

Between group

Figure 4.11 shows the attribute score comparison between the group with and without illustrative introduction. The bar chart only shows the attribute scores rated on the organza projection. Overall, the group with introduction scores higher on average on the attributes beauty and immersion. The depth attribute is rated higher by the group without introduction across all sequences. The depth attribute shows a great difference between the groups on the first part of the sequence. The immersion attribute shows the greatest overall difference between groups. Figure 4.12 shows the rating of the engagement and the coherence of the total experience for both groups. Both attributes are rated higher for the group with the illustrative introduction. Even when considering the standard error values, the group with introduction shows a clear difference in rating the full experience.

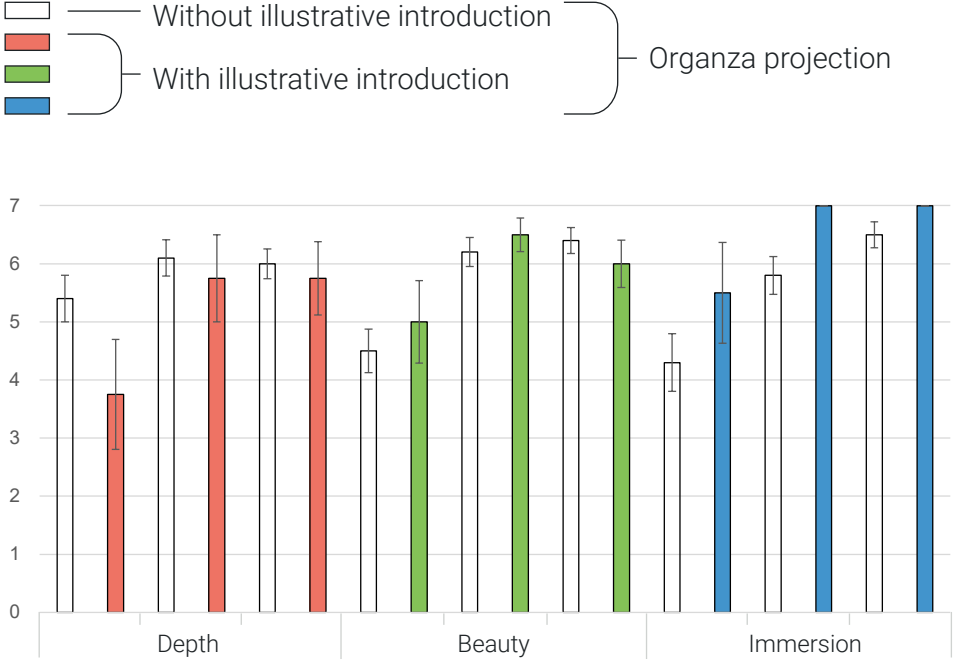


Figure 4.11: Organza projections rated per attribute for both groups

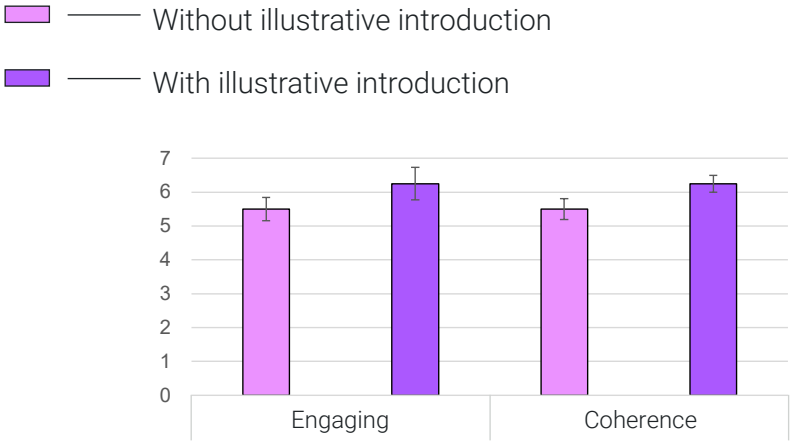


Figure 4.12: Engagement and coherence rated for both groups

Qualitative data

The only qualitative data retrieved from the test emerged from the open question at the end. Figure 4.13 shows a selection of comments and remarks from the open question categorized by visual narrative, setup and communication. Some comments were repeated by multiple participants and are numbered accordingly. The selection is made by choosing the comments which could directly improve the current design or comments that prove that some design features work as intended.

The comments on the visual narrative showed a contradiction between the participants. The participants that stated that the sequence is too long also found the first part of the sequence less engaging. This is in contrast with the participants that stated that they liked the simple and slow build-up of the sequence. In terms of the setup, three participants stated that they would like to have sounds that accompany the visuals to keep the users more engaged. Three participants commented about the positive effects of the fabric and how the luminosity was comfortable. On the other hand, two participants were not sure about the presence of the cardboard projection. One would remove it completely and one suggested to keep it turned off for a certain amount of time. Regarding the communication, the first comment was written down by only one participant, but expressed by multiple participants after the test. This was the case for the group with no illustrative introduction. Such comments were not made by the participants who had the illustrative introduction before the start of the test.

Visual narrative

- 3 The sequence is too long
- 3 Great that it starts simple and slowly builds up
- 2 The first part of the sequence is less engaging
- 2 The square grids are in favour

Setup

- 3 Sound could help with keeping the users engaged
- 2 Fabric adds engagement as you can change what you see by moving
- 2 Hesitant about cardboard projection
- 1 Make it short people friendly
- 1 The fabric gave a dreamy quality and the luminosity was comfortable

Communication

- 1 At first, I was not sure what the installation is about

Figure 4.13: Comments on the full experience by count

4.4 Conclusion

After analysing the data, multiple conclusions can be made. Figure 4.8 shows an increase of attribute score per part of the sequence. In figure 4.9, this trend is slightly less clear, but still present. This means that the intended build-up in the visual narrative works when considering depth, beauty and immersion. This applies to both projections, on cardboard and organza. Besides, both figures show that, except for one score, that the cardboard ratings are always lower than the organza ratings. It can be concluded that the projections on organza clearly facilitate more depth, beauty and immersion.

The results of the action observations showcased that almost all participants shift their perspective during the experience without being told to do so. Reading the title on a voluntary basis did not work out well. The participants who had read the title still were not sure what the installation was about. Therefore the second test was initiated with the illustrative introduction. In both conditions the QR-code is not scanned. This could be due to the fact that it is a test environment where participants feel obliged to execute the actions of the test.

When comparing both conditions, the group with the illustrative introduction scored higher on the beauty and immersion attributes. This probably shows that there is a relation between the amount of knowledge about the installation and the appreciation for it. Only the depth attribute scored lower in all sequences for the group with the illustrative introduction. There is no obvious explanation for this fact. When rating the full experience, the group with introduction scored higher on the engagement and coherence attributes. This could also be explained by the relation between understanding and appreciating the installation.

The open question at the end of the test about any remarks or comments, resulted in a variety of answers. One thing that stood out right away was the difference in preference for visual effects. Some visual effects were mentioned multiple times, but the variety was so large that no clear conclusion can be drawn from that. A lot of contradictions about the visual narrative occurred. This once again, shows how varying personal taste can be. Despite this fact, the visual narrative can still be slightly adjusted while keeping multiple opinions in mind. In terms of the setup, multiple participants discussed the cardboard projection. Some were in favour of completely removing the cardboard while others stated that they almost only look at the organza projection as it was more engaging and beautiful. Besides, multiple participants stated that sound could help in enhancing the total experience.

4.5 Discussion

The aim of this research was to test if the current design is meeting the objectives. In terms of the first communicative objective, the test made clear that an introduction is needed before experiencing the installation. In this case an illustrative introduction with a subtitle was enough to reach the desired effect. The second objective has been achieved to a lesser extent by giving an introduction. It could be possible that the attention with an illustrative introduction shifts away from depth and moves to the technology, and the absorption and reflection of light. Adding 'depth' effects to the illustrative introduction could solve this problem, but it can also lead to too much introductory information that could harm the first objective in return.

Apart from the first experience objective, the other experience objectives were directly put to the test. The objectives were better achieved by the group with introduction. It is important to note that this group was deliberately pointed to the introduction. In the final design, visitors will not be obliged to watch the illustrative introduction. The placement and the way it will be presented should be considered to achieve the objectives on the same level as in the test. It is now clear that the first experience objective is slightly dependent on the introduction as well. While the experience still showcases the effect of spectral tuning in an experiential manner, the understandability and appreciation is dependent on the introduction.

Communicative objectives

1. The installation showcases how spectral tuning influences the absorption and reflection of light by material.
2. The installation showcases how the textile layers and tuned projections can facilitate differences in depth perception.

Experience objectives

1. The installation showcases the effect of spectral tuning in an experiential manner.
2. The visuals should immerse the visitors in the narrative
3. The narrative keeps the visitors engaged
4. The visuals are appealing to look at
5. The total experience of the installation is coherent

Recommendations

Out of the test results, conclusion and discussion multiple recommendations can be made. These recommendations can be worked out in the last part of the project. The recommendations are listed below in their corresponding category.

Visual narrative

The full narrative can be made a little bit shorter, to keep more people engaged. The introductory scene can be made more interesting so people won't drop out and lose attention early. All visuals can be slightly adjusted to make the experience more smooth and professional.

Setup

The representation behind the cardboard projection needs to be reconsidered. The function of it should be kept, to show how the organza layers influence the projection. Especially the size and placement in the space should be reconsidered. Besides, audio needs to be included to keep people more engaged during the visual narrative.

Communication

Time should be spend on the placement and size of the illustrative introduction. The test proofed that the introduction is of significant importance for understanding and appreciating the installation.

5

Final design

This chapters shows the final developments of concept 2. Each part of the design will be elaborated on, to provide a clear overview on the steps that led to the final design decisions.

5.1 Visual narrative

Overview

The communicative part developed during concept 2 serves as the foundation for what is communicated to the visitors of the festival. Subsequently the visual narrative is based on the building blocks of the communicative part. This is shown in figure 5.1 below.



Figure 5.1: Visual narrative

First, the visitors will slowly be introduced to the technology spectral tuning. This will be done by tuning the light of the projection in such a way, that the absorption and reflection of light on each layer will be showcased. The absorption and reflection of light is logically an ongoing process for the whole narrative. After introducing the technology and the accompanying optics, the narrative will slowly introduce more visuals that show great differences when viewed from different perspective. This does not mean that the visitor is forced to shift perspective, but the visuals are made in such a way that they already provide different results when moving your view on the organza. In the last part of the visual narrative, the main focus will be on increasingly creating more depth. This already happens during the whole narrative, but is slowly building up to keep the viewer engaged. The visual effects focusing on depth, show less differences in perspective or viewing change. The remainder of this subsection explains each visual effect in the narrative in more detail.

Details per visual effect

The images in the following section show the same visuals being projected on the red and blue organza layer and on the screen. All images are taken in front of the frame except for the one in figure 5.2. The last page of this subsection shows each projection from an angle.

The narrative starts with projecting three white lines (figure 5.2). The white lines projected on the organza layers, will result in red and blue reflection on each layer. This is done to show that the installation consists of a red and blue layer. There is chosen for three vertical lines, making the difference in colour clearly visible from multiple perspectives. Subsequently, the lines will be tuned to blue, white and red, to showcase how the visual elements can be situated on a specific layer.

Figure 5.3 shows the final stage of the introduction to absorption and reflection. The projection area is split in two rectangles following an opposite colour gradient. This composition facilitates visitors to watch the rectangles occupy two different layers, making the possibilities of the installation clear in a simple manner.

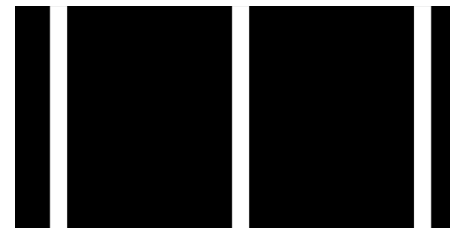
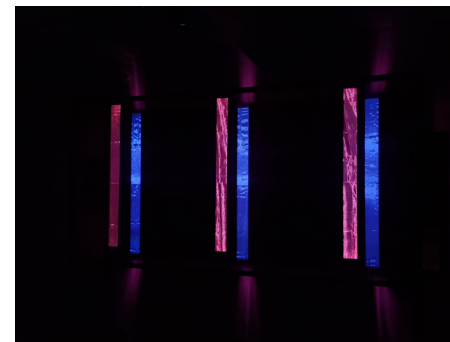


Figure 5.2: Three white lines introducing the colours of the layers

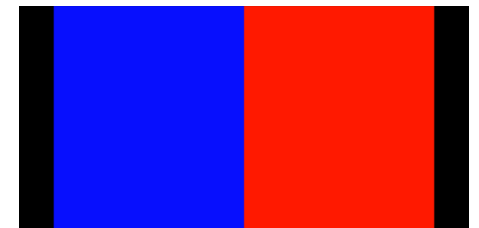
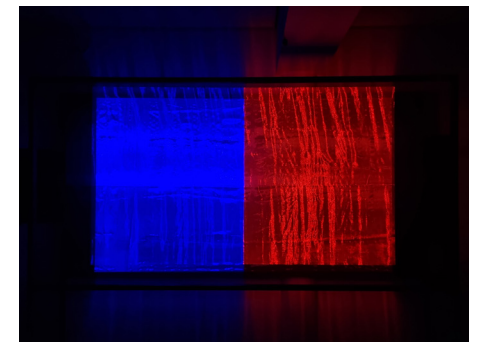


Figure 5.3: Two rectangles following an opposites colour gradient

The two rectangles of the introduction will form one large, red projection that opens up as curtain on the organza layers (figure 5.4). By slowly revealing multiple blue rectangles, the organza layers facilitate the interposition of objects. The blue rectangles seem to be revealed behind the red rectangles. While this depth cue is slightly visible on the screen, the organza layers really strengthen this depth cue.

Subsequently, a red gradient moves from top to bottom over the blue rectangles (figure 5.5). This is where the visuals create a different view for each perspective, matching with the theme of Highlight “Do you see what I see?”. A small image of this visual effect is showcased on the last page of this subsection. The gradient ensures that the rectangles occupy both layers. In front of a rectangle, it appears to wave back and forth to the viewer, while an off-centred position creates a dynamic play with depth as rectangles overlap and simultaneously show different reflections.

To keep the attention span of the viewer high, more motion is added to the visuals. The gradients now move simultaneously in opposite directions with a faster pace (figure 5.6). The occupation of the rectangles per layer is now doubled compared to the previous visual effect. While the rectangles in the previous effect cross each other once mid-air, the current rectangles cross each other on the rear layer and with the rectangle next to it. It is difficult to distinguish on which layer the rectangle is located and therefore this contradictory movement works great to create higher perceived differences in depth.

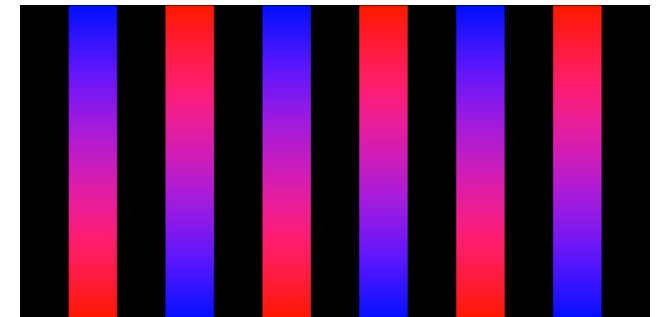
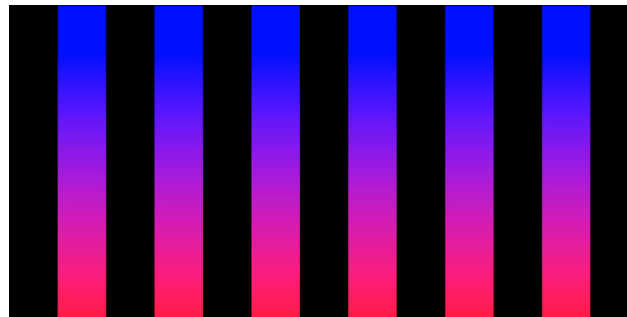
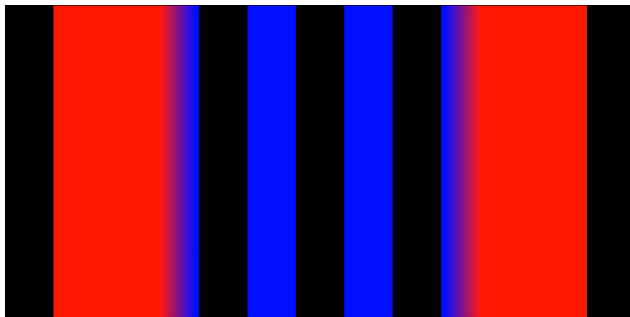
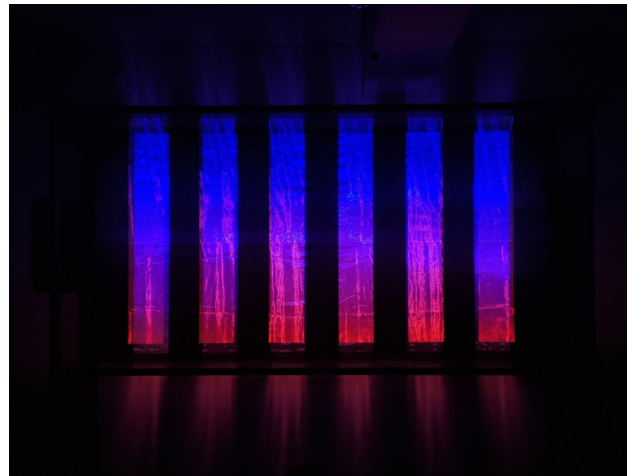
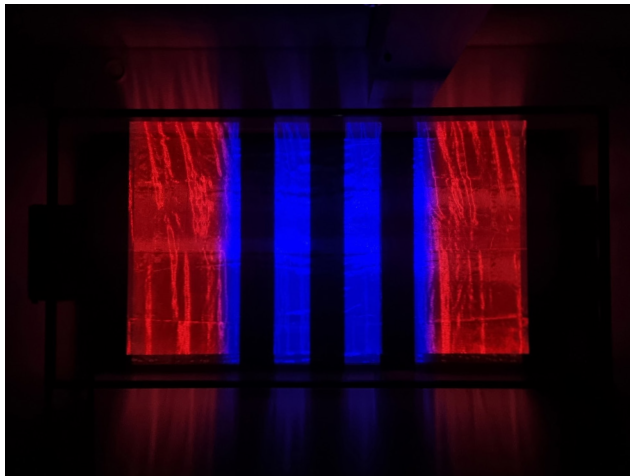


Figure 5.4: Revealing the blue rectangles

Figure 5.5: Gradient moving over the rectangles

Figure 5.6: Opposite gradients moving over the rectangles

The last visual effect and the rotating loops in figure 5.7 are both additions since the last test. They both add more motion and tension, to keep viewers more engaged. First, each colour rotates individually to show how the half red loop disappears and re-emerges on the blue layer to complete the loop. Subsequently, each colour starts simultaneously like shown in figure 5.7. Now the rotating movement is directly presented on both layers, showing the viewer how a simple 2D loop can be extracted in depth by the organza layers.

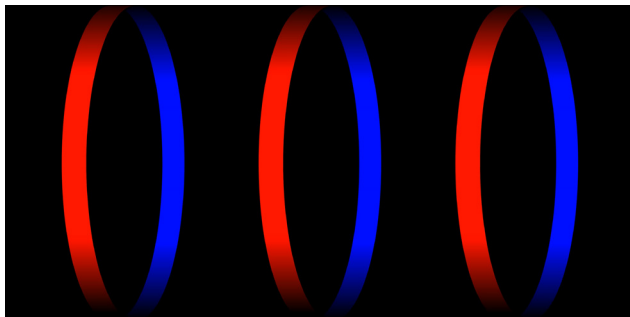
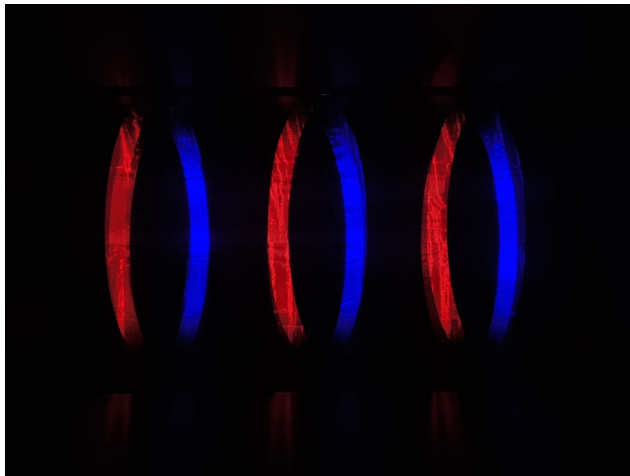


Figure 5.7: Rotating loops

In the next step, the previously used rectangles are split up into cubes. By choosing three different starting times for the gradient, the cubes showcase a lot of different colours at the same time (figure 5.8). Together with the quantity of the cubes, this visual effect facilitates even more perceived differences in depth. With this visual effect, changing perspective results in a lot of interplay between the colours and their occupation on each layer. Besides, the cubes facilitate the completion of rectangles again when shifting to certain perspectives. Although the effect is slower, the playfulness compensates for it.

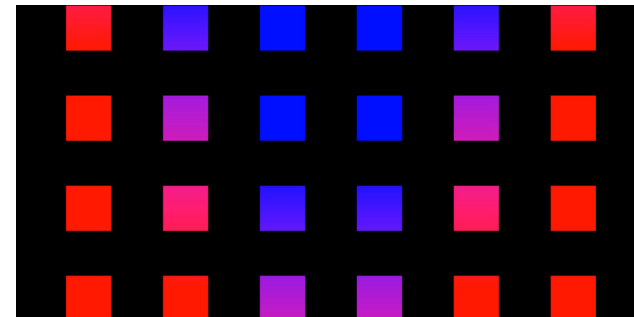
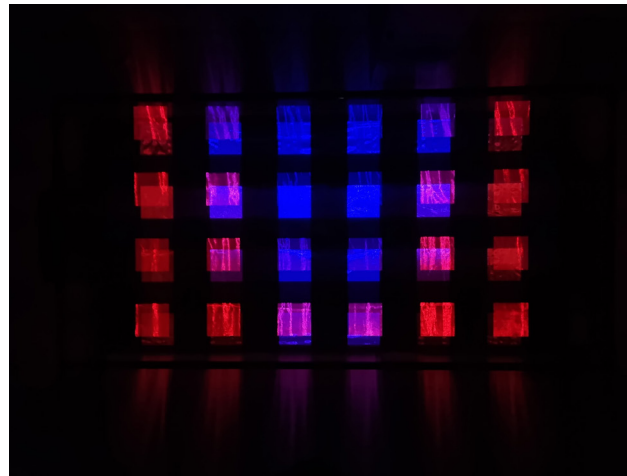


Figure 5.8: Offset gradients moving over the cubes

The perspective part of the narrative is finalized by putting the blue cubes in a dynamic context instead of a static black background. Figure 5.9 shows how a gradient of red and blue moves along the cubes. This visual effect showcases how simultaneous colour contrast can play with depth perception using the organza layers. The blue cubes appear upfront when the red gradient is passing by. On the other hand, the blue gradient make the cubes disappear to make them move back to the blue organza layer when the gradient changes back to black again. This would be a moment where the chromostereopsis effect is apparent on the front layer.

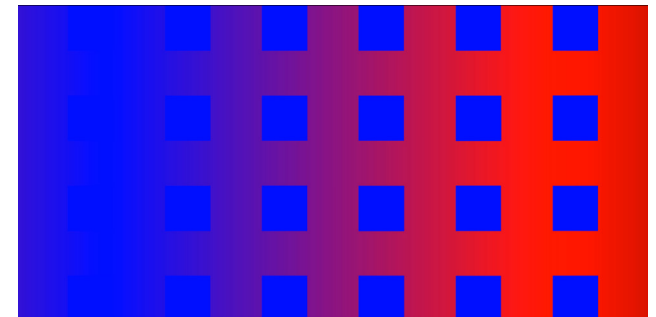
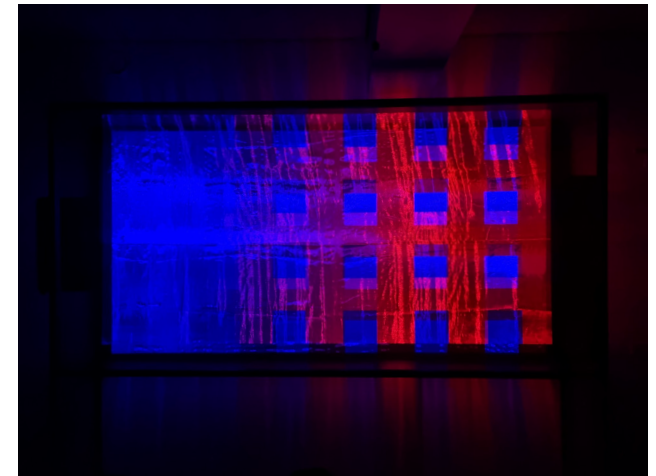


Figure 5.9: Cubes placed in a dynamic context

The circles in figure 5.10 are animated to showcase a ripple effect. By putting a black circle in the middle and gradually expand each circle, a 'tunnel' effect is created. When focussing on the black centre, the circles move in our peripheral vision and this can trick the brain into perceiving depth similar to actually moving through a tunnel. Additionally, the circles change from red to blue and vice versa. When an area changes from red to blue, the viewer loses focus on the front layer and the focus automatically switches to the highlighted rear layer. By increasing the expansion of the circles, the perceived 'tunnel' effect is strengthened over time.

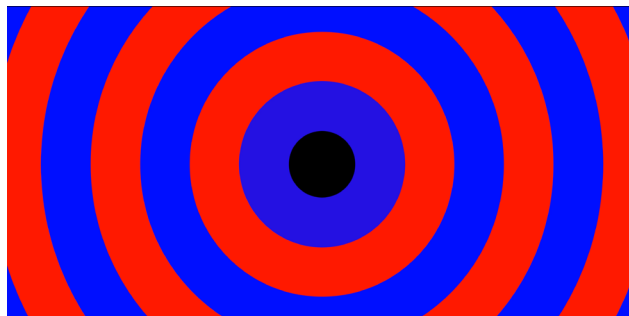
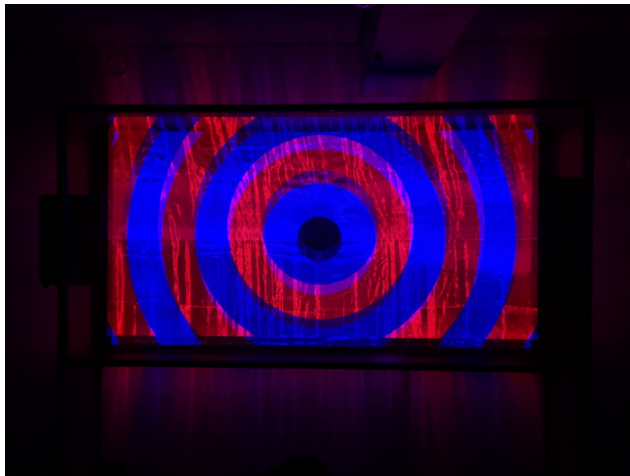


Figure 5.10: Red and blue circles animated as ripple effect

The last visual effect consists of the previously mentioned portal (figure 5.11). The portal continuously consists of an expanding and shrinking circle moving from layer to layer. By precisely adjusting the gradients and glow levels, a continuous play with depth is created. As described in the previous visual effect, the motion in the peripheral vision tricks the brain into perceiving depth. This time, the motion is controlled in two opposite directions resulting in the largest difference in terms of depth. By continuously fading in new circles, a constant play with depth is created.

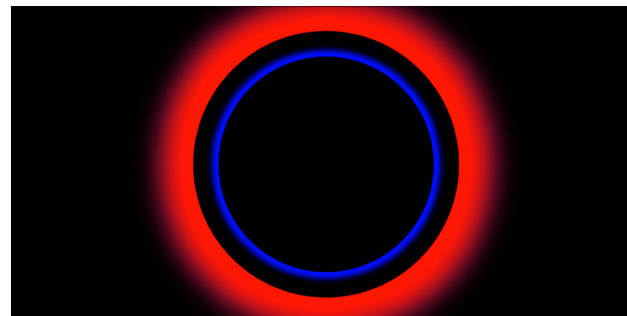
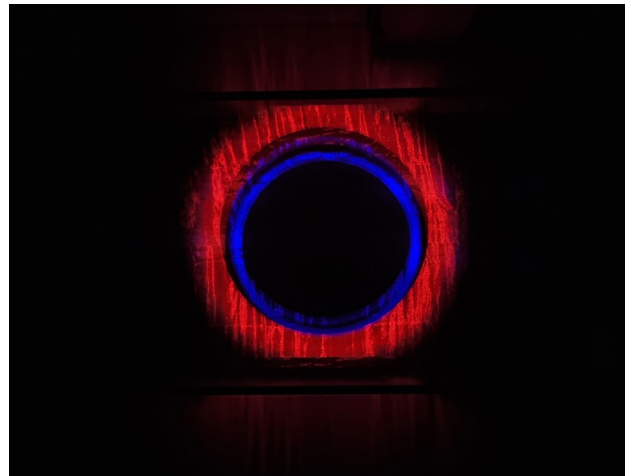


Figure 5.11: Red and blue circle creating the portal effect

The visual narrative is concluded by showing the title of the installation (figure 5.12). First "Selective" appears in red and subsequently "Reflections" appears in blue to show the occupation on the different layers one more time. Then both words fade to white to showcase how each layer selectively reflects its own colour. This final effect is carried out to complete the cycle that the viewers has been through. By ending with the white words, the viewer receives one last cue on what the installation was about. Besides, the white words also smoothly transition to the white lines, when the sequence is repeated again.

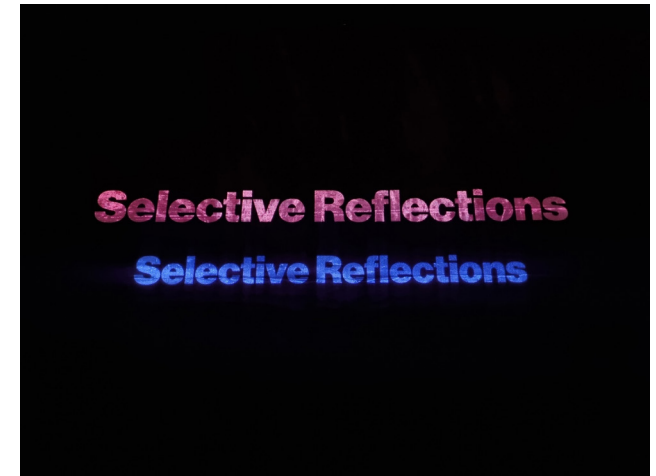
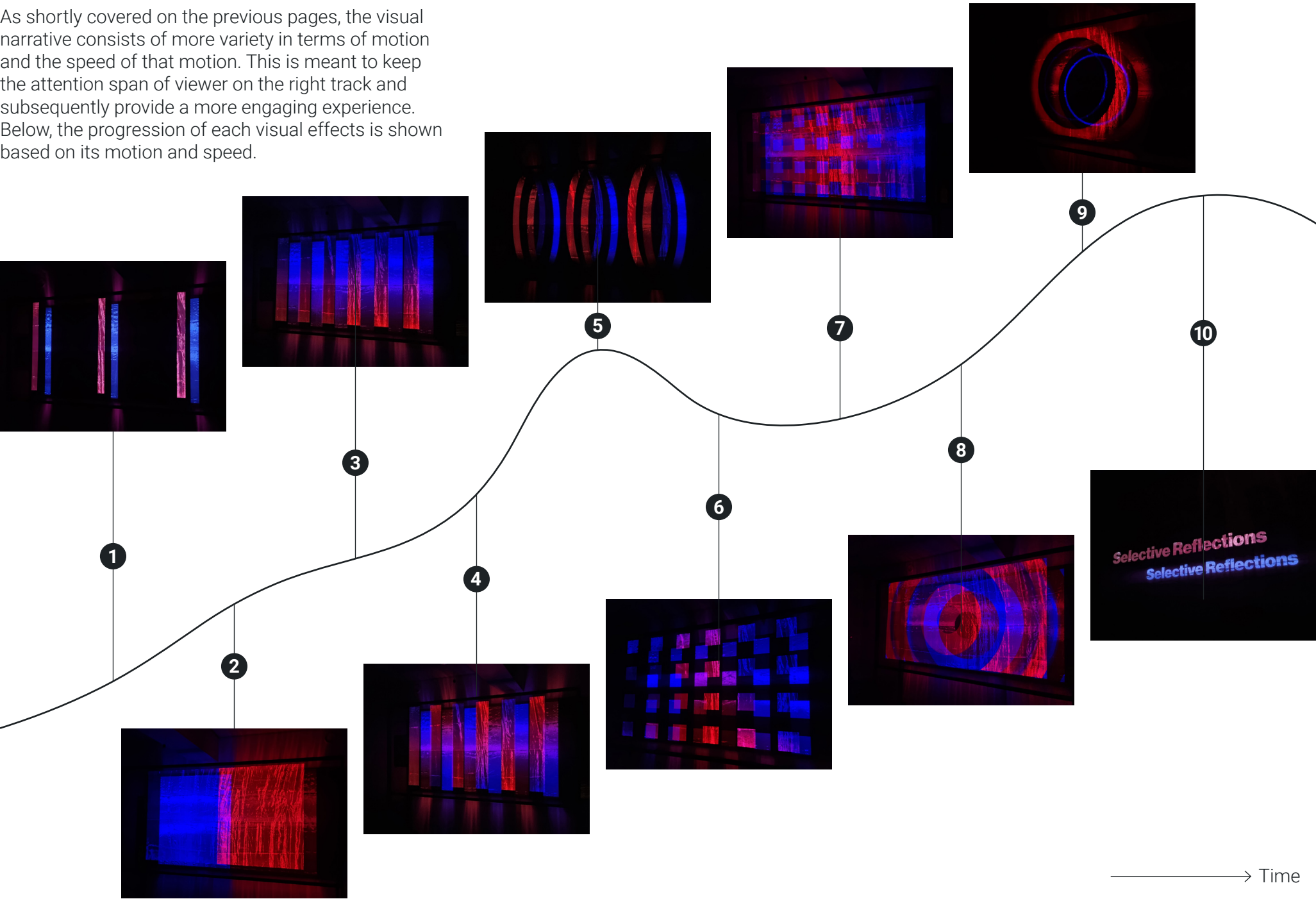


Figure 5.12: Installation title as credit

As shortly covered on the previous pages, the visual narrative consists of more variety in terms of motion and the speed of that motion. This is meant to keep the attention span of viewer on the right track and subsequently provide a more engaging experience. Below, the progression of each visual effects is shown based on its motion and speed.



5.2 Audio

Audio is added to the experience because of multiple reasons. The audio triggers an extra sense next to the visuals, it improves the viewer's attention span, it strengthens the visual differences in depth, it strengthens the visual movements, it increases the multi sensory integration and therefore provides a more meaningful perceptual experience. The audio is made in a Digital Audio Workstation called FL Studio and uses multiple synthesizers, samples and effects. Zooming out on the whole composition, the audio goes from mysterious and exciting in the first sequence, to calm and peaceful at the square visuals, to more hopeful and subsequently tension near the end. One of the most used effects in the audio is explained in figure 5.15. To imitate the visual movements, most of the time a filter is used. Figure 5.15 shows two images of a bandpass filter moving from left to right, going from low to high frequencies and subsequently changing the sound from dull to bright. This effect is the strongest at the circulating loops, because of the bandpass filter that only allows a narrow band of frequencies to pass through. This kind of effect is used multiple times, like in the portals shown in figure 5.14. A low pass filter, which only allows low frequencies to pass through, is automated to let more high frequencies pass through overtime. This increases the brightness of the sound and simultaneously increases the tension. Transitions between visual parts are most of the time defined by FX samples shown in figure 5.13. FX samples can consist out of a 'whoosh' sound or an impact sound for example. By adding reverb to the sounds, which means placing the sound in a certain space, transitions can be bridged more smoothly. By precisely matching the synthesizers, samples and effects with the visuals cues a complete, coherent experience is created.



Figure 5.13: Combination of multiple FX

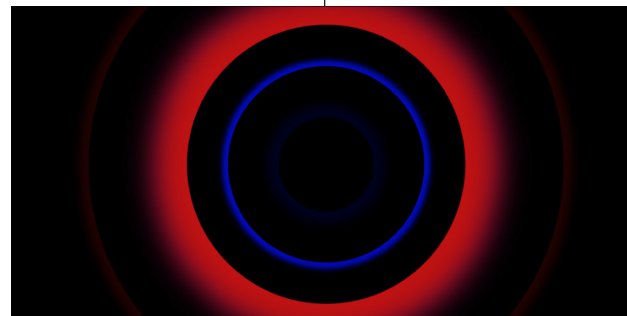
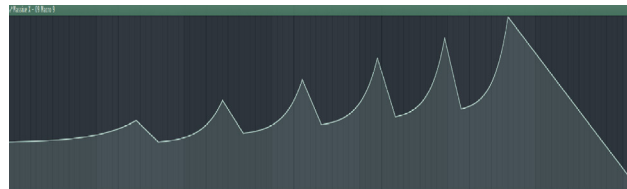


Figure 5.14: Increasing filter to increase tension

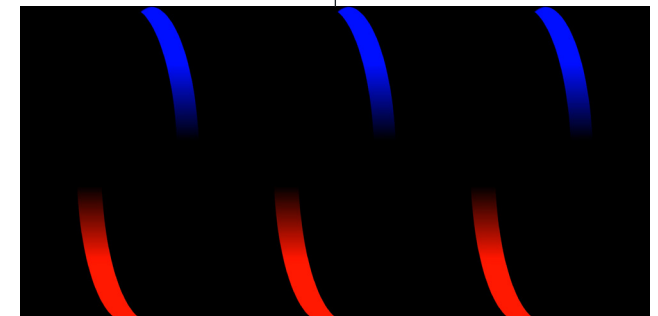
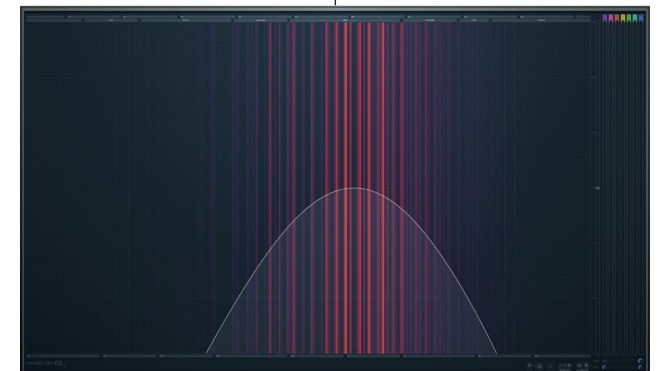
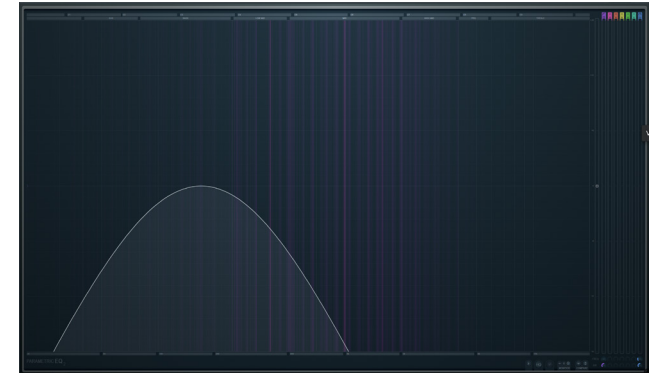


Figure 5.15: Moving bandpass filter to enhance movement

5.3 Textile

Explorations

During the project, multiple textiles were explored to see how the projections would reflect, absorb and transmit light. Over time, the goals for the best textile became more clear. The front red layer had to be transparent enough to provide enough light transmission and keep the rear layer visible. The front red layer should minimize the blue reflections, to strengthen the colour separation per layer. The blue layer need to provide strong blue reflections, as it is the rear layer of the installation. These goals also became more clear by testing different textiles. Figure 5.16 and 5.17 both showcase a test with different textiles. In both situations the textiles in the frame upfront are compared to the organza layers in the large, main frame. Especially, the test in figure 5.17 was insightful. Instead of using organza, silk was used. The silk showed highly vibrant colours for both red and blue, but lacked the transparency property. Besides, the blue projections were strongly reflected by the front red layer. Subsequently, the rear layer of silk was not visible anymore, which was undesirable. Even testing with different types of organza resulted in great differences. Figure 5.19 shows a red and blue circle projected on red glitter organza. It can be seen that the red glitter organza facilitates vibrant red reflections, but also reflects the blue projections strongly. Figure 5.18 shows an exploration on the absorption cloth distance. When placing the cloth at a certain distance of the rear blue layer, a reflection was still clearly visible. This exploration made clear that the absorption cloth should be directly attached to the rear layer to cancel out an unwanted third reflection.

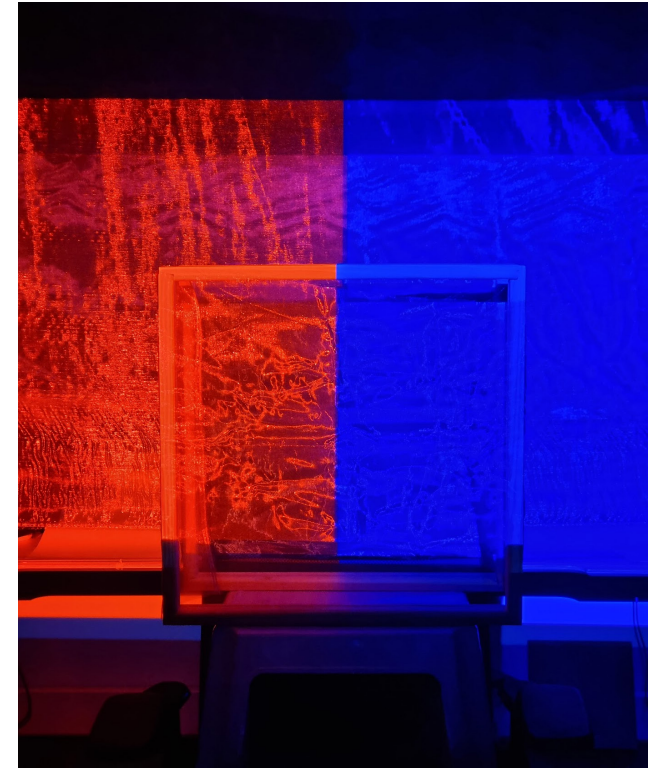


Figure 5.16: Two different shot organza's in front frame

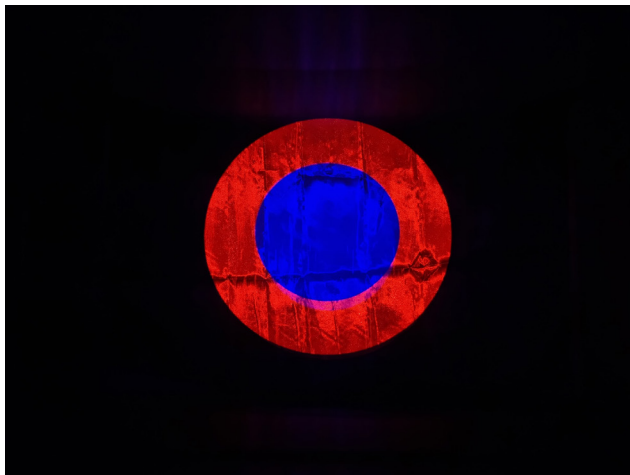


Figure 5.19: Exploration on red glitter organza



Figure 5.18: Exploration on the absorption cloth distance

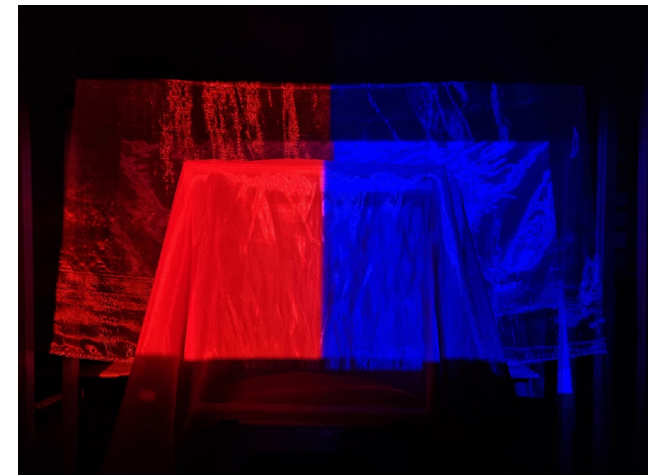


Figure 5.17: Red and blue silk in front frame

Final textiles

After testing out multiple textiles in the light lab at the faculty, the blue organza was defined but the red organza was still not found. By setting up a meeting with Noëlle van der Hagen, a light and textile artist, more red organza's were explored. This meeting resulted in finally ordering the right type of red organza. Figure 5.20 shows the final red shot organza. It effectively meets all the requirements listed on the previous page. Especially the vibrancy of the red reflections was insufficient before, but this type solved this problem. Figure 5.21 shows the final blue glitter organza. During the explorations, it soon became clear that this was the type of organza that met the requirements. The absorption cloth in the final design is a professional thick absorption cloth used to minimize reflections to a great extent. Figure 5.22 shows the process of preparing the textiles before stretching them onto the frame. The absorption cloth was first sewed to match the dimensions of the frame. Subsequently, the red layer and the blue layer together with the absorption cloth were ironed. Ironing helped to flatten out the folds that emerged in the packaging of the textile, but it did not result in completely flattened layers. Especially the blue layer showed some imperfections that did not disappear when ironing. These imperfections can be seen in the upper right part of figure 5.23. Fortunately, these imperfections are not as evident when it is dark and when the visuals are projected. The layers are stretched in such a way that it is still able to move a bit. When someone walks by or when there is an airflow in the specific room, primarily the front red layer slowly waves in the frame.

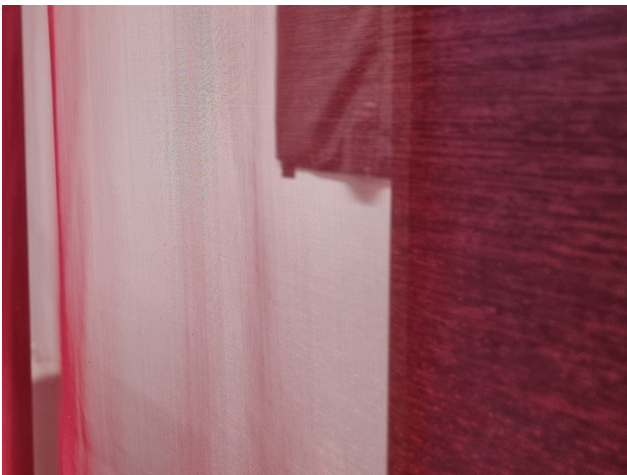


Figure 5.20: Final red short organza



Figure 5.21: Final blue glitter organza

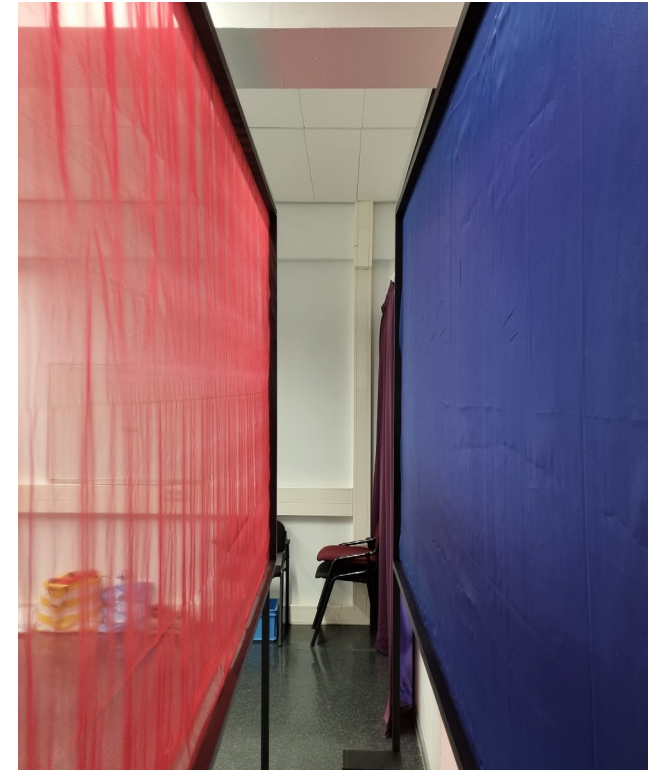


Figure 5.23: The three textile layers stretched in the frame

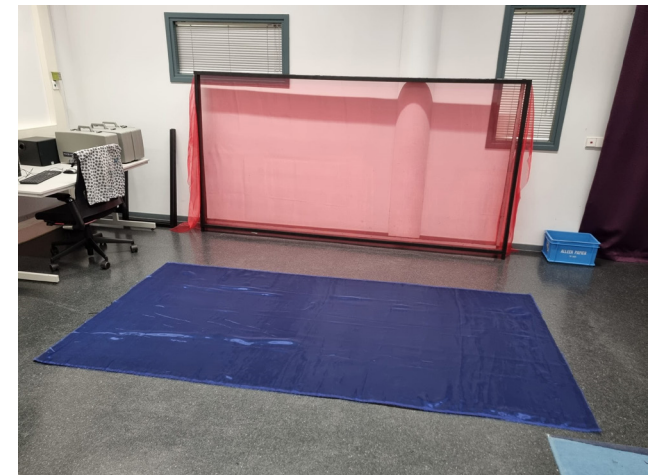


Figure 5.22: Preparation process for the textiles

5.4 Frame

Design

As no parts may be attached to the wall and ceiling, a frame with integrated supports was chosen. Figure 5.24 shows the CAD model of the frame and figure 5.25 the final design itself. By directly connecting both frames through one support, the design eliminates the need for two separate supports for each frame. This also ensures that there are no protruding parts in any direction. This design choice prevents visitors in the dark environment from stumbling over the support of the frame. In addition, this design facilitates visitors to have a clear look on the rear layer, when looking from both sides. This can help in seeing the colour and reflection of the rear layer and subsequently understand the installation in a better way. The design consists of square tubes used for construction and U-profiled beams on the rectangular parts used for clamping the textile.

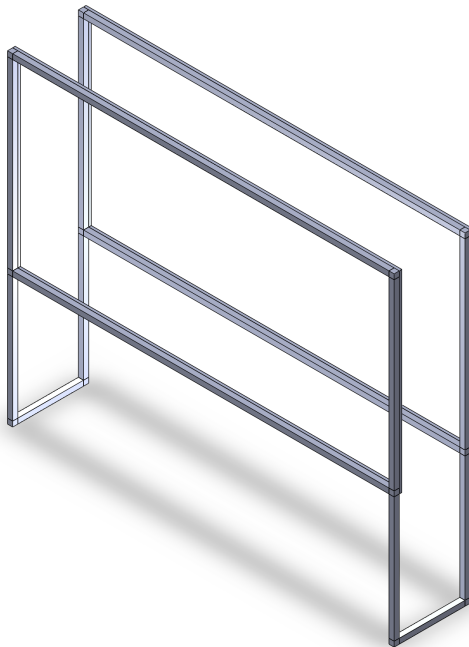


Figure 5.24: CAD model of the frame

Material

Multiple factors have led to the decision to make the frame and support out of aluminium. The ability to easily disassemble and rebuild it at the festival location is the most important factor. The aluminium tubes are connected by pre-made joints. Additionally, the aluminium tubes have a great machinability. This made it possible to press blind rivet nuts into the square tubes. The nuts have a screw thread inside them to which the U-profiled beams could be attached to with several bolts. By combining the aluminium tubes with pre-made joints and screw threads, the design is made suitable for disassembly. Another factor is the rigidity of the aluminium tubes. The aluminium tubes must remain rigid over a reasonably long distance and this could not be achieved with for example wooden beams having the same dimensions. The rigidity of the aluminium tubes also facilitates the frame and support to be thin. A thin design provides more area for the organza to stand out. Lastly, the organza has a low weight, which also facilitates a thinner profile. Only the professional absorption cloth is considerably heavier than the organza, but this is solved by adding enough blind rivet nuts with screw threads to divide the forces.



Figure 5.25: Perspective view on the build frame

Details

Joints

The joints used have a steel core for extra strength and load-bearing capacity, which can be seen on the right image of figure 5.26. The joints provide a simple assembly, by simply hitting the joint in the according tube with a plastic hammer. Additionally, the joints can be dismantled and reused multiple times. Figure 5.27 shows how one of the T-shaped joints connects three aluminium tubes. Besides, the colours of the joints and the chosen paint match great. Figure 5.28



Figure 5.26: Different joints used in the design (Verpas, z.d.)

Paint

The paint that is used for the aluminium parts is a matte, black paint by the brand Hammerite. It is especially made for metals and it can directly be painted on the material, without the need of a primer.

Textile

The two organza layers and the absorption cloth are clamped between the square tubes and U-profiled beams. As described previously, the press blind rivet nuts with screw thread allow both profiles to be tightly attached by bolts. In the textile layers holes were made at exact same positions as the screw threads to allow the bolts to pass through the U-profile and textile. By attaching the textile to the frame per side there is the possibility stretch it reasonably tight onto the frame. Figure 5.29 shows a side view of the frame. In this view it is clearly visible how the U-profiles are tightly attached to the square tube. A connection detail can be seen in figure 5.30. This detail also shows that the back part of the U-profile is not painted to save paint for possible restoration moments. Besides, the back part of the U-profile is not directly visible for the viewers of the installation.



Figure 5.27: Joint connection



Figure 5.28: Intersecting of U-profiles

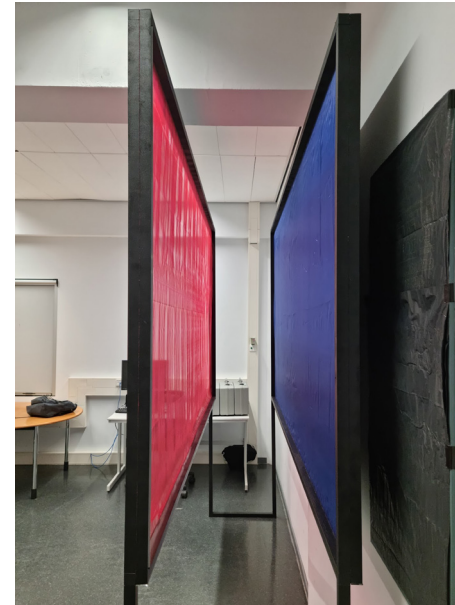


Figure 5.29: Side view



Figure 5.30: Connection detail

Dimensions

The distance between the organza layers is kept on 55 centimetres. This distance works best when keeping all the visual effects in mind. The visuals that consist of rectangles work better with a shorter distance, while the distance can be increased when the portal effect is projected. As the organza can be ordered with a maximum width of 1,5 meters, the height of the frame is limited at 1,5 metres maximum. The width of the frame is defined at 3 meters, because of two main reasons. The material shop at the faculty only offers tubes of 3 meters long. When longer tubes were desired, the tubes should have been ordered at a metal shop. In addition, the aluminium price was more expensive than expected. A wider frame would have led to a great increase in material costs, which was not desired. The main measurements of the design are shown in figure 5.31. The vertical centre of the organza layer is based on the average length of a Dutch adult, which is 1,76 metres (CBS, z.d.). The aluminium tubes have a rectangular profile with a dimension of 30 by 30 millimetres and a wall thickness of 2 millimetres. The U-profiled strips have a cross section of 30 by 30 millimetres and a wall thickness of 2 millimetres. Figure 5.32 shows how the measurements worked out in a real environment.

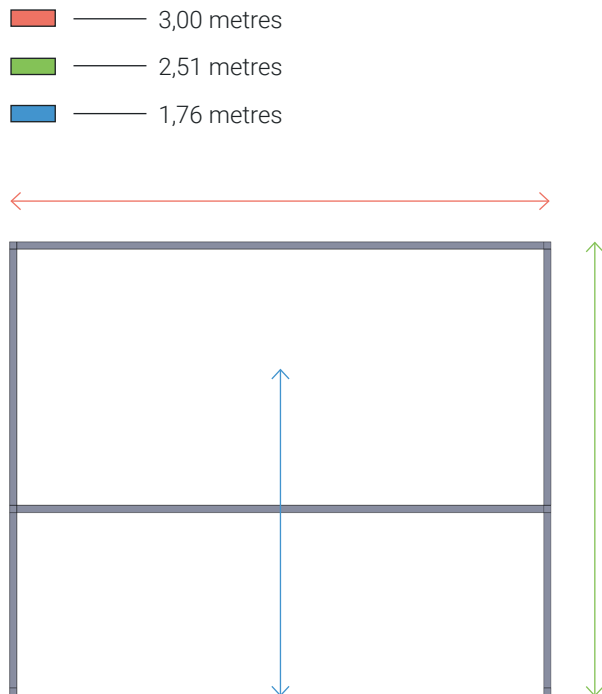


Figure 5.31: Front view with measurements



Figure 5.32: Front view of final design

Safety

The frame itself is heavy enough to not fall over when someone bumps into the frame. Therefore no additional features are added to the frame to add weight. One thing that should be added is a wire at the end of each frame opening. This frame opening is shown in figure 5.33. Visitors could possibly feel the urge to walk in between the layers, which is undesirable. A fishing thread could be a solution to this problem. It is strong, but it is hardly visible, which makes the appearance of the frame unchanged.

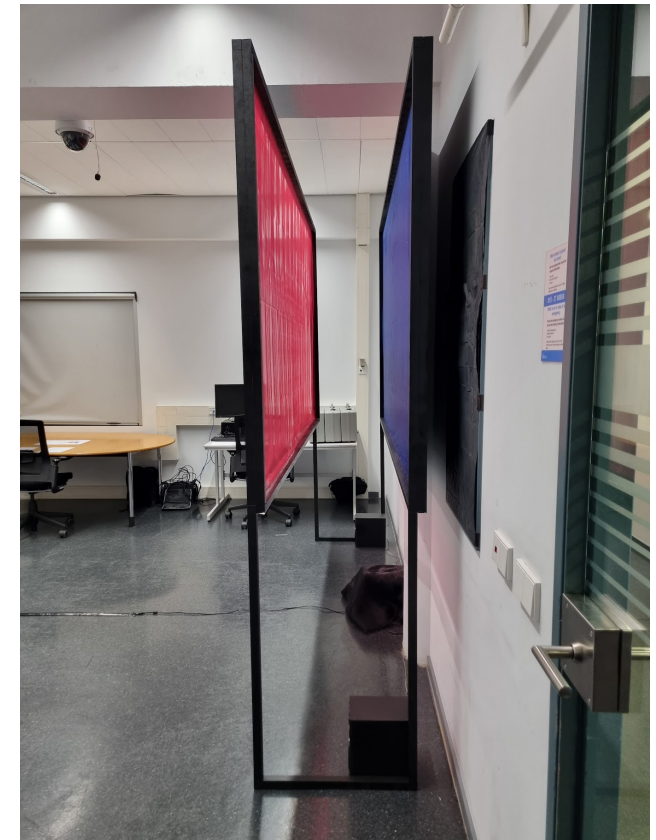


Figure 5.33: Side view where the frame is open

Frame with reference screen

The last test revealed that the projection on cardboard took too much space and attention away from the participants. As the organza projection is the part of the installation that the attention should mainly go to, the cardboard projection is converted to a small screen. The screen shown in figure 5.38 has a resolution of 1280 x 800 pixels and is around 23 centimetres wide and 15 centimetres high. The screen is placed in a frame following the same design language as the frame where the organza is stretched in (figure 5.34). To minimize costs, the wooden beams of the prototype are reused to construct the frame. To make the screen perfectly fit into the frame, the wooden beams will be milled in the region where the screen will be positioned. In this way, the screen is tightly concealed in the frame and this minimises the chance that visitors might want to do something with it. In addition, it creates a minimalistic and calm view to look at (figure 5.35). Another feature to make the frame with reference screen as clean as possible is the notch in the frame for the cable management of the screen shown in figure 5.36. The cables can be hidden in the notch which also add to the clean appearance of the frame. To prevent the frame from falling over, the frame is dimensioned in such a way that general sized tiles can be placed on the beams of the frame (figure 5.37). Lastly, the wooden frame will be painted with matte black spray paint to match the appearance of the frame with organza. Depending on the availability of wood, the tiles will be covered with thin wooden panels or they will directly be painted black to match the overall appearance. The centre of the screen is positioned at around 117 centimetres. With this height, the view to the frame with organza is not obstructed.

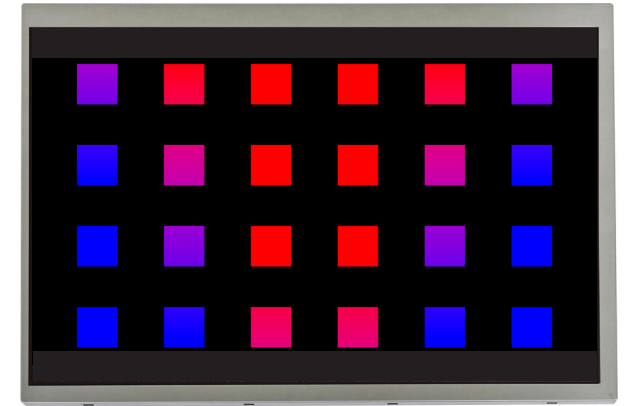


Figure 5.38 Screen with visuals

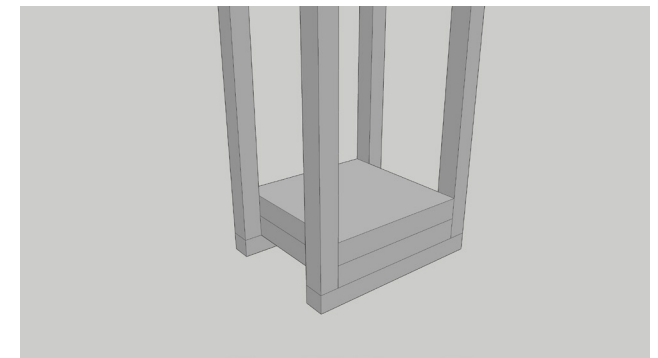


Figure 5.37: Space for tiles to add weight

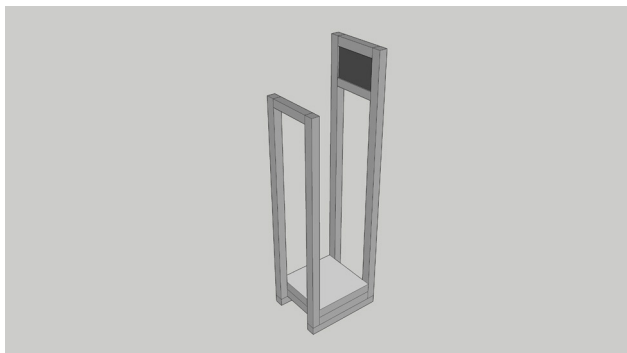


Figure 5.34: Overview on frame for reference screen

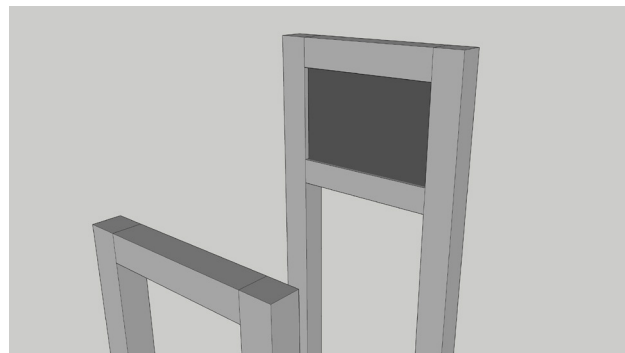


Figure 5.35: Screen concealed in the frame

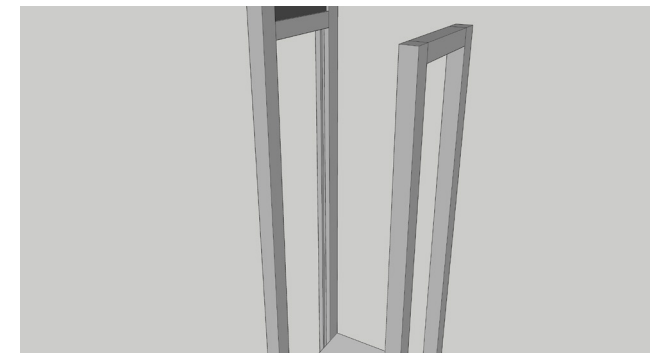


Figure 5.36: A notch in the frame for cable management

5.5 Exhibition space

Exhibition space

The exhibition space will be one of the hotel rooms in The Social Hub in Delft. Figure 5.39 and 5.40 shows the room from two different perspectives. Simplified, the room consists of an entrance, bathroom and sleeping area. The room has multiple windows that need to be covered up to completely darken the room. Besides, the furniture and decoration in the room will mostly be removed to make room for the frame and for the visitors to walk around. Highlight wants to keep the hotel atmosphere somewhat alive and therefore the desk and television will not be removed, as they do not obstruct the experience.

Projector

In terms of the projector, two specifications are important for this context. The contrast ratio and throw ratio. Figure 5.41 shows a projection of a projector with a low contrast ratio. Black visuals are still being projected as low intensity light. Therefore the projector has to have a high contrast ratio, so black visuals will not be projected. The throw ratio is the ratio between the projector distance and projection width. A projector with a throw ratio of 1:1 can project an image of 1 meter wide at a distance of 1 meter. It would be preferred to choose for a projection distance a little but further away from the frame. This will create less offset (figure 5.42) and better alignment of visual elements when watching perpendicular to the frame.

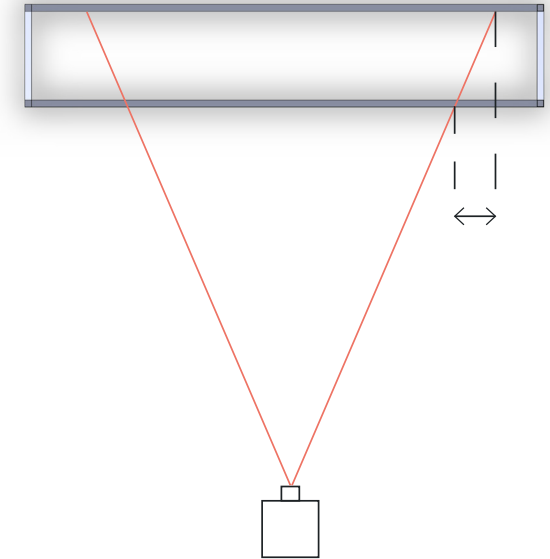


Figure 5.42: Projection offset on layers depending on projection distance



Figure 5.39: Perspective on frame side



Figure 5.40: Perspective on entrance side



Figure 5.41: Black visuals projected with low light intensity

Room layout

Figure 5.43 shows the room layout with accompanying dimensions. The legend is as follows:

- C — Curtains
- P — Projector
- S — Frame with screen
- O — Frame with organza

Both frames are drawn in scale, except for the projector and the curtains. The frame with organza is positioned on the right side of the room. This side is completely coverable with black curtains. This provides a calm and consistent background in front of which the frame can be placed. The frame is positioned a little bit off the wall to make room for the black curtains. In addition, this frame position allows visitors to enter the room without disrupting the view of visitors who are already in there. The black curtains also facilitate the speakers to be positioned out of sight, which also enhances the calm appearance of the space. The projector will be delivered with a stand. Currently, it is positioned against the bathroom door. If the projector is too close to the frame with organza, it could be an option to position the projector a little bit inside the bathroom to minimize the projection offset. This is only possible if the projection height is great enough from within the bathroom. This issue is illustrated in figure 5.44. The frame with screen is now freely positioned between the projector and the frame with organza. When the position of the projector is fixed, the frame with screen can be positioned accordingly. Visitors should be able to walk behind it and stand in front of it without disrupting the projection. In this way, visitors can enjoy the organza projection without the screen in sight. The two curtains placed at the entrance of the room are optional. If there is too much light coming in the room from the hallway, the curtains could be an option.

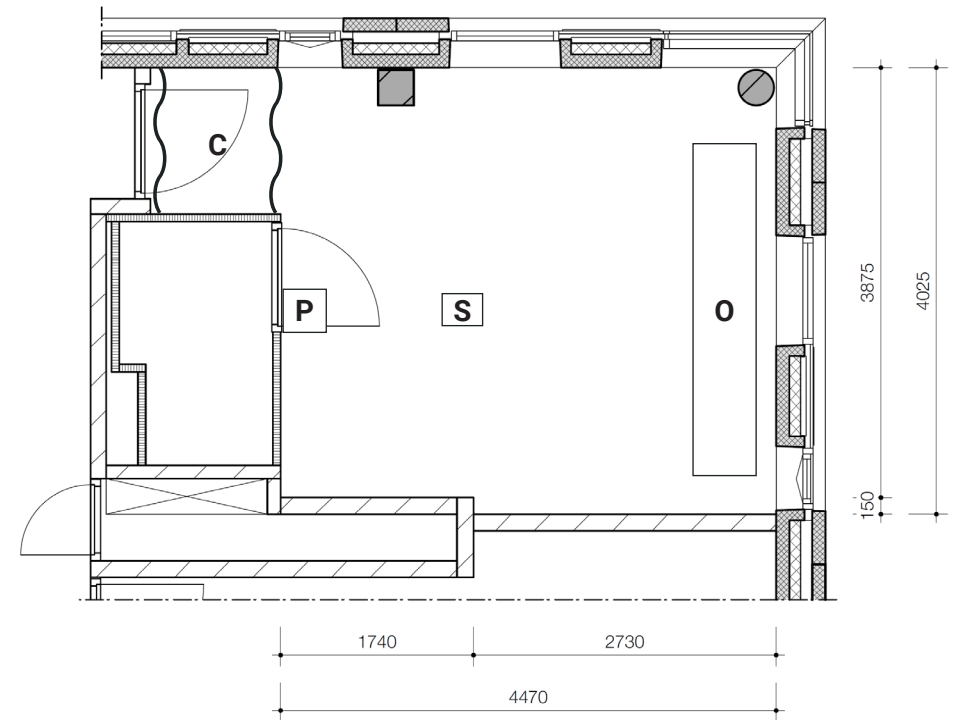


Figure 5.43: Room layout

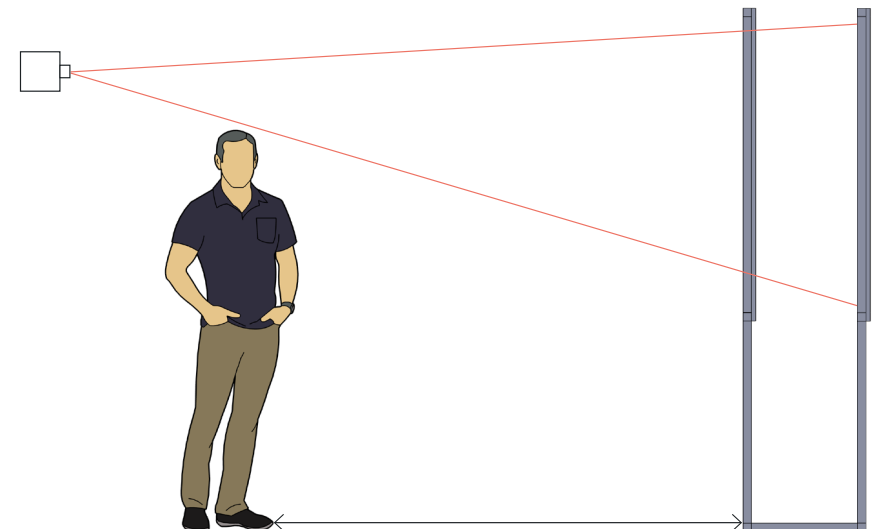


Figure 5.44: Projector height and visitor distance

5.6 Communication

Information sign

Next to the communication aspects of the installation itself, the information sign proofed to be of great importance for understanding the experience. The information sign in figure 5.45 was used during the last test. It is presumed that festival visitors do not want to spend too much time reading or completely understanding signs. Therefore the sign is kept simple since the beginning. It only consists of a title, subtitle, illustration and QR-code. Figure 5.46 shows a dark version of the information sign. This version matches the actual environment, but the red and blue colours stand out less clearly. The sign in figure 5.45 worked during the last test, but the participants were pointed to it. By discussing the information sign with the supervisory team, a new iteration could be made. In the iteration shown in figure 5.47 the title is removed and the subtitle enlarged. As the title is already present on the general information sign, it was not necessary to repeat it again. Instead, the subtitle obtains more focus. The question in the subtitle ensures that the reader is being activated and hopefully gets motivated to understand the sign. While this iteration is used for the validation test, it could still be improved. Especially, the words spectral tuning can be too difficult to get a grasp on for many visitors. As consequence, this could result in visitors to drop out and not check the illustration, harming the understandability of the experience. In addition, the visitors should enter the room with the right expectations as the experience is more on the educational side than the art side. The information sign could help in setting the right expectations before entering the room. Figure 5.48 shows that the room is at the end of a hallway, which makes the wall next to the door perfect for hanging up the information sign. This ensures that visitors will always encounter the sign, reducing the likelihood of missing it.

Selective Reflections

How to select reflections?
Spectral tuning!

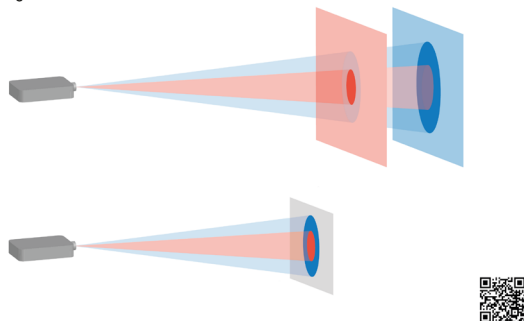


Figure 5.45: Information sign used in second test

Selective Reflections

How to select reflections?
Spectral tuning!

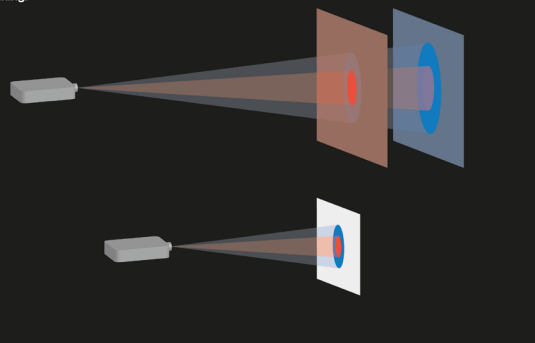


Figure 5.46: Dark version of information sign

How to select reflections? Spectral tuning!

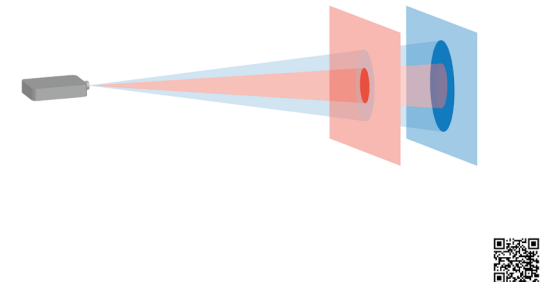


Figure 5.47: Latest iteration of information sign



Figure 5.48: Hallway to exhibition space

6 Validation

This chapter functions as the final validation moment of the final design. This chapter will describe how the research on the final design is conducted and which results it has brought. The chapter will be concluded with a conclusion, discussion and recommendations for future improvements.

6.1 Test setup

Research aim

The aim of this research is to test whether the final design meets the objectives defined during the design process. The test conducted in earlier stages of the process indicated that the prototype had already achieved the objectives to some extent. Despite this, the final design was yet to be completed, and there were still aspects that could be improved. This last validation test is intended to determine whether the improvements still align with the objectives or even exceed them.

The test setup is almost kept the same as the previous test. There is only one question added, covering the audio aspect of the installation. This question ensures that the test will reveal if the added audio enhances the experience. Once again, this test tries to mimic the characteristics of the environment where the final design will be presented. For a list of the objectives and an explanation about the recruited participants, see chapter 4.1. This test was conducted on 8 participants.

6.2 Method

Tools and equipment

The test setup consisted of the following tools and equipment:

- Frame with two organza layers (red and blue) and an absorption cloth
- Laptop stand
- Laptop
- Projector
- Sound installation
- Information sign
- A dark environment

The test is conducted in the multi sense lab of the Industrial Design faculty. In comparison with the audio lab, the multi sense lab allowed for enough space for the frame, while also providing enough space for the participants to comfortably switch viewing angle. The test setup, with all the tools and equipment can be seen in figure 6.1. Figure 6.2 shows that the position of the laptop stand facilitates participants to watch both the screen and projection. As the multi sense lab did not feature a dedicated cabin similar to the audio lab, where participants could fill in the documents in a well-lit environment, the decision was made to fill out the documents on one of the tables. This involved turning on the lights between rounds to ensure readability of the text (figure 6.3).

Procedure and data collection

This test follows almost the same procedure as the test with illustrative introduction described in chapter 4.2. As stated in the research aim, the only thing that is added to the test is the question about the audio. This Likert-scale question is part of the post-test questions and reads: The audio enhances the experience. The adjusted survey can be found in appendix 10. The only difference is the new information sign and the fact that the documents are filled in in the same space as the experience itself. The information sign used in this test, is showcased in chapter 5.6. The data collection also follows the same structure as described in chapter 4.2.



Figure 6.1: Test setup

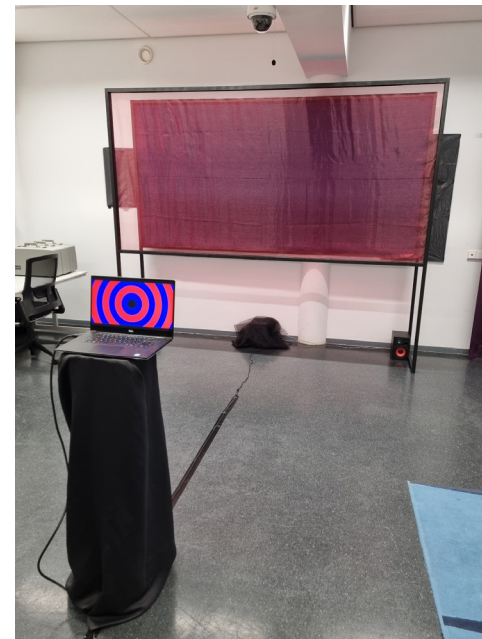


Figure 6.2: View on screen and projection

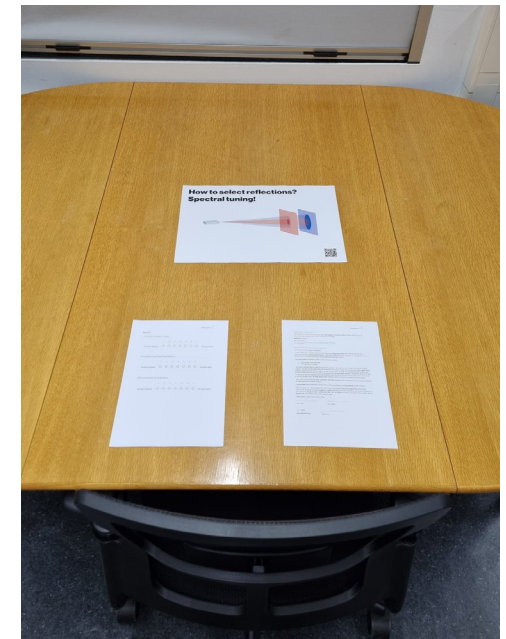


Figure 6.3: Survey and information sign

6.3 Results

The quantitative data consists of the results of this test (within group) and a comparison of the results from both tests (between group). This subsection is finalized by a summary of the qualitative data.

Within group

Figure 6.4 shows a bar chart with the results of the attribute ratings on the laptop screen and organza projection. The y-axis shows the rating score and the x-axis is divided into the attributes depth, beauty and immersion, and the sequences ranging from 1 to 3 for each attribute. The bars represent the means of the attribute ratings, while the error bars show the standard error. The chart clearly shows that the attribute scores of the laptop screen are considerably lower than the attribute scores of the organza projection. In addition, there is no gradual increase in the score per sequence. The second sequence scores somewhat higher than the third sequence on every attribute.

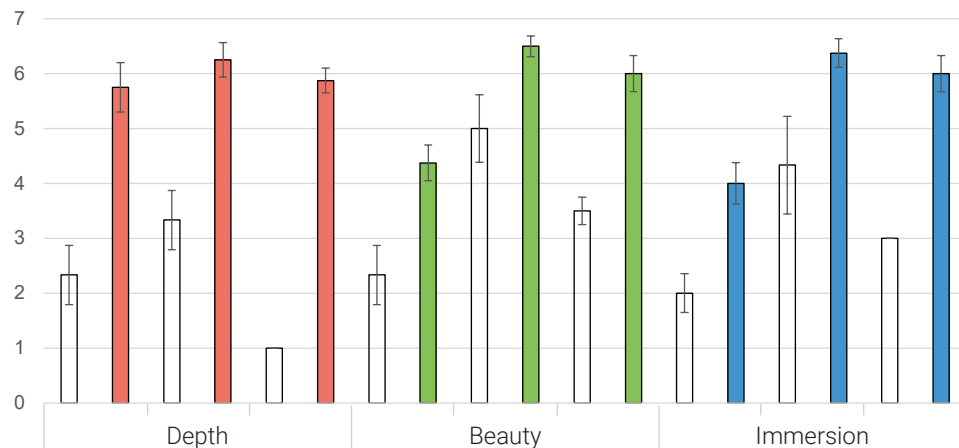
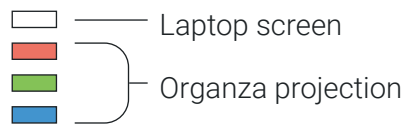


Figure 6.4: Laptop screen and organza projection rated per attribute and sequence

In addition, it is notable that the scores of the depth attribute for the organza projection are reasonably close together in comparison with the other two attributes. Lastly, it can be seen that the error bars are quite small for the organza projection and slightly larger for the laptop screen. Figure 6.5 shows the score of the observed actions during the test. The bar chart shows that seven out of eight people walked around to switch viewing angle. Each participant has read the information board since they were pointed to it. The accompanying QR code was not scanned in any case. Figure 6.6 shows the ratings of the post-test questions. It can be seen that each attribute scored in the upper region of the scale. Only the engaging attribute scores slightly lower than the coherence and audio attribute. The coherence and audio attribute have the exact same score. Once again, the error bars are fairly small.

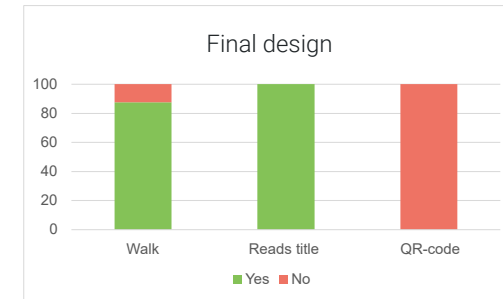


Figure 6.5: Observed actions during the test

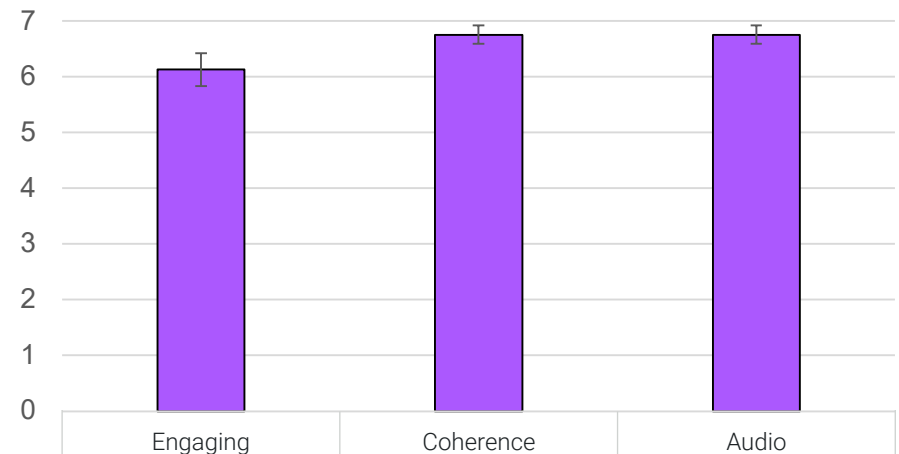


Figure 6.6: Ratings on post-test questions

Between group

The bar chart in figure 6.7 showcases the attribute scores of the organza projections from each test to provide a complete overview of the tested conditions. The legend shows the corresponding information to read the chart correctly. It is important to note that the final design is also tested with an illustrative introduction and the names of the first conditions are just to distinguish them from each other. When analysing the depth attribute, the final design scores higher, on average, than the conditions tested previously. For the beauty attribute, the scores for each condition are consistently close to each other within each sequence. The immersion attribute shows the largest differences for each condition tested. On this attribute, the previous conditions score higher on average than the final design condition. Especially the condition of the second test scores higher than the final design condition. In summary, the final design scores better on depth, equal on beauty and less on immersion.

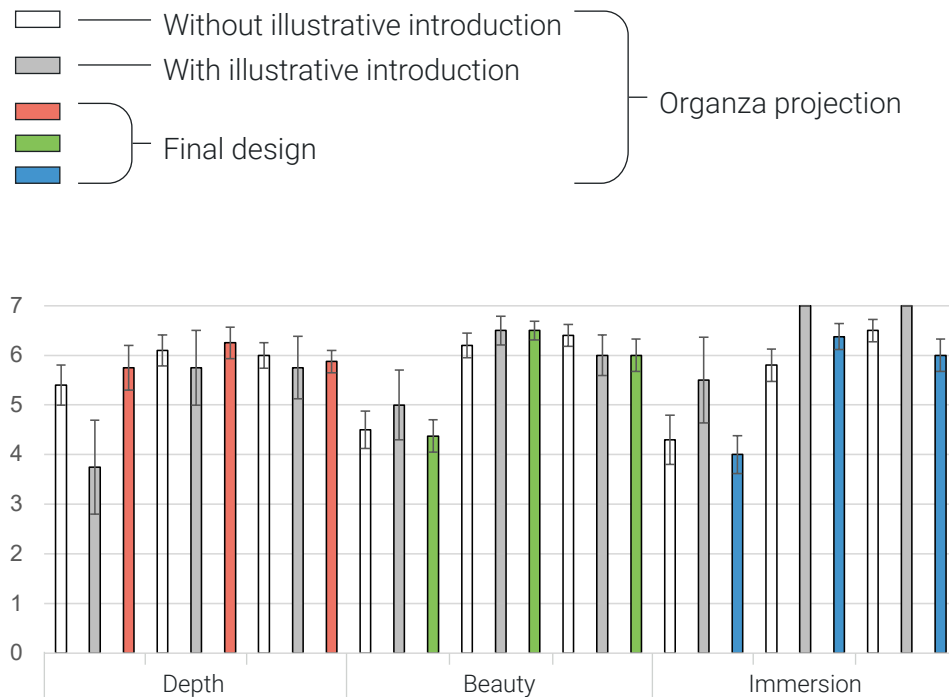


Figure 6.7: Organza projections rated per attribute and sequence for each group

Figure 6.8 shows the ratings of the post-test questions for each condition except the audio. When analysing the engaging attribute, the final design scores slightly lower than the condition with illustrative introduction, but higher than the condition without illustrative introduction. The coherence attribute shows a gradual increase in score, with the final design scoring the highest. The audio was only present in the final design and could therefore not be compared to earlier conditions. Despite this fact, participants in the latest test strongly agree that the audio enhances the experience.

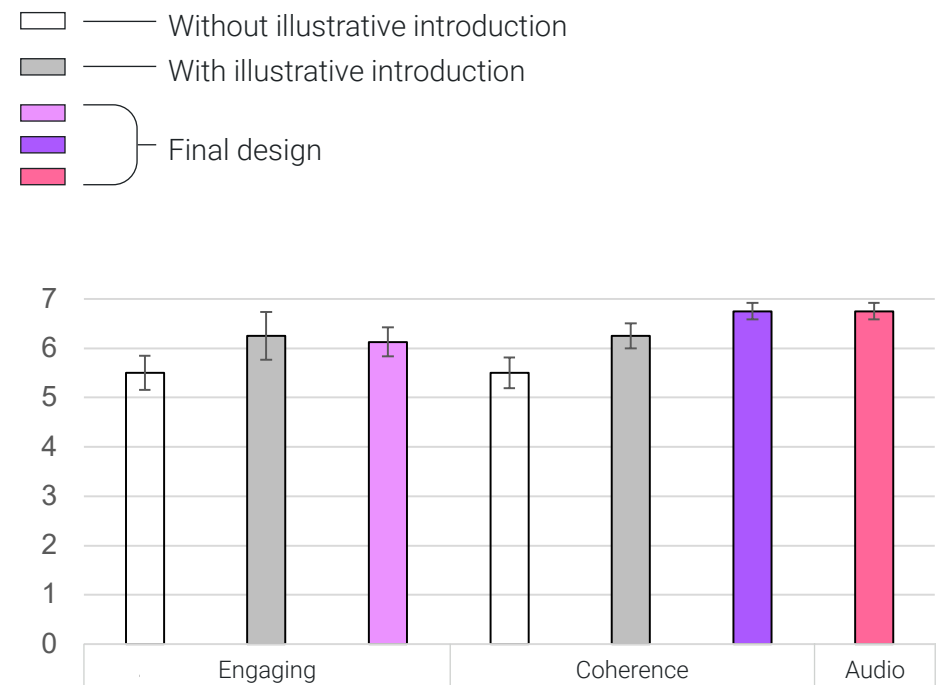


Figure 6.8: Ratings on post-test questions for each group except the audio

Qualitative data

The only qualitative data retrieved from the test emerged from the open question at the end. Figure 6.9 shows a selection of comments and remarks from the open question categorized by visual narrative, setup and audio. In the previous test there were comments about the communication aspect, but this was not the case for this test. Some comments were repeated by multiple participants and are numbered accordingly. In contrast with the previous tests, figure 6.9 shows all the comments that were made instead of only showing a selection. There were not a lot of comments made so that's why the choice was made to show them all.

When looking at the comments on the visual narrative, two participants stated that they favoured the rotating loops. One of them also stated that the squares are not satisfying in comparison with the loops. One participant would like to see more colours. The comments on the setup consists of one approval and three recommendations. The recommendations vary from frame position, screen distance and the possibility to sit. The approval focusses on the texture of the fabric that makes the visuals more intriguing. Furthermore, three participants explicitly commented that the audio improves the experience. There was one comment suggesting to play with the panning of the audio.

Visual narrative

- 2 Rotating loops are in favour
- 1 The squares are not satisfying
- 1 I would like more colours

Setup

- 1 Texture of fabric makes visuals more intriguing
- 1 Would be cool to experience this while looking at the ceiling
- 1 Interesting to see how screen distance would affect the experience
- 1 Installation would be more engaging if there was a place to sit

Audio

- 3 Audio improves experience
- 1 You could play with the right and left side of the speakers

Figure 6.9: Comments on the full experience by count

6.4 Conclusion

This last validation of the final design and the comparison with the previous tests resulted in different insights. One of the large changes in the final design is the screen instead of the cardboard projection. Figure 6.4 shows that this change still results in a difference between the screen, the 2D image, and the organza projection. Another important aspect that stands out, is the fact that for each attribute there is no gradual increase per sequence anymore. This could be caused by multiple reasons. The most plausible reason is the amount of motion added to sequence 2. A second reason could be the addition of the loops, which were in favour of some of the participants. A third reason could be the audio which energetically accompanies the moving visuals. In addition, the audio is more varied in this sequence and the audio in the last sequence is a bit more calm and focused on creating suspense rather than mystery. All the reasons above could have directly led to more perceived depth, beauty and immersion. When analysing the observed actions in all tests, one notable aspect is that not all participants felt the need to switch their viewing angle. This aspect is currently not communicated to the user and perhaps that is something that is required to make this group change perspective as well.

When analysing the data between the three groups several things stand out. As described in the results, the final design scores better on depth, equal on beauty and less on the immersion attribute. When looking at the improvements made going from the prototype to the final design, one would expect to see that these improvements also result in overall higher scores. It could be possible that the visuals in the prototype were already perceived as beautiful and immersive, and that the improvements such as the frame, flattened organza and the audio did not directly contribute to a higher score. In addition, the scores of the second test were already quite high, especially when considering the immersion attribute. Another reason could be the amount of participants for the second test, which was fairly low ($n=4$). Despite the equal and lower score on beauty and immersion, the depth attribute scores notably higher on each sequence. One of the reasons could be the audio that tries to emphasise the movements of the visuals. By emphasising the visual differences in depth with audio, the participants seem to experience more depth, which is preferable.

When comparing the depth, beauty, and immersion attributes per sequence to the attributes of the entire experience, a contradiction emerged. While the final design scores nearly the same on the engaging attribute and higher on the coherence attribute, one would expect these scores to be reflected in the beauty and immersion attributes. Apparently, there is no clear relationship between the perceived overall experience and the beauty and immersion of single visual sequences. Once again, there is no obvious reason for this occurrence. The reasons stated in the previous paragraph could also be applicable in this situation. In addition, the differences between the scores are so small that it may not even be possible to extract a correlation. Another noteworthy observation is that the high score for enhancing the experience through audio is not directly reflected in the engagement score. When zooming out on the different results and tests, the few inexplicable results could also be caused by the expectations of the participants. When seeing the prototype in the first two tests, the visuals could exceed the expectations. When seeing the final design with accompanying audio, the visuals might not live up to the expectations.

As described in the previous subsection, little qualitative data emerged from the open-ended question. Some of the qualitative data confirms the quantitative data. For example the comments about the audio is reflected in the high audio score and the rotating loops could justify the higher attribute scores for the second sequence. Most of the comments were not directly applicable for the current context, such as adding more colours, positioning the frame on the ceiling or making the screen distance adjustable. Two notable comments that are relevant in the current context were about the option to sit and adjusting the sound panning to align with the visual movements.

6.5 Discussion

The aim of this last validation test was to check if the final design was still meeting the objectives positioned on the bottom of this page. The first communicative objective was already met in the second test by providing an illustrative introduction to the participants. In this last validation test the illustrative introduction is slightly improved, the organza is ironed, tightly stretched in the frame and audio accompanies the visual movements. The improvements facilitated achieving the first objective to a greater extent. The participants did not express uncertainties like the first test and this is also represented in the results. Therefore the first objective is met. The second objective is met by a greater extent than the previous tests. Especially, the depth attribute scores of the validation test confirms that the differences in depth are experienced by a greater extent.

The first experience objective is realized more successfully than before. By adding audio, the installation triggers an extra sense next to the visuals, expanding the experience. Besides, the audio enhances the visuals effects to highlight the effects of spectral tuning even more. Experience objectives two and three are less well achieved than in the previous test, as the scores for the immersion and engaging attributes are lower. Despite scoring slightly lower than in the previous test, the scores still remain at the high end of the scale. In terms of experience objective four, the final design scored equally well on the beauty attribute as it did before. The last objective is met more successfully as the attribute score is considerably higher than the scores of the previous tests.

Communicative objectives

1. The installation showcases how spectral tuning influences the absorption and reflection of light by material.
2. The installation showcases how the textile layers and tuned projections can facilitate differences in depth perception.

Recommendations

As the project consisted of two test moments, most of the recommendations that came forward from the first moment were already processed in the final design. Despite that fact, this last validation test still raised new recommendations. Some of these recommendations can be worked out before the display of the installation at Highlight and others could be processed when the installation will be reused later on. The recommendations are listed below in their corresponding category.

Visual narrative

The results of the validation test showcased that the attributes score a little bit higher at the middle part of the full sequence. The visual narrative could be improved to achieve a gradual increase in score over time, to lead the visitors to a climax at the end of the sequence instead of in the middle.

Setup

The full installation could incorporate seats. This way, users have the option to experience the installation seated, standing, or walking around. While the inclusion of seats may seem contradictory to the goal of allowing users to shift perspectives, it could also serve as a great solution for users with mobility impairments.

Communication

The information sign with illustrative introduction should be further iterated to set the perfect expectations for the users before entering the experience.

Audio

The audio could be improved by playing with the panning of sounds. Visual movements can be enhanced by giving the sound a matching direction, improving the overall experience.

Experience objectives

1. The installation showcases the effect of spectral tuning in an experiential manner.
2. The visuals should immerse the visitors in the narrative
3. The narrative keeps the visitors engaged
4. The visuals are appealing to look at
5. The total experience of the installation is coherent

References

- An, J., Won, K., Kim, Y., Hong, J. H., Kim, H., Kim, Y., Song, H., Choi, C., Kim, Y., Seo, J., Morozov, A., Park, H., Hong, S., Hwang, S. J., Kim, K., & Lee, H. (2020). Slim-panel holographic video display. *Nature Communications*, 11(1). <https://doi.org/10.1038/s41467-020-19298-4>
- Ashish. (2018, 29 maart). What Exactly Is A Tesseract? ScienceABC. <https://www.scienceabc.com/pure-sciences/what-exactly-is-a-tesseract-real-life-geometry-4-dimensional.html>
- Berg, A. S. (1993). Beauty. Tate. <https://www.tate.org.uk/art/artists/olafur-eliasson-5239/yes-but-why-olafur-eliasson>
- Bios. (z.d.). What is Circadian Lighting and How Does it Work? BIOS Lighting. <https://bioslighting.com/what-is-circadian-lighting-and-how-does-it-work/architectural-lighting/>
- Borkhataria, C. (2017, 9 augustus). "Café Wall" illusion makes straight lines look slanted. Mail Online. <https://www.dailymail.co.uk/sciencetech/article-4772156/Caf-wall-illusion-makes-straight-lines-look-slanted.html>
- brainHQ. (z.d.). Titchener Circles. <https://www.brainhq.com/brain-resources/brain-teasers/titchener-circles>
- Brambilla, A., Hu, W., Samangouei, R., Cadorin, R., & Davis, W. (2020). How correlated colour temperature manipulates human thermal perception and comfort. *Building and Environment*, 177, 106929. <https://doi.org/10.1016/j.buildenv.2020.106929>
- Čeněk, Š., & Čeněk, J. (2015). Cross-cultural differences in visual perception. *Questa Soft*. <https://www.ceeol.com/search/article-detail?id=290668>
- Changing Minds. (z.d.). Hue, Saturation and Luminosity (HSL). <https://changingminds.org/explanations/perception/visual/hsl.htm>
- Chung, S. (2013). Chiaroscuro. Sougwen. <https://sougwen.com/project/chiaroscuro>
- Cotter, K. N., Fekete, A., & Silvia, P. J. (2022). Why Do People Visit Art Museums? Examining Visitor Motivations and Visit Outcomes. *Empirical Studies of The Arts*, 40(2), 275–295. <https://doi.org/10.1177/02762374211011740>
- Craven, B. (2021, 27 september). Coloured shadows. Bencraven. <https://bencraven.org.uk/2021/09/27/coloured-shadows/>
- Datacolor. (z.d.). The Science of How We See Color—And Why We Need Spectrophotometers. <https://www.datacolor.com/business-solutions/blog/why-we-cant-agree-color-perception/>
- Dickau, R. (z.d.). 3-D L-Systems. Robert Dickau. <https://www.robertdickau.com/lsys3d.html>
- Dutt, S. (2021, 21 februari). Color Interaction Studies. Medium. <https://shreyadutt25.medium.com/color-interaction-studies-cc3f31e14b4b>
- DyViTo. (z.d.). Dinosaur skull rises from a 3D point cloud. <https://dyvito.com/2020/10/12/dinosaur-skull-rises-from-a-3d-point-cloud/>
- Eaton. (z.d.). Spectral tuning and IES TM-30-15. <https://www.eaton.com/ph/en-us/company/news-insights/lighting-resource/design/spectral-tuning-and-ies-tm-30-15.html>
- Ekroll, V., Sayim, B., & Wagemans, J. (2017). The Other Side of Magic. *Perspectives on Psychological Science*, 12(1), 91–106. <https://doi.org/10.1177/1745691616654676>
- Eliasson, O. (z.d.). Seu corpo da obra (Yo. . . • Artwork • Studio Olafur Eliasson. Olafur Eliasson. <https://olafureliasson.net/artwork/seu-corpo-da-obra-your-body-of-work-2011/>
- Ellard, G., & Johnstone, S. (2006, 1 oktober). BOMB Magazine | Anthony McCall. BOMB Magazine. <https://bombmagazine.org/articles/anthony-mccall/>
- Encyclopedia Britannica. (1972). Introduction to Holography [Video]. Internet Archive. <https://archive.org/details/IntroductionToHolography>
- Fraser, C. L., & Lueck, C. J. (2021). Illusions, hallucinations, and visual snow. *Handbook of Clinical Neurology*, 178, 311–335. <https://doi.org/10.1016/b978-0-12-821377-3.00014-3>
- Froner, B., Purves, S., Lowell, J., & Henderson, J. (2012). Perception of visual information - What are you interpreting from your seismic? *Proceedings*. <https://doi.org/10.3997/2214-4609.20148526>
- Gentet, P., & Lee, S. (2022). True holographic ghost illusion. *Optics Express*, 30(15), 27531. <https://doi.org/10.1364/oe.465247>

Gilbert, C. D., & Sigman, M. (2007). Brain States: Top-Down Influences in Sensory Processing. *Neuron*, 54(5), 677–696. <https://doi.org/10.1016/j.neuron.2007.05.019>

Glendenning, H. (2006). Between You and I. *Bomb Magazine*. <https://bombmagazine.org/articles/anthony-mccall/>

Hanover College. (z.d.). Subtractive Color Mixing. <https://isle.hanover.edu/isle2/Ch06Color/Ch06ColorMixerSub.html>

Hariharan, P. (2002). *Basics of Holography*. Cambridge University Press. <https://books.google.nl/books?hl=nl&lr=&id=K658764HVUIC&oi=fnd&pg=PR11&dq=holography&ots=T-REBrUPRD&sig=511ePfkRTHs2eAPBJmfJHg6e0el#v=onepage&q=holography&f=false>

He, D., Nguyen, D., Ögmen, H., Nishina, S., & Yazdanbakhsh, A. (2023). Perception of rigidity in three- and four-dimensional spaces. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1180561>

Herd, C. (z.d.). Perceptions of Light. *Aesthetica Magazine*. <https://aestheticamagazine.com/perceptions-of-light/>

Houser, K. W., Boyce, P., Zeitzer, J. M., & Herf, M. (2020). Human-centric lighting: Myth, magic or metaphor? *Lighting Research & Technology*, 53(2), 97–118. <https://doi.org/10.1177/1477153520958448>

Hypersonic. (2016). Constructive Interference. <https://www.hypersonic.cc/art#/constructive-interference/>

i8. (z.d.). Anthony McCall. <https://i8.is/exhibitions/109/>

Johnson, N. (2012, 31 oktober). Hopf Fibration. Wikipedia. https://en.wikipedia.org/wiki/Hopf_fibration

Katz, M. (2002). *Introduction to Geometrical Optics*. World Scientific Publishing Co. Pte. Ltd. <https://books.google.nl/>

Komarac, T., & Došen, Đ. O. (2021). Discovering the determinants of museum visitors' immersion into experience: the impact of interactivity, expectations, and skepticism. *Current Issues in Tourism*, 25(22), 3675–3693. <https://doi.org/10.1080/13683500.2021.1952941>

Kruisselbrink, T., Dangol, R., & Rosemann, A. A. (2018). Photometric measurements of lighting quality: An overview. *Building and Environment*, 138, 42–52. <https://doi.org/10.1016/j.buildenv.2018.04.028>

Laeng, B., Nabil, S., & Kitaoka, A. (2022). The Eye Pupil Adjusts to Illusorily Expanding Holes. *Frontiers in Human Neuroscience*, 16. <https://doi.org/10.3389/fnhum.2022.877249>

Lauer, D. (2022, 1 juli). Skyspace. *Dezeen*. <https://www.dezeen.com/2022/07/01/james-turrell-skyspace-installation-rocky-mountains/>

Ledmotive. (z.d.). Spectra Tune HCL - Ledmotive. <https://ledmotive.com/store/spectratune-hcl/>

Li, Y., Yu, Q., Yu, W., & Wei, C. (2022). Research on Hologram Based on Holographic Projection Technology. *Mathematical Problems in Engineering*, 2022, 1–9. <https://doi.org/10.1155/2022/3142599>

MacLeod, R. B., & Weld, H. P. (2006). Spatial perception. In John Wiley & Sons, Inc. eBooks (pp. 439–473). <https://doi.org/10.1037/11249-014>

Mandal, M. (2003). *The Human Visual System and Perception*. Springer eBooks, 33–56. https://doi.org/10.1007/978-1-4615-0265-4_3

Mason, M. (2020). The Elements of Visitor Experience in Post-Digital Museum Design. *Design principles & practices*. <https://doi.org/10.18848/1833-1874/cgp>

Masuda, T., Ellsworth, P. C., Mesquita, B., Leu, J., Tanida, S., & Van De Veerdonk, E. (2008). Placing the face in context: Cultural differences in the perception of facial emotion. *Journal of Personality and Social Psychology*, 94(3), 365–381. <https://doi.org/10.1037/0022-3514.94.3.365>

Mausfeld, R. (2002). The physicalistic trap in perception theory. *Perception and the Physical World*. <https://philpapers.org/rec/MAUTPT>

Middleman, R. R., & Goldberg Wood, G. (1991). Seeing/Believing/Seeing: Perception-Correcting and Cognitive Skills. *Social Work*, 36(3), 243–246. <https://doi.org/10.1093/sw/36.3.243>

Nishitsuji, T., Kakue, T., Blinder, D., Shimobaba, T., & Ito, T. (z.d.). An interactive holographic projection system that uses a hand-drawn interface with a consumer CPU. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-020-78902-1>

NIST. (2010, 27 april). Nanotechnology, measurements, atomic scale moire patterns. <https://www.nist.gov/image/nanotechnologymeasurementsatomicscalemoirepatternsjpg>

Novikova, V. (z.d.). Anthony McCall / The light building a dialogue • XIBT Contemporary Art Magazine. XIBT Contemporary Art Magazine. <https://www.xibtmagazine.com/2019/12/anthony-mccall-the-light-building-a-dialogue/>

Ou, Q. (2017). A Brief Introduction to Perception. *Studies in Literature and Language*, 15(4), 18–28. <https://doi.org/10.3968/10055>

Pantone. (z.d.). How Do We See Color? <https://www.pantone.com/articles/color-fundamentals/how-do-we-see-color>

Priya, A. (2023, 17 oktober). Gestalt Principles. Behance. https://www.behance.net/gallery/182485445/The-Gestalt-Design-Principles?tracking_source=search_projects|gestalt+principles

Puhalla, D. M. (2008). Perceiving hierarchy through intrinsic color structure. *Visual Communication*, 7(2), 199–228. <https://doi.org/10.1177/1470357208088759>

Rahimi, Z., & Steen, L. (2020). HOW CAN LIGHT ART MANIPULATE THE VISUAL PERCEPTION OF SPACE? INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION. <https://doi.org/10.35199/epde.2020.51>

Rautkylä, E., Puolakka, M., Tetri, E., & Halonen, L. (2010). Effects of Correlated Colour Temperature and Timing of Light Exposure on Daytime Alertness in Lecture Environments. *Journal of Light & Visual Environment*, 34(2), 59–68. <https://doi.org/10.2150/jlve.34.59>

Recupero, A., Talamo, A., Triberti, S., & Modesti, C. (2019). Bridging Museum Mission to Visitors' Experience: Activity, Meanings, Interactions, Technology. *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.02092>

Roelfsema, P. R. (2006). CORTICAL ALGORITHMS FOR PERCEPTUAL GROUPING. *Annual Review of Neuroscience*, 29(1), 203–227. <https://doi.org/10.1146/annurev.neuro.29.051605.112939>

Science World. (z.d.). PEPPER'S GHOST: HOLOGRAM ILLUSION. Science World. <https://www.scienceworld.ca/resource/peppers-ghost-hologram-illusion/>

Showtex. (z.d.). Pepperscrim. <https://www.showtex.com/nl/producten/vlamwerend-textiel/tulle-netten-gaas/pepperscrim>

Skye, V. (z.d.). Skye Blue Café Wall Illusion [Video]. Victoria Skye. <http://www.victoriaskye.com/>

Soranzo, A. (2016). Simultaneous color contrast. *Encyclopedia of Color Science and Technology*, 1149–1152. https://doi.org/10.1007/978-1-4419-8071-7_268

Strasnick, S. (z.d.). Shifting Perceptions. *Aesthetica Magazine*. <https://aestheticamagazine.com/shifting-perceptions-3/>

Tanya Bonakdar Gallery. (z.d.). Olafur Eliasson: Your ocular relief. <https://www.tanyabonakdargallery.com/exhibitions/585-olafur-eliasson-your-ocular-relief-tanya-bonakdar-gallery-new-york/>

Tate. (z.d.). How Eliasson is changing our perceptions. <https://www.tate.org.uk/art/artists/olafur-eliasson-5239/yes-but-why-olafur-eliasson>

Thompson, P., May, K. A., & Stone, R. (1993). Chromostereopsis: a multicomponent depth effect? *Displays*, 14(4), 227–234. [https://doi.org/10.1016/0141-9382\(93\)90093-k](https://doi.org/10.1016/0141-9382(93)90093-k)

Toal, V. (2023). Introduction to Holography (2de editie). CRC PRes. https://books.google.nl/books?hl=nl&lr=&id=Jl-bEAAAQBAJ&oi=fnd&pg=PP1&dq=holography&ots=TI5c1eJMGX&sig=vM8ChT_f_eh_T0IUyLnLJU5lE#v=onepage&q=holography&f=false

Todorović, D. (2008). Gestalt principles. *Scholarpedia*, 3(12), 5345. <https://doi.org/10.4249/scholarpedia.5345>

Tom Powel, T. (z.d.). OLAFUR ELIASSON: YOUR OCULAR RELIEF. Tanya Bonakdar Gallery. <https://www.tanyabonakdargallery.com/exhibitions/585-olafur-eliasson-your-ocular-relief-tanya-bonakdar-gallery-new-york/>

Tozzi, A., & Peters, J. F. (2019). Topology of Human Perception. ResearchGate. <https://doi.org/10.13140/RG.2.2.24396.05764>

Trabskaya, J., Zelenskaya, E., Sinitsyna, A., & Tryapkin, N. (2022). Revisiting museums of contemporary art: what factors affect visitors with low and high levels of revisit intention intensity? *Museum Management and Curatorship*, 38(2), 210–227. <https://doi.org/10.1080/09647775.2022.2073559>

Van Seggelen, S. (z.d.). Aperiod Penrose tiling in three dimensions. Stefan van Seggelen. <https://www.stefanvanseggelen.com/penrose.html>

Vaz, R., Fernandes, P. O., & Veiga, A. C. R. (2018). Interactive Technologies in Museums. *Advances in hospitality, tourism and the services industry (AHTSI) book series*, 30–53. <https://doi.org/10.4018/978-1-5225-2927-9.ch002>

Walker, A. (2022, 18 juli). Olafur Eliasson and James Turrell: how perception can shift perspective. ACMI. <https://www.acmi.net.au/stories-and-ideas/olafur-eliasson-james-turrell-perception-can-shift-perspective/>

Wikipedia. (z.d.). 3 Layers of depths "Rivers, Valleys & Mountains". <https://en.wikipedia.org/wiki/Chromostereopsis>

Wikipedia contributors. (z.d.-a). Chromostereopsis. Wikipedia. <https://en.wikipedia.org/wiki/Chromostereopsis>

Wikipedia contributors. (z.d.-b). Color rendering. Wikipedia. https://en.wikipedia.org/wiki/Color_rendering

Wikipedia contributors. (z.d.-c). Holographic display. Wikipedia. https://en.wikipedia.org/wiki/Holographic_display

Wikipedia contributors. (z.d.-d). Illusory motion. Wikipedia. https://en.wikipedia.org/wiki/Illusory_motion

Wikipedia contributors. (z.d.-e). Moiré pattern. Wikipedia. https://en.wikipedia.org/wiki/Moir%C3%A9_pattern

Wikipedia contributors. (2023a, januari 29). Ganzfeld Effect. Wikipedia. https://en.wikipedia.org/wiki/Ganzfeld_effect

Wikipedia contributors. (2023b, juni 1). Physical optics. Wikipedia. https://en.wikipedia.org/wiki/Physical_optics

Wikipedia contributors. (2023c). Color Constancy. Wikipedia. https://en.wikipedia.org/wiki/Color_constancy

Xin, J. H. (2006). Total Colour Management in Textiles. Woodhead Publishing. <https://books.google.nl/>

Yi, T., Lee, H., Yum, J., & Lee, J. (2022). The influence of visitor-based social contextual information on visitors' museum experience. PLOS ONE, 17(5), e0266856. <https://doi.org/10.1371/journal.pone.0266856>

Appendix 1

Personal Project Brief - IDE Master Graduation



Perceptual light & sound installation

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 05 - 09 - 2023

02 - 02 - 2024

end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The final context in which the project will be presented is called Highlight Delft, a festival which is focussed on showcasing innovative art and technology. They show innovative ideas at unique locations created by artists, designers, researchers and companies. The theme of this festival edition is perception. Perception is the process by which organisms interpret and make sense of sensory information from their environment, forming a mental representation of the world around them. The perceptual light & sound installation will focus on combining two lighting techniques, holographic projection and spectral tuning. Holographic projection has a strong connection with perception because it offers a three-dimensional representation to create a highly realistic and immersive visual experience. This closely aligns with how our brain naturally process and interpret visual information. Spectral tuning on the other hand, directly influences how we perceive and interpret the colors of objects and environments. Therefore, both techniques fit the festival's theme perception and a combination of the two could lead to something new and innovative.

In this context, the creative director and programme maker of the festival can be seen as the main clients of the project. Despite the fact that they are my main clients, they will not interfere in the design process and therefore there will be a great extent of creative freedom. While there is a lot of creative freedom, the project still needs to fit the festival's theme and deliver something innovative for the visitors of the festival. The visitors of the festival can be seen as the users of the installation. The background of the visitors varies greatly in terms of age, cultural background, educational level and expertise. While they probably value different aspects when visiting a festival, some main values can be assumed. For example, the value of experiencing something new, innovative, and artistic which performs on a decent technological degree without compromising the educational and amusement level. The location where the installation will be placed is relatively free of choice. The festival is located in the city centre and the TU Delft campus, where there are multiple spaces available for the installation. There are resources available to adjust and design the space where the installation will be located. This means that the context where the users will operate in is customizable to facilitate the best experience possible.

The main opportunity in terms of technology, is to explore the combination of holographic projection and spectral tuning. Normally, both techniques are used separate, but by combining the two an interesting interplay could occur. The interesting aspect of the combination is that holographic projection creates a three-dimensional image which consists of reflections of light. By adding spectral tuning, these reflections can be adjusted in terms of their spectra, creating an extra dimension to control light. This main opportunity also creates a challenge: letting the visitors experience this technology and educate them about what they are experiencing. As stated before, the opportunity and subsequently the challenge is to fulfil the main values of the visitors in the best way possible.

Pont's light lab provides testing possibilities with resources such as a spectral tuning setup and other light(ing) and optical equipment. Next to those expensive setups, working at geometrical optics scales can in most cases be done with affordable materials. Right now, the festival offers €2000 to €3000 for building the installation. When there are more resources required, a well-grounded plan should be written to increase the amount offered by the festival. It is also an interesting challenge to make the combination of technologies as impressive as possible within the budget. The first phase of the graduation project should reveal the extent to which the two technologies can be satisfactorily combined.

space available for images / figures on next page

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30

Page 3 of 7

Initials & Name S.R.C. Ammerlaan Student number 4683447

Title of Project Perceptual light & sound installation

introduction (continued): space for images

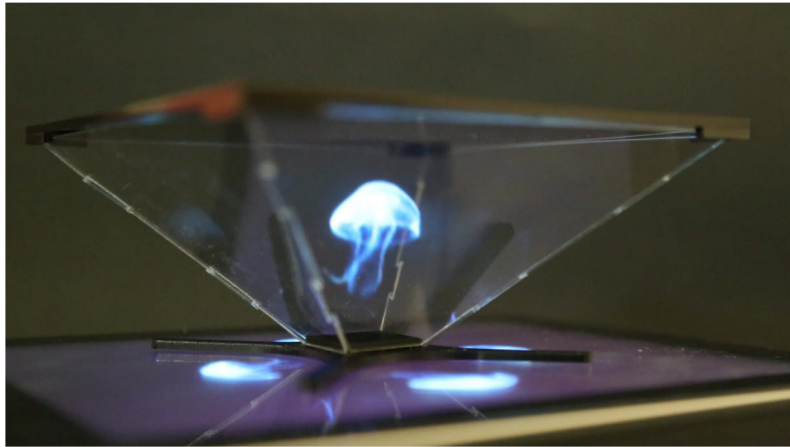


image / figure 1: Hologram made with a holapex



image / figure 2: Spectral tuning used to give two different materials a more similar appearance

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

These are the main issues that should be addressed in this project:

1. Explore both lighting techniques and experiment with combinations to see what effects can be reached.
2. Defining the perceptual phenomenon that the installation will demonstrate and how the technologies will make that possible.
3. Researching how to communicate the message to the audience and design all the possible interactions accordingly.

While the scope of the project is narrowed down to holographic projection and spectral tuning, it could be necessary to narrow down the scope even further. The beginning of the graduation process should reveal if using both techniques on a general level is still to large to process into a manageable end result. Choosing a smaller element of each technique could solve this issue.

One aspect that is important for the project, but should not take too much time, is the content of the holographic projection. The content is important, because it could help in enhancing the experience of the installation, but creating high quality content can also be time consuming. Creating the content could take too much time away from designing the experience and that is something to keep an eye on.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I will start the graduation project by doing research on holographic projection and spectral tuning, and how these techniques can support a to be defined perceptual phenomenon. Subsequently, I will conduct a lot of iterations on how to communicate the phenomenon with these techniques to the audience by prototyping and experimenting. I will conclude the graduation project by creating a final product which is based on my research and experimenting phase.

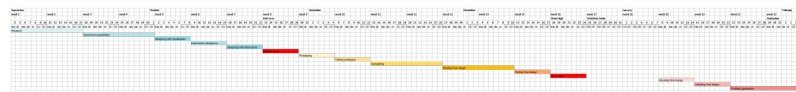
I expect to deliver an interactive installation where the visitors of the festival will experience a perceptual phenomenon which will be communicated through the two lighting techniques. I want the visitors of the festival to interact with the perceptual phenomenon to help them understand what they are actually experiencing. For the visitors, it would be interesting to uncover the phenomenon, switching between two or multiple scenes to provide enough communication to get a grasp on the subject. All designed interactions need to facilitate a smooth delivery of the message to a diverse audience.

I want to aim for an experience where people take their time to experience the installation and slowly immerse themselves into the designed space. I want people to be educated about the phenomenon they are experiencing in a natural way, without investing a lot of energy to understand what they are looking at. The installation should evoke the intrinsic motivation to explore, but also facilitate to be a calm observer of the content that is presented. Lastly, the installation should be enjoyable and visitors should leave with their values fulfilled because they experienced something new and exciting.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 5 - 9 - 2023 2 - 2 - 2024 end date



Broadly speaking, the planning was made to do research, experiment quickly, and work on the final design in time to have room for testing and improvements at the end. The planning starts with two weeks of research to get myself acquainted with the subjects. Subsequently, a period of iterations is scheduled to experiment with the two technologies and analyze what ideas and combinations could work. One week is used for experimenting general possibilities and one week is used for experimenting with possible interactions. The period between the midterm evaluation and green light is used to already work to a final design. This will provide time to test and adjust the design which is necessary to deliver a fully working end product. After the midterm evaluation, there is two weeks of time to prototype towards the more mature parts of the installation. Next, the gained knowledge from the research, experiment and prototype phase will be used to start conceptualizing to a final design. Then, it is time to build the final design and test it before the green light. The Christmas break is used to recharge for the final phase of the graduation project. The test results from before the green light will be used to do the final adjustments to the design. Finally, the design will be validated and there will be two weeks to finalize the graduation project. Below, the weeks of all the important meetings are listed. Each meeting is currently scheduled at the end of the specified week.

Kick-off meeting week 1
Midterm meeting week 8
Green light meeting week 16
Graduation ceremony week 22

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

During my studies at the Industrial Design Engineering faculty I always felt that creativity was not really supported. Everything was focussed on being functional and following the path the faculty has in mind for you is a must. Besides, I was always interested in creating an experience instead of a product or service. I wanted people to feel something instead of only using a product or service in a functional manner. After following the Lighting Design elective, I noticed that light touches both worlds. It can be functional and it can provide people with a certain feeling, creating an experience in the end. This project feels like the perfect graduation opportunity for me. Doing research on two fairly difficult lighting techniques and having all the creative freedom to create an experience out of it, while still designing with a user group in mind.

During my bachelor and master I developed all-round skills, but I developed the most skills on the interaction side. Researching the user, analyzing their motivation, translating these motivations into design choices and combining the design choices into experiences. The faculty taught me all the theoretical tools and my internship taught me a lot of practical skills. From being in the workshop to bring a design to life, to communicating with different stakeholders and collaborating with colleagues on a professional level. This graduation project feels like a natural last step after all the skills I gained before.

I have multiple ambitions I want to address in this project. The first one, is to acquire more knowledge in the field of lighting design. Right now, the two chosen lighting techniques both demand a high degree of researching, which is challenging. Experimenting with both lighting techniques and how they can work together will provide me with a lot of practical experience. The final step in the graduation process, bringing the concept to life, will also provide me with practical experience, but with more focus on placing the idea in a real life environment. The limitations in terms of resources is something I did not experience before as well. All these learning ambitions stated before can help me in setting the right step into the professional working environment after graduation.

My second ambition is to finally create an experience which will be brought to life and will be used by real users. Until now, each project ended up in a digital version or a physical version which was not used by real users. After I developed both, it feels like the right step to develop for a real life situation. The biggest ambition is to match the envisioned interactions with how the users will interact with the final product. To reach this ambition I need to experiment and check which interactions evoke the right feelings.

My final ambition is to realize an Industrial Design Engineering graduation on my own terms. Where previous courses always focussed on particular parts of the design process, it feels like a challenge to finally do a full project with my own subject, fitting my preferences. My ambition is to put all the skills I developed over the past years, into this graduation project and work in an autonomous and independent way to a satisfactory end result.

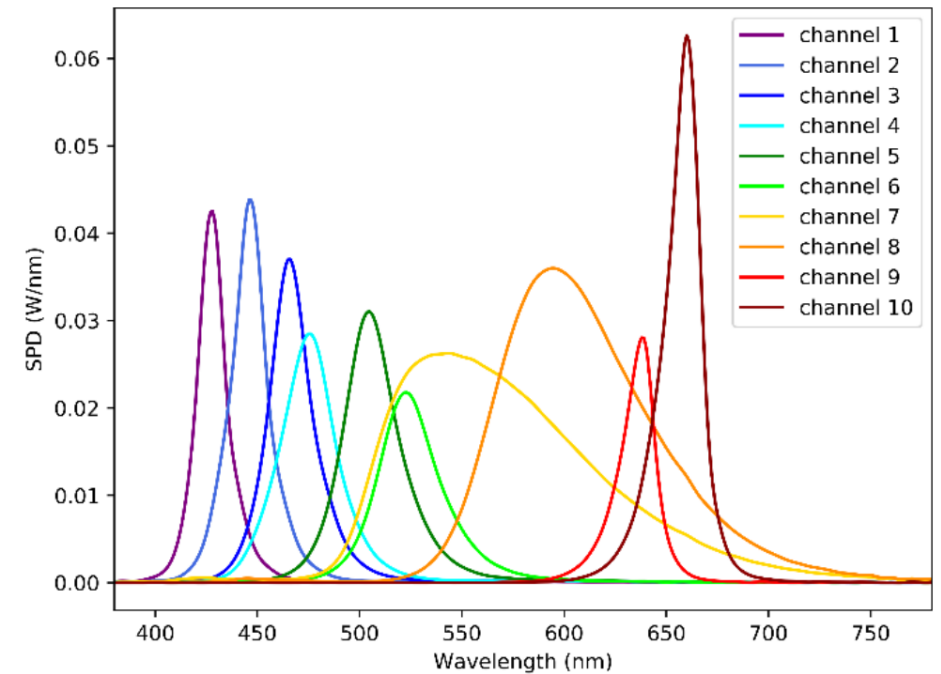
FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix 2

Channel	Color	Peak Emission (nm)	Radiometric value (W)	Photometric value(lm)	FWHM (nm)
CH 1	UV	430	0.74	13	16
CH 2	Royal Blue	445	0.95	36	19
CH 3	Dark Blue	465	0.94	74	23
CH 4	Blue	475	0.89	97	30
CH 5	Cyan	505	0.98	319	30
CH 6	Green	525	0.77	389	34
CH 7	Lime	545	2.75	1256	110
CH 8	PC Amber	595	2.76	990	82
CH 9	Red	640	0.62	102	19
CH 10	Deep Red	660	1.25	81	18

Generic features of the SPECTRA TUNE LAB light engine (Ledmotive, z.d.)



Spectral Power Distributions (SPDs) of the LED channel (Ledmotive, z.d.)

Appendix 3

Diffuser sheets

The experiment phase started with tools which were already available in the light lab of the industrial design faculty, starting with acrylic diffuser sheets. The light lab offered a wide range of samples with different patterns and different pattern sizes. By putting two sheets behind each other and slowly moving them, moiré patterns are created. By adding a light source behind the sheets, the interference patterns became more apparent.

In figure 2.1 two sheets with a fine pattern were held against each other, resulting in a noise pattern. This noise pattern could even be made more fine, by slowly separating the sheets. This occurred because each small pyramid on the front sheet got the opportunity to scatter more light from pyramids of the rear sheet. Figure 2.2 shows two sheets with a larger pattern, which also results in a relatively large moiré pattern in comparison with the effect in figure 2.1. The scattering of light by the front sheet is now clearly defined by bright and dark areas instead of a noise pattern. This is caused by the position of the sheet structures which can have an effect on the refraction of light, extinguishing or enhancing itself between two structures. Resulting in the bright and dark areas.

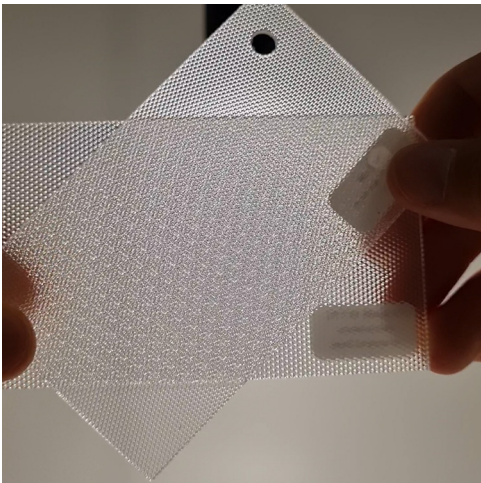


Figure 2.1: Two diffuser sheets creating a noise pattern

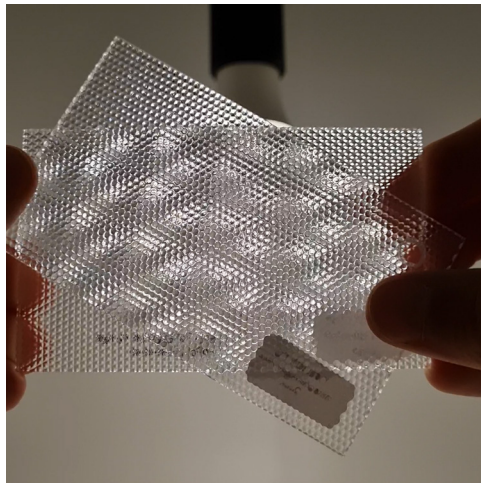


Figure 2.2: Two diffuser sheets creating a moiré pattern

In figure 2.3 a diffuser sheet is held against a sheet consisting of straight lines. Besides creating various moiré patterns, a constant movement of the front sheet results in a moiré pattern moving in the opposite direction. Another interesting side effect of the moiré pattern with these sheets, is that it plays with the perception of depth. While the sheets are held against each other, the front sheet seems to be at a certain distance from the rear sheet.

Figure 2.4 presents an example of experiments with the diffuser sheets and a laser. By shining the laser through the different sheets, the light of the laser got refracted in certain shapes. While this particular figure shows the result of a circle bended by the surface on which it is projected on, the sheets provided diverse projections of the laser. Sometimes the projection represented geometrical shapes and sometimes it had a crystal like appearance where the light of the laser was more hail-like. Shining the laser with different angles on the diffuser sheet did not change the shape which was projected. This is probably caused by the fact that diffuser sheets are made to distribute light equally, resulting in uniformly scattered light, regardless of the incident angle.

While these experiments do not embody high level use of technology, they still provide some small visual effects which can be used or enhanced in a bigger setup. Besides, these small experiments help in learning about the basic processes of light.

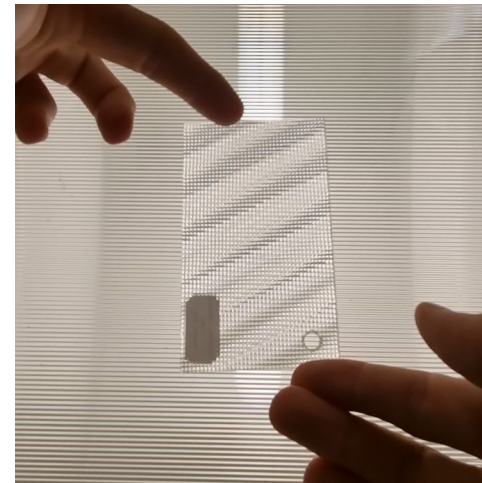


Figure 2.3: Two sheets creating a interference pattern

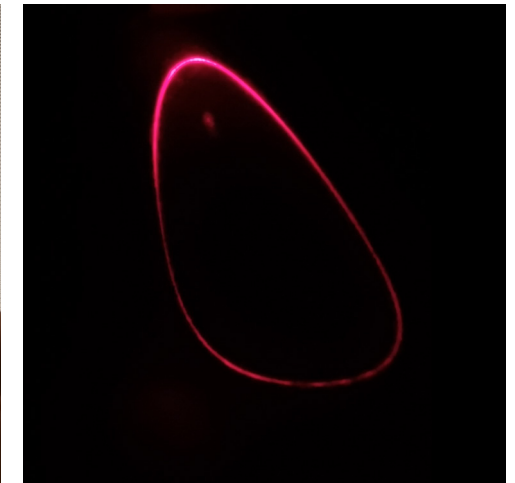


Figure 2.4: Laser light shining through a diffuser sheet

Moiré & spectral tuning

By using spectral tuning and moiré patterns which use different colours, each pattern could be influenced on its own resulting in a whole new moiré effect. It is important to note that the moiré patterns used for the coming experiments are static patterns which already consist of a recorded interference pattern. The spectral tuning installation used for this setup consists of ten different channels which separately can be configured to a value from 0 to 4095. The names of colours used during experimenting with spectral tuning derive from Ledmotive. The characteristics of each channel can be found in appendix 3. Figure 2.5 shows the moiré pattern where the lighting channels are equally configured. Figure 2.6 till 2.8 shows how the different spectra influence the colour absorption and reflectance of the illustration. For example, figure 2.6 shows how the wavelengths of green light cancels out the red colour of the illustration, appearing almost black. This happens because red and green are complementary colours. Figure 2.7 shows how the wavelengths of red light result in a darkened blue area as well, because red light contains no wavelengths which belongs to blue. The appearances are also influenced by the context. Figure 2.6 and 2.7 shows that the respectively red and blue colours of the illustration blend into the chromatic lit environment, making the colours almost disappear in their context.

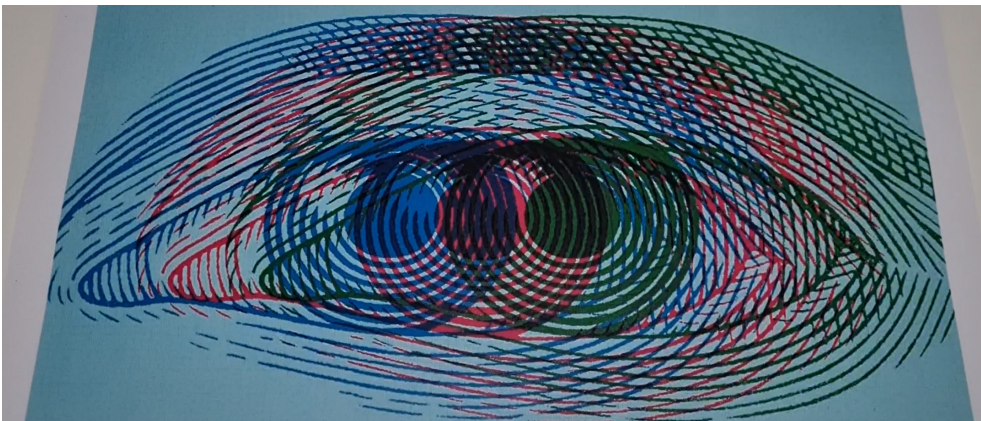


Figure 2.5: Moiré pattern with all light channels on 50%



Figure 2.6: Moiré pattern illuminated with green light



Figure 2.7: Moiré pattern illuminated with red light

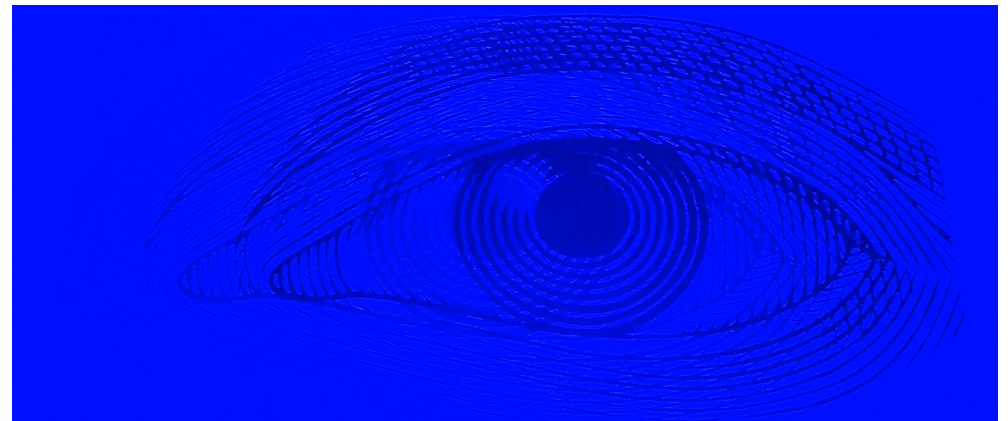


Figure 2.8: Moiré pattern illuminated with dark blue light

In comparison with the pattern on the previous page, the following moiré patterns were chosen based on their high line density and the movement (figure 2.9-2.11) which was already recorded in the interference pattern. Because of the line density, movement and colours used for both aspects, it was of it interest how spectral tuning could influence the colours in such a way that a static image appears to be dynamic.

While the figures show a static image, each pattern appeared to move while tuning the spectrum of light. The left pattern in figure 2.9 till 2.11 showed small circular motions. Because of these perceived motions, the pattern appeared to zoom in and zoom out. The pattern on the right sides of the same figures, showed less of these clear movements. Instead, this pattern played with the perception of depth. This phenomena can partly be seen in the difference between figure 2.10 and 2.11. The patterns highlighted in a magenta colour in figure 2.11 are not visible in figure 2.10. By tuning the spectrum, a continuous interplay occurs of colours becoming dark or highlighted, resulting in patterns appearing more up front and patterns appearing more in the background. Figure 2.9 shows the moiré patterns being distorted by the camera which was adjusting to a direct change in lighting conditions. This moment of 'adjusting' could be interesting to design with. Figure 2.12 till 2.14 shows a moiré pattern which seems very static at first glance, but appeared to have the strongest perception of movement. In comparison with the two other patterns in figure 2.9 till 2.11, this pattern moved in multiple, unpredictable directions. Some parts of the pattern appeared to expand and some parts appeared to shrink at the same time, comparable with the characteristics of a motion illusion, where a static image seems to move as a result of cognitive effects of interacting colour contrasts, the shape of objects and its position (Wikipedia contributors, z.d.). This expand and shrink effect can be seen, looking at the white area which is positioned a little bit above the centre of the pattern. This area is decreasing in size, moving from the left to right figure.

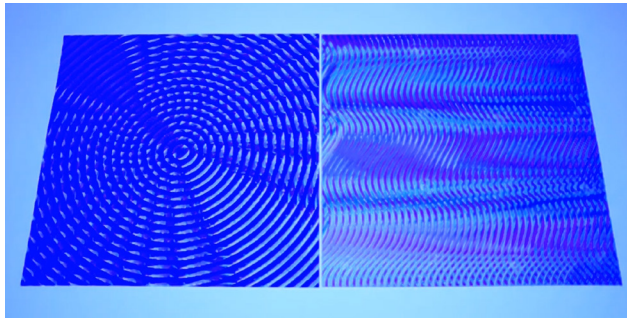


Figure 2.9: Moiré patterns distorted by the camera adjusting to a direct change of light settings

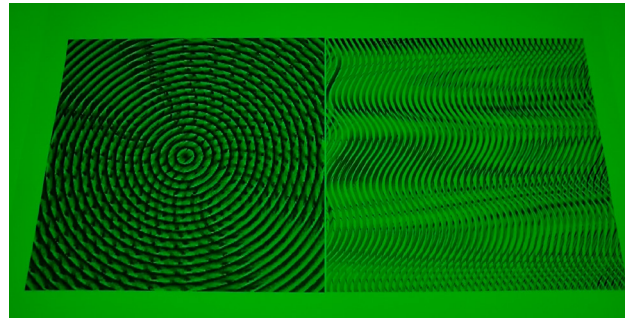


Figure 2.10: Moiré patterns illuminated with green light

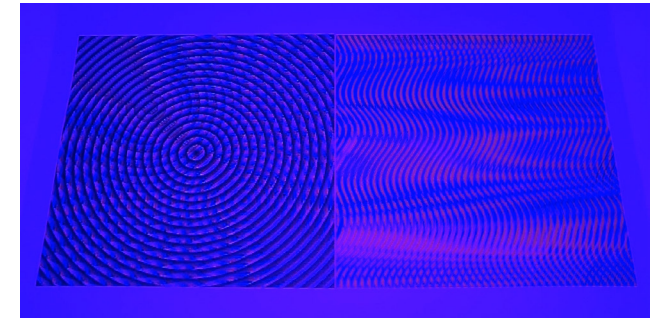


Figure 2.11: Moiré patterns illuminated with dark blue light and a little bit of red light

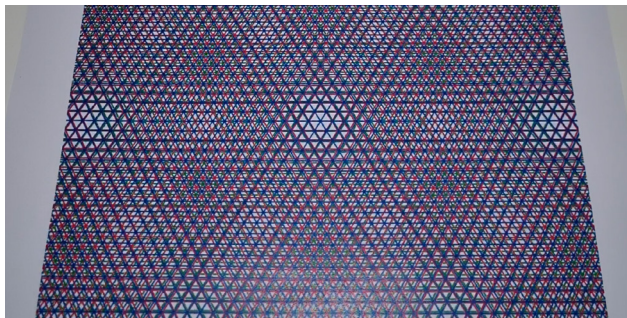


Figure 2.12: Moiré pattern with all light channels on 50%

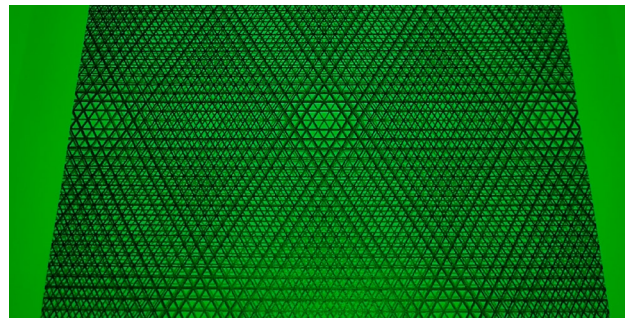


Figure 2.13: Moiré pattern illuminated with green light



Figure 2.14: Moiré pattern illuminated with dark blue light

Moiré, spectral tuning & holographic projection

In this section, a real moiré pattern is created with a holographic projection and a piece of paper. The holographic projection uses the pepper's ghost technique by projecting a black and white line pattern with a screen on acrylic glass (figure 2.15). The paper consists of the pattern of the previous page, which can be spectrally tuned.

Figure 2.16 shows the moiré pattern where the light channels are equally configured on a low intensity to keep the holographic projection visible enough. Moving the rear pattern did create interesting interference patterns. The curvatures in the front pattern appeared to bend the rear pattern. Despite the interesting new interference patterns, it was obvious that the two separate patterns did not blend very convincing together. This is probably caused by the shaky movements of the rear pattern and the front pattern being out of balance in terms of white and black lines. The white lines prevent the rear pattern from coming through and blend together in a balanced way.

In figure 2.17 till 2.19 the rear pattern is fixed and spectrally tuned. This setup prevents shaky movements and facilitates the previously perceived movements of the rear pattern to come through and create a new interference pattern. This setup resulted in various visual effects. Figure 2.17 presents the interference pattern with the best blend of the two separate patterns. The most obvious reason for this great blend may be that the red, blue and green light together provide a lot of light intensity, making the white lines less visible and the rear pattern more visible. Figure 2.19 shows how red light strengthens the front pattern in terms of shape.

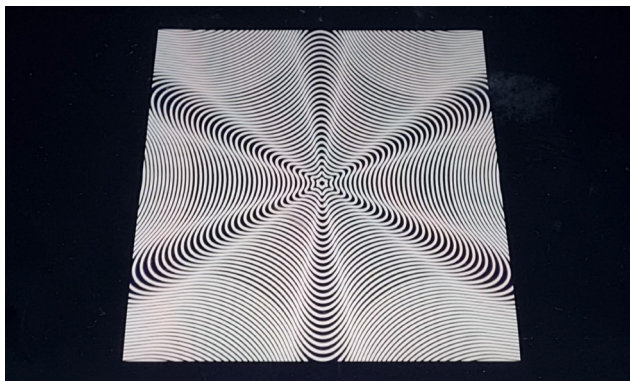


Figure 2.15: Pepper's ghost of black and white line pattern

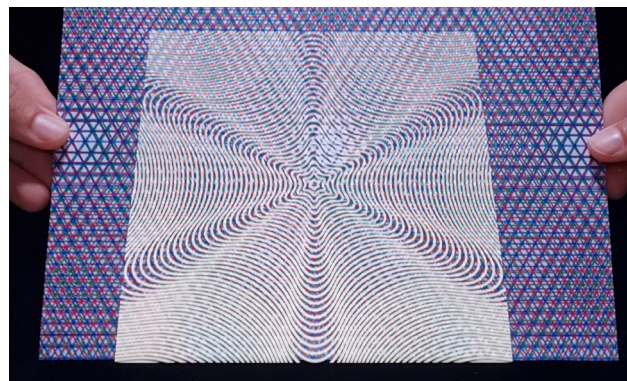


Figure 2.16: Pepper's ghost pattern combined with pattern on paper with all light channels equally configured

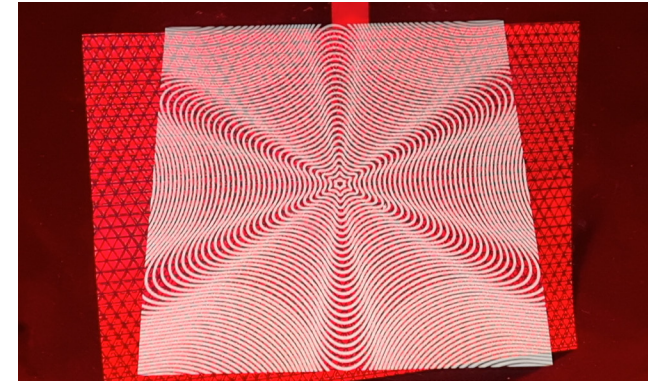


Figure 2.19: Moiré pattern illuminated with red light

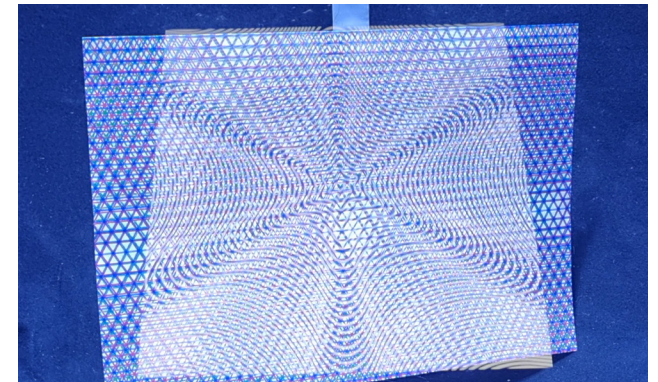


Figure 2.18: Moiré pattern illuminated with ultra violet, dark blue and a little bit of PC amber light

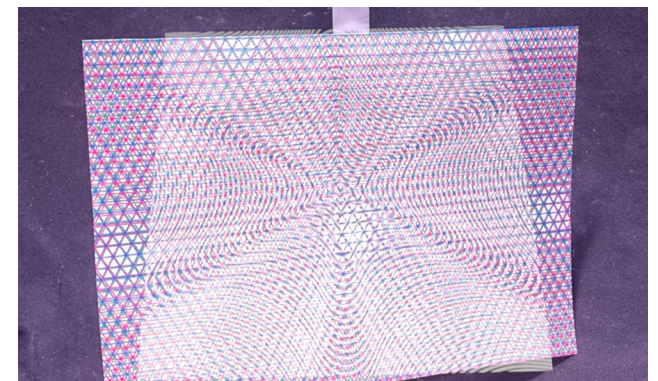


Figure 2.17: Moiré pattern illuminated with red, blue and a little bit of green light

Penrose tiling & spectral tuning

As stated in the research chapter, mathematical models could be suitable to combine with holographic projection and spectral tuning. One mathematical model which stood out during the experiments is the penrose tiling. Figure 2.20 shows the penrose tiling with equally configured light channels. When illuminating the penrose tiling with green light, only shades of green remain, but a bigger pattern arises (figure 2.21). The tiling appears to consist out of chains and bigger diamond shapes can be seen. By analysing the tiling for a longer time, the chains appear to be three-dimensional sometimes. Figure 2.22 shows a completely different appearance, where the chains are exchanged for a woven pattern of red and green waves. The woven pattern is enhanced by the darker areas around the red waves, normally represented by magenta and two shades of purple, and the different shades of green, normally represented by cyan and blue. The orientation of the different faces contributes to the woven pattern as well. The tiling in figure 2.23 seems to enhance the direction of the white faces. In this lighting condition, the dark blue and dark red lighting seems to lower the luminance of the colours, but enhances the saturation of the colours. The white areas are probably so distinct because a large part of the spectrum is represented by the dark blue, PC amber and dark red lighting.

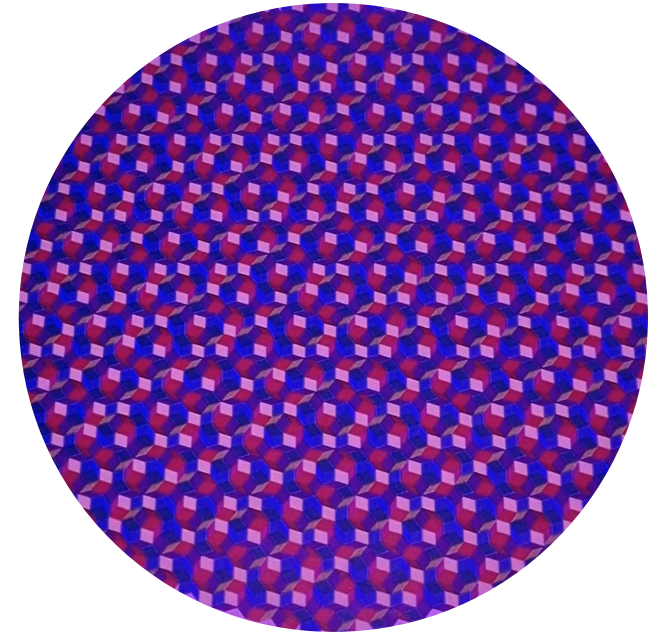


Figure 2.23: Penrose tiling illuminated with dark blue, PC amber and dark red light

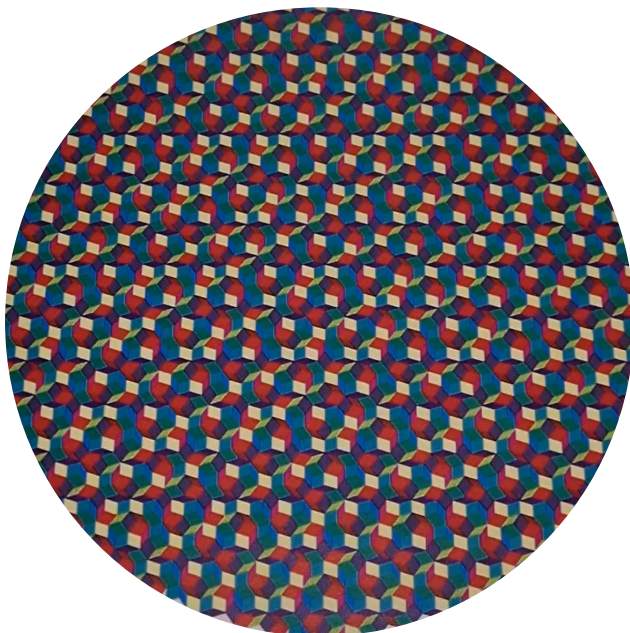


Figure 2.20: Penrose tiling with all light channels on 50%

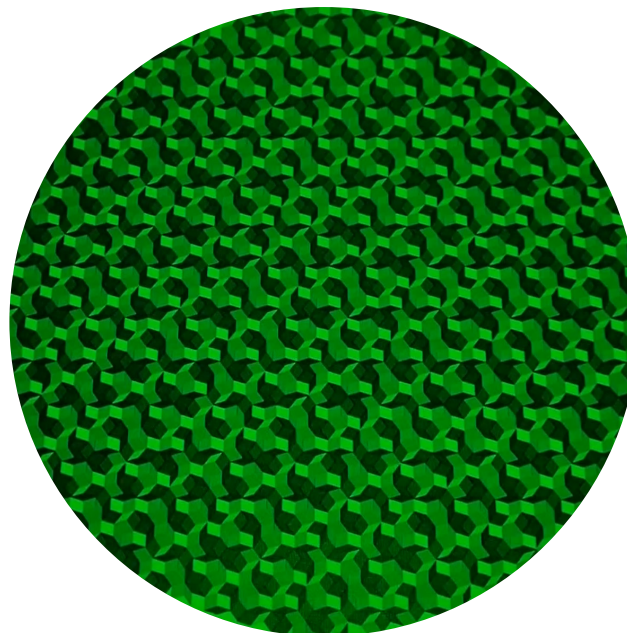


Figure 2.21: Penrose tiling illuminated with green light

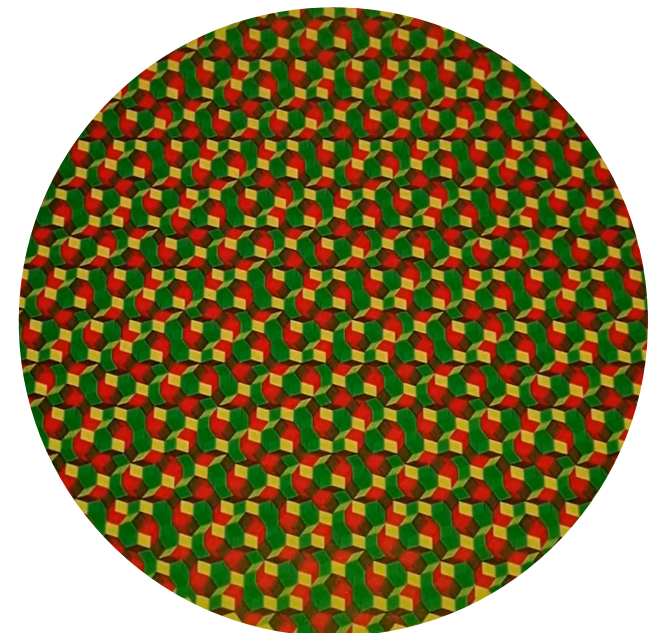


Figure 2.22: Penrose tiling illuminated with green and deep red light

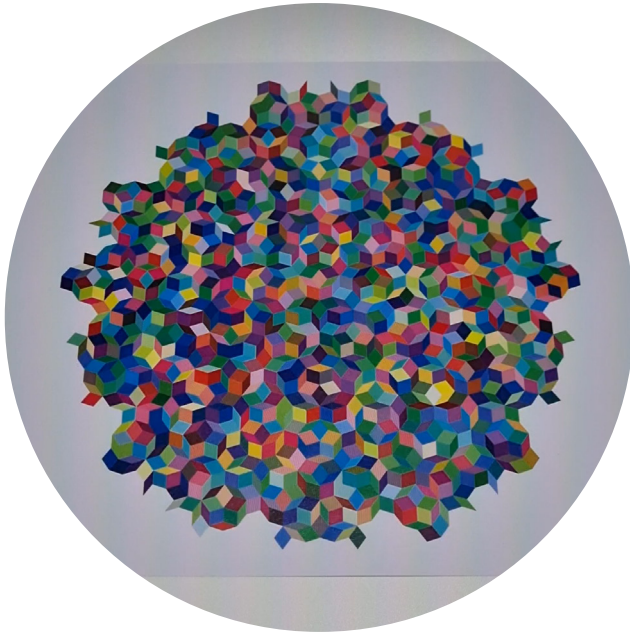


Figure 2.24: Penrose tiling with all light channels on 50%

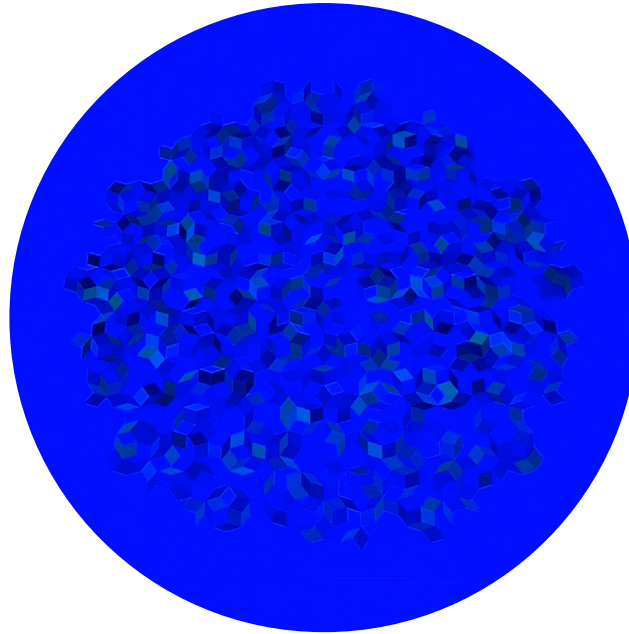


Figure 2.25: Penrose tiling illuminated with ultra violet and a little bit of green light

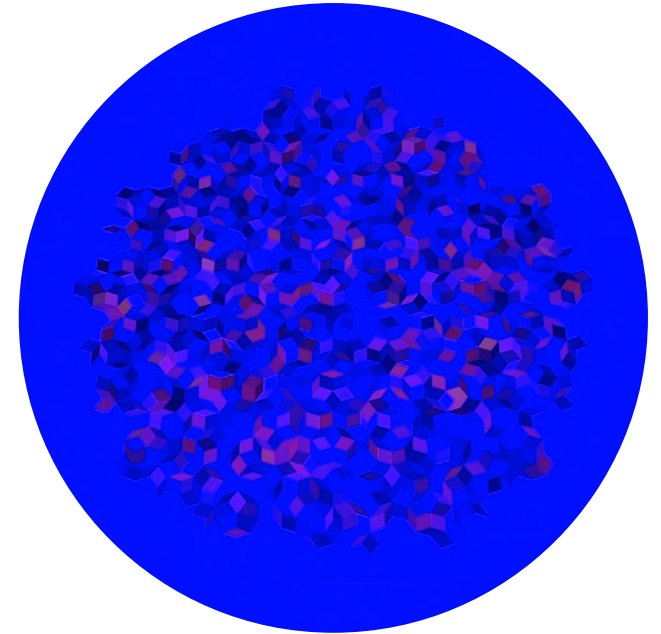


Figure 2.26: Penrose tiling illuminated with ultra violet, royal blue, dark blue and a little bit of PC amber light

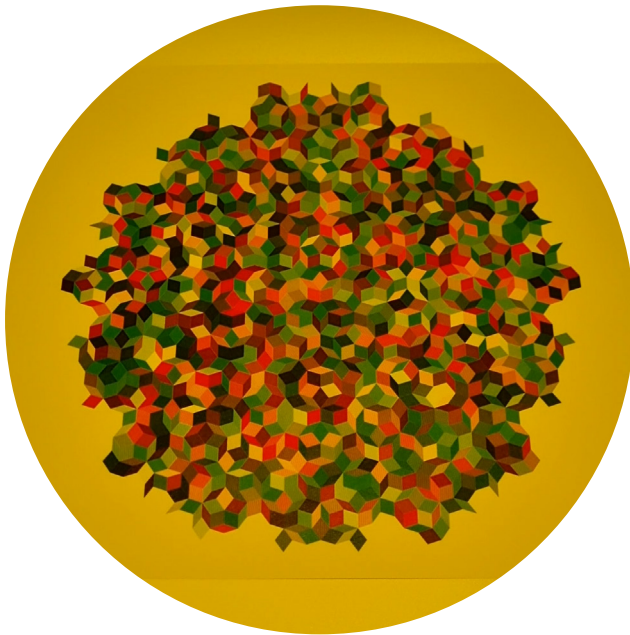


Figure 2.27: Penrose tiling illuminated with CP amber, red and dark red light

This time, a penrose tiling is chosen with a wide variety of colour, but without a repeating colour pattern. The faces of the tiling are directed the same way as the previous penrose tiling, but the inconsistent colour pattern makes it more difficult to distinguish these directions. The figures with this tiling are not fully cropped like the figures of the previous tiling, because the context in figure 2.25 and 2.26 plays an important role in experiencing the colour interactions. Figure 2.24 shows the penrose tiling illuminated by equally configured lighting channels, clearly showing the randomness of the chosen colours. And this aspect of a random colour palette is one of the first things that stands out in figure 2.25 and 2.26. The ultra violet light in figure 2.25 ensures that almost all colours blend into their surroundings, leaving some faces appearing a darker tint of blue. By adding a little bit of green light, all the different shades of green in the tiling stand out, creating a shimmer like appearance which feels natural because of the randomness of shades. Figure 2.26 shows the same effect, but then the PC amber light highlights the yellow, orange and red colours. Keeping chromostereopsis in mind, this illumination setting seems to create a stronger perception of depth than the illumination setting in figure 2.25, caused by the red and blue interplay. Figure 2.27 is displayed to present how different illumination settings can enhance the visibility of the face directions. The visibility of the face directions also contribute to the three-dimensionality of the pattern. It is important to note that the camera had difficulties adjusting to a completely blue environment, resulting in images which do not fully correspond to the real situation.

Projections on organza

The projections on organza opened up a complete new range of possibilities, because of its transparent and reflective properties. A wide variety of experiments resulted in a lot of knowledge and insights on which effects can be used later on in the process. Figure 2.28 shows a dynamic, distorted moiré pattern being projected on white organza. The fast changes of the distorted black and white lines appeared to let the static organza vibrate and shake. The fast switches in black and white resulted in the organza reflecting white light or being almost fully transparent when no light is projected (black). Figure 2.29 till 2.31 shows how a motion illusion is being projected on organza of different colours. The motion illusion is meant to create an afterimage after looking at the red dot for a certain amount of time, but the motion illusion directly occurred on the organza itself. Inside the circle the organza appeared to expand and outside the circle the organza appeared to shrink. The transparency of the organza in figure 2.29 and 2.31 contributed to perceiving the motion illusion, because the static background could clearly be seen. The organza in figure 2.30 was almost not transparent and not seeing the background resulted in hardly any motion. The strongest motion illusion was found in figure 2.29, where the black and white lines appeared closest to their true colour.



Figure 2.28: Projection of distorted moiré pattern on white

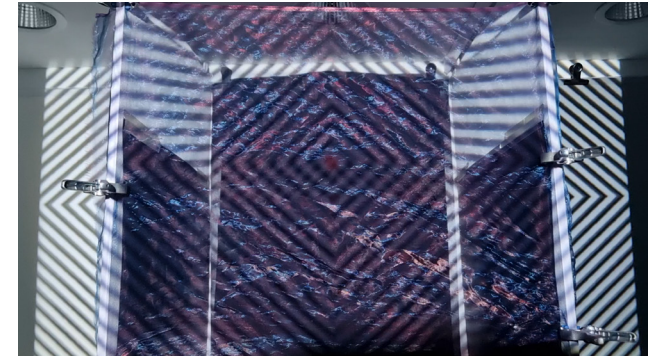


Figure 2.31: Projection of motion illusion on purple/blue organza

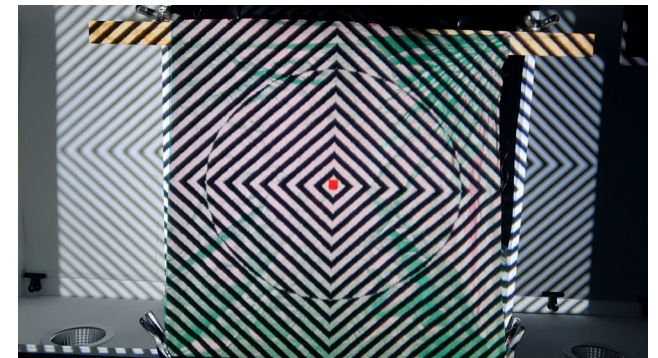


Figure 2.30: Projection of motion illusion on purple/green organza

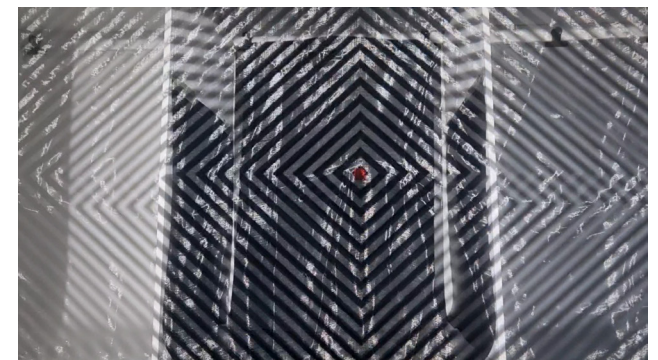


Figure 2.29 Projection of motion illusion on white organza

Projecting on multiple layers of organza is a great method to achieve motion parallax, which is one of the characteristics of holographic projection. Besides, this setup is an interesting way to see the effects of projecting a object which appears on multiple layers, already creating a three-dimensional object. Figure 2.32 till 2.34 shows the projections of a spinor model on two layers of organza. Figure 2.32 shows how the spinor appears to have more perceived depth than the projections of the previous sections on a single layer of organza. Figure 2.33 clearly shows that the hue, saturation and luminosity of the projection on the rear layer are hardly effected by the light absorption of the front layer. The projection on the rear layer only seems a little bit blurry, which is probably caused by the focus of the projector being adjusted to the front layer. The refraction of the light by the first layer could also be a cause of the rear projection being less sharp. Figure 2.34 shows a detailed imaged of the strings of the spinor curving around the organza. This curvature effect could be of inspiration in the design phase of this project.

Figure 2.35 till 2.37 shows the same spinor model being projected on five layers of organza. Despite the layers not being tightly hung, the projection still creates an obvious three-dimensional object in the five organza layers. The five layers provide a lot more perceived depth than the two layers of the other experiment. The only disappointing aspect is the blurriness across the layers. An experiment with tightly hung organza should reveal if the level of blurriness on multiple layers is acceptable. The spinor in figure 2.35, which consists out of a rotating sphere connected with coloured strings, appears as a dynamic lump, especially with the lines curving around multiple layers of organza. Figure 2.36 clearly shows the level of blurriness through the multiple layers when a spinor with sharp edges is projected. Despite the blurriness, the rear layers in figure 2.37 still show a great level of hue, saturation and luminosity in comparison with the front layer. The next page will present various experiments and insights while working with projections on organza.



Figure 2.32: Two layers of organza with projected spinor + strings

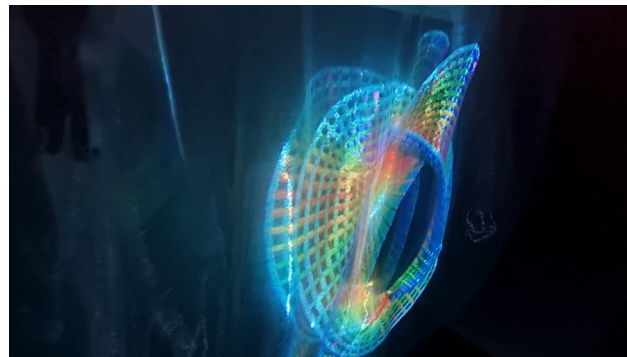


Figure 2.33: Two layers of organza with projected spinor



Figure 2.34: Curvature of projected spinor strings

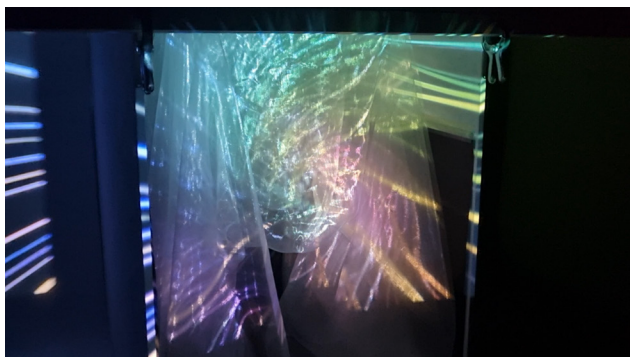


Figure 2.35: Five layers of organza with projected spinor + strings



Figure 2.36: Five layers of organza with projected spinor



Figure 2.37: Five layers of organza with projected spinor (detail)

In figure 2.38 and 2.39, a motion illusion is projected on purple/blue and white organza. The figures illustrate the playful, reflective properties of organza. The purple/blue organza constantly highlights one of the two colours as the perspective of the viewer changes. However, it is almost not reflecting any light when the background behind the organza has a white colour. This phenomenon can be seen in the upper left corner of figure 2.38. One possible explanation for this event to occur, is the white background that reflects a full spectrum back to viewer which leads to not seeing the reflected wavelengths of organza. This results in perceiving a white background and nearly seeing the organza itself. Lastly, the visibility of the projections improve when viewed from the side, because there are less reflections from the background being visible.

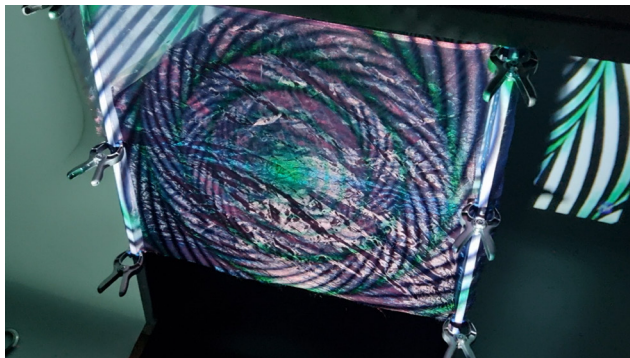


Figure 2.38: Motion illusion projected on purple/blue organza

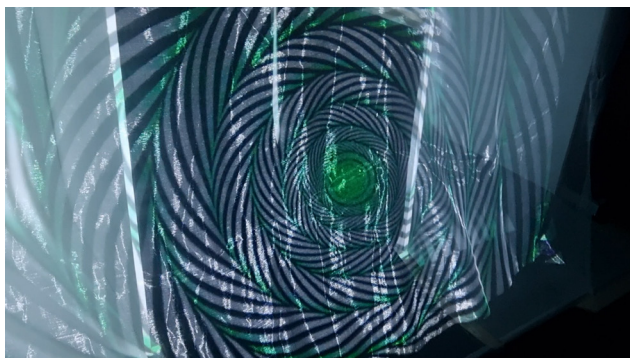


Figure 2.39: Motion illusion projected on white organza

Figure 2.40 and 2.41 show the effects of projections having black parts. The black parts do not project any light on the surface, resulting in not seeing any reflections coming off the organza. By combining this with white projections a strong contrast is made. Figure 2.40 shows a black dot being projected, which appears as a so called portal. Figure 2.41 shows an inverted black circle being projected. At the black parts of the projection, the effects are even more obvious than the at the black dot. At the black areas, there are no cues of the organza being present anymore. Even the area projected with white light appears to have the curvatures of the organza projected instead of the curvatures of the textile being real. The contrast between the black and white projections interacts with the perception of the material in an interesting way.

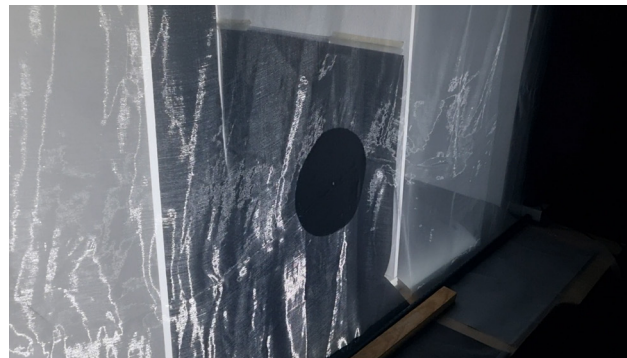


Figure 2.40: Black dot projected on white organza

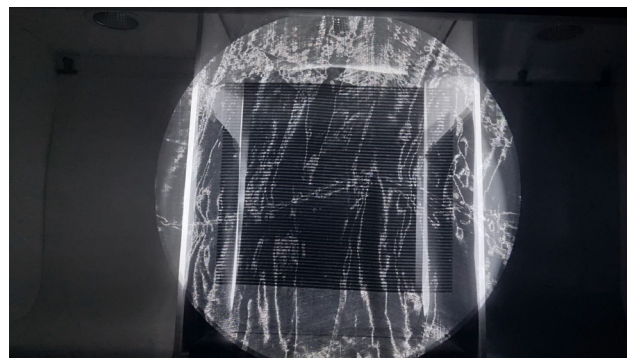


Figure 2.41: Black inverted circle projected on white organza

Figure 2.42 and 2.43 show two moiré patterns being projected on five layers of organza. In comparison with the spinor model on the previous page, the projection of the moiré patterns appeared a lot cleaner. The moiré patterns do not appear like a lump despite the organza still not being stretched tight. Figure 2.42 shows that a simple pattern with evenly distributed lines create a lot of depth. The clarity of the projection adds to the amount of motion parallax being observed when changing viewpoint. Figure 2.43 shows a more complex pattern which directly influences the clarity across the layers. An advantage of this pattern is the difference in line density across the pattern, which creates a dynamic effect when the pattern is moved around. In this situation, the curvature of the lines around the organza enhance this dynamic effect.

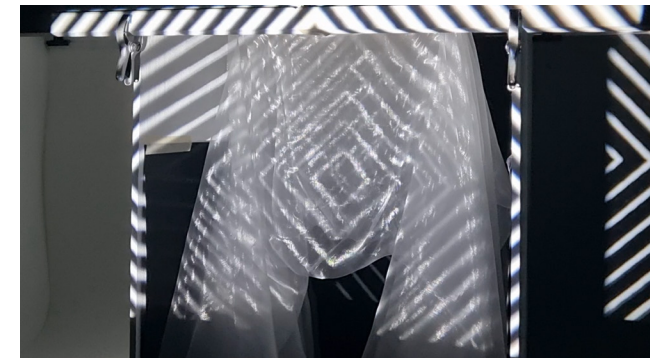


Figure 2.42: Moiré pattern projected on five white organza layers

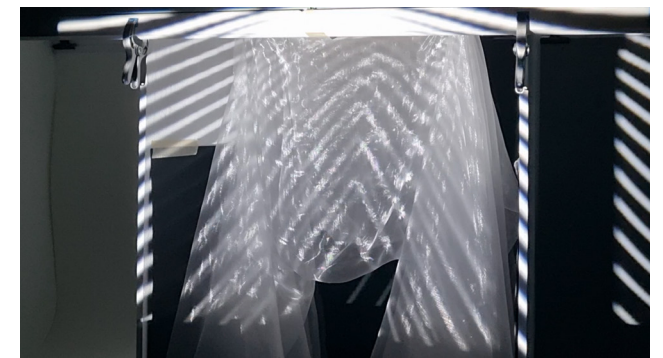


Figure 2.43: Moiré pattern projected on five white organza layers

Aquarium, holographic projection spectral tuning

The following experiments were done with a container filled with water with a little bit of milk powder. The milk powder ensures that the light reflecting of the objects in the aquarium is being scattered around. Figure 2.46 till 2.48 shows an experiment where objects with six different colours are positioned in the aquarium. The objects only received light from the slit above to minimise the scattering caused by the light source. The results did not exceed expectations of the experiment. Only figure 2.46 shows an interesting view, where the light reflections of the three objects on the left blend with their environment while the three objects on the right are being highlighted. Figure 2.44 and 2.45 shows an experiment with a pepper's ghost projection of a spinor in the aquarium. As can be seen in figure 2.44, the spinor already appeared hazy without illumination. Figure 2.45 shows the spinor where the aquarium is highlighted with dark blue light. It was expected that the blue light of the projection would blend in with the dark blue light scattered in the aquarium, but the blue outlines of the spinor are still visible. The experiments with the aquarium do not seem to be effective and useful for later stages in the process.

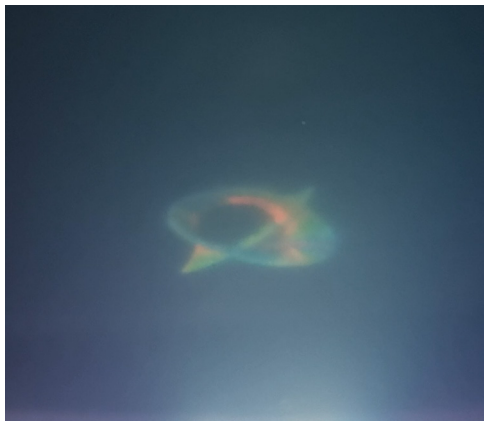


Figure 2.44: HP spinor in aquarium

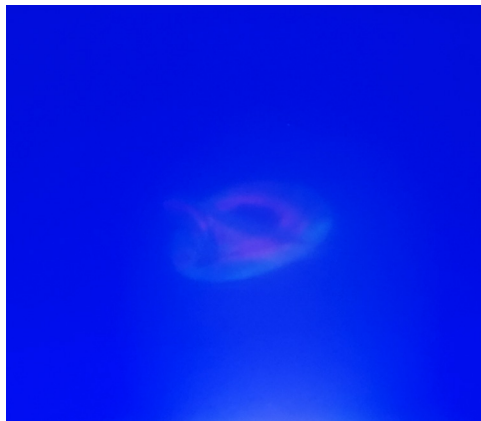


Figure 2.45: HP spinor in aquarium with dark blue light



Figure 2.48: Aquarium filled with coloured objects and illuminated by equally configure light channels (50%)

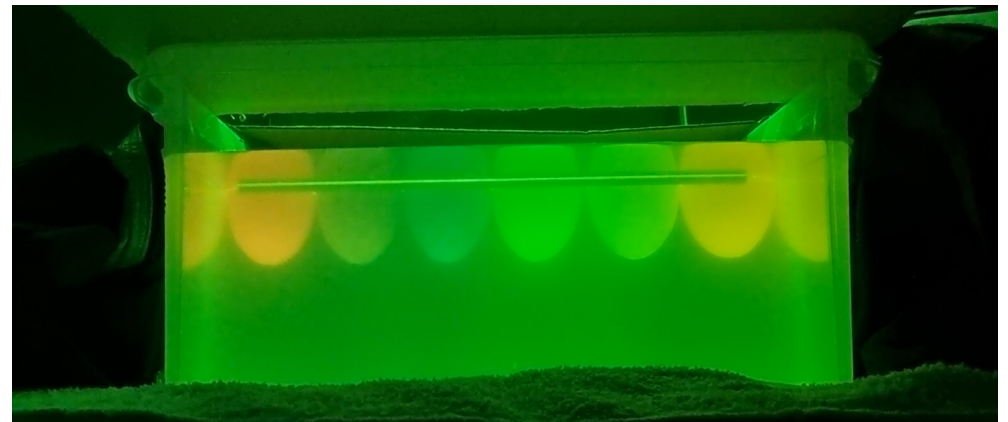


Figure 2.47: Aquarium filled with coloured objects and illuminated with green light

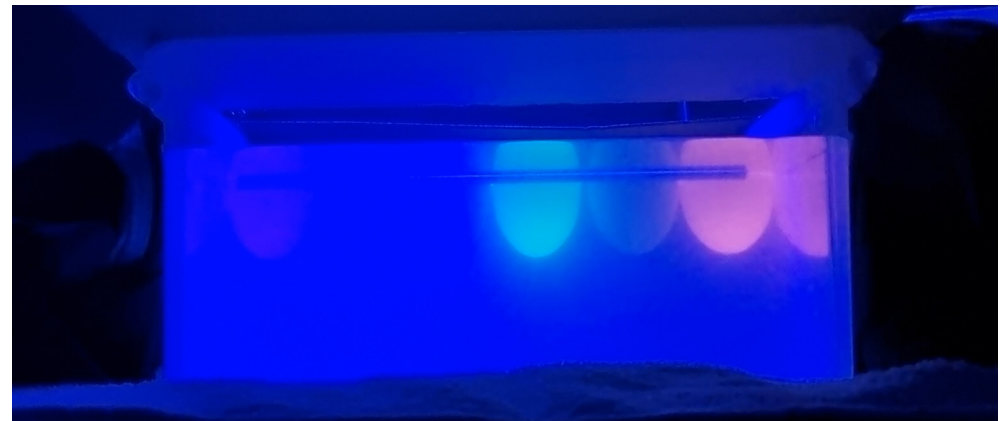


Figure 2.46: Aquarium filled with coloured objects and illuminated with dark blue light

Experiment analysis

To analyse the experiments in a structured manner, a C-box is used to make the categorization of the experiments a lot easier. Normally the axes of a C-box consist of feasibility and novelty and they are meant to create awareness about the level of novelty and feasibility of each idea. By mapping out the ideas on the axes, it becomes more clear what needs to be done to make an innovative idea more feasible for example. In this case, it would be more suitable to choose the axes based on the context of the project. The following axes are used for this C-box:

Perceptual depth

This axis measures how deeply an experiment delves into the visitors' perception. Experiments on one end may offer a surface-level experience, while those on the other end may provide a profound exploration of perception.

Technological impact

This axis assesses how significantly technology is utilized in shaping the visitor's perception. On one end, experiments may use technology occasionally or on a low level, while on the other end, they may heavily rely on innovative technology.

Figure 2.49 shows the C-box where every experiment is represented by one image and mapped out on both axes. A larger version of the C-box can be found in appendix 4. The experiments were then categorized based on their position on the C-box and the technology or materials used. The categorization process resulted in six different groups:

1. Projections on organza
2. Projections on multiple layers of organza
3. Spectral tuning
4. Holographic projection and spectral tuning
5. Optical sheets
6. Aquarium

The c-box illustrates that group 5 and 6 had a surface level exploration of perception, which is not preferred for this project. The upper part of the C-box shows the groups where a profound exploration of perception is reached. As explained in the experiments on the previous pages, group 1 till 4 showed a lot of different perceptual phenomena like motion parallax and colour interactions. These phenomena ensure that the experiments underwent a profound exploration of perception. Additionally, the upper part of the C-box shows an interesting separation of groups which lightly rely on technology and heavily rely on technology. This split is caused by the spectral tuning installation weighing more heavily than the simple projector being used with organza. To conclude, the C-box provides an insightful overview of the experiments. Analysing the position of each group on the matrix helps in zooming out on the past activities and it provides an overview of how the experiments communicate certain aspects like perception and technology.

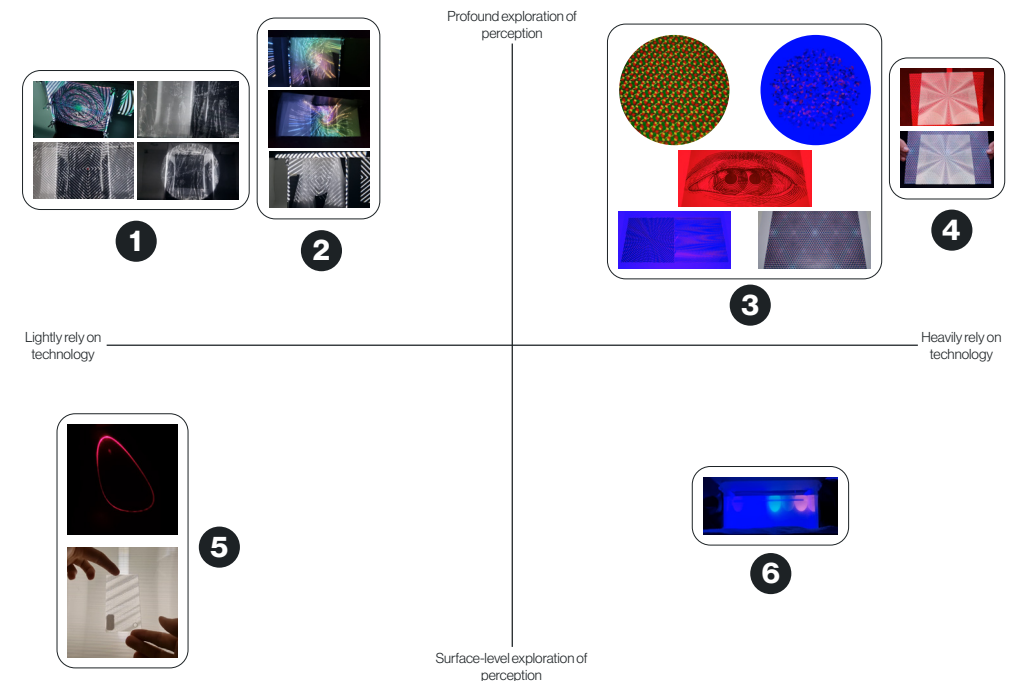


Figure 2.49: C-box with categorized experiment groups

A Harris Profile is used to evaluate each experiment group. Despite the fact that a Harris Profile is normally used in the concept phase of a process, the results can provide an overview of the status of the current experiment groups. This means that a Harris Profile can evaluate if the experiments are on the right track according to the previously compiled requirements or if the experiments need some adjustment in the next steps. The Harris Profile in figure 2.50 shows the best scoring experiment groups according to the demands of the list of requirements. Only the demands are used for this evaluation as the wishes are a factor of consideration when choosing between different concepts or experiments in this case. The evaluation of the other experiment groups can be seen in on the next pages. The upper part of the requirements table is filled with demands from Highlight Delft and the lower part is filled personal demands. Each experiment group is subsequently evaluated per demand on a four- point scale matrix. The overall score is shown below the table.

Requirements
Enable visitors to experience their own perception.
Facilitate visitors in learning about and reflecting on their perception.
Make the environment sensory-accessible.
Examine the visitors' perspective on the world.
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.
Allow visitors to experience both technologies (holographic projection and spectral tuning).
Educate visitors about the perceptual phenomena with minimal effort.
Ensure a seamless delivery of perceptual experiences.
Foster intrinsic motivation for exploration.
Evoke joy in visitors.
Present novel and innovative concepts.

The experiment group projections on multiple layers of organza, and holographic projection and spectral tuning achieved the highest score. While both groups mainly score on the positive side of the table, some demands are not yet met or insufficient. The demands about sense accessibility and the transition from the physical to the digital world are not sufficient. The experiments are not triggering multiple senses yet and adding a story to the perceptual phenomena could solve the transition demand. The personal demands on providing a seamless delivery, being novel and innovative, joy and exploration are demands that needs to be involved in a later stage of the process. As mentioned before, this Harris Profile is used to check the status of the experiments. It is not used as decision model, but only provides information of what demands needs to be considered in a later stage of the process.

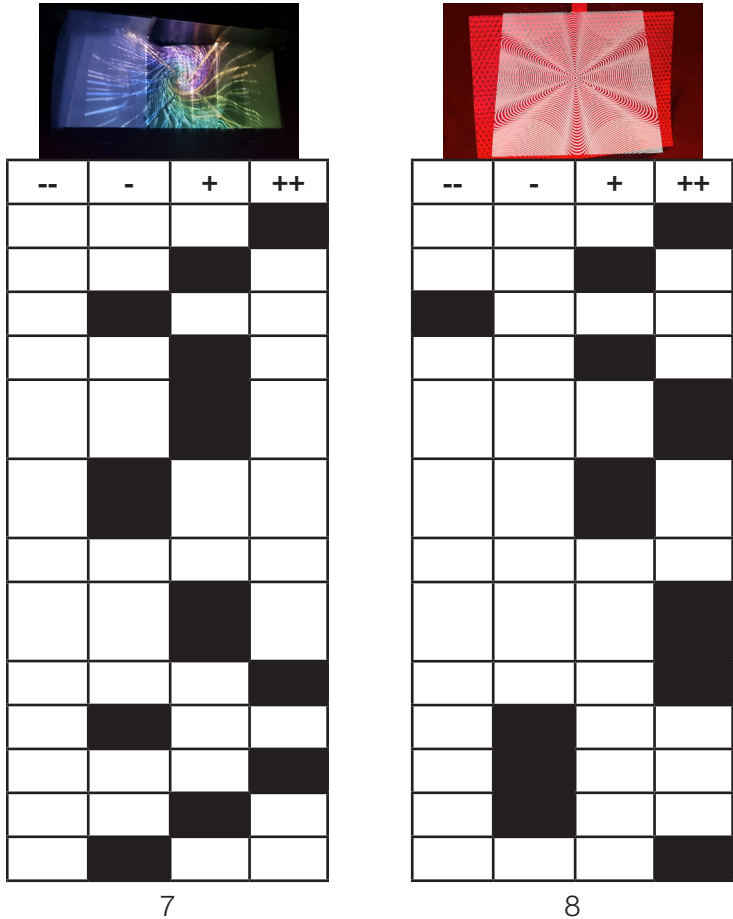
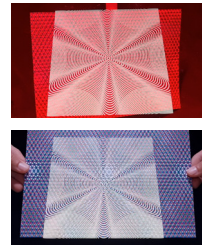
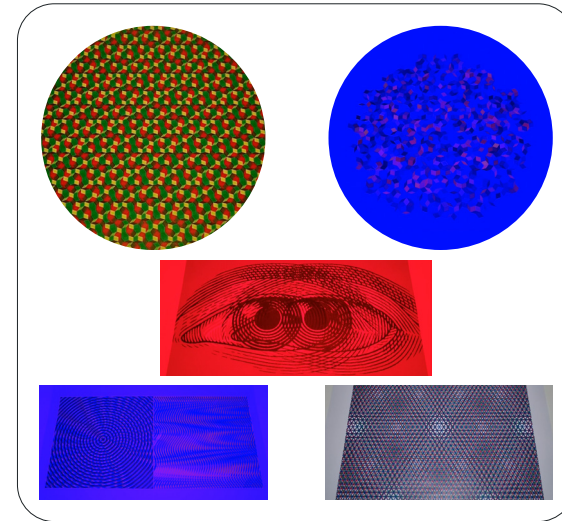
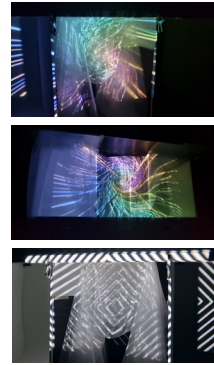
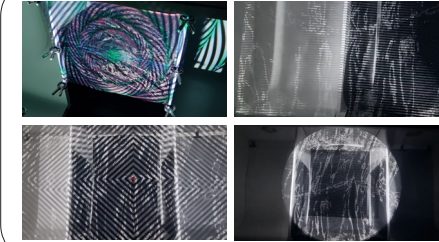


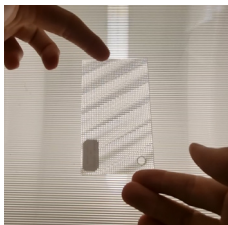
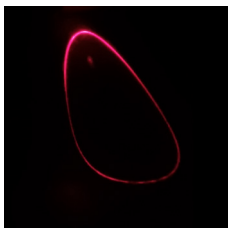
Figure 2.50: Harris Profile with the two highest scoring experiment groups

Profound exploration of
perception

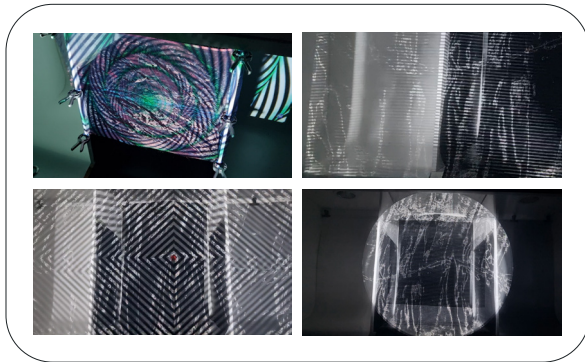


Lightly rely on
technology

Heavily rely on
technology

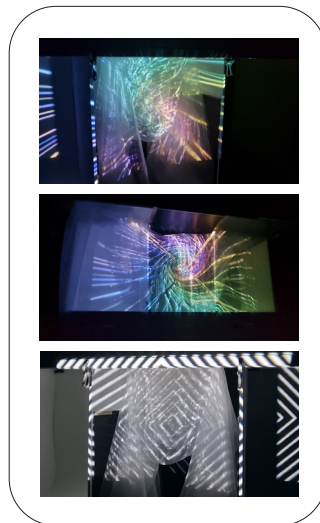


Surface-level exploration of
perception



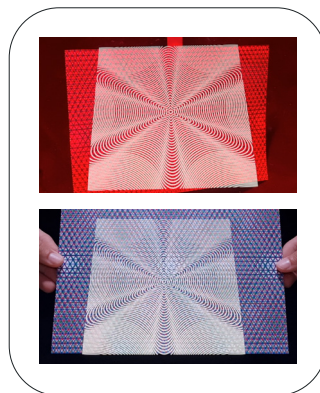
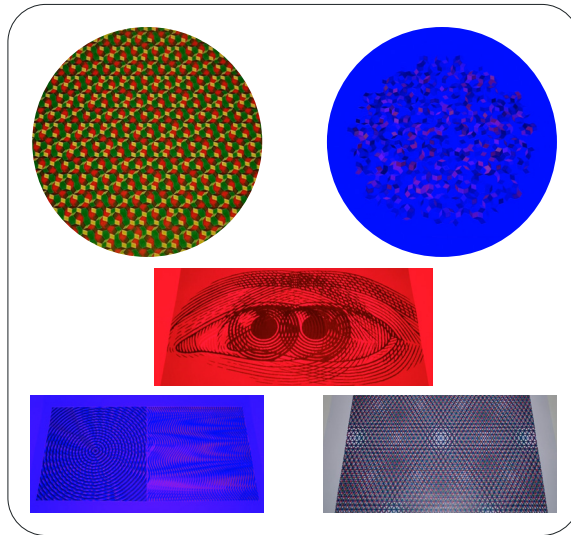
Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

4



Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

7

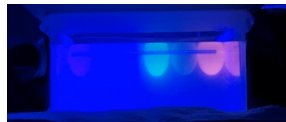
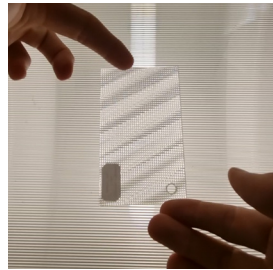
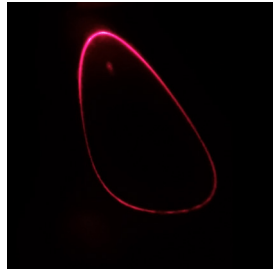


Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

1

Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

8

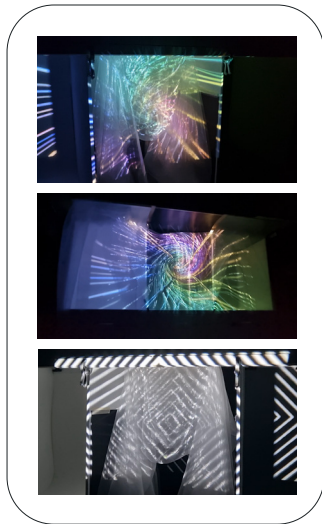


Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

-15

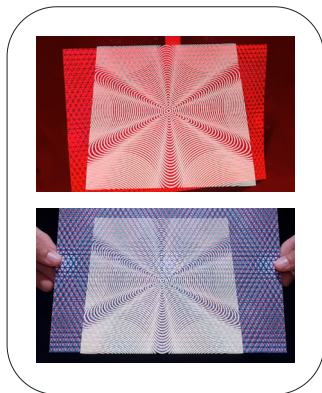
Requirements	--	-	+	++
Enable visitors to experience their own perception.				
Facilitate visitors in learning about and reflecting on their perception.				
Make the environment sensory-accessible.				
Examine the visitors' perspective on the world.				
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.				
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.				
Allow visitors to experience both technologies (holographic projection and spectral tuning).				
Educate visitors about the perceptual phenomena with minimal effort.				
Ensure a seamless delivery of perceptual experiences.				
Foster intrinsic motivation for exploration.				
Evoke joy in visitors.				
Present novel and innovative concepts.				

-6



Requirements	--	-	+	++	
Enable visitors to experience their own perception.					
Facilitate visitors in learning about and reflecting on their perception.					
Make the environment sensory-accessible.					Sensory-accessible
Examine the visitors' perspective on the world.					
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.					
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.					Physical -> digital
Allow visitors to experience both technologies (holographic projection and spectral tuning).					
Educate visitors about the perceptual phenomena with minimal effort.					
Ensure a seamless delivery of perceptual experiences.					Seamless delivery
Foster intrinsic motivation for exploration.					
Evoke joy in visitors.					
Present novel and innovative concepts.					Novel & innovative

7



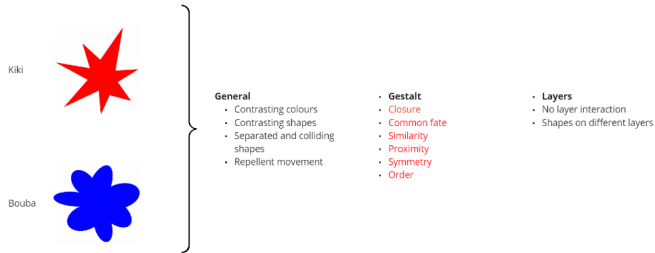
Requirements	--	-	+	++	
Enable visitors to experience their own perception.					
Facilitate visitors in learning about and reflecting on their perception.					
Make the environment sensory-accessible.					Sensory-accessible
Examine the visitors' perspective on the world.					
Showcase creative use of technology to shape the visitors' perspective and impact their worldview.					
Contribute to Highlight Delft's vision to take the visitor on a journey at the transition between the physical and digital world.					
Allow visitors to experience both technologies (holographic projection and spectral tuning).					
Educate visitors about the perceptual phenomena with minimal effort.					
Ensure a seamless delivery of perceptual experiences.					Seamless delivery
Foster intrinsic motivation for exploration.					Exploration
Evoke joy in visitors.					Joy
Present novel and innovative concepts.					

8

4 Appendix

1

Standby scene



Interactions



2

Start scene



Interactions



3

Colour scene



Interactions



4

Order scene



Interactions



5

Blend scene



Interactions



6

Portal scene



Interactions



5 Appendix

Participant ID:

Selective reflections

This research is conducted as part of the MSc study Design for Interaction Master Thesis at the faculty of Industrial Design Engineering at Delft University of Technology.

Researcher contact:

Bas Ammerlaan

bas.ammer@gmail.com or s.r.c.ammerlaan@student.tudelft.nl

+31 6 40327331

Informed consent participant

I participate in this research voluntarily.

I acknowledge that I received sufficient information and explanation about the research and that all my questions have been answered satisfactorily. I was given sufficient time to consent to my participation. I can ask questions for further clarification at any moment during the research.

I am aware that this research consists of the following activities:

1. Viewing abstract projections
2. Participating in a survey

I am aware that data will be collected during the research. I give permission to collect this data during the research. The data will be processed and analysed for this master thesis only. At the end of this master thesis (February 2024) this data will be made accessible to the public, through the repository of the TU Delft. Any personal identifiable information will be destroyed after the graduation project is completed. Before this date, the personal data (the consent form) will be locked away by the researcher and the supervisory team of the graduation project, and the experimental data statistics will be analysed and published anonymously.

I give permission to store the data I provide in the Delft repository after completion of this research and use it for educational and research purposes.

I acknowledge that no financial compensation will be provided for my participation in this research.

With my signature, I acknowledge that I have read the provided information about the research and understand the nature of my participation. I understand that I am free to withdraw and stop participation in the research at any given time. I understand that I am not obliged to answer questions which I prefer not to answer and I can indicate this to the research team.

I will receive a copy of this consent form.

Last name

First name

.. / .. / 2023

Date (dd/mm/yyyy)

Signature

6 Appendix

Participant ID:

Round 1

The colours separate in depth

1234567

Strongly disagreeStrongly agree

The projections are appealing/beautiful

1234567

Strongly disagreeStrongly agree

I felt immersed by the projections

1234567

Strongly disagreeStrongly agree

4x

Participant ID:

Post-test questions

At first you have seen the whole sequence and subsequently the separate sequences. Answer the following questions while keeping the chronological experience in mind.

The installation is engaging

1234567

Strongly disagreeStrongly agree

The total experience is coherent

1234567

Strongly disagreeStrongly agree

Do you have any remarks or comments?

7 Appendix

Visual sequence per participant

Participant	Round 1	Round 2	Round 3	Round 4
1	0 ¹	1	2	3
2	1	2	3	0 ²
3	2	3	0 ³	1
4	3	0 ¹	1	2
5	0 ²	1	2	3
6	1	2	3	0 ³
7	2	3	0 ¹	1
8	3	0 ²	1	2
9	0 ³	1	2	3
10	1	2	3	0 ¹
11	2	3	0 ²	1
12	3	0 ³	1	2
13	0 ¹	1	2	3
14	1	2	3	0 ²

Participant 1

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Yes	No

Participant 2

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 3

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 4

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 5

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 6

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 7

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 8

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 9

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 10

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 11

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 12

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

Participant 13

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

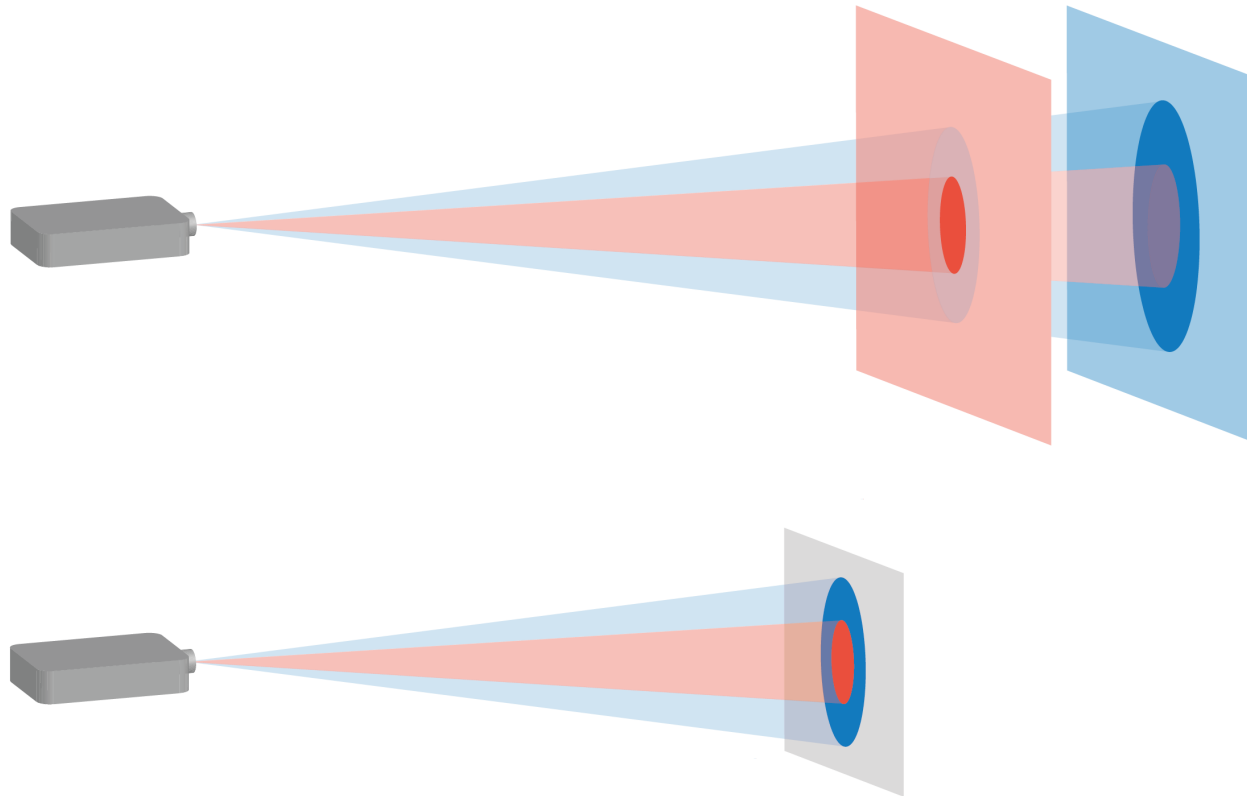
Participant 14

Participant walks from left to right or vice versa to vary viewing angle
Participant reads title on sign
Participant scans QR-code on sign for additional information

8 Appendix

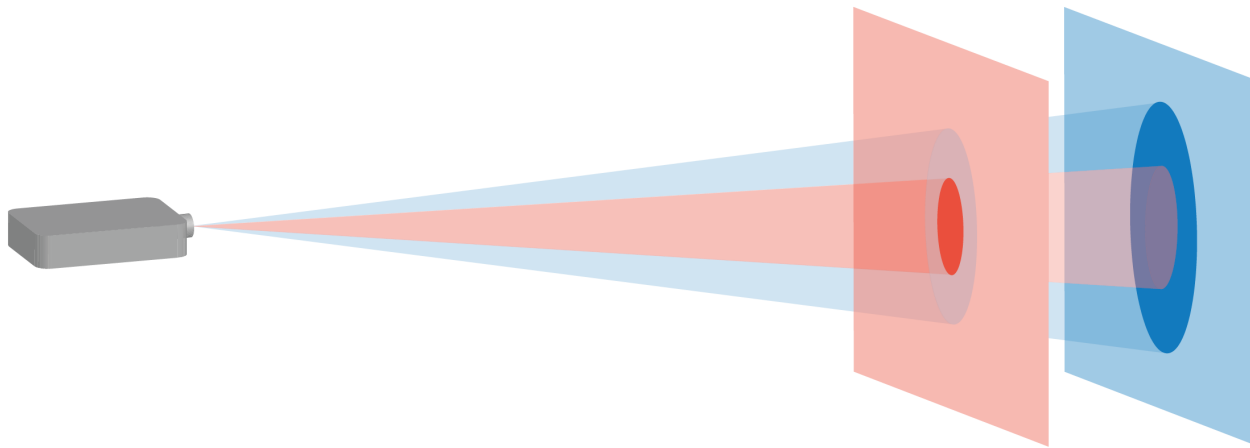
Selective Reflections

How to select reflections?
Spectral tuning!



9 Appendix

How to select reflections? Spectral tuning!



10 Appendix

Participant ID:

Round 1

The colours separate in depth

1234567

Strongly disagreeStrongly agree

The projections are appealing/beautiful

1234567

Strongly disagreeStrongly agree

I felt immersed by the projections

1234567

Strongly disagreeStrongly agree

Participant ID:

Post-test questions

At first you have seen the whole sequence and subsequently the separate sequences. Answer the following questions while keeping the chronological experience in mind.

The installation is engaging

1234567

Strongly disagreeStrongly agree

The total experience is coherent

1234567

Strongly disagreeStrongly agree

The audio enhances the experience

1234567

Strongly disagreeStrongly agree

Participant ID:

Do you have any remarks or comments?

4x

Selective Reflections

Selective Reflections