



**Semester:** LID 10, Spring 2022

**Title:** Evoking Nature Experience-  
Nonfigurative immersive creative lighting in  
outdoor public spaces

Aalborg University Copenhagen

Frederikskaej 12,

DK-2450 Copenhagen SV

**Project Period:** February - May 2022

Semester Coordinator: Ellen Kathrine Hansen

**Semester Theme:** Master  
thesis - 30 ECTS

**Supervisor(s):** Mette Hvass

**Project Group no:**

N/A

**Members:**

Filipe Sequeira Pinto de Jesus  
Almeida

## ABSTRACT

With the advancements in lighting technology creative lighting is being more and more requested for outdoor public spaces at night. Public space is increasingly being populated with standardised solutions that lack meaning and fail to establish connections with the pedestrians. Industrialised creative lighting solutions made out of a selection of figurative luminous effects leave very little to our imagination and its homogenising public space. Architectural Lighting Designers are looking at light art as a source of inspiration and knowledge in order to respond to this new challenge., to give meaning to creative lighting. Light art can be very powerful in manipulating our senses through which we experience space physically, generating a cognitive and emotional reaction and in turn establishing stronger connections between the viewer and the work.

Through an analysis on Light Art's history we found that the road to the immaterial, the immersive experience and the exploration of lights qualities and phenomena led to works that faced us with ourselves as sentient beings, heightening our connection with our surroundings and creating connections with our natural environment. This led us to analyse the importance nature experience, its benefits for humans and if it could help foster our creativity. Complementary to this an analysis on light fundamentals and on the state of the art lead us to a set of criteria that would inform the design of a creative lighting effect that aimed to evoke, in a nonfigurative way, nature experience through light phenomena.

A set of design criteria informed the creation of both a physical and a virtual mockup. The resulting criteria where: Nonfigurative, Materiality, Immersive, Spaciousness, Density, Unpredictability and Variation in movement. The mockups where used to test the emotional response from a group of participants. The findings demonstrated that an immersive nonfigurative creative light effect that is based on a pattern created through material reflections moving organically (unpredictably and with variations) may have a higher positive response than a standardised figurative solution relying on a pattern that has regular motion, is predictable and lacks variation. The first has a significant capacity to enhance creativity due to its high potential to work as a soft stimuli, that captures our attention in a non intrusive way, inducing mind-wandering and restoring our mind.

# EVOKING NATURAL LIGHT PHENOMENA



Nonfigurative immersive  
creative lighting in outdoor  
public spaces

Author: Filipe Sequeira Almeida

Master thesis in Lighting Design  
25<sup>th</sup> May 2021 - Copenhagen, Dk  
Supervisor: Mette Hvass



# ABSTRACT

With the advancements in lighting technology creative lighting is being more and more requested for outdoor public spaces at night. Public space is increasingly being populated with standardised solutions that lack meaning and fail to establish connections with the pedestrians. Industrialised creative lighting solutions made out of a selection of figurative luminous effects leave very little to our imagination and its homogenising public space. Architectural Lighting Designers are looking at light art as a source of inspiration and knowledge in order to respond to this new challenge., to give meaning to creative lighting. Light art can be very powerful in manipulating our senses through which we experience space physically, generating a cognitive and emotional reaction and in turn establishing stronger connections between the viewer and the work.

Through an analysis on Light Art's history we found that the road to the immaterial, the immersive experience and the exploration of lights qualities and phenomena led to works that faced us with ourselves as sentient beings, heightening our connection with our surroundings and creating connections with our natural environment. This led us to analyse the importance nature experience, its benefits for humans and if it could help foster our creativity. Complementary to this an analysis on light fundamentals and on the state of the art lead us to a set of criteria that would inform the design of a creative lighting effect that aimed to evoke, in a nonfigurative way, nature experience through light phenomena.

A set of design criteria informed the creation of both a physical and a virtual mockup. The resulting criteria where: Nonfigurative, Materiality, Immersive, Spaciousness, Density, Unpredictability and Variation in movement. The mockups where used to test the emotional response from a group of participants. The findings demonstrated that an immersive nonfigurative creative light effect that is based on a pattern created through material reflections moving organically (unpredictably and with variations) may have a higher positive response than a standardised figurative solution relying on a pattern that has regular motion, is predictable and lacks variation. The first has a significant capacity to enhance creativity due to its high potential to work as a soft stimuli, that captures our attention in a non intrusive way, inducing mind-wandering and restoring our mind.

# TABLE OF CONTENTS

|                                 |    |                            |    |
|---------------------------------|----|----------------------------|----|
| INTRODUCTION                    | 6  | Online survey              | 70 |
| Introduction to study           | 6  | Findings                   | 72 |
| Motivation                      | 6  | Hypothesis conclusions     | 81 |
| Background                      | 8  | Final design suggestions   | 81 |
| Vision                          | 15 | CONCLUSION                 | 82 |
| METHOD                          | 15 | LIMITATIONS & FUTURE WORKS | 83 |
| Analysis topics                 | 15 |                            |    |
| Design method                   | 16 |                            |    |
| Testing method                  | 16 |                            |    |
| ANALYSIS                        | 18 |                            |    |
| Light Art                       | 18 |                            |    |
| Light Fundamentals              | 42 |                            |    |
| Nature Experience               | 47 |                            |    |
| State of the art                | 53 |                            |    |
| RESEARCH QUESTION               | 57 |                            |    |
| DESIGN                          | 57 |                            |    |
| Development criteria            | 57 |                            |    |
| Material Exploration            | 58 |                            |    |
| Material mockup                 | 60 |                            |    |
| Gobo Projector                  | 61 |                            |    |
| Video Simulation                | 62 |                            |    |
| TEST                            | 66 |                            |    |
| Hypothesis                      | 66 |                            |    |
| Participants & procedure        | 66 |                            |    |
| Scenarios and video simulations | 69 |                            |    |

# INTRODUCTION

## Introduction to study

This thesis sets to investigate the importance of light art for architectural lighting design as a source of inspiration and knowledge and meaning. Furthermore to what degree can some attributes of the first be integrated in the second when designing for an outdoor public space that requires functional lighting and has a permanent nature.

It is also analysed how a nonfigurative and reductionistic approach when designing creative lighting may prove beneficial due to its openness for interpretation, potentially prompting creative thinking. Furthermore by focussing on what is the essence of light and its qualities, as many light artists did, one may also establish links with the natural environment bringing other benefits for peoples wellbeing and fostering creativity.

Conclusions from this analysis will form the basis for the setup of a test comparing different lighting scenarios and its findings will give us some guidance on the design and applicability of a creative lighting effect layer for an outdoor public space.

Note: The author will avoid the terminology “Light Art” when describing an effect layer that is used as part of an architectural lighting design, instead favouring “creative lighting” or occasionally “effect layer”.

## Motivation

Through my internship in a Scandinavian Lighting Design Office I was exposed to the complexity of lighting public outdoor spaces and buildings. As I gained more knowledge in the field and dove deeper in research I have realised that the tendency to include creative lighting, aiming to embellish and “reactivate” public space is growing. Clients, in most cases municipality's, are more and more asking for lighting schemes that are not only functional but also include lighting to embellish, more colourful and graphic. Light projections of patterns, symbols or images is becoming more common. With the lighting technology in constant development and smart LEDs achieving lower power consumptions and being economically more attractive the integration of dynamic lighting is also becoming more common place. Introducing luminous choreographies of changing intensities and colours into the public realm is not only seen as an opportunity to attract people and extend local economy into the night but also as a branding factor (ARUP, 2015). In the same way that commercial advertisement uses video billboards, neons and other luminous artefacts to sell products, municipalities also want to publicise their values, activities and attract people. Cities are transforming into “spectacles of colour, light, motion and sound” (Jackson, 2015). Frequently things loose meaning and purpose therefore we loose the sense of connection with others and our surroundings as pointed out by Artist Julio le Park (as cited in Menezes, 2014) “... with this huge

amount of images, one gets lost, there is no common thread, there is nothing that leads to a more precise connection.”

Social media has gained high importance in local economies and no one seems to want to lose the opportunity to have the “instagramable” colourful public square or bridge that could spread the name of the municipality, event or business into the four corners of the world wide web. Lighting in public space is increasingly being used to communicate and advertise whether it is a new car or pair of shoes, pride day, national day, or solidarity to any given cause, etc. As further elaborated in the following chapters public space is becoming too cluttered with visual stimulation, saturating us with standardised images that homogenise culture and behaviours leaving very little room for the imagination. Like Guy Debord (1992; originally written in 1967) argued that this dominance of economy, leading to consumption and latter appearance, brought the deterioration of social life with damage to our social space.

*“The alienation of the spectator to the profit of the contemplated object (which is the result of his own unconscious activity) is expressed in the following way: the more he contemplates the less he lives; the more he accepts recognising himself in the dominant images of need, the less he understands his own existence and his own desires. The externality of the spectacle in relation to the active man appears in the fact that his own gestures are no longer his but those of another who represents them to him. This is why the spectator feels at home nowhere, because the spectacle is everywhere.” (Debord, 1992)*



Figure 1: Left: Verberg, Sweden (Source: TRS Consulting); Right: Kielland, Stavanger, Norway (Source: Lyskulturs magasin 02/16)

Lighting designers (LDs) are now given the opportunity to be more creative, becoming even more responsible for understanding what are the benefits for everyone. It is also important to understand how we can use creative lighting in a way that entices our imagination and for a moment allows us to escape the “spectacle”, the daily life routines and hopefully help us to reconnect with ourselves and our natural surroundings.



Figure 2: Nordvestparken, Copenhagen - Project by SLA (Source: Author)

Throughout the centuries artists have always been the ones that questioned our societies, our human condition, our place in the world and also the role of technology. Artists constantly push the envelope contributing to social advancement. I believe that one can find answers and tools within light art history that can help us address these issues. In fact it is common to see the intersection of the art world with other fields like architecture, or lighting design. It is my conviction that we can find a link between light art and architectural lighting design that we can explore in order to better support outdoor public spaces at night.

## Background

Architects and other creators have always recognised light as a powerful formgiver and a means to put man in touch with his environment (Lam, 1977). Throughout time daylight informed the design of spaces and was one of the main components in how our built environment changed throughout the years. With technological development came an ever growing ability to create and manipulate light allowing us to extend daytime activities into night profoundly changing our societies and our environment, both built and natural, indoors and outdoors. In this context it was only natural that an independent profession that involved designing with light would appear. Architectural Lighting Design (ALD) as we know it now would emerge in the 20th century and Richard Kelly was one of its pioneers. Having worked as a lighting consultant since the mid 1930s for some of the most influential architects of the modernist architectural movement. He defined some of the canons that are still followed today. Since then multiple lighting designer associations, societies and groups have popped up here and there helping to further establish the profession within the AEC industry and amongst general population.

But lighting public spaces was in most of the cases left on the hands of lighting engineers or others consultants mainly interested in functional needs, lacking an holistic view of how humans experience space and disregarding aesthetics. For the past decades a bigger focus has been given to the spatial experience and to light aesthetics with more Lighting Designers stepping outside the confinements of indoor space and intervening in the urbanscape after dark. ALD has been incorporating lighting technology and research with a growing interest in its non image forming effect, computation either as a simulation tool or as a means to control and choreograph light and it has also been using light as a promotional/branding tool (Mansfield, 2018). By incorporating technological innovation some architectural lighting designers have been stretching the boundaries of creativity taking full advantage of these new tools, introducing creative and dynamic elements as an added layer to the spatial experience. Running through different lighting design competitions (<https://darcawards.com> and <https://litawards.com> among others) throughout the years one can quickly see that the use of new lighting technology that allows for the usage of colour, movement, dynamics, interaction, changing settings, video mapping, etc. is becoming more and more common in ALD.

We can also see that Architectural Lighting Designers (ALDs) often refer to Light Artists as being sources of inspiration, sometimes even collaborating with them. Some of the more known offices have sections on their website dedicated to showcasing or discussing light art (ACT Lighting design, Light Bureau, Spears + Major, Nulty, L'Observatoire International, 2022). So one can assume that ALDs are using knowledge collected from observing and/or collaborating with light artists.

Light Art is merging with Architectural Lighting Design. It is then important to look into what makes light art works relevant for ALDs and try to reason how these characteristics can be transferred into the illumination of architecture that has functional requirements.



Figure 3: L'Observatoire with James Turrell - Post du Gard, Nîmes, France (Source: <https://lobsintl.com/project/pont-du-gard>)

According to the Oxford Dictionary Light Art is defined as:

*"A general term for works of art in which artificial light (usually electric) plays an important role. Although artists had experimented with artificial light since the 18th century, it was not until the 1960s that Light art could claim to be a recognised movement and there was widespread use of fluorescent and neon lighting, lasers, and holography. Several important exhibitions of Light art were held in both Europe and the United States." (Clarke, 2010)*

After literature research on the subject it was understood that light in art developed from figurative and restrained to being expansive and reduced to its very essence, playing with our perception making us question our very existence, our place in the universe and our primordial connection with nature. By doing so it evokes natural phenomena in a primal nonfigurative way leaving room for interpretation, questioning and imagination.

### **Investigation of the problem**

Different intervenient's in illuminating public spaces (not only lighting designers but also light engineers and landscape architects, among others) are being allured by the array of possibilities that LED lighting technology brings. We start seeing more often the usage of dynamic lighting, colour, movement and interaction (CIE, 2019). These arising forms of lighting are being used somewhat indiscriminately but also as part of regeneration strategies in unattractive, problematic or socially inert urban spaces but without much study put in to it (Ebbensgaard, 2015). Today, "the display of creative, coloured lighting" adds another layer to the "prolonged negative impact artificial lighting at night has on the environment" (Zielinska-Dabkowska 2018). This may also have a great impact in manipulating our senses through which we experience space emotionally, cognitively and how we behave in it, therefore we need to understand more clearly the repercussion of such usage. The integration of light features or elements that may be perceived as luminous embellishments or "creative lighting" may have an unintended effect if not applied in a reasoned and research based manner. They could also be used as mere "readymade thought-out conceptual solutions that merely appear as aesthetic improvements of the neighbourhood" (Ebbensgaard, 2015) and that by itself does not improve public space usage.

On a bigger scale Night-time illumination and "creative lighting" as being part of it can also "influence the perception of urban space as well as the atmosphere and quality of life in modern metropolis" (Zielinska-Dabkowska, 2014). Referring to Kevin Lynch concept of "mental maps", a mental picture of the external physical world that supports our navigation in the urban space where the elements that order it such as districts, landmarks, nodes, paths and edges (Lynch, 1998), could be negatively rearranged at nighttime through "the imbalance between the various elements of the nightscape". The legibility of the urban landscape after dark is dependent on well planned and designed illumination that allow people to "recognise the scale and dimension of the space they are navigating" also supporting the recognition of others. If there is visual clutter and unreasoned spatial hierarchy many of the clues that support navigation are lost and that may leave people with a sensation of disorientation and confusion. (Zielinska-Dabkowska, 2014) Another aspect on a more psychological level is the use of creative lighting with ready-made figurative content. This tendency leaves barely anything to the viewers imagination therefore leaving little for our brain to create its own interpretation

depriving it from stimulation on the higher-level areas of the brain responsible for creativity and imagination. It is in the challenging of the brain that comes with non-figurative art that we are mentally stimulated. It exposes ourselves to the unfamiliar potentially increasing our tolerance to it and very importantly allowing us to, for a moment, escape reality to create imaginative and creative responses (Kandel, 2016). By using figurative content it is also more likely to exclude parts of the population that for cultural, religious, geographic, or other reason may not identify with the imagery or have a negative emotional response to it. This is an important issue if we aim for an inclusive society.

It is therefore relevant to better understand what are the characteristics of light art, how and which can we transposed to architectural lighting design that has functional requirements, is context based and serves a number of diversified users in their daily lives.

### **A philosophy based approach towards nonfigurative light art**

Regarding the study of light art and what elements can we incorporate in architectural lighting design, it is of my personal interest to focus on non-figurative light art.

I believe this is also how one can contribute to current practice and research focusing on spatial experience and wellbeing. I use the following theories and research analysis to support this. Deleuze et Guttari (1987) critic on representational thinking and what psychiatry and neuroscience tell about the importance of abstractionism or "reductionism" like Nobel prize winner Doctor Eric R. Kandel (2016) would describe it.

*"Light art: A general term for works that use artificial light (generally electric) as an artistic medium of its own or as an important constituent of a piece." (Chilvers et Glaves-Smith, 2015)*

The above sentence from the Oxford dictionary of modern and contemporary art demonstrates how broad Light art can be. It also mentions that it can be about the piece (the luminous object) or the light itself.

In order to establish some limits and have a more precise target of research the works of Gilles Deleuze with Félix Guttari and their critic on representational thinking will be used. They argued that we are too dependent on a representational mode of thinking and therefore we are not focusing on the possibilities of the subject itself and that prevents us from understanding it better and being innovative. We are constantly imitating. Representing the real, the origin. They criticise the platonic view of perfection that for every entity (origin) there is an ideal form of that entity. The closer that entity is to its ideal form the more perfect it is. They called it an "arborescent" way of conceptualising. The root represents the ideal form and the branches are multiple instances of that form. The closer a particular branch is to the root the more perfect it is (Deleuze et Guttari, 1987). In the history of art one can see that it was only in mid 19th century when artists started to break from the academic traditions of representation that true innovation started. Before that innovation was mostly on a technical level. The focus was not on representing anymore but on expressing and therefore moved more and more towards the experience. Innovation comes from throwing away representation. In that sense instead of using light in an "arborescent" manner and asking: What can I do with light? (as in how can I use light to represent/imitate something) one should ask **What can light do? What can it create that other media cannot?** In that way light is not a mere tool used to produce a faulty

representation of something but becomes an entity that has its own capacities.

So Deleuze proposes a “non-arborescent” way of viewing things. In the tree metaphor there is a constant replication of the origin where the root is copied in each new branch always referring back to a point, always tracing something existent. He proposes a “rhizomatic” way of thinking. In opposition to trees, rhizomes do not grow in a sequential manner, they do not refer back to any origin point (root). Nothing in a rhizome represents something else. Unlike trees that a small branch is a replication of a bigger branch that in turn is a replication of the entire tree that in turn replicates its roots. “In a rhizome there are only connections” (Adkins, 2015) We can also understand this “arborescent” vs “rhizomatic” dichotomy in the distinction they do between tracing and mapping. Adknis (2015) suggests that tracing is like a sticker that is a ready made image (reproducing something existent) used over and over again. Mapping is more like a map where you can move in multiple directions and take new routes, more directly related to free drawing. It is about constructing something new, creating connections. It represents free expression. So if we are fundamentally researching light and it’s effect it is only logical that we are interested in: **What can light do?**

To further support our choice one can find some validation in some psychology and neuroscience theories and findings. The sentence below perfectly describes the powerful effect

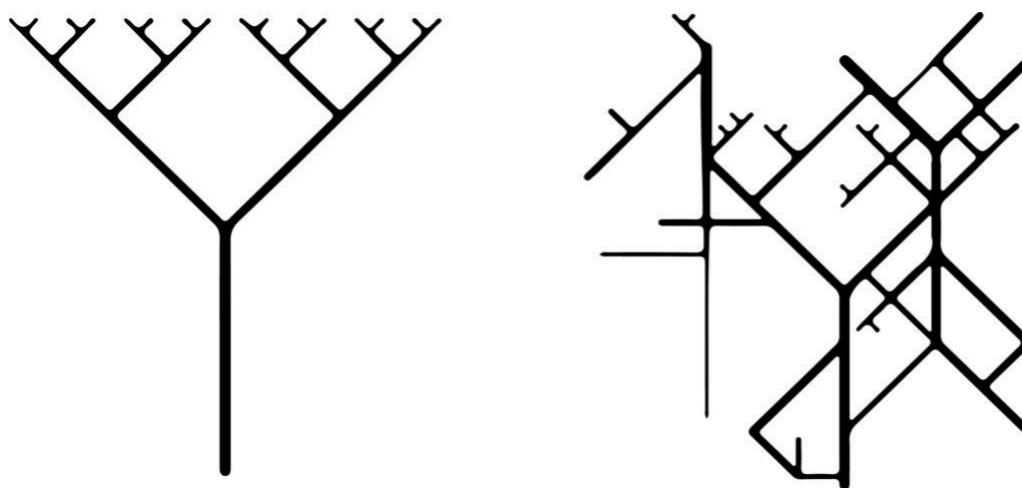


Figure 4: Left - Arborescent growth; Right - Rhizomatic growth  
(Source:<https://medium.com/@meitarkeshet/think-like-fungus-f2ac7a6a116>)

that nonfigurative art can have in how we relate with it, with the space that surrounds us and the space within ourselves.

*“... abstract art frees our brain from the dominance of reality, enabling it to flow within its inner states, create new emotional and cognitive associations, and activate brain-states that are otherwise harder to access. This process is apparently rewarding as it enables the exploration of yet undiscovered inner territories of the viewer’s brain.”* (Aviv, 2014)

In the same manner Kandel (2016) argues that reducing art to its elements and therefore avoiding mere representation puts us in contact with what is unfamiliar making us more accustomed to abstract thinking, creating imaginative responses. This “rhizomatic” way of both creating and organising thoughts is, according to Deleuze and Guttari (1987) more likely to spawn innovation and therefore contribute to societies development.

As a conclusion our research focus will be on light artists that are interested on the essence of light (not using it as a mere representational tool) creating immersive experiences aiming to summon it. How can this essence enhance our creative cognition and how can we integrate in outdoor public spaces.

This will be further investigated in the following chapters. Sculptures that use light sources, video mapping and other art forms that may be categorised as light art but are clearly “arborescent” will only be considered within this paper as a developing step in history that led to contemporary light art.

Our goal will also be to answer the question **“What can light do?”** Through research within 3 different knowledge fields: Art/Humanistics, Natural science, Social science in order to achieve and holistic outcome.

[Deleuze et Guttari \(1987\) critic on representational thinking](#)

**What can light do? What can it create that other media cannot?**

- More likely to spawn innovation

**non-figurative/  
non-representational light art**

[Doctor Eric R. Kandel \(2016\) “reductionism”](#)

- Puts us in contact with what is unfamiliar making us more accustomed to abstract thinking, creating imaginative responses.
- Escape reality to create imaginative and creative responses

Figure 5: Summary (Source: Author)

## Creativity

For clarity it is important to explain what is creativity and how come it is important. Although it is commonly associated as an almost exclusive trait of an artist it is relevant to mention that on a psychological level there is no distinction between creativity that we associate with being and artist, and the creativity that we all rely on when trying to solve a problem from a different angle, to improve or create something new within our field (Mikkelsen, 2009).

Psychologist Mihaly Csikszentmihalyi (1997) describes creativity as: "...any act, idea, or product that changes an existing domain, or that transforms an existing domain into a new one"

Although there are multiple definitions of creativity it can also be generally defined as coming up with something useful, as observed by Plambech & van den Bosch, 2015 a "*useful novelty – not a novelty for its own sake, but a novelty that can be applied, and add value to products and services*".

It is in this respect that creativity can boost social advancement, by creating new value or adding it to products and services that facilitate our lives in multiple fields such as health, education and even how we socialise and use public space. As an example the creation of public illumination, that required creative thinking, enabled us to extend our social activities into the nighttime. Singh (2018) explains how creativity is important to society with the following examples:

*"... Apple re-inventing or creating a new look home computer to the iPhones and iPads of today that have changed our lives and the way we communicate and do business to Elon Musk and the way that he takes a creative approach to car manufacturing, to space travel and even energy."*

This can also be coming up with new ideas or philosophies that change our societies for better or worse, like politicised concepts of living in society like capitalism, communism or socialism.

Mihaly Csikszentmihalyi (1997) also describes that creativity helps us find meaning in our lives and therefore improve our wellbeing.

*"a central source of meaning in our lives ... most of the things that are interesting, important, and human are the results of creativity ... [and] when we are involved in it, we feel that we are living more fully than during the rest of life."*

Some research also suggest that creativity may extend our life expectancy. Doctor Nicholas Turiano (as cited in Rodriguez, 2012) explains that may be because it draws on a variety of neural networks within the brain. "Individuals high in creativity maintain the integrity of their neural networks even into old age.". It is argued that because the brain as the organ that controls all our bodily functions, if one exercises it (by questioning and being creative) it helps to keep it healthier and therefore functioning better and more efficiently in running our systems smoothly. Turiano (as cited in Rodriguez, 2012) further argues that "Keeping the brain healthy may be one of the most important aspects of ageing successfully—a fact shown by creative persons living longer in our study."

To conclude creativity is responsible for social advancement in the sense that it generates new ways of thinking or new tools that enable its advancement. It may also be responsible for a more prolonged and meaningful life.

## Vision

What if by using nonfigurative creative lighting as an added layer to outdoor lighting one could heighten creativity of those who use outdoor public spaces at night thus contributing to social advancement?

## METHOD

In this chapter we briefly outline our methods that led us to a research question and a means to answer it.

## Analysis topics

Our background chapter set the stage for our vision. From that Light art was the first topic to be analysed and that led us to two more topics: Light Fundamentals and Nature experience.

### Light Art

Why did artists use light as a material? With what purpose? What could light do that other mediums couldn't? What can we learn and apply in future lighting designs? What can light do?

In this analysis of the history of light art we aim to answer the above questions in order to find criteria to develop future designs. This criteria not only will give meaning to our design but the knowledge that comes with it will also give us an alternative to the industrialised standard creative lighting solution that lack meaning.

### Light fundamentals

What is light? What can light do?

It is important to understand from a scientific point of view how light works and how does it interact with other medium in order to be able to shape it into a creative lighting design. We learned from the analysis on Light Art history that when moving away from physical materials like paint and clay into an ephemeral and invisible one like light one needed to understand how it works and how can it be rendered visible.

### Nature experience

What is the effect nature has on humans? How can it support us in being more creative?

One of the findings from our analysis on Light Art history was that reducing light to its essence

may create connections with the natural environment by evoking natural light phenomena or experiences in nature, either intended or unintended by the artist. This lead us to analyse the importance of a nature experience and how this connection may give us some criteria that when applied to a design may trigger creativity.

Following the analysis of these topics a review on the state of the art will provide us with some practical applications of nonfigurative creative lighting in an outdoor public space at night.

## Design method

Through an experiment-based approach we aim to design a creative lighting effect based on light patterns. We set to create them through two different approaches: one nonfigurative and reduced to the use of light and its interaction with materials and the other using a standard figurative gobo projection.

The findings from the analysis chapter gave us some design criteria that would be applied into the creation of a physical mockup. This mockup and a gobo projection will be the basis for a number of different immersive scenarios that will allow us to test a set of hypothesis derived from our research question.

A virtual mockup of a generic outdoor public square in a residential area will also be used to simulate how the creative lighting design would work in practice. It will also be used for testing purposes. Twinmotion and Unreal engine software was used to create the mockup and simulate the lighting effects.

## Testing method

In order to validate the hypothesis and answer our research question user-feedback was needed. A number of participants will be exposed to a set of immersive scenarios, setup in a light lab and asked to give their feedback.

In order to quantify the participants perceptions and emotional responses, that are by nature qualitative, a small research on the most appropriate method to quantify them was undertaken. This resulted in the development of a 2 part questionnaire. First part being based on Lee H and Lee E (2021) modification on the Pleasure Arousal Dominance (PAD) emotional state model developed by Mehrabian & Russel (1974) and the second one was a Likert scale type of assessment questionnaire. The PAD emotional state model includes three groups of emotional states: pleasure, arousal and dominance, but this study will disregard dominance because it has been found “to be non-significant in many studies” as elaborated by Lee H and Lee E, 2021 that developed a study similar in nature to the present one. Therefore the current study focuses on two groups of emotional states: pleasure and arousal. In Lee H. and Lee E. (2021) the following pairs of emotional words where used:

“Four pairs for pleasure including pleasant-unpleasant, happy-unhappy, satisfied-dissatisfied and comfortable-uncomfortable; four pairs for arousal including excited-calm, aroused-unaroused, wide awake-sleepy and stimulated-relaxed.” (Lee & Lee, 2021).

For the purpose of our research an adaptation was needed to include emotional pairs that would be more relevant and exclude the ones that are not. Similar to Lee & Lee (2021) eight pairs of emotion words with a seven-point semantic differential scale were used. Some of the pairs where reverse-scored, with the positive emotion being irregularly placed on the left or right column of the questionnaire, in order to “reduce response biases related to multi-item measurement scales such as acquiescence or straight-line responding when the wording is in a single direction”. The pair aroused-unaroused was excluded as well as satisfied-dissatisfied and wide awake-sleepy being replaced with predictable-unpredictable, constraining-unrestrained and connected-meditative. It is clear to the researcher that by doing so the model now only has two pairs (stimulated-relaxed and excited-calm) for the arousal group but one may also relate connected-meditative as states that require and are associated with opposite levels of arousals. Furthermore constrained-unrestrained has a positive or negative emotional response that relates to pleasure so one may include it in the pleasure group. Predictable-unpredictable may have emotional responses associated to them but those are of a more complex nature. What was important was to have a quantification of this pair because, from our literature review we know that it may be an important factor in mind-wandering.

The participants where given a two part questionnaire: the aforementioned PAD model questionnaire (Figure 5, Left) and a 7-point Likert scale type assessment questionnaire comprised of three questions (Figure 5, right). How the different scenarios where perceived as being close to a nature experience, if they envisioned them as being spaces for contemplation and mind-wondering and a third question to understand how relevant it is to know how the effect is being done. They where also asked to provide some basic demographic information regarding gender identity, age and nationality just to register how diverse was the participation group.

|  |                       |                       |                       |                       |                       |                       |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Please rate your experience using the scale below.<br>Example: In Happy/ Unhappy 1 is for very happy and 7 for very unhappy. 4 is neutral. |                       |                       |                       |                       |                       |                       |
| DOES THIS SCENARIO EVOKE A NATURE EXPERIENCE?  |                       |                       |                       |                       |                       |                       |
| 1  | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     |
| <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| (Totally NOT applicable)   |                       |                       |                       |                       |                       |                       |
| (Neutral)  |                       |                       |                       |                       |                       |                       |
| (Very applicable)  |                       |                       |                       |                       |                       |                       |
| DO YOU SEE THIS SCENARIO AS A SPACE FOR CONTEMPLATION AND MIND WONDERING?  |                       |                       |                       |                       |                       |                       |
| 1  | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     |
| <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| (Totally NOT applicable)   |                       |                       |                       |                       |                       |                       |
| (Neutral)  |                       |                       |                       |                       |                       |                       |
| (Very applicable)  |                       |                       |                       |                       |                       |                       |
| WHEN ENGAGING IN THIS SCENARIO IS IT IMPORTANT THAT YOU UNDERSTAND HOW THE EFFECT IS DONE?   |                       |                       |                       |                       |                       |                       |
| 1  | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     |
| <input type="radio"/>  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| (Totally NOT applicable)   |                       |                       |                       |                       |                       |                       |
| (Neutral)  |                       |                       |                       |                       |                       |                       |
| (Very applicable)  |                       |                       |                       |                       |                       |                       |

Figure 6: Left: PAD questionnaire; Right Likert scale questionnaire - Source: (Author)

# ANALYSIS

## Light Art

### From depicted light to light to be seen

"Modernity is the transient, the fleeting, the contingent; it is one half of art, the other being the eternal and the immovable." (Baudelaire, 1986) written in 1863

Contemporary light art evolved alongside technological advancements in electric light, materials and scientific findings. Early 19 century saw the appearance of electric light and the development of the light bulb making electric light a possibility in every household (Tregenza, 2014). In field of physics Heinrich Hertz (1857-1894) elaborating on the work of Christiaan Huyges (1629-1695), Thomas Young (1773-1829) and Augustin-Jean Fresnel (1788-1827) proven that light is an electro magnetic wave and therefore flows in waves and is affected by surfaces. Later on Albert Einstein's (1879-1955) photon theory gave matter (in the form of particles) to light thus we now speak of light as both wave and particle. In 1916 chemist Friedrich Wilhelm Ostwald (1853-1932) claimed that our eyes see nothing but radiant energy triggering chemical changes in our cornea enabling us to sense light. This meant that colour is also radiant energy and therefore it is light. This realisation made it easier for artists to change from paint/colour to light. Colour was now a phenomenon of light (Jackson, 2015). These scientific discoveries were crucial in the art world in the turn of the century.

By the end of the 19th century, art had already shifted from the academic representational way of depicting reality to a new way of expression that relied more on the sensorial, emotional and cognitive worlds, on new ways of seeing and on the invisible. By the start of the 20th century the technological advancements of the era where always depicted by movements such as the Italian futurism not as in a mere representation but in a way that emphasised benefits of industrialisation and the capabilities of machines. It is the "visualisation of movement and energy" (Janson, 2011) that one can see represented in Giacomo Balla's painting "Street light" (fig 7 Left). But still it was just using paint on a canvas to depict light like it has been for the past centuries. This representation of energy in futurism and movement in both futurism and cubism led to the desire for the reality of movement and energy in constructivism and kinetic art movements. (Weibel et Jansen, 2006)

It was only in the first decades of the 20th century that light was being used as a medium in its own right. As modern art would get more and more abstract and moving towards the immaterial and as society would get more and more accustomed to electric light there was the realisation that electricity and light could not only be utilitarian but it could also be aesthetic. Light in order to see was becoming light to be seen (Piemontese, 1993). Light and movement (powered by electricity) became new materials to work with that add all the progressive values that early 20th century modernist artists wanted and it was an unexplored new territory.



Figure 7: Left: Street Light by Giacomo Balla dated 1909 (Source: MoMA)/ Right: Light Space Modulator by Moholy-Nagy, dated 1930 (Source: Moholy-Nagy Foundation)

*"We have now reached the stage when it should be possible to discard brush and pigment and to "paint" by means of light itself."* Moholy-Nagy 1936 in a Letter to Frantisak Kalivoda (as cited in Kostelanetz, 1991)

One of the first artists to integrate light as material in their works was László Moholy - Nagy. A teacher at the Bauhaus a German art school founded in Weimar in 1919 influenced by the period's belief that industrialisation and machines would create a better world. As early as 1922 he started using light and movement in his Light-Space Modulator pieces (Fig. 7 Right) in which rotating machinery with perforated acrylic and steel plates illuminated by spotlights would project refracted, reflected light and shadow patterns onto its surrounding surfaces creating a moving luminous spectacle reminiscent of shadow theatre. Moholy - Nagy used his kinetic luminous sculptures as a tool to study light and how it affects space (Janson, 2011). Because of its spatial nature his kinetic sculptures were starting to give the observer a more immersive experience and this was in fact one of its major innovations.

Roughly in the same period Czech light-kinetic artist Zdeněk Pešánek created is Spectraphone (1924-30) where he experimented with electric light to give the impression of depth by manipulating shadow and shapes. A simple relief object hung on a wall would be illuminated by different light sources that the artist could control with a keyboard. This allowed him to do a live luminous performance where he could choreograph the changes in the objects appearance. He called the device a Spectraphone. After multiple versions and the failed attempt to start its serial production he decided to abandon it. Shortly after this experience, Zdeněk Pešánek created what is regarded as the first public light-kinetic sculpture in the world. Edisonka is a reinterpretation of is Spectraphone that is fully automatized. It counted 420 colour bulbs (seven rows of white, yellow, green, blue, violet, red, and orange, 15 bulbs each, in each of four constituent parts) and produced a pre-programmed light-kinetic performance. It was in operation above the entry of the Edison transformer station building in the city of Prague from October 1930 to 1937. Pešánek had an understanding of the importance of discussing artistic considerations into the context of street lighting and light in advertising. He organised a cycle of lectures and workshops called O světle (meaning About light) advocating the role of kinetic-light art in the urbanscape (Zemánek, 1999).

In his collaboration with the Electric Company of the City of Prague he continued to develop light-kinetic sepultures celebrating inventions in the field of electricity from 1932 to 1936. He continued to use a system of choreographed colour bulbs and started using neon lights for the first time as an artistic material. It was only 15 years later, that Italian artist Lucio Fontana created a large sculpture made entirely out of glass neon light for the 1951 IX Triennale di Milano.

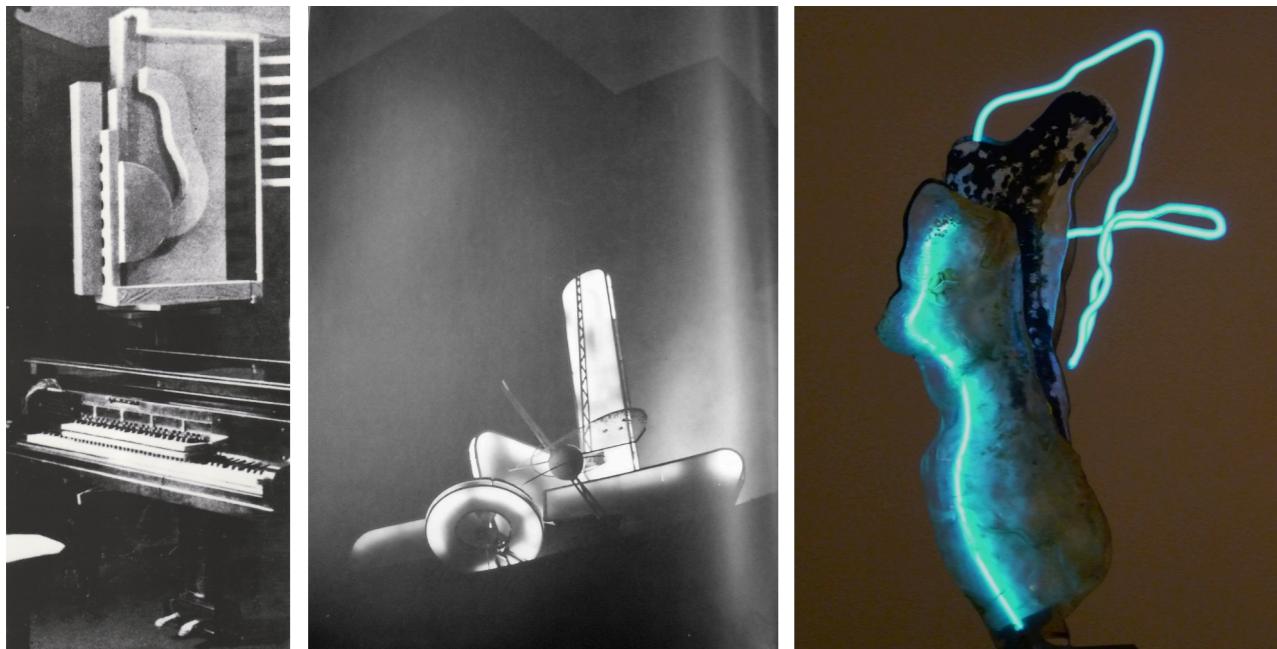


Figure 8: Left: Spectraphone, first version, 1926; Center: Edisonka, 1929-30; Right: Torso from Spa Fountain, 1936 (Source: Zemánek, 1999)

There was yet another key figure crucial for light art, that was ignored until the 1960s (Stein, 1968) and is still not often mentioned in history books. Danish-born artist Thomas Wilfred (1889-1968). After two major retrospective exhibitions of his work in the USA, one in 1971 and one in 2017, more research has been done on this artist who is in the origin of Light Art and coined by some to be the first Light Artist.

*"Thomas Wilfred was the first artist in this century (20th) to use light as the means for expression rather than for the illumination of real objects from nature. He began his experiments in 1905, and although Wilfred was certainly not the first to emphasise the integration of form, color, and movement as a separate art, he clarified its possibilities and invented a means to communicate his concept."* (Rutkoff, 2017)

Wilfred had a very important role in kinetic art and the introduction of light as a material. It is now known that he influenced many of his contemporaries including Moholy-Nagy, who mentioned him in one of his books during his period as a professor at the highly influential Bauhaus school of art (Petersen, 2018). As early as 1905 Wilfred was experimenting with light. He shared with the early modernist movements (like the impressionists) the desire to capture the radiance of colour and movement but he observed that painting would always remain static and that the existence of painting was dependent on a light source and therefore the perception of colour would always change according to said source. He concluded that imitating light effects on canvas or on stone could never replicate the character of luminosity. To Wilfred (1968, as cited in Orgeman, 2017) light "is part of the universe of flux and therefore motion is a necessary dimension, in fact, in any visual art involving light". For the artist movement was crucial for his work not as a means to glorify the technological advancements by engaging with the mechanisation of society, like the aforementioned Moholy-Nagy and Zdeněk Pešánek, but "as a means of suggesting the true nature of light - a force of energy that travels constantly through space" (Orgeman, 2017). This is the foundation of his work and what makes him unique at that time. He is interested in light not as a mere symbol of modernity or man's capabilities but as a thing in itself. He was obviously not interested in using light to represent something else but he was also not interested in imitating light or represent the cosmos but to simply reveal their presence. Wilfred (1968, as cited in Orgeman, 2017) was interested in creating "purely non-objective luminous form[s] moving slowly through a curved space orbit."

*"Light for Wilfred was both an elemental fact of nature the sun as ultimate life source and metaphysically suggestive: "the greatest symbol of conscious mankind's longing for understanding and spiritual liberation."* (Rutkoff, 2017)

He wanted to explore new spatial realities through the use of pure light and was heavily influenced by the first steps of astronomical photography and science fiction, in pursuing a new "cosmic consciousness". He did so by combining his knowledge in science, philosophy and spirituality in light-kinetic artworks. His otherworldly imagery in fact suggests and has been frequently compared to "the flicker of flames, the evanescent patterns of the aurora borealis, and the subtly shifting light at dawn or dusk." (Petersen, 2018)

In 1919 (3 years before Moholy-Nagy first experiments with his Light-Space Modulator) and after 14 years of experimentation Wilfred made his first successful Clavilux a soundless light organ (Stein, 1968). During the 1920s Wilfred iterated and developed this instrument. It consisted of an assembly of electric, mechanical and reflective components that allow him to paint with the electro-magnetic waves of the light bulb. The beam emitted by the bulb would be transformed when passing through rotating transparent discs with hand painted colour and

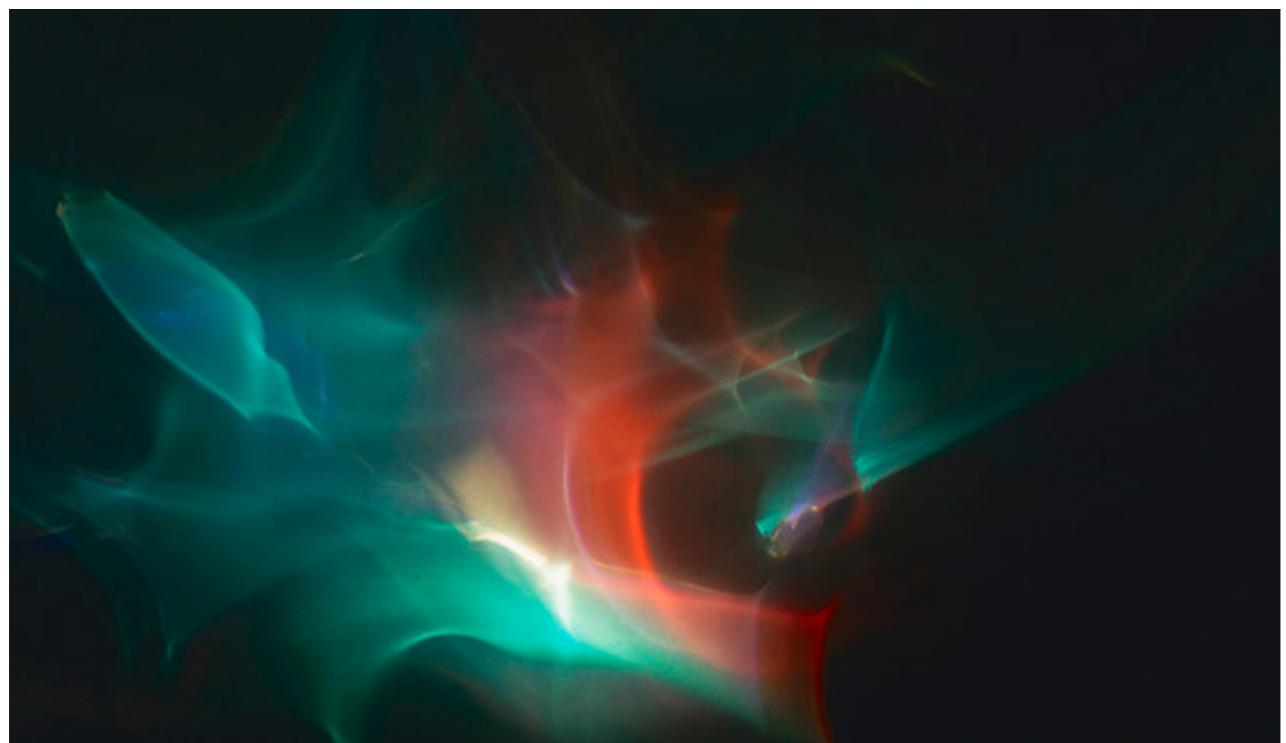
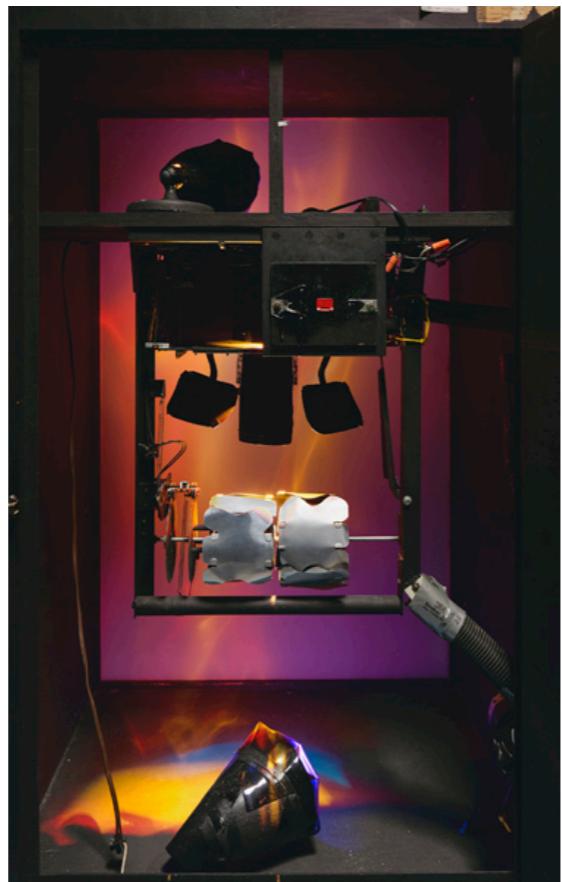


Figure 9: Left: Unit #86, from the Clavilux Junior , 1930;  
Right: Lumia Suite, Op.161, Interior mechanism, 1965. (Source: Carol and Eugene Epstein Collection)  
Bottom: Lumia Suite, Op.158, Projection still, 1963. (Source: Yale University Art Gallery)

subsequently transmitted onto moving reflective surfaces that would then project the light onto the back of a flat screen. The mechanism was encased in a box with a screen that could differ in scale from television size to cinema with only the face of the screen visible to the observer. What one would see was the light being refracted and reflected in a gently and constant movement creating an immaterial spectacle. Thomas Wilfred would refer to his works as Lumia claiming a new category of art. In a New York Times review by Edward Alden Jewell (1939 as cited in Rutkoff, 2017) he described the spatial-temporal experience of Lumia *“as if one were witnessing a kind of sidereal choreography—a dance of comets and galaxies with the boreal aurora as backdrop and, beyond that, the velvet blackness of infinite, universal space.”*

### Light as expansion

After the second world war (1939-1945) art moves definitely beyond the traditional representative forms of sculpture and painting. The observer moves from a passive experience of looking towards a more embodied experience. Some artists start to the sense of spatial relations where an individual image or object can be distinguished from the whole, instead focusing on an *“aerial and impalpable experience”* (Celant, 2019), that is to say on atmosphere.

*“What prevails is no longer a crystallised thing, but an indeterminable flow of energy that envelops and includes: a continuum, an everything.”* (Celant, 2019)

One of the first artists to encourage this symbiosis between space and subject was Lucio Fontana. In his “Ambiente spaziale a luce nera” (1949) a cubic black space accessed by a narrow corridor, visitors would be faced with a variety of abstract organic forms painted in phosphorescent colours radiating under ultraviolet light. Object and space blend forming a whole. This piece was an attempt to eliminate the distinction between sculpture, painting and architecture. He focused on the bodily presence of the spectator, engaging him in space. With Fontana we are now starting to include the phenomena in art.

*“When you entered you were completely isolated, by yourself, and every viewer reacted specifically with his or her mood at the moment... Each person was there with himself, with his awareness, ignorance, matter, etc.”* Lucio Fontana (cited in Crispolti, 2006)

In this sentence Fontana implies that the subject is also part of the art piece as it is in his reaction, in how he moves through space sensing it that the work becomes complete. This also means that the subject is free to experience and interpret the work as he pleases. The artist does not impose a narrative nor a theme and leaves it to the subject to create it through its own imagination. This also demonstrated the self-reflexive potential art has that would latter be explored by the Californian Light & Space movement and artists like Olafur Eliasson.

Fontana theorised the concept of Spatialism by taking some premises of the Futurism movement of incorporating the scientific and technological advancements into art and adding the rupture with the limited space of the canvas and sculpture. Fontana started using neon lighting in his “Spatial Light piece” for the 9th Milan Triennale in 1951. A 100m long curvaceous neon tube suspended above a wide staircase created a “spatial environment” in which there was a synthesis between the architecture and the art medium with the convergence of light, colour and form (Pasini, 2008). In this environments where he manifested the need to liberate art from the material, Fontana “laid the foundations for that cult of emptiness” that would later be



Figure 10: Above: Lucio Fontana, Ambiente Spaziale a luce nera (1948) (Source: Fondazione Lucio Fontana)  
Bottom: Lucio Fontana, Ambiente Spaziale made with neon for la IX Triennale di Milano 1951 (Source: Fondazione Lucio Fontana)

explored by Yves Klein (1928-62) and Italian artist Piero Manzoni (1933-1963) (Jackson, 2015).

These artists, including Fontana would join a network of likeminded artists called Group ZERO idealised in 1957 by Heinz Mack and Otto Piene. The essence of the group was to break free from the current artistic tenets and propose a reduction, concentration and renewal of artistic forms. Besides rejecting formalism they also rejected the idea of the artwork being a visualisation of the artists spiritual and emotional expression (ZERO, n.d.). The group would dissolve in 1966 redefining the meaning of art and form.

Yves Klein was one of these artists that wanted to create a new language for art that would reduce form, space colour dissociating art from object and image to such an extent that it would render it immaterial. In 1958 Klein created *Le vide* (The void) at Galerie Iris Clert in Paris. From the outside windows were covered in his patented Klein Blue and the entry was covered with tick curtains in the same deep blue staging what was inside. Once inside the visitor would be faced with the dark void, with a nothingness that is rich in sensitivity in the intensity of the invisible. The sensation or feeling is no longer given by the object nor thing what is left is the vibration. Germano Celant (2019) suggests an association to an hallucination state where there is a certain abandonment of self to the “flow of the journey” stimulated by the strength of perception. Celant (2019) further infers that the result “is an assumption that art is a vector for sensory and visual rebirth”.

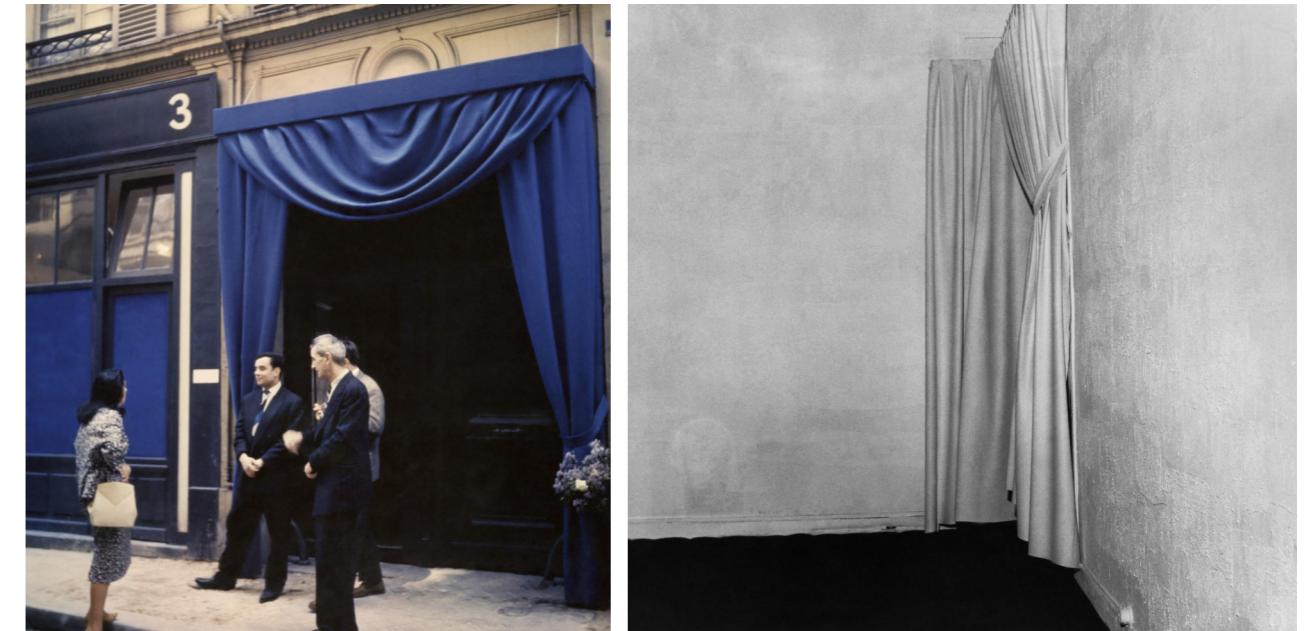


Figure 11: Left: Yves Klein , Entry to la galerie Iris Clert, for the opening of "Le Vide"(1958)  
Right: Yves Klein, View of the exhibition "Le vide" (1958) (Source: Fondation Ives Klein)

Otto Piene (1928-2014) besides being one of the founders of group ZERO he was also a prominent figure of the kinetic art scene. In his 1961 work, *Lichtballett* light would be projected from within multiple perforated three dimensional objects placed in a darkened space. Piene wanted to dematerialise space with an array of constantly moving luminous forms and patterns. “*When they are large (the light forms) the claustrophobia caused by the ordinary cubicity of our interior spaces recedes.*” (Piene, 1969) In an essay included in the catalog for his solo exhibition at Howard Wise Gallery in New York The author further elaborates on the purpose of this work:

*“My endeavour is twofold: to demonstrate that light is a source of life which has to be constantly rediscovered, and to show expansion as a phenomenal event. Everything is striving for larger space. We want to reach the sky. We want to exhibit in the sky, not in order to establish there a new art world, but rather to enter new space peacefully—that is, freely, playfully and actively, not as slaves of war technology.”* (Piene, 1969)

He then very eloquently explains his manifest where we can infer the same principles of group ZERO and Lucio Fontana Spatialism but we can also trace it back to the Futurists and Constructivists such as Moholy-Nagy.

*“Previously paintings and sculptures seemed to glow, today they do glow, they are active, they give, they do not merely attract the eyes, they do not merely express something, they are something. A filament glows and warms, a painted halo only reflects light. Energy in a contemporary form produces the living media. Is the filament in itself a piece of art? Transformation still has two meanings, one technical, one spiritual. He who leaves his house leaves the light on to make it appear inhabited.”*

We can in fact see the resemblance of Piene’s *Lichtballett* with Moholy-Nagy’s Light-Space Modulator as they both are light-kinetic sculptures that project patterns into the surrounding space but we can also see two big differences in their approach. In Moholy-Nagy’s the object is a very elaborate kinetic sculpture with all its moving parts and mechanisms. Where the light is external to it. Sharp focussed spotlights shine on the object making it the focal point in the room. It is then in its illumination that moving shadow patterns appear on the surfaces along with some reflected light. The object is the centrepiece and the spectacle of light and shadows is revealed on a second plane and thus the observer is still very aware of the object and space. In Piene’s work the opposite happens. Light comes from within the objects, piercing their shell and projecting light patterns on the surfaces of a room that is engulfed in darkness. The objects themselves are purposely camouflaged in the darkness with their black matte surface. The focal point is the light in space and not a mechanical object that interacts with it in a dimly lit room. Piene’s point of departure is the dark void.

Piene explained light could be divided into three basic qualities to be used in art: the energetic, the expansive and the dematerialised. *“Light can be used for the effects it produces but likewise for itself in art. It can take the form of daylight or sunlight, of fire, electrical light, invisible or chemically produced light. It can present its own continuity or appear in the alternation of passive and active frequencies... All three basic qualities of light can be used in art.”* (Weibel et Jansen, 2006).

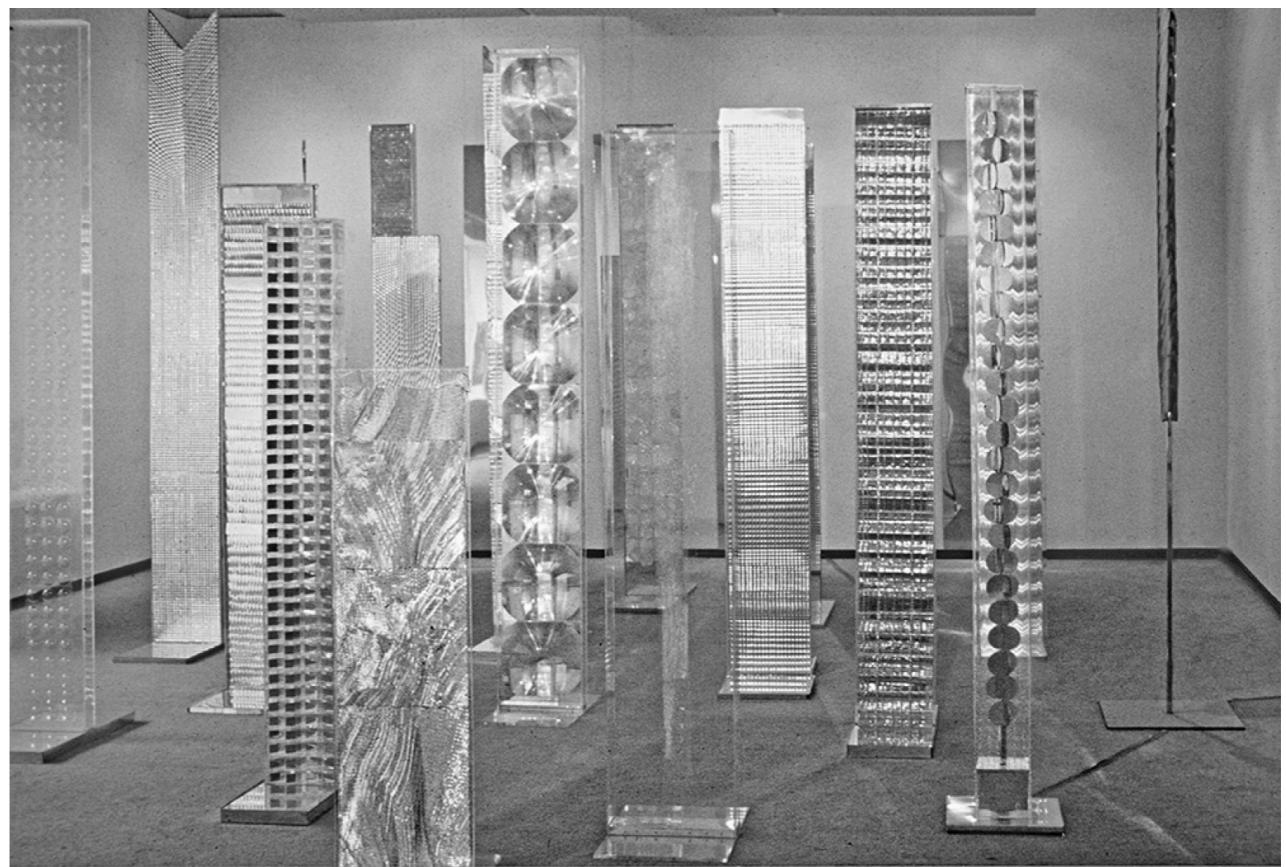
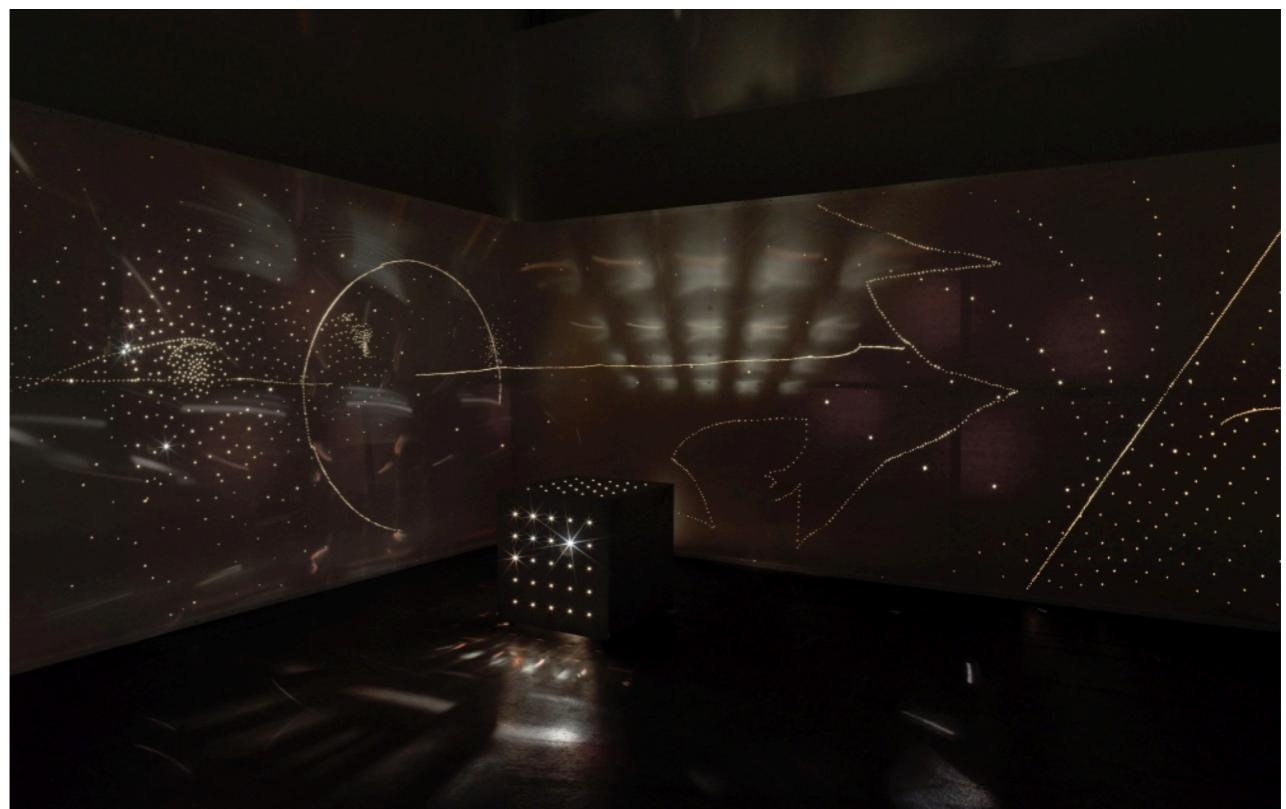


Figure 12: Above: G. ZERO - Otto Piene *Lichtballett* (various pieces) from 1960s at Museum Haus Konstruktiv, 2020 (Source: ProLitteris)  
Bottom: Group ZERO exhibition at Howard Wise Gallery, New York, Heinz Mack 1964 (Source: Heinz Mack)

Fellow founder of group ZERO, German artist Heinz Mack had a different approach to light in his works. He was more interested in “making the light visible” by exploring materials that are reflective and translucent such as polished aluminium, lenses, glass or plastic where he sometimes added movement with electric motors or with the natural elements such as the wind or water (Friedel, 2017).

*‘For me, light is immaterial, and in my case, I prefer to make works that are instruments of light,’ Mack related. ‘My sculptures do have a kind of function: of making light visible’ (H. Mack as cited in Mack, n.d. 2015)*

During the 60s he realised his Sahara project and later in the 70s he has made an incursion into the arctic (Mack, n.d.). In both scenarios he experimented with different materials to capture the light as a means to reveal it through refractance and reflected radiance. *“The clarity of light and the fullness of the silence are forever expanding. From the light, the space gets its sensuality, its atmosphere, its transparency. Light unburdens space”* (H. Mack as cited in Schavemaker, 2015).

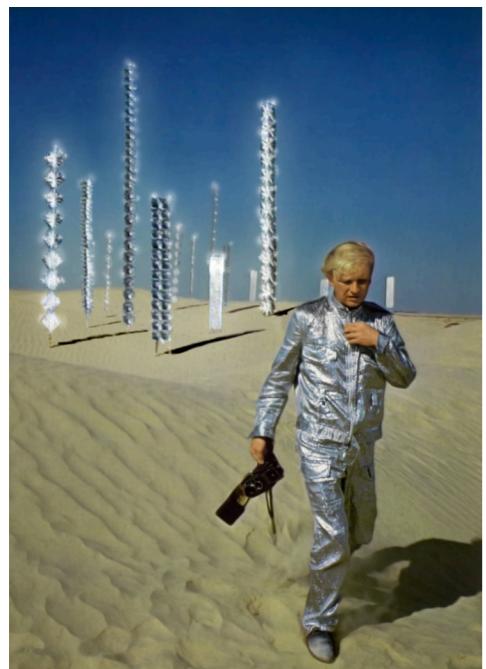


Figure 13: Left: Heinz Mack during the shooting of TELE-MACK in the Tunisian Desert, 1968  
Right: Light-wings, filmstill from TELE-MACK, 1968 (Source: Heinz Mack)



During the 50s and 60s there was a proliferation of innovative artists all using light as a means to escape the old tenets of art. Among them were Julio Le Parc and Dan Flavin. Le Parc was an Argentinian artist born in 1928. In 1958 he received a study grant to go to Paris. There, 2 years later, he formed the very influential Groupe de Recherche d’Art Visuel (GRAV) that furthered the debate on the relation between artistic phenomena and the human eye. In that same year (1960) he began experimenting with light, shadows, movement and the properties of materials with his series Continuels-mobils (Menezes, 2014). He explored these series both indoors and outdoors.

These artworks consisted mostly of suspended geometric shapes, squares or rectangles made out of a semi translucent or opaque materials. These shapes would be aligned in a regular grid and suspended with a nylon string in front of a white or black background. The almost paper thin materials and the very thin nylon string would offer very little resistance to air flow making it move in an interaction with the space and the people that moved in. This would also allow for a constant variation on how the work would capture the light and create shadows or patterns of light coloured through transmission depending on the material’s reflectance or transparency.

From here Le Parc started further experimenting with reflections with the same approach as Hanz Mack, to materialise light, to “visualise rays of light in the space” (Le Parc, 2022). By adding movement to the reflection he would further emphasise the fluidity of light. These experiments with the reflective properties of materials and the contrasts between light and dark resulted in radiant patterns that could render the projection surfaces boundless and give a perception of infinity when projected in all surfaces surrounding the subject. When asked about what impact on todays visitors that are used to being overloaded with stimuli could these gentle pure light works (without colour because the author argued that light itself added to movement was “more powerful, precise...I didn’t want colour to create a distraction”) have today in comparison to visitors reaction back in the 60s, Le Parc (as cited in Menezes, 2014) said:

*“I think they will see it in the same way (very easily accessible and charming). It is the opposite of being overloaded. The enormous use of light projections everywhere, the light coming from the television, issuing from computers, music shows, the amount of light. At that time, in the 60s, these mediums of communication did not exist... Then technology was developed and is used intensively, and images keep on being added, but in the end there is no vehicle transmitting a real idea of something, they don’t reach a conclusion. I think the different themes are limited, but within these limitations there can be richness due to the multiplication and the variations and the successions even within just one experience. But sometimes, with this huge amount of images, one gets lost, there is no common thread, there is nothing that leads to a more precise connection.”*

The artist explains his concerns about the overload of images and light and that this amalgamation of information may in fact lead to a less informed society because there is no “common thread” and therefore we are disconnected from each other, ourselves and the space we inhabit, may it be the room or the universe. Le Parc wanted the involvement and visual stimulation of the spectator and he tried to achieve that in his light works through movement and patterns that would be non objective, non figurative, rizomatic, otherworldly, similar to what Tomas Wilfred intended in the beginning of the century, but would also be immersive when they extrapolated the boundaries of the frame including space and subject in the art piece as Lucio Fontana and group ZERO proposed. Art to be part of instead of art to look at.



American artist Dan Flavin (1933 - 1996) was one of the most important pioneers in the use of light in art coming from that period. He started working during the 60s as a result of his reductionistic approach he was associated with the minimalist movement, whose main concept was that art should be itself and nothing else. He disliked the association. They advocated that there should be no visual or emotional cues to the world outside the art itself. The viewer should see the piece as it is in its full individuality, unpretentious and unrelated to anything external to it (Janson, 2011). Flavin used different lengths of standard fluorescent light bulbs as his artistic material sometimes using white light with different colour temperatures and some other times using contrasting vivid colours. It was important for him to use an industrial material that is ready made so that the observer could focus on the experience of being in presence of the light instead of focusing on the aesthetic values of the light fixture itself. This resulted in very reductionistic works material wise, but with great spatial impact. His proposals engaged the space it occupied and the viewer. Due to its radiance the proposal would extend beyond itself affecting space and subject. Has explained by Katharine J. Wright, curator of the exhibition “Minimalismo, posminimalismo y conceptualismo/ 60 - 70” held at Fundación PROA in Buenos Aires, referring to his gallery works: *“It exists as a singular object...complete in itself but also because of the glow it casts in the room, on the floor, on the walls, on us, it takes out more space than its physical footprint”* (ProaTV, 2019). Flavin’s work was situational both in how it was informed by the space and in how it created a new situation activating it. His proposals depended on the space they were in and on the subject who would navigate it sensing with its full bodily presence in a very grounded experience. The intention wasn’t to create a spiritual or mystical experience but instead to draw our attention to the space we are inhabiting at that moment and to the way we see. In the artist’s own words on how he discovered this ability that light has for spatial manipulation:

*“In time, I came to these conclusions about what I had found in fluorescent light, and about what might be done with it plastically: Now the entire interior spacial container and its parts-wall, floor, and ceiling, could support this strip of light but would not restrict its act of light except to enfold it... Realising this, I knew that the actual space of a room could be broken down and played with by planting illusions of real light (electric light) at crucial junctures in the room's composition. For example, if you press an eight-foot fluorescent lamp into the vertical climb of a corner, you can destroy that corner by glare and doubled shadow. A piece of wall can be visually disintegrated from the whole into a separate triangle by plunging a diagonal of light from edge to edge on the wall; that is, side to floor, for instance.”*

Throughout the years, Flavin kept expanding the scale of his proposals eventually escaping the exhibition white cube and occupying the architectural space. This also allowed for the creation of more permanent works that would be part of the social fabric, of peoples daily lives and no longer reserved to the experience of a few. In 1996 Flavin was commissioned by Italian Priest Giulio Greco to create a permanent installation in the church Santa Maria Annunciata in Chiesa Rossa located in Milan in what would be his final proposal. The untitled proposal (like all of his other proposals although they were often accompanied by a humorous or homage subtitle) made a parallelism with the succession of spaces that the believer walks from the mundane exterior, to the entrance, through the central nave, to the transept to the apse where the connection with the Divine is observed. Green, blue, pink, golden and ultraviolet would suggest this “ascendance” in this progression of light from night, to dawn, to day. Although is

Figure 14: Above: Julio le Parc, Continuel-mobile, 1963  
Bottom: Julio le Parc, Lumière en mouvement-installation, 1962-1999 at Palais de Tokyo, Paris 2013; (Source: Julio le Parc)

work rejects any kind of representation or symbolism, in this particular proposal it is often inferred this symbolism of “enlightenment”(Franceschini, 2021). Another source of light that the artist was conscious about was daylight. He insisted that the windows should be made out of clear uncoloured glass to allow for the different natural hues to flood the space and interplay with the electric light. It is interesting that today, a few decades later, this conscious combination and interaction of daylight and electric light is becoming the staple of lighting design (Govan et al, 2004). The artist would die one year before the inauguration in 1997.

Regardless of illuminating a public space that requires functional lighting, Flavin adopted the same principals he would apply in his gallery proposals in a gesture of coherence but also as a statement of its industrial nature, of its universal applicability. Flavin used light and how the colours mix in space to draw our attention towards it and by doing so drawing attention to the way we see and not just the luminous object itself. Bathed in its fluorescent radiance the architecture would be activated immersing the subject. His latest works were bringing the immersive experience to public space.



Figure 15: Dan Flavin, the nominal three (to William of Ockham), 1963; at the LACMA, 2007 (Source: LACMA)

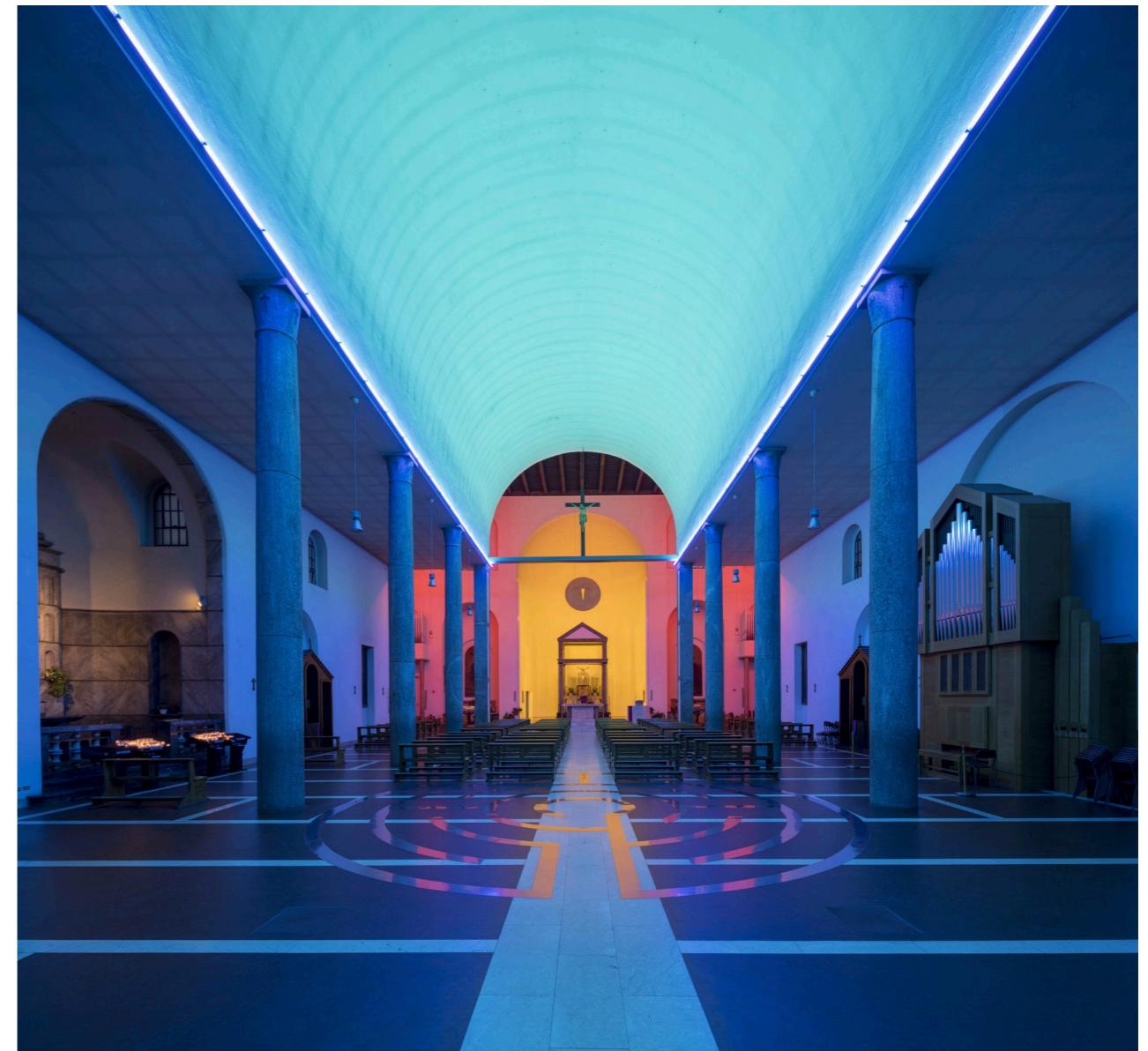


Figure 16: Dan Flavin, Church Santa Maria Annunciata 1996; at the LACMA, 2007 (Source: Fondazione Prada)

## Light as perception

The aforementioned experimental tendencies of moving towards immateriality and “total space” where space, sensorial and conceptual phenomena come together with the observer as a fundamental part of the artwork is in great contrast to the still predominant biased sensibility towards the object that can be transported from gallery to museum to private collector, that can be easily valued and included in the market. With the end of World War II came the consumer boom and environmental artworks where not in tune with the dominant taste of the time. The desire to consume, to own and to display the possessions was growing rapidly and therefore ephemeral and space dependent works where not practical in a context of material circulation and rapid exchange. There was an ascension in the number of art galleries in the United States and Europe and new artists start to be seen has celebrities boosting the culture of the artistic object (Celant, 2019). Art is more and more an exchangeable commodity and artists become commercial brands. Nevertheless the reductionistic tendencies remain.

During the 40s abstract expressionism with figures like Jackson Pollock, who was an admirer of Thomas Wilfred’s work (Orgeman, 2017) and Mark Rothko, among others, became recognised as the leading form of advanced art and extended this recognition well into the 50s and 60s. With the 60s came international affirmation of Pop Art, that incorporated popular commercial iconography and mass production technics and on the other side of the spectrum was minimalism. The later was a reaction to abstract expressionism’s emphasis on spontaneous and pure expression of self, psychological authenticity and philosophical content. Minimalism was a reductive art form focusing on aesthetic purity, art for arts sake that eliminates the artists hand, his expression in the work produced focusing on the physical existence and perceptual experience. Donald Judd, Sol Lewitt, Carl Andre and Dan Flavin (who, as previously mentioned, did not see himself as a minimalist) where some of the main figures of that movement. These movements had its origin in New York making that state the epicentre of world art, dethroning Paris.

At the same time (the 60s) on the West Coast of the United States of America another art movement started to emerge in southern California. The sunny location of Los Angeles, the outdoor lifestyle, the ocean and the proximity to aerospace industries all contributed to the inception of what would later be called the *Light and Space movement* (Morgan, 2018). Being far from this epicentre of art and without any particular expectations of being part of the art market most of the artists did not embark in the “fetishism of the object” and even rejected it (Celant, 2019). The movement was mostly characterised by nonobjective subjects as described by Celant (2019)

*“... something transparent and intangible, totally perceptual, where it is not possible to project oneself, but where one could lose oneself—the construction of a reference model that is immaterial and impalpable, that does not refer to any criterion of anchorage, but is only phenomenal.”*

It’s about perception, environmental effects and light being a means to manipulate them. How the movement was labeled in the beginning clearly described the ephemeral and immaterial nature of ambient art, environmental art and eventually light and space. This was due to their use of light and the light channeling properties of different materials. Reflective, translucent and transparent materials would be used to create an environmental engagement with space and many times creating an ambiguity between shape and form. There was this interest in

pushing the boundaries of perception placing the subject in a position that surpasses habitual experience. Like Art Historian Matthew Simms quoting Helen Pashgian (KCET, 2020) said “*disconnect between what we see and what we think we know about what we are seeing*”.

There are many artists that were part of this movement like, Allan Pashgian and Larry Bell, but for the purpose of this thesis we will focus on the ones that have created luminous environments because they are close to the architectural lighting language in the sense that the focus is in the spatial experience of navigating through space. We will focus on the works of three of the main artists of this movement: Robert Irwin, Doug Wheeler and James Turrell.

**Robert Irwin (b. 1928)** started his artistic career in the 50s through the medium of painting but rapidly moved to spatial works. He created art that was responsive to context rather than being something that was created in the studio. The room wasn’t a receptacle for art but art could already be there and it was just a matter of making it an event where one could notice it. What already had some aesthetic interest was brought to evidence by the use of materials.

*“Being an artist started becoming much more about inquiring. It’s not about making pictures, it’s not about telling stories but it’s about examining who we are. Perceiving beings and information is coming out on all kinds of levels and can I work with them? Can I play with them? Can I make something from them?”*  
Robert Irwin on (KCET, 2020)

Irwin started to refer to his works as Conditional Art, meaning that it is completely responsive to its environment with the goal of enhancing the viewer’s perception of a space. (Griffin, 2015) If one observes his untitled piece from 1971 (Fig. 17 Above) one can easily understand that the choice of materials, how they positioned in space, their reflective and translucent properties and how they interact with light is how the artist is trying to capture “information coming out” making it more evident that our perception of given space is dependent on our senses and our presence and that beauty is there too be experienced if we could only give it some focus and time for it to be absorbed. This conditional art concept is even more clear in his 1977 work Scrim veil—Black rectangle—Natural light (Fig. 17 Bottom). The introduction of a scrim veil changes our perception of the room engaging the space and the natural light. It makes us more aware on how the window and the natural light coming from it play an important role in that space, heightening its effect. With the added “Black rectangle” Irwin gives the spectator more tools to focus, by contrast, on the natural phenomena of light giving him means of seeing more clearly different luminous values and hues throughout the surfaces of the room while also changing how we perceive scale and therefore making us aware that our bodily presence and movement are also part of how we perceive our environment. It is all about the experience. Irwin tested our spatial and temporal experience through engaging space by introducing new materials and shapes. These materials would often be very light and not imposing like multiple white translucent fabric (scrim) and white paint (sometimes also black) with different reflectances or much later in his career fluorescent light bulbs (no colour) displayed in a wall with different geometric compositions.

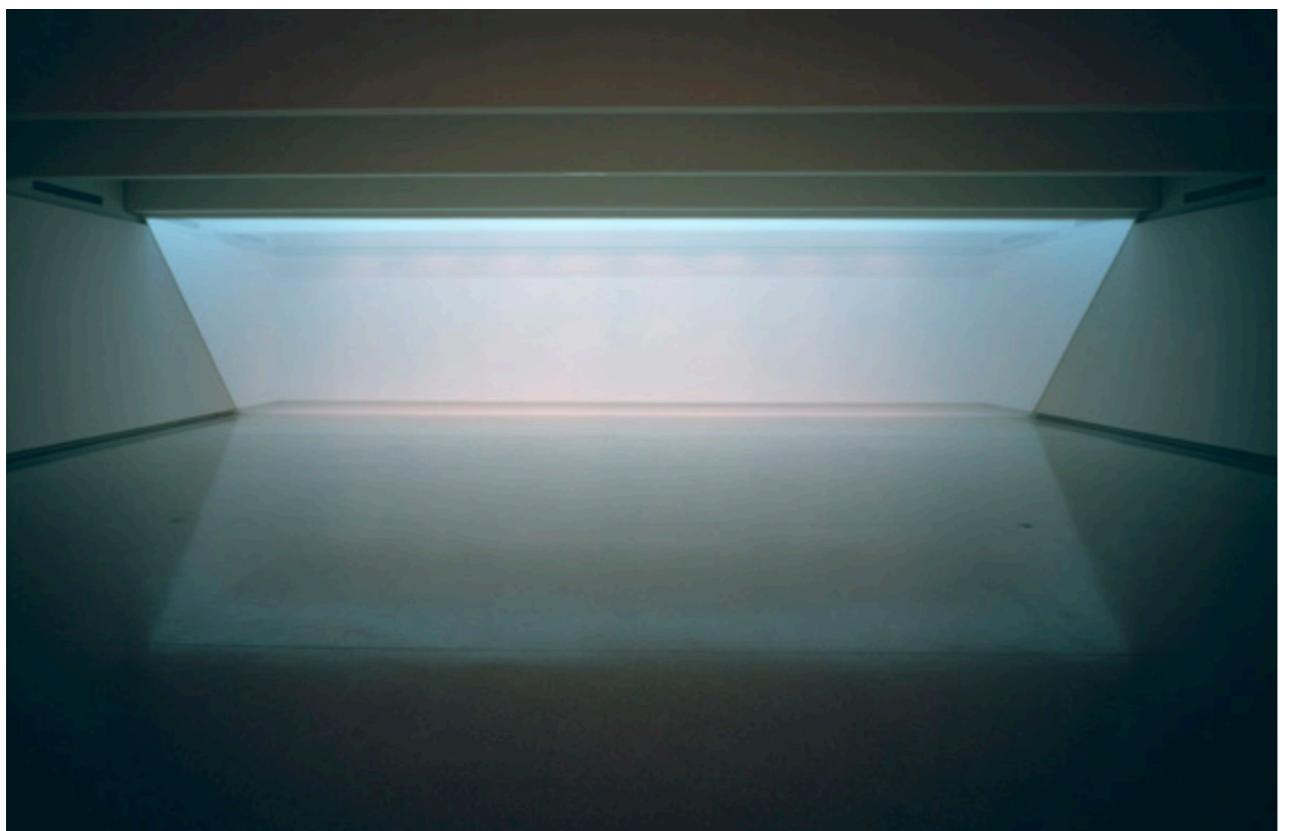


Figure 17: Above: Robert Irwin, untitled, 1971  
Bottom: Robert Irwin, "Scrim veil/ Black rectangle/ Natural light"  
at the Whitney Museum of American Art, New York, 1977 (Source: Robert Irwin)

**Doug Wheeler (b. 1939)** was one of the pioneers of the commonly named “Light & Space” movement. Differently to Robert Irwin and his “conditional art” where the existing space is part of the artwork, Wheeler was more interested in creating “infinity environments”, where space is just a shell that is manipulated by the artist in a way that it eliminates its limits by removing room angles thus removing spatial references. As critic and curator John Coplans (1968) explains in the exhibition brochure for the solo exhibition at the Pasadena Art Museum:

*“primary aim as [an artist] is to reshape or change the spectator’s perception of the seen world. In short, [his] medium is not light or new materials or technology, but perception.”*

So like other artists of the movement, Wheeler experiments with the perception and experience of space, volume, and light but in his case he dematerialises space to a point that they become perceptually infinite, like experiencing the void. When we are faced with this void we perceive light as matter that redefines space and time by erasing all our perceptual markers, like room corners, and we are *“left between a mirage and reality, nature and artifice, fullness and emptiness, moment and duration,”* (Bourgeois, 2014). Although his work is reduced to light and how it changes our perception of space, from the artists own words (as cited in Butterfield, 1993) we can also understand that there is a strong connection to the experience of nature:

*“I wanted to effect a dematerialisation so that I could deal with the dynamics of the particular space. It was a real space—not illusory—it was a cloud of light in constant flux. That molecular mist is the most important thing I do. It comes out of my way of seeing from living in Arizona—and the constant awareness of the landscape and the clouds.”*

It is in reducing light and space to its essence, eliminating all other stimuli the we engage with our perception and explore the qualities of light itself. It is in this essence that we can evoke natural phenomena that are part of the nature experience.

**James Turrell (b. 1943)** is probably the most recognised figure of the light & space movement. One could dedicate an entire thesis on his work but we will focus on its most important aspects. Similar to Doug Wheeler he focuses on the presence of light, out it shapes space and therefore challenges our perception. The viewers are engaged with his work through sheer perception, they challenge their sense of vision and therefore heightening the awareness on our sensorial dependence (Turrell, 2022).

In his early light experiments named Projection Pieces (fig 19 left) Turrell aimed for revealing the *“thing-ness of light”* and he did so by projecting a sharp flat geometric shape into the corner of a room. The difference in contrast and the distortion that the shape suffered in the junction of two with walls gives the viewer the impression of seeing a 3dimension solid object floating in space. This perceptual distortion gave mass to light revealing its *“thing-ness”* its physical nature. (Govan & Kim, 2013)

Latter in his career Turrell explored the concept of the Ganzfeld effects another means to engage viewers and challenge their perception. Ganzfeld effect is a phenomenon of perception and occurs when the subject is exposed to an unstructured, uniform stimulation field (Metzger, 1940). In his Ganzfeld installations the white room has rounded corners to remove any spatial reference also removing any kind of shadows that could give the user spatial hints. This results in a loss of depth perception. Diffused light floods the room revealing what appears to be an endless space. Without any spatial references or architectural details the user is found in a situation where he has nothing to focus on. This creates an unusual situation where his eyes fail

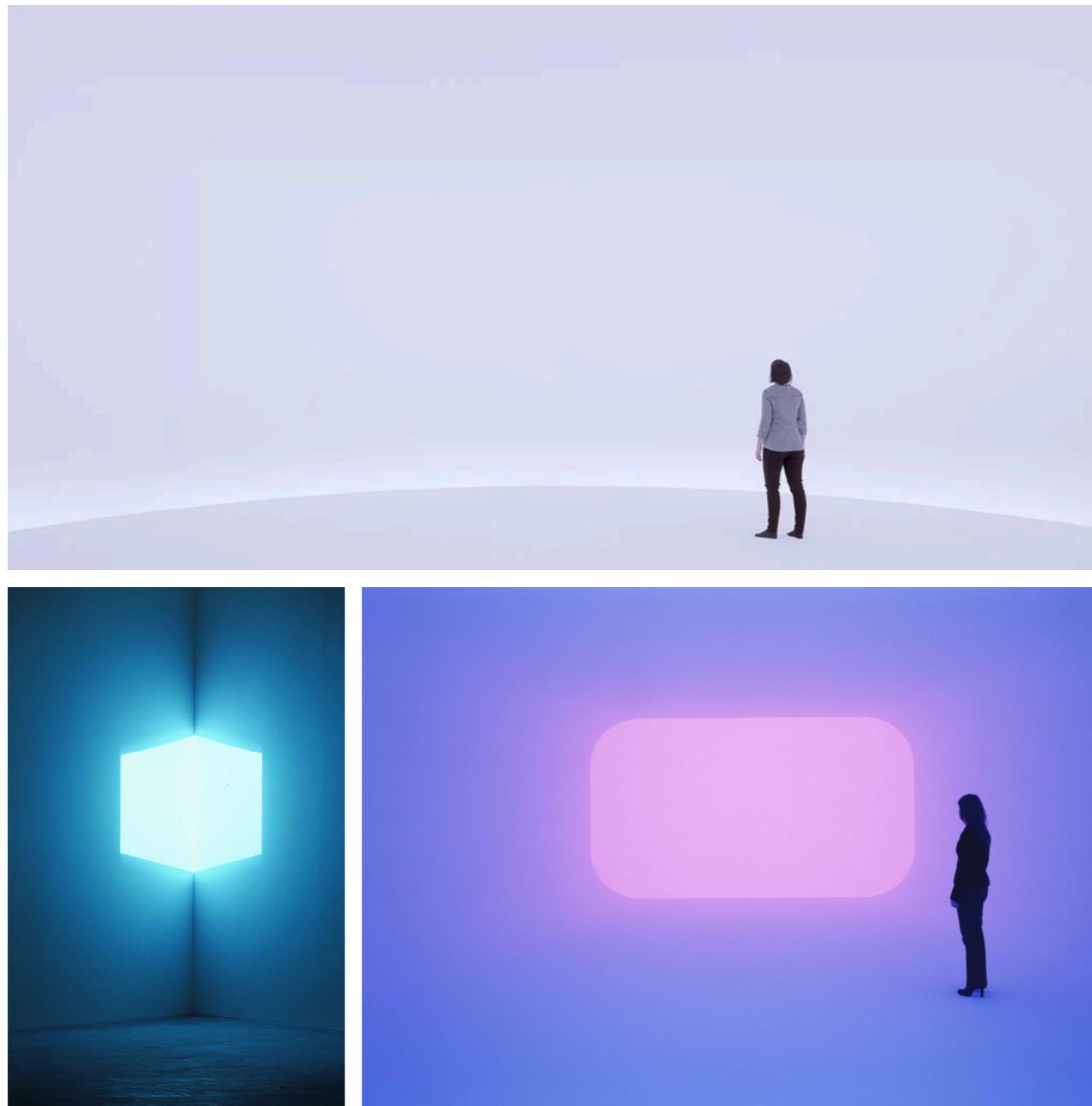


Figure 18 Top: Dough Wheeler, LC 71 NY DZ13 DW, 2013 (Source: David Zwirner)  
 Figure 19: James Turrell; Left: Projection Pieces: AFRUM PALE BLU, 1968; Right: Ganzfeld: DHATU, 2009 (Source: James Turrell)

to focus on anything in his surroundings. We are deciding on which direction we look but without actually seeing anything, only the light that is reflected from the surfaces. This creates an acute sense of disorientation that forces us to focus on how we perceive the space engaging us with our senses, with our body. (Govan & Kim, 2013)

By isolating light in space, it gains a primary physical presence changing the concept of light being just an element that enables vision. We are faced with nothing but the light and therefore we are encouraged to contemplate light's qualities, how it behaves, how it contains colour, volume, texture and it distorts our sense of time. Turrell's creation is the seeing in itself.

### Light & (Social) Space

From the 90s onwards some artists start to use light as a means to advocate social change. Besides using it as an immersive medium to engage perception, artists like Olafur Eliasson (b. 1967) are also using it to bring their social conscience into their works. (Clark, 2011: 76). Eliasson, same as Turrell and other light artists in the past did, works regularly with scientists and has an explorative design approach that is in close articulation with multiple fields of knowledge. In this way he aims to create designs that are less based on perceptual tricks created to force you in engaging with your senses but more focused on pushing the viewer to engage with the environment we are all part of, both natural and built and question our role as humans in it. Olafur refers to it as “the self-reflexive potential in art: our ability to evaluate ourselves in our surroundings” (in an interview for Aitken, et Noel, 2005). By engaging us with our selves and our surroundings through art in a challenging way, Eliasson is pushing us to reassess our concepts of what is the significance of being part of the world and to be an active player in it. How we build our environment, how does it affect us and how can we change it are common question in Olafur’s work (Eliasson, Behmann et Engberg-Pedersen, 2016). In his work the awareness to environmental issues is very predominant. He creates works where light enables him to stage a physical experience of natural phenomena inciting us to reevaluate the subjectivity of perception and mental constructions. By recognizing that the way we sense our surroundings, interpret them rationally and how we create connections is a construction of our culture and therefore we can explore this construction in a critical way. Eliasson elaborates on this *“if we can evaluate what it means to touch and feel something, rather than just take it for granted as being natural, if we can evaluate the consequences of what it actually means to be in a relationship with our surroundings, then we can also evaluate what it means to be critical, what it means to be responsible for the environment and towards other people”* (Eliasson et Sans, 2010).

In contrast to Turrell and Wheeler in most of his works he does not aim to create seamless spaces where the mechanism and light sources are all hidden from view but instead intentionally leaves them exposed. He does this to engage with the viewer, an engagement through transparency, with no illusion. Has the artist explains *“in order to achieve a challenging engagement with art that avoids the manipulation of the viewer, every part of the construction behind the presentation of art must be made a transparent part of that presentation.”* (Tiffany, 2008)



## Conclusion

In the beginning of the century some artists were searching for a new aesthetic in opposition to the static nature of painting and sculpture. Kinetic art started to emerge taking advantage of the technological and scientific advancements of the time. As we have observed in the Lazlo Moholy-Nagy, Zdeněk Pešánek and Tomas Wilfred kinetic-light sculptures light was used either to cast light on an object, contained in a box or framed but the following years saw light leaving those constraints and expanding into space. As light became more independent of object it also gained its role as a material by itself and it proved to be perfect to represent the ever-growing need of artists to leave the symbolic and representational nature of art behind. Light served as the fundamental element in the reductionist approach of the art movements since Lucio Fontana and group Zero. It gave them the freedom to explore new territories, to finally produce art for the sake of art itself. To produce art that was of its time where light expands space, activates it while the subjects interaction in it gives it meaning. Light expanded the limits of the artwork and brought the dimension of the immaterial, of the void, of nothingness where the experience is reduced to light. We are now immersed by the artwork, by the light and we are confronted with ourselves and our own existence.

In the process towards immersive art that is reduced to the element of light what we are left with is a heightened awareness of being a sensorial entity and that these senses enable us to perceive our surroundings and connect us to nature and the cosmos. Art may restore our primordial connection with the natural surroundings that is most of the times disabled by the artificial environments we inhabit. Many light artists since the 50s and Heinz Mack, Julio Le Parc, Doug Wheeler and more recently Olafur Eliasson, just to name a few are interested in triggering this connection with nature and the cosmos not by replicating or representing them but through the essence of light, through sheer primal seeing, through perception.

*“...like Robert Irwin manipulated space I do manipulate what I do to get a certain alchemical result when we look at it, that triggers something in our perceptual system. I am interested in changing the individual looking at something, into another level of consciousness... I am interested in the humans relation to nature and to the cosmos.” (Albuquerque, 2022)*

This raised the importance of the phenomenon of light and how to harness its qualities. Light is ephemeral and light is invisible. So how can we shape it? How can we reveal it? It was in the interaction between light and materials that artists found a means to do that. They could “make the light visible” through this interaction so they explored materials that have different optical qualities, materials that technological advancement made available.

Answering the Deleuzian question “What can light do?” From the perspective of the history of light art:

Light enables the inclusion of the immaterial, of the phenomenon into art. Light can bring dynamics to art. Light can expand space. Light can immerse. We can harness light’s qualities through material interaction establishing a nonfigurative connection with the natural environment. Light phenomena can be a tool for social and environmental awareness.

Figure 20: Top: At Studio Olafur Eliasson, testing “Sometimes the river is the bridge, 2020  
Bottom left: Sonnenenergie 22, 2022 at Pinakothek der Moderne  
Bottom right: Atmospheric wave wall, 2020 (all images source: Studio Olafur Eliasson)

# Light Fundamentals

In the previous chapter we have tried to answer the question “What can light do?” in the field of art, in the current one we will answer the same question through the natural sciences perspective. We have learned that many artists shaped light through interaction with materials with different qualities, reflecting and transmitting light. They rendered light visible. We have also learned that light in art introduced the opportunity of expansion into space, of immersion, playing with perception and many times in doing so it evokes natural phenomena in a way that is nonfigurative, that is more universal or cosmical. Like dusk and dawn chromatic phenomena, or the aurora borealis, or the “plastic” properties of light when reflected, refracted or transmitted through artificial materials such as glass, resins or fabric. In the same way one can observe the qualities of light in nature through water reflections, being filtered by the threes and fog or shining through semi translucent leaves. In this chapter we will analyse what is light in order to understand how does it interact with materials and how these natural luminous phenomena occur in order to best understand how to summon them.

For this thesis we will focus more deeply in how light interacts with reflective and transparent materials and how **light caustics** are produced in order to replicate them. It is assumed that the reader has some basic prior knowledge on light and photometric quantities.

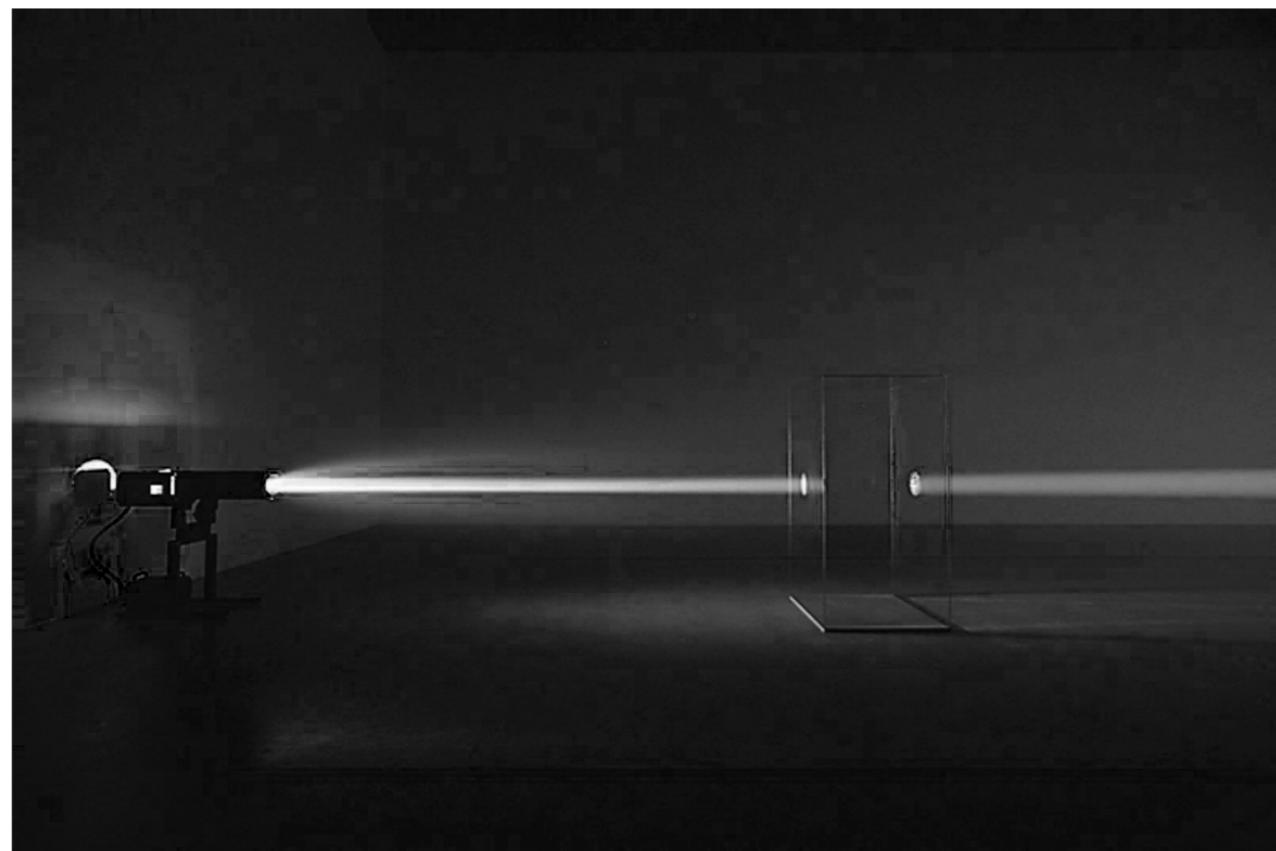


Figure 21: Olafur Eliasson, 21<sup>st</sup> Century museum of Contemporary Art, Japan 2009 (Source: Olafur Eliasson)

## What is light?

According to physics light is a small part of the electromagnetic spectrum, it is a flow of two continually changing oscillating fields, one magnetic and one electric perpendicular to each other (Fig. 22 Left). The electromagnetic spectrum ranges from low wavelengths like radio radiation, stretching for kilometres or in the high range like gamma radiation or x-rays in the picometres range. Light just happens to be radiation in the wavelength region between 380 and 780nm (Fig 22 Right) that the visual photoreceptors within the human eye respond to enabling us to see. (Tregenza & Loe, 2014; Boyce, 2014, Ganslandt & Hofmann, 1992)

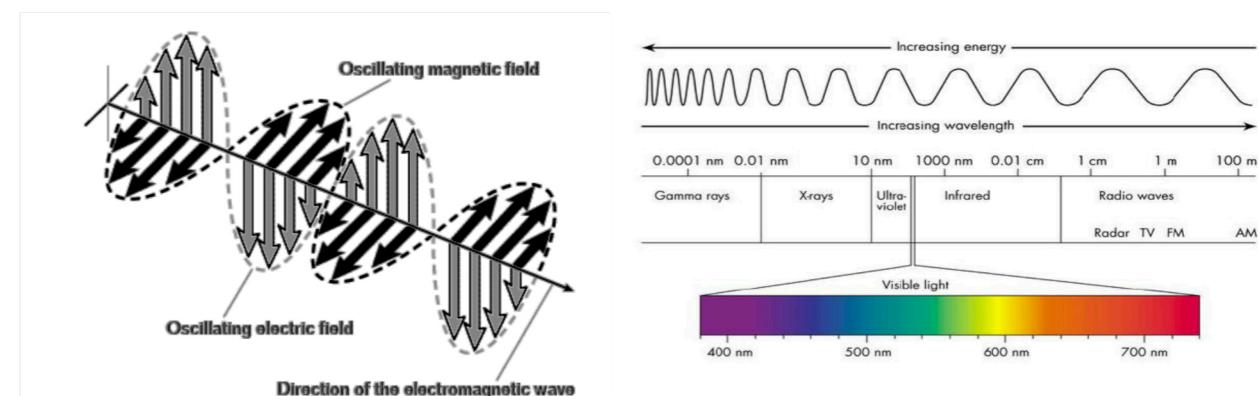


Figure 22: Left: Electromagnetic Wave; Right: Visible Spectrum

So light is an electromagnetic wave. The interaction between a constantly changing electric and magnetic field creates this self-propagating wave that can travel through space or material mediums. In this sense light flows and, like sound or water it is affected by material surfaces.

## How does light interact with materials?

Light is invisible. It is only rendered visible when it hits a material and its reflected back to our eyes (Fig. 21). When light hits material there are 4 different outcomes. It can be reflected, transmitted, diffracted or absorbed.

**Reflected** - Occurs when the waves hit a material that does not absorb the radiated energy bouncing them away from the surface. The direction taken by the reflected waves depends on the surface. If it is rough or matt the light is reflected in multiple directions, its a diffuse reflection. If the surface is glossy the waves bounce off at an angle that is equal and opposite to the incident angle, its specular reflection. Reflectance is the factor of incident light that bounces off the surface of the material.

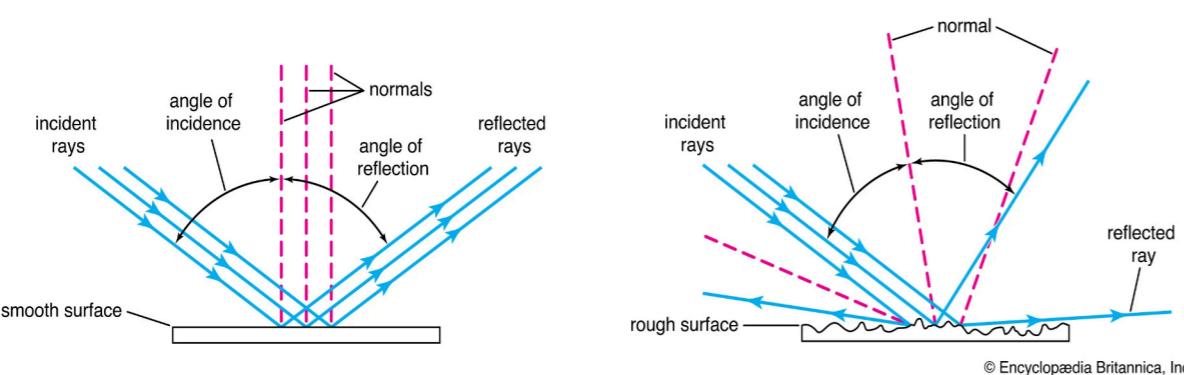


Figure 24: Left: Specular reflection; Right: Diffused reflection (Source: Encyclopaedia Britannica)

**Transmitted** - The waves travel through the material. When light travels through a transparent medium, like air and hits a second transparent medium, like water a portion of it is reflected and another portion is transmitted. When the transmitted light moves into the second medium it slows down and changes its travel direction, it is refracted. The law of refraction also known as Snell's law "describes the relationship between the angle of incidence ( $\theta_1$ ) and the angle of refraction ( $\theta_2$ ), measured with respect to the normal ("perpendicular line") to the surface" (Encyclopaedia Britannica, 2022). Transmittance can be diffuse, where the incident light is scattered, or regular, when it passes through as a clear beam. Transmittance is the fraction of incident light that passes through the material.

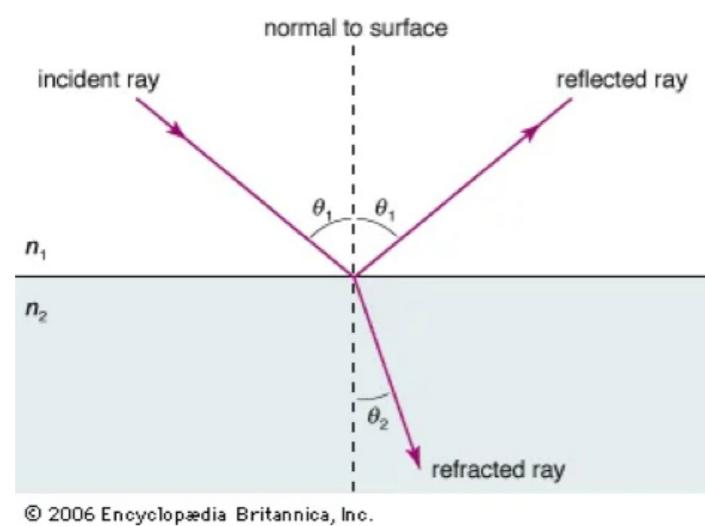


Figure 25: Law of refraction (Source: Encyclopaedia Britannica)

**Diffraction** occurs at the edges of materials. It is when the waves bend around objects or openings. When light beams hit the edge of a material, it will not continue in a straight line but it will be bent by the contact and this causes a blur at the edge of the shadow of the object or it may render the colour spectrum visible by bending multiple different wavelengths in different directions. This principle is used in diffraction grating "consisting of a surface ruled with close, equidistant, and parallel lines for the purpose of resolving light into spectra" (Encyclopaedia Britannica, 2022).

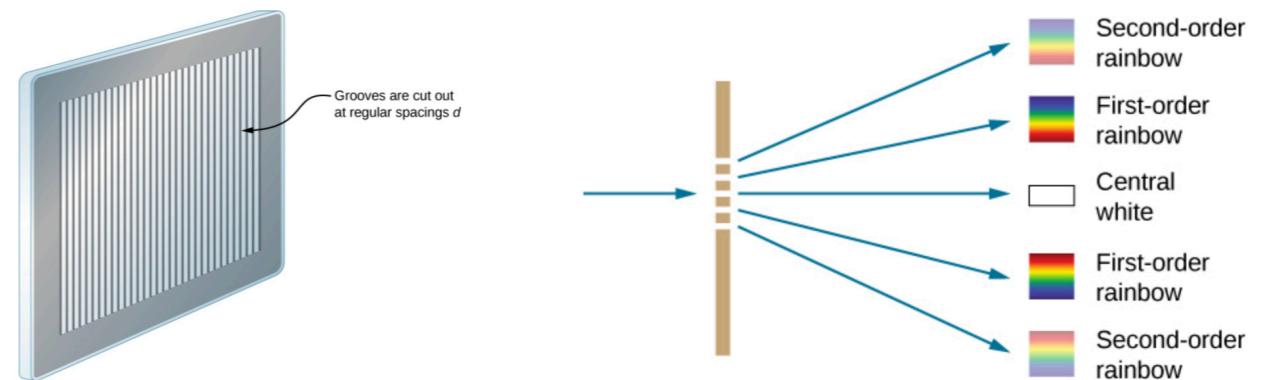


Figure 26: Light being diffracted revealing its spectra (Source: <https://opentextbc.ca/universityphysicsv3openstax/chapter/>)

**Absorbed** - The radiated energy of light is absorbed into the molecules of the material and turned into heat. Absorption is the fraction of incident light that is absorbed. If the absorption factor is 100% it means that the material has absorbed all the wavelengths of the visible spectrum and is therefore total black with 0% light being reflected back to the eye.

To quantify these outcomes a ratio between incident light and each of the individual outcomes is calculated. The factor of reflection, transmission or absorption is obtained and it can be between 0 and 100%. The sum of all three is equal to 100%. These factors depend on the optical qualities of the material for example clear transparent glass may have a reflection factor of 7%, a transmission factor of 90% and an absorption factor of 3% telling us that 90% of the light passes through it. The angle at which the light beam hits the surface also plays a role in these numbers. Taking this example of the clear transparent glass if the beam hits it perpendicularly, in a 90° angle in what is called the normal to surface, 90% of the light passes through but if it hits it in an steep angle that just glances the surface most of it will be reflected. (Tregenza & Loe, 2014; Descotes & Ramos, 2011; Ganslandt & Hofmann, 1992)

The optical qualities of materials can be categorised according to how light interacts with them. They can be: Opaque - Absorbing or reflecting all light without any transmission. If the material is glossy it reflects light specularly, if it is matte with a rugged surface the light is reflected diffusely; Transparent - Allowing light to travel through them in straight lines. Transparent materials can be selectively transparent to certain wavelengths; Or they can be Translucent - equal to transparent materials light travels through the material but in this case it is scattered in all directions when doing so. (Fox, 2002; Ganslandt & Hofmann, 1992)

## Light Caustics

Caustics result from this interaction of light and material. It may be defined as “the envelope of light rays that have been reflected or refracted from a curved surface and projected onto a surface where they can be visualised.” (Lynch & Livingston, 1995). To make it more clear and related to our research, caustics are a pattern of light projected into a surface that is generated by focusing and diverting light through a reflective or refractive material. Lynch and Livingston (1995) describe how this effect happens in a very simple and illustrative manner using the example of caustic generated by the interaction of light and water:

*“Water’s wavy surface can be thought of as a series of positive and negative lens. The positive lens focus sun light onto the bottom creating the bright network. The negative lens refract light beam and increase contrast of the network”.*

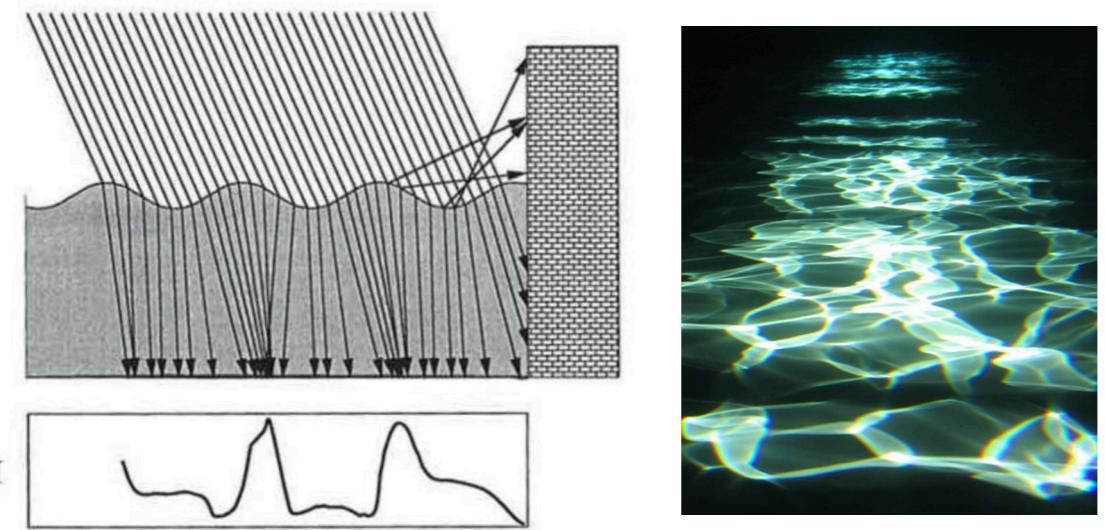


Figure 26: Left: Reflected and refracted caustics. Right: Refracted Caustic at the bottom of a pool  
(Source: <https://insightsaboutlightandglass.com/architectural-caustics/>)

If the incident light hits an irregular glossy surface that reflects specularly, the concave parts of it will focus the light and the convex part of it will scatter them on the surface of projection. The same happens if the material is transparent when incident light is transmitted it is refracted (diverted) diffusely (scattered) by the convex parts and it is refracted regularly and concentrated into a brighter light envelope when concave as illustrated by figure 26. This interplay of focused bright light and diffuse softer light creates contrast on the surface of projection generating these sharp patterns of light. If one has a material like water, clear glass, PMMA or PVC clear plastics that are both reflective and transmissive and a sharp concentrated light one can generate reflective and refractive caustics.

## Conclusion

We now have a better understanding on how to render light visible. By combining a specular material that is irregular with an incident light and adjusting their relative position one may be able to achieve such patterns. By diffracting light making it bend around edges or forcing it through carefully crafted openings one can also reveal the normal invisible colour spectrum of the light source.

When posing the Deleuzian question: What can light do?

Light, being a wave, can interact with materials shaping and defining our visual surroundings. It interacts with materials in multiple ways. Being an invisible electromagnetic wave it can only be rendered visible when this interaction occurs. When light hits a material it can be reflected, transmitted, diffracted or absorbed and it is in the multiplicity of combinations of different ratios that we find visual variability in spaces. Different material properties (transparency, opaqueness, translucency) can be used to bend and shape light, to render visible what is normally hidden.

## Nature Experience

As observed in the literature review on Light Art, in the process of using light to reduce art to its essential elements one can establish connections with the natural environment and evoke natural experiences.

But why is the connection with our natural environment important? Why does the nature experience matter and can it trigger or boost our creativity?

There are multiple studies that try to identify in what way nature experience is beneficial for humans. These studies demonstrate that there are multiple effects brought about by interacting with nature. It is important to point out that for the purpose of this report we will focus more on the benefits that derive from visual interaction with nature and its effect on creativity and only a few other benefits, for exemplification purposes since there are many other sensorial forms of interaction and many studies.

## NATURAL ENVIRONMENT AND HUMAN WELLBEING

On a 1984 study Ulrich (1984) demonstrated how window views to greenery can bring beneficial effects to patients recovering in hospitals. Postoperative patients assigned to rooms with views to a natural scene recovered faster and took fewer potent analgesics than the patients in similar rooms but with windows facing a building’s brick wall. Similarly Tennesen & Cimprich (1995) study revealed that students living in university dormitories in rooms where they could see nature from their window, in general, performed better on attention-demanding tasks than students with little or no visual access to nature. Also, being immersed in nature may enhance cognitive performance as demonstrated by Gidlow et al. (2016). Li & Sullivan (2016) in a similar study demonstrated that *“classroom views to green landscapes cause significantly better performance on tests of attention and increase student’s recovery from stressful experiences”*. Barton & Pretty (2010)

study revealed that exercising in the presence of nature leads to positive short and long-term health outcomes improving self-esteem and mood confirming that the environment is an important factor in human health. It is also worth mentioning that this same study demonstrated that the presence of water generated greater effects than just greenery. There are also positive effects that go beyond human health and wellbeing. 2015 study by Zelenski et al. showed that contact with nature may incite environmentally sustainable behaviour showing that social awareness may also arise when in contact with our natural environment. Soga et al. 2016 claimed that this contact/interaction with the natural environment increases the opportunities for understanding nature's benefits or enables emotional connections and therefore a higher predisposition to protect and/or preserve it. Groot et all (2015) pointed out that short and intense experiences, "epiphanies" that constitute a revelation may also change people's views. If one experiences an "epiphany" when immersed in nature or in the presence of a depiction or representation of it one may change the way one sees it and therefore is more likely to take positive or negative action towards it. But we need to interpret these findings with caution because these studies assume a very direct causal link between experience and value missing cultural and moral references that may greatly shape how we interpret our experiences of nature as evidenced by Neutelaers & Deliége (2019).

Within this context of human-nature interaction there are other elements within the natural environment, besides flora, that have been studied. In the following we will address the most relevant ones for the purpose of this report: Water and Light. Water due to its optical properties and emotional/biological benefits and light being the subject of interest.

## **Water**

Some studies on human-nature interaction highlight the visual and auditory importance of the presence of water and its significance in reducing stress, lower heart rate and blood pressure, enhancing the feeling of tranquility, its positive impact on concentration and memory restoration (Alvarsson et all, 2010; Pheasant et al. 2010; Biederman & Vessel, 2006) and enhancing perception and psychological responsiveness (Alvarsson et al., 2010; Hunter et al., 2010). Research also demonstrates that a preferred view contains bodies of water (Kellert & Wilson, 1993). There is also some findings that demonstrate that urban scenes with water features and natural scenes without water may have equal benefits (Jahncke et al., 2011; Karmanov & Hamel, 2008; White, et al., 2010) revealing that the presence of water alone may have similar benefits to an immersive experience in nature. Also as mentioned above when exercising in the presence of nature, its presence boosts the improvement in self-esteem and mood as opposed to a less pronounced improvement when water is not present (Barton & Pretty, 2010).

## **Natural light - light dynamics**

Natural Light is of course a primary component of the natural environment therefore multiple studies have focused on this element. Some have demonstrated how daylight "has strong direct effects on mood, cognition, alertness, performance, and sleep" (Wirz-Justice et all 2021). Similar to the benefits for patients in contact with nature (Ulrich, 1984), studies conducted focusing on daylight in hospitals rooms have demonstrated that daylight can promote faster

recovery and reduce pain and therefore painkiller dosage (Walch, et al., 2005). In the past years there has been growing evidence on the importance of daylight dynamics and its influence on our non-visual based systems, on circadian rhythm and our sleep-wake cycle (Figueiro, et al., 2017; Blume et al., 2019). Studies also demonstrated that daylight may increase cognitive performance (Münch et al., 2012). There has also been studies on the benefits of natural daylight phenomena, such as the sunrise and its simulation. In a 2013 study Gabel et al. investigated the role of morning light exposure using 17 participants and three different light settings after two six-hour sleep restriction night: "a blue monochromatic LED (light-emitting diode) light condition (BL; 100 lux at 470 nm for 20 min) starting 2 h after scheduled wake-up time, a dawn-simulating light (DsL) starting 30 min before and ending 20 min after scheduled wake-up time (polychromatic light gradually increasing from 0 to 250 lux), and a dim light (DL) condition for 2 h beginning upon scheduled wake time (<8 lux)." Data extracted indicated that exposure to an artificial morning dawn simulation light (DsL) may improve well-being, mood and cognitive performance. This study is relevant for this report because it demonstrates that simulating natural light phenomena with electric light (excluding digital and graphic representation through virtual simulation or video display) may prove beneficial for human subjects.

Furthermore, natural light (daylight and nocturnal from the moon and the stars) also has cultural and spiritual values, gives temporal cues about time of day and seasons connecting us with natural systems. Kellert (2008).

## **Symbolic or indirect human-nature interaction**

Apart from studies of direct interaction with nature other studies have been done on indirect interactions through viewing images, videos and representations may also prove beneficial to humans. In one of the most recent studies, Pilotti et al. (2015) demonstrated that student advisors that by the end of a workday have watched a video of a natural environment performed better on subsequent tasks. In another study performed in an hospital environment revealed that patients in a waiting room with real plants or poster sized pictures of plants reported lower stress levels as opposed to the patients that where in a waiting room without real plants nor representations or visualisations of plants (Beukeboom et al. 2013). But one feels tempted to ask was it the presence of nature (real or depicted) or was it the fact that it made the room more visually pleasant, more beautiful than the neutral and unembellished room?

## **Natural elements and creativity**

There as been some attempts on explaining why natural elements or environments are of benefit to human wellbeing. The focus seems to fall on nature's restorative potential (Kaplan, 1995; Kaplan & Kaplan, 1989) and stress-reducing impact (Ulrich, 1984) as observed by van Rompay et al. (2016). Interaction with nature has the quality of providing rest and relief from our everyday life challenges and stressful modern living (Kaplan and Kaplan, 1989). It is commonly assumed that "Hygienic" walks in the park may help to "wash away" some stress and alleviate mental fatigue.

The Attention Restoration Theory (ART) developed by Kaplan (1995) is based on how our attention can be divided into two forms - "directed attention" that demand more mental effort and it is for example when we are focusing on a task, and "involuntary attention" that requires

very little to no effort. In this theory it is argued that directed attention is a limited mental resource causing mental fatigue when it drops to low levels. Mental fatigue affects our cognitive performance negatively with difficulties to perform and focus on tasks that require more directed attention. It is in moments of involuntary attention when the mind engages with soft stimuli that directed attention is allowed to rest and restore because it does not demand cognitive effort or attention (Kaplan & Kaplan, 2011). What sparks these moments of involuntary attention is soft fascinations. Soft fascinations are these moments of visual stimuli that capture our attention “in an undramatic fashion” and are naturally captivating and fascinating to our mind. These moments abound in nature and are often qualified as mesmerising and serene, such as the soft movement of branches or the sparkling reflections of sunlight in a water pond. They provide an opportunity for reflection and mind-wandering (Kaplan, 1995; Kaplan & Kaplan, 1989). This leads us to the importance of internal reflection, of mind-wandering on cognition and particularly creativity (creative cognition).

### Mind-wandering

Mind-wandering can be described “as a spontaneous flow of thought that is not connected to the current environment” (Russ, 2020). Or in other words it is when thoughts shift away from the task at hand. As Barnett et Kaufman (2020) mention there are many different terms used to describe these task-unrelated thoughts. Some of those could include daydreaming, spontaneous thought, zoning out, perceptual decoupling, internally generated thoughts, undirected thought, self-generated thought and the list goes on. All these terms give us a more precise idea of what we mean by mind-wandering.

An important aspect of mind-wandering is that in this internal process ideas, associations, and images come and go and spontaneous associations between them occur, and that is related to creativity (Williams, et. al, 2018). Moreover it provides opportunities for exploration it “generates creative results through metaphor and association by recombining the raw material stored in memory and external stimuli.” (Dobson et Kalina, 2020). Research on creativity elaborate that having these broad associations and transforming them into something new is an important factor of creativity. Furthermore the ability to constantly change between a state of mind-wandering and directed attention is also an important aspect for creativity. A dynamic iterative creative process keeps alternating between focusing on the task, elaborating and exploring by wandering. This state of wandering is achieved through external stimuli (as also suggested by Kaplan, 1995) that release us for a moment from routine associations and established thought processes (Russ, 2020; Dobson et Kalina, 2020). Atchley et al (2012) and later Williams, et. All (2018) reinforces the idea outlined by Kaplan (1995) that it is prompted by exposure to soft stimuli in nature. There are other types of stimuli that have this outside nature that also triggers this effect but those are outside the interest of this thesis.

### But what are the elements in nature that may enhance creativity?

A number of recent studies have demonstrated that exposure to natural environments, bringing natural elements indoors or simply having visual contact with them can have a positive influence and foster creativity (Yu & Hsieh, 2020; Chulvi et all 2020; McCoy & Evans, 2002). Plambech & van den Bosch (2015) elaborate that nature can indeed enhance creativity by

making us more curious (the notion of mystery and soft fascination) and therefore questioning more, getting new ideas and being more flexible in our associations. They also mention its ability to restore our directed attention (ART) which is fundamental to analyse and further develop ideas. But none of these cases specify what particular elements in nature generate this response. There is a big lack on research in that field due to the complexity of evaluation and the validity of analysing the great universe of elements that nature entails. Nonetheless some studies start to identify specific elements or features of the natural environment that have an important role in how we perceive it and are a relevant factor regarding creativity. **Density** was identified by Berman et al. (2014) as one of those features:

“Features that seemed most related to perceptions of naturalness were related to the density of contrast changes in the scene, the density of straight lines in the scene, the average colour saturation in the scene and the average hue diversity in the scene.” (Berman et al., 2014)

In a different study Szolosi et al. (2014) demonstrated that nature imagery high on **mystery** (for example scenes that give the observer a sense that there is more to explore) are more often than not among the most preferred nature scenes. This type of scenery could more easily and effectively spark a person’s **sense of fascination**. As previously explained with the Attention Restoration Theory, fascinating stimuli have an important cognitive restorative effect because they engage forms of attention that are less demanding thus allowing some rest to mechanisms of attention that require more effort (Kaplan, 1995). Mystery can be a vague definition and opened to interpretation but it implies a sense of unpredictability meaning that based on the observer’s placement in the scenery and/or on the unfamiliarity of what he sees it is not possible to predict what is beyond or what comes after. So, as suggested by van Rompay et al. (2016) and for the purpose of clarity the term unpredictability will be used for the remainder of this thesis. In their study they have shown a universe of 120 participants (high school students with a mean age of 14) nature-based imagery varying in **unpredictability and spaciousness** before and during a drawing task. They also had to answer a questionnaire reporting perceived creativity and positive effect. The findings demonstrated that both unpredictability and spaciousness (fig XX images 1-4) resulted in higher self-reported creativity demonstrating that nature imagery has the potential to increase creativity with spaciousness and unpredictability having important roles.

“... the combination of these two factors in particular might strike the right balance between needs for overview and orientation on the one hand, and needs for exploration and discovery on the other. “(van Rompay et al., 2016)

Density, unpredictability and spaciousness are fundamental characteristics found in wild forests. This preference for wild and untreated nature, where no human intervention is detected is in fact found to generate the highest positive emotional responses on humans regardless of socio-demographic influences (López-Martínez, 2017). Therefore one could extrapolate these are also the types of natural sceneries that are more beneficial to creativity because they are richer in opportunities for exploration, soft fascination and mind-wandering.

## Conclusion

Natural light is undoubtedly a fundamental aspect in how we perceive nature visually, therefore it is undissociated with studies that focus on how visual contact with nature can enhance human wellbeing and creativity. When one concludes that density, unpredictability and spaciousness are elements in nature that may enhance and foster creativity (Szolosi et all, 2014; van Rompay et al., 2016) one is also saying something about light. **Density** is perceived visually so how the light is filtered by the vegetation, or how dense are the caustic ripples at the bottom of a lake would not exist without the presence of light. The same goes with unpredictability. Besides revealing our way through the forest, how daylight changes through time with variations in colour and intensity, how it interacts with different materials, how it shapes shadows altering the way we perceive volumes are all central elements in how we evaluate **unpredictability**. The notion of **spaciousness**, of something that feels ample in extent, is also given through light and in nature it is directly linked with density. If we are in a tropical forest surrounded by dense vegetation light is more heavily filtered creating a darker atmosphere and a cave like feeling but instead if we are in an open field that is brighter our vision can expand to the horizon. One can use electric light to replicate the same feelings for example if one is under a sharp bright spotlight and the surroundings are under-lit the heavy contrast gives one the feeling of an enclosed space but instead if the surroundings are lit and the centre is darker we feel the space as being more expansive (Descotes & Ramos, 2011).

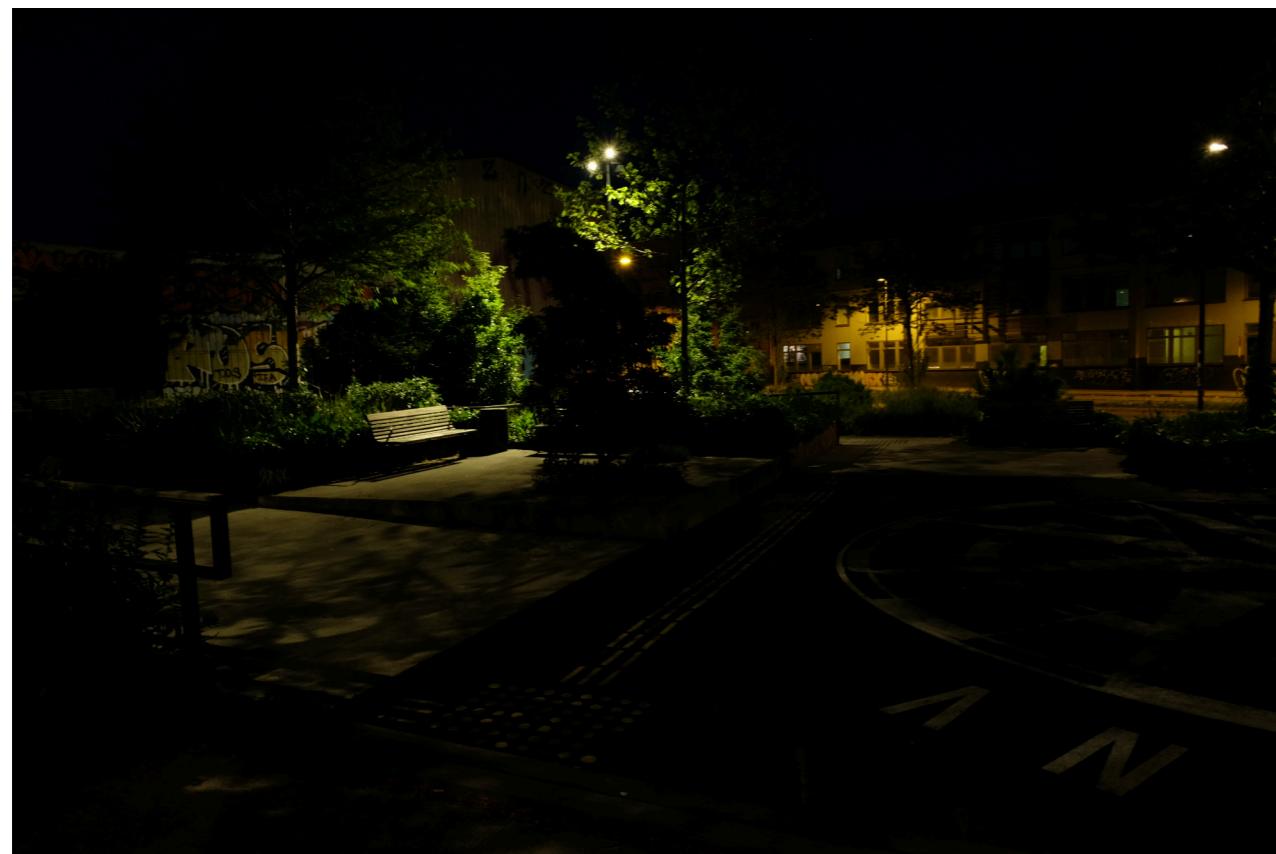


Figure 27: A bench under the spotlight, Nordvest, Copenhagen (Source: Author)

So when posing the Deleuzian question regarding the visual experience in nature and how it affects creativity: What can light do (in a nature experience)?

Light enables our visual interaction with nature being crucial in how one experiences it. It can bring positive effects on wellbeing and may enhance creativity through intermittent directed attention and moments of mind-wondering triggered by soft stimuli. Light gives us information on density and spaciousness that are found to be important elements in triggering creativity.

## State of the art

To our knowledge cases that use immersive nonfigurative creative lighting that is reduced to the essence of light itself and evoke a natural experience are very seldom. On the other hand it is common to see cases where creative light is used in a very figurative way to mimic natural elements like water as seen in figure 28. Normally these types of approaches where a gobo projector is used like a "stamp" are not immersive because it only hits the horizontal plane or the vertical plane and it fails to envelop the subject in its light. It is only when directly under it that one is bathed by it but, still we cannot see its projection in all surrounding surfaces limiting our feeling of being immersed. This may also create the "cave" like effect of being in an enclosed space due to the high contrast with the surroundings light levels (fig, 27).



Fig 28. Left: Parque Fluvial Renato Poblete, Chile. Picture by Maria Cirano. Lighting Design by DIAV Lighting ([https://www.plataformaarquitectura.cl/cl/771404/iluminacion-del-parque-fluvial-renato-poblete-ofrece-una-experiencia-completamente-nueva-del-rio-mapocho?ad\\_medium=gallery](https://www.plataformaarquitectura.cl/cl/771404/iluminacion-del-parque-fluvial-renato-poblete-ofrece-una-experiencia-completamente-nueva-del-rio-mapocho?ad_medium=gallery)) Right: Gare de Saint-Jérôme, Canada. Lighting Design by Ombrages <https://www.rosco.com/spectrum/index.php/2021/08/a-flowing-river-of-light-provides-unique-bike-path-illumination/>

In our research we have only found two projects that use nonfigurative lighting evoking nature that explores the interaction of light and material. The first one is **Boulevard of Arts** in Dnipro city, Ukraine. This project designed by Expolight won the LIT Lighting Design award 2020. It is located in a boulevard surrounded by theatres and art galleries representing a new creative cluster in the city. In the words of the designers they “provide the boulevard with non-intensive “art” light, courteous and non-flooding”, I believe that by non-flooding they mean that it is not homogenous, they continue explaining that the “dominant” lighting is provided by hanging luminaires that have “special lenses that will give good caustic waves to the pedestrian plane”. This dominant, may we say functional, lighting is complemented with other creative effects of figurative nature like gobo projections, colourful luminaires and interactive media screens. There is no further explanation on why the idea of the caustic waves was selected but regardless of the designers intention in this case it seems to balance the saturation in visual stimuli and sets the general tone of the square as more tranquil with occasional moments of visual excitement. The caustic effect layer is still and mostly projected on the horizontal plane but, by mere observation of pictures and videos we believe that there is a general immersive feel supported by the combination of luminous elements in the boulevard. Lighting in this case helped to brand the space as an artistic area.



Figure 29: Boulevard of arts, Ukraine (Source: Expolight)

This design was developed for an area in the city centre that is not residential, our second case was designed for a residential area.

The **Broken Light Project** in Rotterdam by artist and lighting designer Rudolf Teunissen and his firm Daglicht & Vorm won the IALD International Lighting Design Awards 2012 among other prizes. Described as a combination between an art project and lighting it changes the spacial experience in two different ways: on one hand by projecting strips of light onto the building facades giving them some dynamism; secondly by projecting light caustics onto the pavement. The light is static. This combination of vertical and horizontal planes gives an immersive experience to the users. Instead of flooding the space with uniform light the balance between dark and lit was preferred.

In the words of the designer Rudolf Teunissen, Broken light is: *“A social sculpture for street dwellers who welcome a small light into their neighbourhood literally and figuratively. A street in which, until a few years ago, crime reigned. An image that refers to the experience of light, darkness and renewal: when light springs forth, infinity unfolds”*.



Figure 30: Broken Light, street lighting, Atjehstraat, Rotterdam, Netherlands  
- Lighting designer: Rudolf Teunissen © Hans Wilschut - Teunissen

The project brought a new life to the neighbourhood and did so by replacing mere functional lighting with creative lighting that could support all the functional needs in a way that generated interest and beautified the area making it more welcoming. The decision of playing with optics and light qualities resulted in a tranquil scenario that despite the contrasts feels safe as mentioned by Willem Reedijk, Head of Public Lighting in Rotterdam:

*“Reactions to the lighting itself relate to the visual comfort and brightness it brings to the street, with minimum glare. Despite the strong contrast between the bright areas and those in the dark, there is no security problem.” (Willem Reedijk in LUCI Association 2022)*

Furthermore due to its nonfigurative reductionistic nature it could leave enough room for people to live their daily lives without being constantly disturbed by symbols, figurative graphics or dynamic coloured lighting. This also leaves it more open for imagination with multiple descriptions of it with some referring to it as light graffiti when seen from above although the designer says he was inspired by birds and flowers. (IALD, 2022)

The same principle of “Broken Light” was used in a different situation, this time a public park in Hijkerveld, Rotterdam finished in 2019 bringing “a friendly, enchanting atmosphere to the public space” (Studio Kruizinga, 2022). This demonstrates that although “broken light” was developed for a specific situation its principle can be adapted and applied in different ones. In both cases the same principle of reflecting light from a material with an irregular glossy surface installed inside the fixture was used. Limiting the effect to light caustics gives it a more familiar and “natural” feel.



Figure 31: Hijkerveld, Rotterdam (Source: Studio Kruizinga)

## RESEARCH QUESTION

Taking our vision as a starting point and adding the input gained from our analysis the research question we aim to answer is:

How can nonfigurative immersive creative lighting evoking an experience in nature based on moving caustic patterns through reflective materials enhance creativity while supporting the nighttime experience of an outdoor public space?

## DESIGN

In this chapter we will identify the steps that led to the design of creative lighting layers that would be used for testing. The design is directly informed by the findings from the analysis chapter.

### Development criteria

In order to guarantee that our design is aligned with the findings from our analysis as well as our initial intentions of pursuing a nonfigurative design that focusses on the essence of light a set of development criteria are outlined.

As a starting point our proposed creative lighting layer is based on a pattern that takes from forms that one encounters when experiencing nature. Due to our non figurative approach the form that our pattern takes will derive naturally from shaping reflective materials into producing organic light caustics but for comparison purposes we will oppose this with a commercial ready-made creative light effect that is figurative and tries to mimic **water**, or the flow of water.

This reference to water was selected because as a material it can produce reflected or refracted light caustic as explained in the analysis chapter. Furthermore it is an element of nature that has a positive impact on our wellbeing, reducing stress levels and enhancing a feeling of tranquility that has a positive influence on concentration and memory restoration that are beneficial for creativity among other benefits (Alvarsson et all, 2010; Pheasant et al. 2010; Biederman & Vessel, 2006). Research also tell us that there is a preference on views with water (Kellert & Wilson, 1993), so visuals that invoke it may be more positively accepted.

**Criteria 1: Density** as identified by **Berman et al. (2014)** plays an important role in how we emotionally relate to nature. In our literature research all the papers analysed that used images of nature, the ones that generated higher emotional response on the participants were always the ones that contained medium density of vegetation. By medium we mean that there is a balance between density of vegetation and the ability to see beyond it, to see the sky. Therefore variations in density will not be tested and we will use medium density as a criteria for our design.

### Criteria 2: Movement (unpredictability and variability)

In fact it is the nature of the movement that are the relevant criteria: movement as a generator of **Unpredictability** and **variability**.

**Unpredictability** or mystery are motors for curiosity, they intrigue people and lead them to a path of discovery therefore are more likely to create moments of soft fascination, capturing our attention, potentially triggering moments of mind-wandering. **Variability** is inseparable from a nature experience and is part of what generates visual interest and what summons natures benefits for human. It also plays an important role in how unpredictability is perceived.

In our design it will be the unpredictability of variations in speed and small pattern changes in an organic movement that will be tested opposed to a predictable regular mechanic movement with constant speed and variations in the pattern. It will also be tested if a still pattern has a different or equal impact in triggering mind-wandering.

**Criteria 3: Spaciousness** as argued before it is also an important part of the nature experience playing a crucial role in how comfortable one feels navigating in a natural space or how one imagines how that would feel.

**Criteria 4: Immersed experience.** As analysed in the light art chapter, being surrounded by light heightens the effect of how one experiences it and how we engage with space. The same goes with being in nature and being enveloped by the greenery and the light that is filtered through it or when the water reflects the sun rays onto the trees creating a natural choreography of brilliants that catches our attention.

## Material Exploration

In order to achieve a nonfigurative light pattern to serve as a base for our creative lighting layer, that is based on material reflection an investigation on the most appropriate material for the caustic effect was undertaken. It was a requirement that the material could be flexible and light so that we could reshape it easily and also be able to quickly and smoothly change the reflected patterns through gentle movements. Two reflective foils will be tested: a Crystal clear glossy PVC foil and a mylar reflective foil.

PVC sheet has the advantage of being easy to work with however its reflective properties are limited. Similar to clear water it has a low reflectance factor of about 4% when the light beam is perpendicular to the surface at an incidence angle of 0°. If the angle of incidence is higher the amount of reflection increases and less light is transmitted through the water. That is why when the sun is lower the light reflected from a body of water creates sharper caustics (fig 32 left).



Figure 32: Left: Water caustics (Source: <https://blender.stackexchange.com> edited by the Author) Middle: PVC Right: Mylar (Source: Author)

On the other hand the Mylar film has a very high reflectance factor of 95% (according to the manufacturer) at the normal incidence angle (0°). This means that it has the capacity of creating sharp casting with considerably less light than the PVC foil. This also means that with such a high specular reflectance it is much more likely to create glare spots that can damage the overall experience. Furthermore when combined with its 100% opacity (0% transmittance factor) it creates a mirror effect that may also condition the experience.

It is very visible that both materials even if they were stretched and laid completely flat they would create some reflected caustic, that is due to irregularities in the material that come from its fabrication process that are invisible to the eye but interact with the light waves. They create very dense caustic patterns. A thicker material could solve this problem but malleability would be lost (Fig 33). Nonetheless if one creates irregularities in the surface with multiple concave and convex areas one can have some control over the caustic pattern. The dimensions of those irregularities and the light source angle of incidence will determine the end result pattern.

The PVC foil was found to be the best solution for the mockup because the mylar foil due to its high reflectance and full opacity created a strong mirror effect making its presence too imposing and distracting therefore conditioning the experience.



Figure 33: Left: Soft reflective material; Right: Flat material (Source: Author)

## Material mockup

In order to have participants test an immersive caustic light effect a reflective surface would be needed. A mockup material wall was created using a Millenium LST-310 stand to hang a black molton curtain, that would absorb transmitted light from the clear PVC foil that was laid over it, reducing overall illuminance in the room. An iGuzzini Palco Spotlight ø 142 mm (6200 lumen output, 30° flood lens, 3000K CCT and 90 CRI) as the sole light source was mounted on a light track 3 meters above the floor and tilted towards the mockup in a way that could minimise glare when participants where standing up in-between them.



Figure 34: Material Mockup (Source: Author)

## Gobo Projector

A common way of introducing creative lighting into outdoor public lighting is through the use of gobo projectors. In the context of outdoor urban lighting a gobo is an object, usually a metal or glass disk that contains a design, placed inside or in front of a light source to control the shape of the emitted light and its shadow or to project images similar to what a slide projector does. These types of projector are preferred to other projectors, like video projectors, because of their much higher resilience to weather, durability and cost effectiveness. But one shouldn't really compare them because gobo projectors lack the versatility of video projectors. They can produce moving graphics but do not have video capabilities. On the other hand they are also becoming smaller and with higher lumen output which means that they can be integrated more seemingly into the architecture with better results.

After the analysis of multiple models the one that seemed more fit for the purpose was the ROSCO X-Effects LED Projector because from all the tested projectors this one had, in our view, the most believable graphic simulation of water. This was achieved due to its mechanism that uses 3 glass gobos: 2 of them have "bubbles" creating multiple concave and convex micro lenses that redirect incident light creating refractive caustics through variations of concentrated light as explained in the light fundamentals chapter; the other gobo has a dichroic layer that tints the light in a cyan colour and has wavy lines drawn that had to the figurative representation of water ripples. The dichroic gobo is placed directly in front of the light source and the 2 glass gobos are overlapped and placed in front of it in a mechanism that makes them rotate continuously. The projected pattern can be either still or rotating. The rotating movement can be controlled by two knobs, one for each gobo, that change the direction of rotation and speed. An extra knob changes the intensity of the light. It was very important for the testing phase that one could control those factors to be able to match as closely as possible the speed of movement and luminous intensity of both gobo and the material mockup. It was also important that the visual effect of the gobo wasn't to "drawn", to symbolic or even to "cartoony". It was important to clearly identify that it is a figuration of real water in order to have an optic result closer to light caustics. In fact if one would remove the dichroic gobo with wavy lines all that would remain would be a regular pattern of projected white light caustics.



Figure 35: Rosco X-Effects LED Projector ; Right: Mechanism (Source: Author)

# Video Simulation

In order to have a better understanding of how the creative light layer would look in an outdoor public space a 3d mockup was produced. It was meant to represent a generic outdoor public space in a residential area that one can find in nordic countries, would serve as a basis for testing the creative light. The 3d mockup was done taking inspiration from an open square that serves a block of medium density buildings (3 to 6 floors). In this case we took direct inspiration from a small semi-public square located in Frederik VII's Gate in Nørrebro, one of the neighbourhoods surrounding Copenhagen city centre.



Figure 36: Location of inspiration (Source: Author)

Street lighting that serves the roads was kept with the same general characteristics but a new lighting design was proposed for the square. The lighting design followed a framework (fig 37) developed as a result of the investigation of current guidelines for lighting heritage in outdoor spaces (Almeida, 2022). Although its focus was on heritage sites it can be applied whenever we have subject, space and electric light involved. The main difference would be the heightened importance to research and surveys have when dealing with an heritage site. The framework also gives high value to a careful and meaningful manipulation of atmosphere. In the report that lead to the framework it is argued that atmosphere is only possible in the combination of people (subject), space and light and that one can shape it through the manipulation of lighting variables. These lighting variables where heavily based on Descottes and Ramos (2011) "six visual principles of light": illuminance, luminance, colour and temperature, height, density, and direction and distribution. Their application in a lighting design was framed relying on Richards Kelly's 3 Tenets of lighting design (Kelly, 1952). The following was transcribed and summarised from "Bringing light to history. An evaluation on guidelines for lighting heritage" Almeida, 2022 and it aims to explain them:

## A proposed revised framework

A new revised framework of 6 sequential steps was created taking all the key aspects present in all analysed guides with and adding the findings on atmosphere and the night sky to it. The 3 components (Subject, Space, Light) and their multiple combinations where also integrated in the new revised framework for an easier correlation with the findings. Finally there was a need to structure the framework in a sequential manner that could be easily followed in praxis. Although some of the analysed guides provide a structure there was the need to have one with a more clear holistic approach and that has been extensively tested in practice. In that regard the design model by Hansen and Hvass (2019) was used as a means to achieve that.

### 1 - Research - Space

### 2 - Survey - Space + Subject

### 3 - Design vision

### 4 - Design Proposal - Space + Light

**4.1 - Functional requirements - Ambient luminescence** - Provide appropriate lighting for navigation and spacial perception for all people. Aim for the minimum light levels avoiding excess lighting. Follow the Lighting standards as a guide for light levels and glare ratios (in Denmark use it as an obligation). This step is not independent of the following steps, it is intrinsically connected to them. Balance ambient luminescence against the night sky preserving its darkness as much as possible bringing balance and harmony to the space.

**4.2 - Hierarchy - Focal glow** - Density, direction, distribution, hierarchy, history trough layers of importance. Help the subject navigate the space in a sequential and scripted way that guides him through the history of the space. Highlight what may be more relevant and group light according not only to spacial characteristics but also as "chapters" of the history you would like to pass on.

**4.3 - Light as information - Play of brilliants** - Gobos, sparkle, colour, movement, interaction, reflective materials, etc. This can be a very powerful tool to give some extra help informing about the space or to be information in itself. It can be used in a more abstract way or it can be more figurative. One can also use light to project images, film and words. Like all powerful tools one must not use them in excess because they might create the opposite effect giving a biased and/or wrong impression on the sites history and generate visual noise that damages the experience. Also unnecessary use of resources and excess light might come from it.

**4.4 - Scene settings** - Aim for the creation of different settings based on seasons, time, events (historical or social). This may avoid saturation and add renovated interest every so often. Different settings for different times of the day may also reduce energy consumption.

**4.5 - Sustainability** - Aim for retrofitting when possible. Aim for products that are environmentally friendly. Take the biological effects of light into account paying attention to luminous intensity, CCT, colour rendering, light spilling, etc. Reducing light to a minimum for both preservation of a dark night sky and energy consumption purposes.

### 5. Design evaluation - Subject + Light

### 6. Validation - Space + Subject + Light

Figure 37: Framework (Source: Author)

These 3 tenets (layers) are as follows:

**Ambient luminescence:** General functional light, indirect light.

It is the background lighting that serves to perceive the environment in general. This layer provides general illumination and is characterised by soft shadows and low contrast.

**Focal Glow:** Selective light.

A way to emphasise important elements improving way finding and can also serve to build a visual hierarchy and a narrative.

**Play of brilliants:** Light to be seen. Light not used to draw tension to something but as the focus of attention itself. In the case it is the opportunity to add what we call creative lighting.

To Richard Kelly visual beauty exists in the interplay of these 3 layers and it generally has a higher positive emotional response if one is dominant.

For the lighting design of our generic site we have followed the framework for Design proposal in the following way. After a quick observational research on the site all decisions were made based on the fact that it is a medium density residential area therefore light should be lower and therefore more intimate (Descottes & Ramos, 2011) reduced to a minimum but still providing safety reassurance. Reducing light pollution was also a criteria and the guides from International dark-sky association were followed (<https://www.darksky.org/our-work/lighting/lighting-principles/>). Therefore shielded fixtures were used that avoided spilling light into the atmosphere and into the apartments. A low CCT of 2700k was also used to reduce the non visible impact that the lower part of lights visible spectrum (blues and violets) has on biodiversity and human biology.

For **Ambient Luminescence** (functional layer) a series of bollards that provided low intimate and warm light (2700k) light were distributed along the square and close to benches. These provide general lighting that has a human scale and gives enough visibility to navigate through the space without disturbing the surrounding apartments. Standards EN-12464-2:2014 recommendation for walkways for pedestrians is 5lx and we took it as a median for the square space.

For the **Focal Glow** layer luminaries were placed above the entry doors to the apartment blocks that not only help to navigate through space and signal the entry but also provide extra light reassuring people, making them feel safe.

For the **Play of Brilliants** layer we will apply our immersive creative lighting using caustics and material reflections evoking a nature experience potentially triggering mind-wandering and therefore supporting creativity. We have experimented with two types of creative lighting: one aiming to replicate our experience with material generated caustics and the other one replicating the Rosco Gobo projectors water pattern.



Figure 38: 3d Mockup (Source: Author)

# TEST

## Hypothesis

The hypothesis to be tested that derive from our research question are as follows:

Hypothesis:

H<sub>1</sub> - Using material reflectance properties to evoke natural light phenomena has a higher potential of being closer to a natural experience than a standard graphic figurative representation of the same subject therefore having a higher positive emotional response.

H<sub>2</sub> - Unpredictability of movement in the light pattern and variability may trigger mind wandering therefore having a positive effect on creativity.

H<sub>3</sub> - Immersive creative lighting that is nonfigurative based on light caustics added to a functional lighting design in an outdoor public space can raise its potential for mind-wandering.

## Participants & procedure

### Participants

In order to assess and quantify people's emotional response to the nature evoking creative lighting layer an experiment was conducted in the light lab at the Aalborg University Copenhagen campus. Eleven participants ranging from 18 to 47 years old, European but from different countries and cultural backgrounds took part in the experiment. 55,6% were male and 44,4% were female. 6 of them worked in creative fields (architecture and design) the remaining 5 worked in others fields such as human resources, business and communication. The test was realised from the 7th to the 9th of May 2022 from 10.00am to 18.30 pm. Each individual was asked to answer a two part questionnaire while exposed to 4 different immersive scenarios and after that they were asked to watch 2 different videos of 52 seconds each and answer same questionnaire.

### Procedure

The participant would enter the light lab with general diffused and low light coming from the ceiling at around 3000K CCT with an illuminance of 5 lx on the horizontal plane (floor level) following the recommendations in EN 12464-2:2014 standard for walkways to be exclusively used by pedestrians in order to have a general precondition closer to the appropriate light levels in outdoor spaces at night. Because all sessions were made during day time this also allowed for subjects to have some time to adapt to lower light levels. At this point the participant would see both the material reflection mockup and Rosco gobo projector (all turned off) and a brief verbal explanation of what was the purpose of the test and instructions on how it would develop where given:

*"The intention of this test is to evaluate the emotional response to an effect layer evoking a nature experience to be used in an outdoor public space in a residential area. This effect layer would be added to functional street lighting so imagine that you are maybe on your walk home at night, navigating through the concrete sidewalk and you find these small squares between buildings that are not really inviting or attractive and not a place where you would linger for a while with your own thoughts." The participants would normally give some examples at this point that I would agree with. "I would ask you to imagine those places and how the scenarios you are about to experience could change or not your emotional response to them. Imagine yourself in that space with the effect in use creating an immersive experience. During each scenario you are free to sit or walk around but avoid looking at the light sources or the effect wall because you may be glared and have an unpleasant experience. You will be asked to fill a 7 point scale type questionnaire to rate your emotional response. You can take your time but I will ask you to fill in the questionnaire if you have not done within a 3 minutes time frame. After running through each of the 4 scenarios I will then show you two small videos and ask you to fill in the same questionnaires. Finally I will ask you to freely comment if you wish so."*

As explained by the above introductory text the participant would have to go through 2 tasks:

**Task 1** - Experience 4 different scenarios. Answer a two part questionnaire, one following the PAD model and one with a Likert scale, during each of them. Each scenario would take roughly 3 minutes until the next one.

**Task 2** - After all the scenarios two videos will be shown and the same questionnaire would be answered for each video. Freely comment.

### Test setup

The test setup at the Light Lab located at Aalborg University Copenhagen Campus was done in a way that would easily allow to go through all 4 scenarios and have a desk area to watch the video simulations on a laptop. Room dimensions are 5,80m depth by 5,80m width and ceiling height of 4,20m. Walls are painted matt white with a reflectance value of about 0,67. Floor is exposed concrete with a sealant finish, reflectance is very low with a value of roughly 0,17. A black molton curtain was used to cover parts of the surrounding walls where the projected light did not fall or where not wanted.

On one corner of the room the Rosco Gobo projector was mounted on a Millenium LST-310 lighting stand at 2,20m height. The projector was pointed towards the opposing wall in a way that the pattern could hit it and the floor, flooding both surfaces as seen on figure 40 (left). On the opposing corner a mockup material wall was mounted using a Millenium LST-310 to hang a black molton curtain that was then covered with Crystal clear glossy PVC foil (as selected in the experimentation phase) as a reflecting material to project an array of light caustics (figure 40 right) on the wall next to it. An iGuzzini Palco Spotlight with 3000K CCT was mounted on the light track 3 meters above the floor and tilted towards the mockup in a way that could minimise glare when participants were standing up in-between them. To make the projected pattern move organically some strings were clamped to the curtain in order to adjust its position and to be able to gently move it by softly and irregularly pulling on them. A handheld fan was also used at times to add more dynamism to the movement. The intention was to have the pattern change softly and organically and therefore in an unpredictable way. At first an electric fan was considered but the movement was too predictable and the combination of sound and wind could leave an undesired impression in the participant.

Finally a table and a chair was placed away from the scenario settings so that it did not interfere with the experience. The participant would be asked to sit and watch two video simulation on a 15" screen laptop computer with the brightness adjusted according to the low light levels in the room.

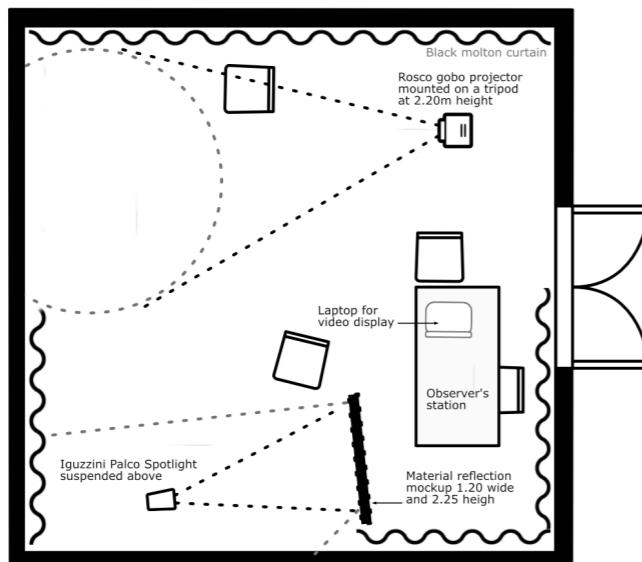


Figure 39: Light Lab setup (Source: Author)



Figure 40: Left: Gobo Projector setup; Right: Material reflective wall setup (Source: Author)

## Scenarios and video simulations

### Task 1 - 4 scenarios immersive experience

The 4 different immersive scenarios to be tested comprised of opposing a figurative graphic representation of an element found in nature, in this case water and a more organic approach using reflected light to evoke naturally occurring daylight phenomena. In order to achieve this the Rosco gobo projector (from now on referred to as Gobo) would be used for the first and a Material reflection mockup (from now on referred to as Material) for the second. Their selection was justified in the exploration phase subchapter. The following diagram demonstrates the 4 different scenarios. The movement, either static, a mechanical regular movement or an organic irregular movement with fluctuations in speed and direction where the different elements that compose the pattern move independently will determine the levels of perceived unpredictability and variability to support our hypothesis 2 (H<sub>2</sub>). We can also test if having dynamic patterns that softly move, provoking these moments of "soft fascination" (Kaplan, 1995) is more positively evaluated than static patterns or if there is no difference when it comes to triggering mind-wandering. Furthermore the duality of graphic against material may also provide us with information on which one has the higher potential to make people more aware of the qualities of light and not only natural daylight phenomena supporting our hypothesis 1 (H<sub>1</sub>).

H<sub>1</sub> - Using material reflectance properties to evoke natural light phenomena has a higher potential of being closer to a natural experience than a standard graphic figurative representation of the same subject therefore having a higher positive emotional response.

H<sub>2</sub> - Unpredictability of movement in the light pattern and variability may trigger mind wandering therefore having a positive effect on creativity.



| GOBO        | MATERIAL         |
|-------------|------------------|
| SCENARIO GS | STATIC           |
| SCENARIO GM | REGULAR MOVEMENT |

Figure 41: 4 scenarios (Source: Author)

## Task 2 - 2 Video simulations visualisation

To further support our findings a video simulation was used so that the participants could have a more clear understanding of what could be the effect of adding this creative lighting to an outdoor public space. The videos were also important to understand how the results would differ from the ones obtained with the exposure to the 4 scenarios.

In the video simulations one is taken on a small walk from the road/sidewalk and through the square with a couple of pauses to better observe the scenery. It is after sunset during early spring. Some people populate the mockup to give it a more human scale and to help the participant place himself in the space. Two videos were made with a 52 second duration. They are both the same video with the creative light layer being the only thing that differs from one to the other. In one a simulation of the Rosco Gobo (same as the one used in the scenarios to be tested physically) with its regular movement and the other one simulates caustics similar to the ones produced by water or other fluid material moving organically. This task could help us reinforce H<sub>1</sub> and H<sub>2</sub> and by placing the participant in a simulated scenario help us to better understand if there is a higher positive response to using material induced dynamic light caustics than a graphic dynamic light (H<sub>3</sub>) in an outdoor scenario.

H<sub>3</sub> - Immersive creative lighting that is nonfigurative based on light caustics added to a functional lighting design in an outdoor public space can raise its potential for mind-wandering.

## Online survey

As an attempt to understand if it is important that the participants physically interact with the light patterns before watching a video simulation as opposed to just watching the video, an online survey was realised. The survey may complement our findings from the lab and it may tell us if this physical contact with light is detrimental in tests of this nature.

The online participants had to see the same two video simulations as the light lab participants have seen for Task 2 but in this case a third video was added. This video was the same as the Gobo video but instead of having cyan colour light the light was changed to 2700K CCT to match the functional lighting selected for the space. This decision came after a number of participants in the Light Lab experiment mentioning the fact that the blue light created some disharmony in the scenery and would like to also see the Gobo video in a "warmer colour" (figure 43). This decision also eliminated a part of the figurative nature of the design. It is now more open for interpretation and that can be interesting to compare with the Material video. The participants were also asked to answer the same two part questionnaire for each video. The participants were instructed to avoid seeing the videos on their smartphones and instead, if possible, watch it in a computer monitor or TV to have a bigger visualisation surface and better screening quality. It was also asked to adjust the screen brightness according to the environment they were in to avoid high contrasts that could negatively influence the experience. For obvious reasons it was not possible for the researcher to evaluate if these conditions were met. The questionnaire was setup using Google Forms and sent to the researcher's network as well as posted in a couple of online groups.



Figure 42: Image stills from the video: Top: Simulating material reflection; Bottom: Simulating Gobo projector (Source: Author)



Figure 43: Image stills from the video simulating Gobo projector with warm colour for online survey (Source: Author)

## Findings

In this chapter we will lay out the findings from: our lab experiment with the questionnaire on the 4 immersive scenarios (Task 1) and the findings from the questionnaire on the 2 video simulations (Task 2); and our online test with the same 2 video simulations with an added 3rd video and a questionnaire.

### Task 1 - 4 immersive scenarios

Regarding movement the findings reveal that there is a positive response when immersed in all scenarios, both with moving patterns (GM and MM) and with static patterns (GS and MS) but there is a higher positive response to the moving patterns. The difference is more pronounced when comparing GS and GM with the first being practically neutral and the second being higher in the Happy, Pleasant and Comfortable emotions. Furthermore it reveals that Material (MS and MM) has, in general higher positive effects and a higher evaluation in calm and relaxed while Gobo (GS and GM) is close to neutral in both moving and static scenarios. Regarding the elements that may enhance creative cognition like unpredictability and spaciousness (constraining-expansive) the response is close to neutral in GS and MS for unpredictability although the first is leaning slightly towards the side of predictable (3,5) and the second towards unpredictable (4,1). Analysing the same pair with moving patterns it is clear that Moving Material (MM) has a much higher unpredictable value (6,2) than Gobo Moving (GM) that had an average close to neutral (3,4) leaning towards predictable. Regarding spaciousness and the feeling of being unrestrained values are higher with the Material scenarios with MS being close to neutral with 4,45 and MM higher with 5,45. GS revealed to be constraining with 2,6 and GM

slightly above neutral and towards unrestrained with 4,64. Regarding variability Material Moving scored highest in positive emotional responses indicating that an organic dynamic movement is preferred and that the slow and unpredictable rate of change and movement within the pattern has the potential to trigger a mind-wandering effect and therefore enhance creative cognition. This claim was reinforced by the answers to the question "Do you see this scenario as a space for contemplation and mind wandering?" That scored an average of 6,2 being evaluated as close to very applicable. GS scored neutral (4,1), GM scored 5,8 so also scoring positive and MS with 5,2. Both scenarios with moving patterns were considered as spaces for contemplation and mind-wandering but the Material Moving scored the highest. The following graphic illustrates all the 8 pairs average scores for the 4 scenarios.

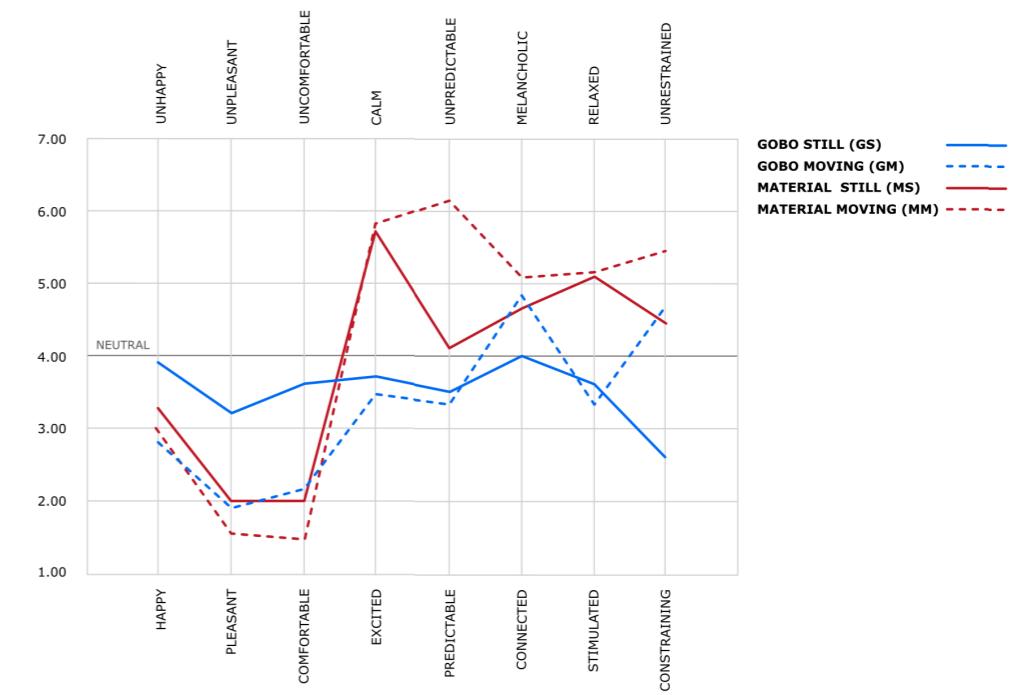


Figure 45: Graphic comparing results from 4 immersive scenarios (Source: Author)

From the second part of the questionnaire from Task 1, it is clear that both moving scenarios (GM and MM) were able to evoke a nature experience. Furthermore it is also clear that the Material Still (MS) was also successful in undoing so. Regarding Gobo Still (GS) the evaluation was neutral suggesting that although they all identified it as water when asked to freely comment, some participants have felt that the pattern was too artificial and in doubt opted to take a neutral position. Regarding the question "When engaging in this scenario in real life would it be important to understand how the visual effect is produced?" the average was neutral in all scenarios (from 4,1 to 4,6 for MS) suggesting that it is irrelevant for the participants to know as mentioned by some during their comments on the experiment. The following graphics illustrate all the average scores regarding the questions asked in the second part of the questionnaire from Task 1.

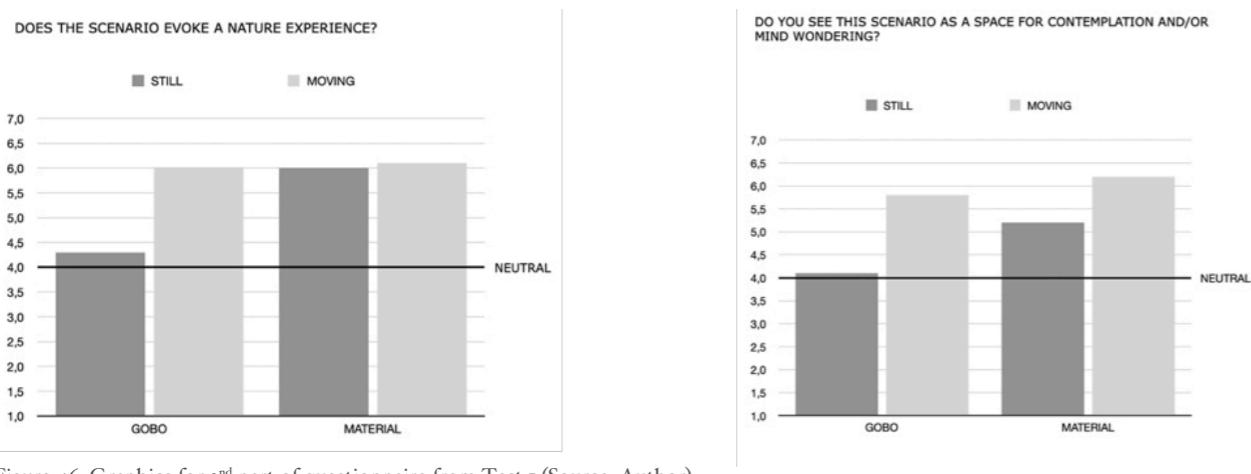


Figure 46: Graphics for 2<sup>nd</sup> part of questionnaire from Test 1 (Source: Author)

The findings from Test 1 with 4 immersive scenarios reveal that the material based creative lighting effect using reflected light had a more positive emotional reaction and scored higher in unpredictability, the feeling of spaciousness and variability. It had even higher positive results when the projected reflection was moving organically. It is also interesting to note that the Material Static (MS) scenario scored very similarly to the Gobo Moving (GM) scenario in the pleasure pairs suggesting that the graphic nature of the second and its mechanic and rotational regular movement may be perceived as a negative factor when used in a space that invites people to linger. The Gobo scenarios also had lower scores in the arousal pairs meaning that they were rated as being more exciting and stimulating. One also needs to consider that colour has also played an important role in how the patterns where perceived, as expressed by some of the participants. The cyan coloured light from the Gobo helped to reinforce the symbolic and graphic representation of water and the Material 3000k correlated colour temperature suggested a quality that is more of light itself, without any associated symbolism.

## Task 2 - Video simulations (Light Lab)

With the intent to complement Task 1 and further assess how the patterns would be perceived in a simulated scenario, the participants have watched two video simulations: one with Gobo moving and one with Material moving. In this case the scenario of having a motionless still pattern was discarded taking in consideration the Biophilia teachings that suggest that movement is an important factor when experiencing nature (Kaplan, 1995; Kellert ,2008) and the findings on the elements in a nature experience that enhance cognitive creativity. The findings clearly show us that the organically moving Material reflection had a much higher positive response in the pleasure and arousal pairs than the moving Gobo. They also reveal that when participants saw the Gobo effect in the simulation their emotional response in the pleasure pairs was much less positive than their evaluation of the GM scene and on average had a neutral response (fig 48).

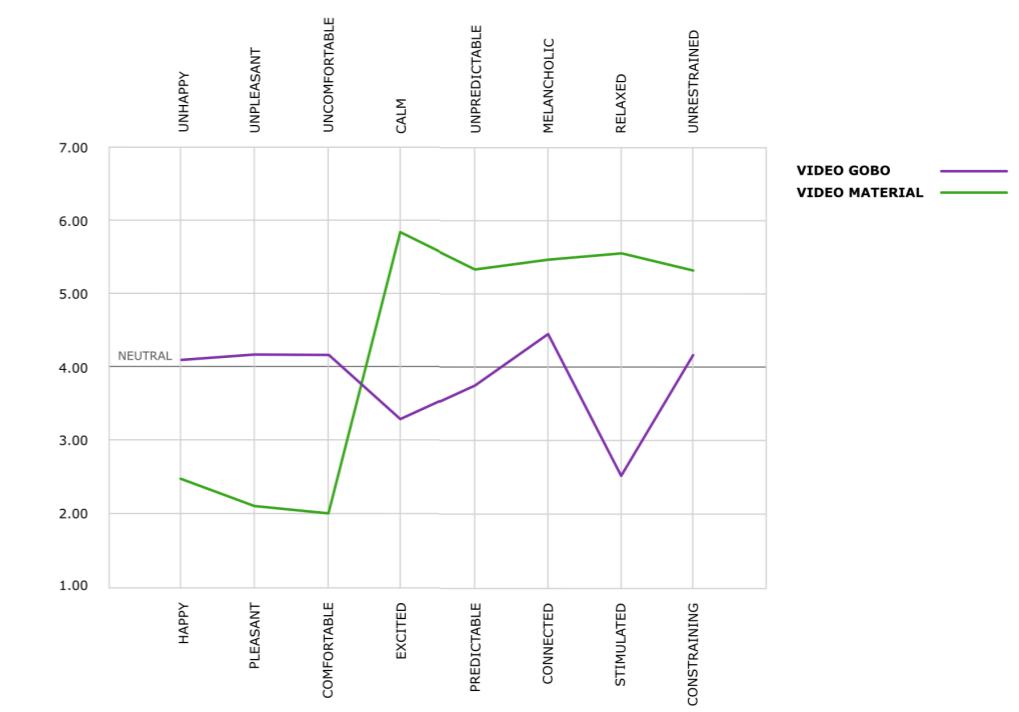


Figure 47: Graphic comparing results from 2 video simulations seen at the light lab (Source: Author)

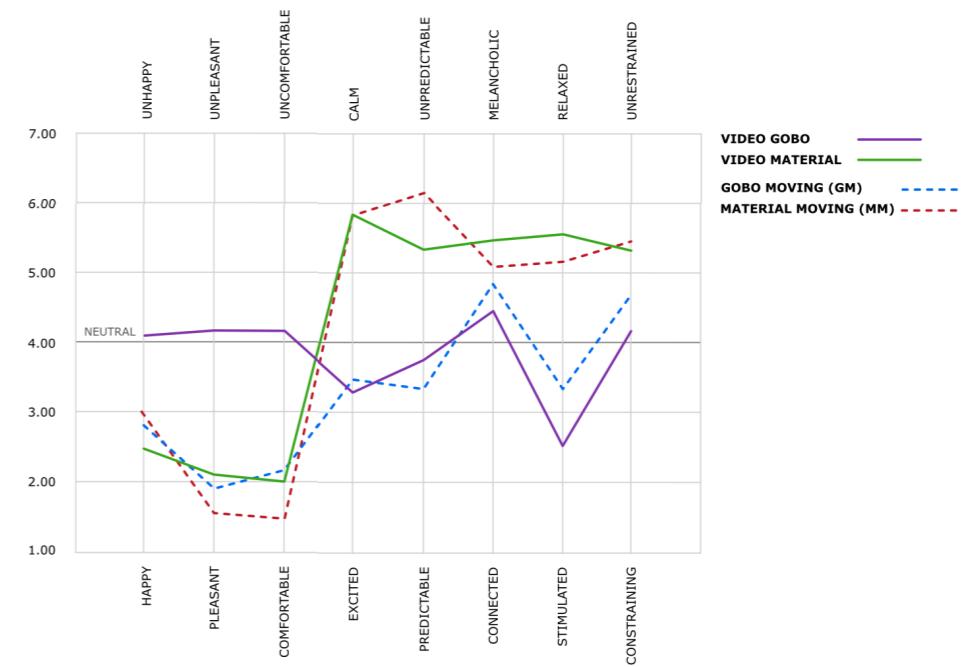


Figure 48: Graphic comparing 2 video simulations with the 2 scenarios with moving patterns (Source: Author)

This response suggests 2 things: that its symbolic nature, representing water, generated a variety of feelings that are contradictory in some cases. For example the presence of water, or a figurative representation of it, may be an enjoyable thing but in this context and seeing it applied on the pavement that is by definition a grounded and stable surface and creates an unpleasant feeling as stated by one of the participants: "*It is not natural to walk on water*". On the other end there were other participants that shared that it created a pleasing effect because it evoked some positive memories. Secondly it suggests that when seen in context the cyan coloured light creates a disharmony within the overall scenario with most of the participants mentioning an unpleasant atmosphere. It is also worth mentioning that even though the average indicates gobo as being neutral in the pleasure pairs when we analyse these numbers individually one can see that the percentage of participants voting negatively was higher, although in some cases very insignificantly higher (fig 49). It was also interesting to realise that the Material effect represented in the Video, simulating light reflection but in a more fluid way and more reminiscent of caustics generated by moving water had a slightly lower positive emotional evaluation than the Material Moving immersive scenario. This could be explained by the more natural feel of MM and again by the participants background and emotional memories. As one participant mentioned: "*I really like to walk in nature and it (Material Moving) reminded me of foliage gently moving with the breeze*". As with the liquid patterns in both videos one participant said: "*I am concerned about having this effect all the time, especially the blue one (Gobo). I enjoy them both but I know that my wife would most likely dislike it and even make her sea sick. She really does not like that feeling of floating in water.*"

| VIDEO GOBO     |                    |                        |            |
|----------------|--------------------|------------------------|------------|
| EMOTIONAL PAIR | AVERAGE EVALUATION | NUMBER OF PARTICIPANTS | PERCENTAGE |
| HAPPY          | 1,2                | 3                      | 27,3 %     |
| NEUTRAL        | 4                  | 3                      | 27,3 %     |
| UNHAPPY        | 5,2                | 5                      | 45,4 %     |
| PLEASANT       | 2,4                | 5                      | 45,5 %     |
| NEUTRAL        | -                  | 0                      | -          |
| UNPLEASANT     | 5,7                | 6                      | 54,5 %     |
| COMFORTABLE    | 2                  | 4                      | 27,39 %    |
| NEUTRAL        | 4                  | 2                      | 18,2 %     |
| UNCOMFORTABLE  | 5,8                | 5                      | 54,41 %    |
| EXCITED        | 2,37               | 8                      | 72,8 %     |
| NEUTRAL        | -                  | 0                      | -          |
| CALM           | 5,67               | 3                      | 27,2 %     |
| PREDICTABLE    | 2,33               | 6                      | 54,60 %    |
| NEUTRAL        | 4                  | 1                      | 9,1 %      |
| UNPREDICTABLE  | 5,75               | 4                      | 36,3 %     |
| CONNECTED      | 2                  | 2                      | 18,2 %     |
| NEUTRAL        | 4                  | 2                      | 18,2 %     |
| MELANCHOLIC    | 5,28               | 7                      | 63,3 %     |
| STIMULATED     | 1,75               | 8                      | 72,7 %     |
| NEUTRAL        | 4                  | 2                      | 18,2 %     |
| RELAXED        | 6                  | 1                      | 9,1 %      |
| CONSTRAINING   | 2                  | 4                      | 36,3 %     |
| NEUTRAL        | 4                  | 1                      | 9,1 %      |
| EXPANSIVE      | 5,67               | 6                      | 54,6 %     |

Figure 49: Graphic comparing emotional response 2 video simulations seen at the light lab (Source: Author)

Finally when analysing part two of the questionnaire, when asked "Do you see this scenario as a space for contemplation and/or mind wondering?" participants had an average neutral position regarding Video Gobo and a very affirmative response regarding Video Material (fig 50 left). Participants also saw Material Video as being more evocative of an experience in nature (fig 50 right). Again this may indicate that a reductionistic nonfigurative version of a nature experience, such as the one provided by using reflected light and irregular organic movements is more likely to be accepted by a broader range of people than a more figurative one that is less mysterious therefore less open for interpretation, .

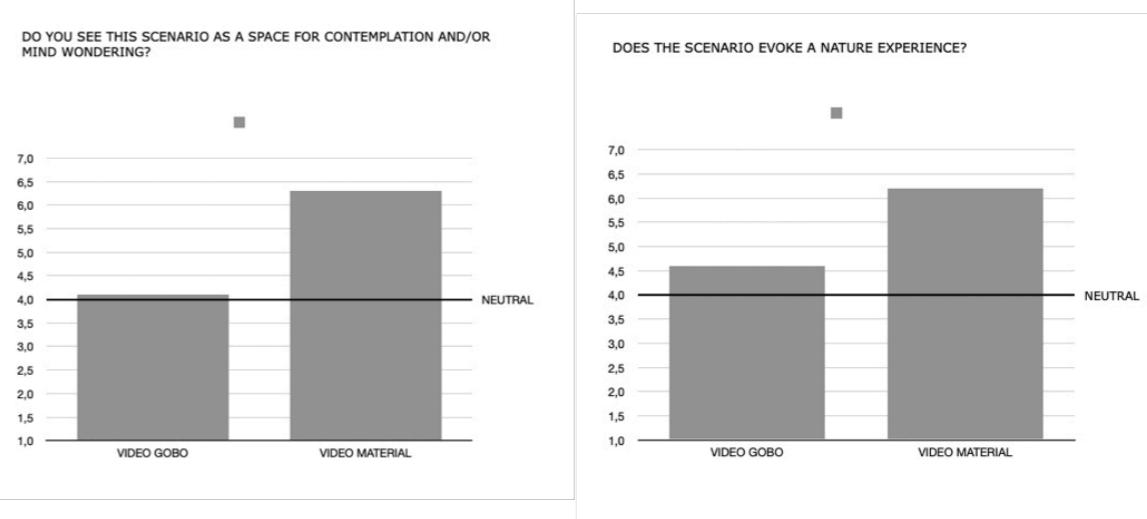


Figure 50: Results from the second part of the questionnaire for 2 video simulations (Source: Author)

To summarise one can conclude the following from Task 2 testing:

- Creative lighting that evokes an experience in nature that is nonfigurative, based on projected light reflections moving organically has higher positive emotional response.
- Regarding unpredictability, spaciousness and variability Material effect also scored higher than figurative gobo effect, suggesting higher potential for mind-wandering and therefore the potential to enhance creative cognition.
- A reductionistic approach taking cues from natural daylight phenomena and solely using light maybe more easily perceived as a natural experience. Without any graphic symbolism light becomes the focus leaving it more open for interpretation. Effects that are more figurative graphic and symbolic may be more likely to be perceived as artificial and therefore be seen as forged, creating a reaction of disdain.
- Spatial context and visual harmony as well as peoples background may change how creative lighting is perceived therefore are important factors to be considered when designing and using such tool.
- Complementing laboratory controlled testing with simulations of the creative lighting layer in use in a real life scenario (in our case outdoor public spaces in residential areas) enriches the experiment potentially giving a more accurate findings.

## Online Survey

The online survey was closed with a universe of 24 participants. 38,9% of the participants are aged 25 to 30, 33,3% are aged between 35 to 45. Regarding gender identification it was split in half with both female and male representing 50% of the universe.

The results are less expressive and more homogenised than the ones obtained in the Light Lab as shown by figure 52. On the pleasure pairs all 3 videos are close to neutral with the Video Material (VM) being the one with the highest positive scores. On the arousal pairs scores are also close to neutral with VM scoring higher on the calm and relaxed side. Regarding unpredictability they are pretty much neutral with results very close to each other with VG, VGW and VM scoring 4,16, 4,05 and 3,89 respectively. Regarding spaciousness VGW and VM scored an average above neutral with 4,44 and 4,11 but still without expressive average response. VG was scored as constraining with 3,17.

If we compare Video Gobo (VG) with Video Gobo Warm (VGW) we see an average evaluation for the second that is more positive on the pleasure pairs but with a minimal difference. All other pairs score practically the same except for the pair Connected/Melancholic with VG scoring 5,05 (somewhat melancholic) and VGW scoring 3,55 (neutral towards connected) and the pair Constraining/Unrestrained with VG scoring 3,17 (somewhat constraining) and VGW scoring 4,11 (neutral towards unrestrained).

On the second part of the questionnaire when asked directly the results are still close to neutral. When asked if the simulated scenario cloud be seen as a space for contemplation and/or mind wondering Video Material (VM) scored the highest with 4,5 (somewhat applicable) and Video Gobo Warm (VGW) scored the lowest with 3,39 (somewhat not applicable). Video Gobo (VG) was neutral scoring 4,17. When asked if the scenario evoked a nature experience the average results are neutral with a minimal lower score for VGW and VM towards somewhat not applicable, but again the difference is insignificant.

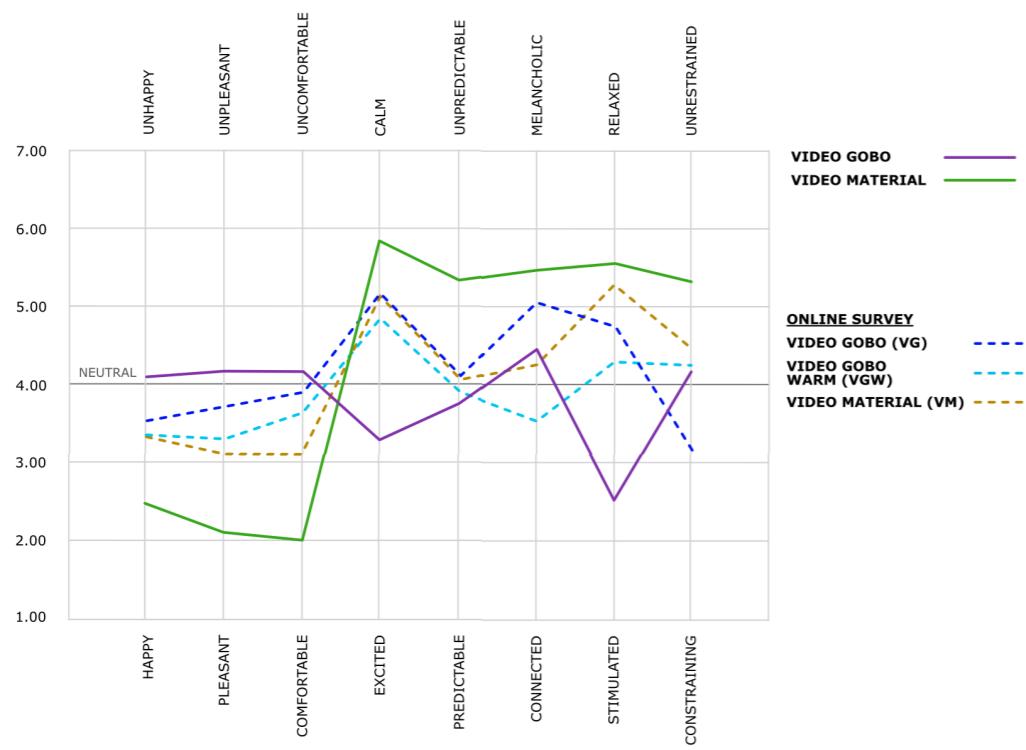
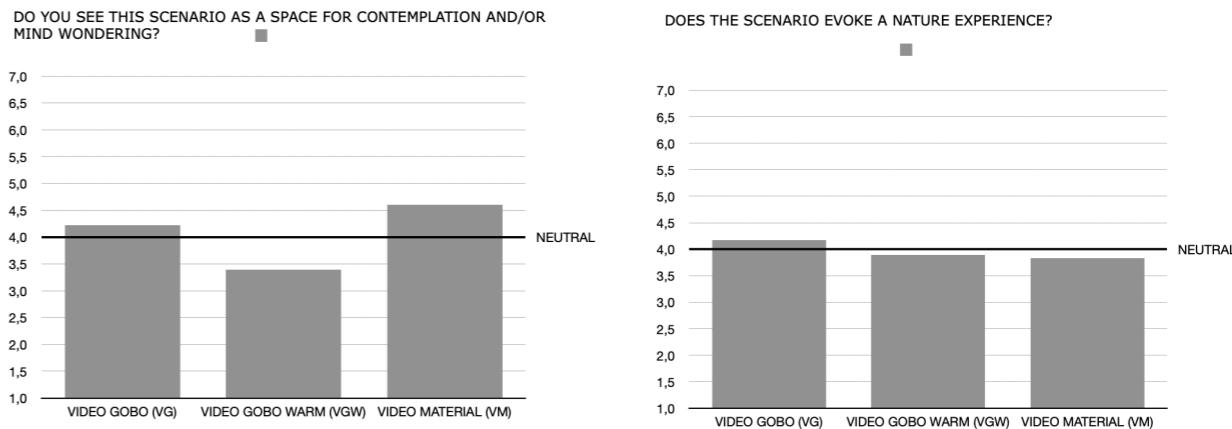


Figure 52: Graphic with results from online survey and comparison with results from the Light Lab on the 2 videos shown (Source: Author)

6 of the 24 participants decided to freely comment. The following comments represent the more common response:

*"The last one (VGW) looks like quicksand so it makes me be uncomfortable. The blue one (VG) feels more immersive than the others but it feels less natural than the second one (VM). I think I would feel more calm with the second (VM)."*

4 participants commented that Video Gobo Warm (VGW) looked like quicksand and therefore was unpleasant. All participants mentioned that Video Gobo (VG) looked like water with one participant saying that it was the coldest and the one that he perceived as being the darkest therefore more uncomfortable and rising some safety concerns:

*"I felt the first was the coldest and least comfortable one. A bit too dark, which made me immediately wonder about safety concerns when there are no people around."*

Another participant also expressed some safety concerns and equally felt that VG was darker and favoured Video Gobo Warm arguing that visibility was better:

*"In the first scenario (VG), despite not being actually darker than in the second video, it felt darker, and that made me feel wary. In the second scenario (VM), despite not being able to see some people's faces, there was something (I can't put my finger on) that made it easier to be there. The third scenario (VGW) was the most pleasant. In Brazil, especially during the night, predictability can be a good thing for a woman coming home alone."*

Another comment worth mentioning argues that none of them evoke a nature experience because the participant felt that the movements are too fast. The participant also arguments that the patterns evoking water are dissociated with the context therefore it is unpleasant.

"Scenario 3 (VGW) is less calming compared to Scenario 1 (VG) and 2 (VM). For all three scenarios I don't have the sense of being connected to nature - the movements are too fast. This is not a sea-screen and it does not mimic waves or light being reflected in the surface of water."

There is some common aspects in the comments and emotional responses and also some disparities. In general one cannot extract any strong conclusion from the online survey. Although it seems to favour material reflections the results are not as expressive as the ones obtained in the light lab.

The researcher finds that there are four important things to point out:

- Because the online participants were not exposed to the 4 immersive scenarios they didn't really have a physical reference of the effect as the participants in the light lab did and that may have played an important role in video results.
- The second thing to point out is that the Video Material simulated a light effect that is more evocative of water caustics and therefore, as demonstrated by the results and comments, more figurative. This water symbolism was evident and didn't leave much room for interpretation and therefore deemed as artificial, as a misleading trick. The physical material reflection experienced at the light lab was not symbolic in the sense that it did not have an obvious connotation. Participants attributed different meanings to it with three referring to light filtered through foliage, others mentioning sunlight without attributing any material interaction and two associating it to water.
- The online participants were in different settings, under different lighting conditions and using different screens for visualising the videos unlike the experiment at the light lab where every participant had the same conditions.
- The findings may also indicate that when testing a luminous effect reliant on the physical qualities of light one needs to experience it in full bodily present. Simulations may be a complement but cannot replace it.

## Hypothesis conclusions

Referring back to our hypothesis we can conclude the following:

*H1 - Using material reflectance properties to evoke natural light phenomena has a higher potential of being closer to a natural experience than a standard graphic figurative representation of the same subject therefore having a higher positive emotional response.*

Indeed the findings from the light lab test suggest that this hypothesis is true. The findings from the online test are neutral and do not offer a robust answer.

*H2 - Unpredictability and variability of movement in the light pattern may trigger mind wandering therefore having a positive effect on creativity.*

Findings suggest that this hypothesis is true. Positive emotional response was higher and was most chosen as a space for contemplation and mind-wandering.

*H3 - Immersive creative lighting that is nonfigurative based on light caustics added to a functional lighting design in an outdoor public space can raise its potential for mind-wandering.*

All results suggest that this is true. Positive emotional response is higher and the sense of fascination is also higher suggesting a higher potential in capturing the pedestrians soft attention thus triggering mind-wandering. In the online test the results point in the same direction but are not expressive.

## Final design suggestions

The findings have demonstrated that a final design suggestion, or to put it more accurately a set of design criteria used for the design of a meaningful creative lighting effect that may enhance creativity is:

Immersive, nonfigurative, based on light patterns produced through interaction between light and material, has unpredictable and variable movement in both speed and density that is similar to the one experienced in medium density forests, is adapted to the current conditions of the site complementing its functional lighting.

The nonfigurative, nonrepresentational and non overimposing nature of the creative lighting effect makes it more likely to be accepted by the users because it is very open for interpretation. Focussing on the essence of light creates a result that is more likely to constantly fascinate and enhance creativity.

Note: As explained throughout this thesis we are focusing on creative light that is permanently installed, becoming part of people's daily routines. Temporary creative lighting or light art would not have to take its long term effect on people into account therefore may enjoy higher less restricted creative freedom.

# CONCLUSION

This thesis aimed to create some knowledge on how to use Creative lighting in outdoor public spaces at night in a meaningful way. With a higher demand for aesthetic visual effects (creative lighting) our nighttime experience of cities is becoming damaged by overstimulation. More and more our cities are being populated with commercial ready-made solutions that are mere questionable aesthetic improvements. They create an unbalanced nightscape, negatively influencing our perception, how we navigate through the urbanscape as well as atmosphere and quality of life. Furthermore, these standard creative lighting solution, due to its decorative figurative nature and indiscriminate application, lack meaning and fail to call for our imagination and sparkle our creativity. Social progress is only possible if we are curious, if we question, if we imagine a better world, if we are creative to come up with better or new solutions for problems that we collectively or individually face.

Architectural Lighting Designers in the past years have been more and more asked to intervene in outdoor public spaces and are searching for ways to design creative light that is unique and meaningful. One can look into the history of Light Art and its key figures in order to gain knowledge and meaning that can be transferred to Architectural Lighting Design.

Through an extensive analysis of **Light Art** history we found that the road to the, **nonfigurative, the immaterial, the immersive experience** and the exploration of the **qualities of light** led to works that faced us with the awareness of ourselves as sentient beings and created connection with our natural environment. These connections were induced by experimenting on how **light interacts with materials**, how it can expand space and trigger our thoughts making us question and see things differently, enhancing our creativity.

This lead us to analyse the importance of the **nature experience**, its benefits for humans and if it could foster our creativity. We found that experiencing nature has a stress-reducing impact and a restorative potential. Interaction with nature provides rest and relief from our everyday challenges and stressful modern living. We can divert our directed attention from tasks or thoughts that require high mental effort and cause fatigue towards things that require very little to no effort, moments of involuntary attention, therefore allowing the mind to rest and restore. This involuntary attention happens best in spaces that are prolific in moments of **soft stimulation**. These moments abound in nature and are often qualified as mesmerising and serene, such as the soft movement of branches or the sparkling reflections of sunlight in a water pond. They provide an opportunity for reflection and mind-wandering. This leads us to the importance of internal reflection, of **mind-wandering** on cognition and particularly creativity. When mind-wandering we not only allow for our mind to restore but it also provides opportunities for exploration that generate creative results through new associations and metaphor, reassembling our memories and external stimuli in ways that we normally would not.

Through an analysis on nature experience and creative we found that the elements that we can identify as catalysts of creativity, in connection to its soft fascination potential are: **Density, unpredictability and spaciousness. Movement and variation** where also found to be an essential element in how we experience nature and how they play an important role in creating these fascinating moments that capture our attention. By combining these criteria with the findings from Light Art history analysis (**Nonfigurative, Shaping/revealing light through**

**material interaction, Immersive**) we have come up with a group of design criteria.

Complementary to this an analysis on light fundamentals and on the state of the art complemented the design criteria that would inform the design of a creative lighting effect that aimed to evoke, in a nonfigurative way, nature experience through light phenomena. The mockups were used to test the emotional response from a group of participants. The findings demonstrated that an immersive nonfigurative creative light effect that is based on a pattern created through material reflections (caustics) that moves organically (unpredictably and with variations) has a higher positive response than a standardised figurative solution relying on a pattern that as regular motion is predictable and lacks variation. The first has the highest potential to spark creativity.

*How can nonfigurative immersive creative lighting evoking an experience in nature based on moving caustic patterns through reflective materials enhance creativity while supporting the nighttime experience of an outdoor public space?*

It may enhance creativity due to its high potential to work as a soft stimuli, that captures our attention in a non intrusive way restoring our mind and inducing mind-wandering. Furthermore, it may suggest nature but its nonfigurative quality leaves it open for interpretation, for the subject to imagine freely, to construct his own images, new relations further supporting creativity. Its immersive nature heightens the experience, its effect, engaging space, our senses, and facilitating the connections to a natural experience similar to what light art can achieve. It is by immersion that we may feel part of it. The findings from the test suggest that it may support the nighttime experience because the space gains meaning, a purpose and people have a positive emotional response to it. The space is not only practical or functional (where one navigates through it to get home/work or to walk the dog) but it may gain a new purpose as a place where you can stop, linger and wonder in your own thoughts. In order for the creative lighting effect to have a higher positive response it needs to be in harmony with the functional lighting and complement the overall feeling of safety and comfort.

## LIMITATIONS & FUTURE WORKS

### Limitations

This study revealed some limitations. The universe of participants in the Light Lab test was reduced. 11 participants does not offer a robust enough result nonetheless the method and test setup to repeat or continue such experiment was tested and demonstrated. Therefore it would be positive to repeat the test and have a higher universe of participants. Nonetheless considering the diversified universe, the difference in results when compared with the online survey, discussing with and observing the participants, it is believed that we had a clear idea on the user perspective.

The online testing also revealed some limitations. The fact that the researcher could not

control the room conditions nor the digital supports in which the video simulations would be viewed gave very different experiences to the online participants. As an example differences in screen brightness and contrast with ambient lighting can negatively influence the experience of watching the videos.

Thirdly the physicality of the material mockup and its strong presence (besides the efforts of dissimulating it) in the test room at the Light Lab could have had a significant influence in the participants experience.

## Future Works

Using the same design principles to further investigate density, unpredictability and spaciousness. Although there is some research on the subject of views with patterns with different densities, it could be positive to further investigate this in the context of organic nonconfigurative creative lighting for outdoor spaces that is not created graphically but through material interaction. One could create multiple scenarios with different densities, where the nature of the pattern changes more drastically and understand how that may impact our perception of space when immersed. Furthermore, the role of colour both correlated colour temperature and saturated colours could be investigated.

Regarding the testing methods, exposing the participants to a physical immersive experience with a creative lighting effect layer in a controlled empty room where they were asked to imagine themselves in an outdoor space and then following it with a video simulation of an outdoor space where they see the simulated application, proved to be beneficial. This sequence of tasks revealed that if we only had the first results would have been very different because the participants were focused on the effect layer in a safe and sterile laboratorial environment therefore not properly envisioning this layer working in combination with existing exterior functional lighting and all the other conditionings like spatial scale, surface materials, general atmosphere, other people, etc. The possibility of using a virtual reality headset to create a more immersive 3 dimensional experience as opposed to a visualisation of a video on a bidimensional flat screen could be considered for future testings. This could provide stronger results. It would also be important to complement the emotional response questionnaires with some creativity tasks to try to understand if indeed participants are able to be more creative after exposure to the creative lighting pattern.

Furthermore, it would be of upmost importance to prove the concept in an actual outdoor public space to understand if the creative lighting layer can achieve what it proposes, if people stop or slow down to be lost in mind-wandering for a moment.

As a final suggestion it would also be important to investigate how strong are the aspects of cultural background, memory and previous experiences in peoples emotional response to this type of creative lighting effects.

## REFERENCES

- Adkins, B. (2015). *Deleuze and guattari's A thousand plateaus; A critical introduction and guide* Edinburgh University Press.
- Aitken, D., & Noel, D. (2005). *Broken screen: Expanding the image, breaking the narrative; 26 conversations with doug aitken*. New York: D.A.P./Distributed Art Publishers.
- Alvarsson, J. J., Wiens, S., & Nilsson, M. E. (2010). Stress recovery during exposure to nature sound and environmental noise. *International Journal of Environmental Research and Public Health; Int J Environ Res Public Health*, 7(3), 1036-1046.
- ARUP. (2015). *Cities alive - rethink the shades of night* (ARUP ed.). London:
- Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the wild: Improving creative reasoning through immersion in natural settings. *PloS One; PLoS One*, 7(12), 1-3.
- Aviv, V. (2014). What does the brain tell us about abstract art? *Frontiers in Human Neuroscience; Front Hum Neurosci*, 8, 85-85.
- Barnett, P. J., & Kaufman, J. C. (2020). Chapter 1 - mind wandering: Framework of a lexicon and musings on creativity. In D. D. Preiss, D. Cosmelli & J. C. Kaufman (Eds.), *Creativity and the wandering mind* (pp. 3-23) Academic Press. doi:<https://doi.org/10.1016/B978-0-12-816400-6.00001-8>
- Barton, J., & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environmental Science & Technology; Environ.Sci.Technol*, 44(10), 3947-3955.
- Berman, M. G., Hout, M. C., Kardan, O., Hunter, M. R., Yourganov, G., Henderson, J. M., et al. (2014). The perception of naturalness correlates with low-level visual features of environmental scenes. *PloS One; PLoS One*, 9(12), e114572-e114572.
- Beukeboom, C. J., Langeveld, D., & Tanja-Dijkstra, K. (2012). Stress-reducing effects of real and artificial nature in a hospital waiting room. *The Journal of Alternative and Complementary Medicine (New York, N.Y.); J Altern Complement Med*, 18(4), 329-333.
- Biederman, I., & Vessel, E. (2006). Perceptual pleasure and the brain. *American Scientist*, 94(3), 247.
- Blume, C., Garbazza, C., & Spitschan, M. (2019). Effects of light on human circadian rhythms, sleep and mood. *Somnologie : Schlafforschung Und Schlafmedizin = Somnology : Sleep Research and Sleep Medicine; Somnologie (Berl)*, 23(3), 147-156.
- Bourgeois, C. (2014). In Exhibit catalogue P. G. (Ed.), *The illusion of light* Electa.
- Boyce, P. R. (2014). *Human factors in lighting*. Baton Rouge: CRC Press.

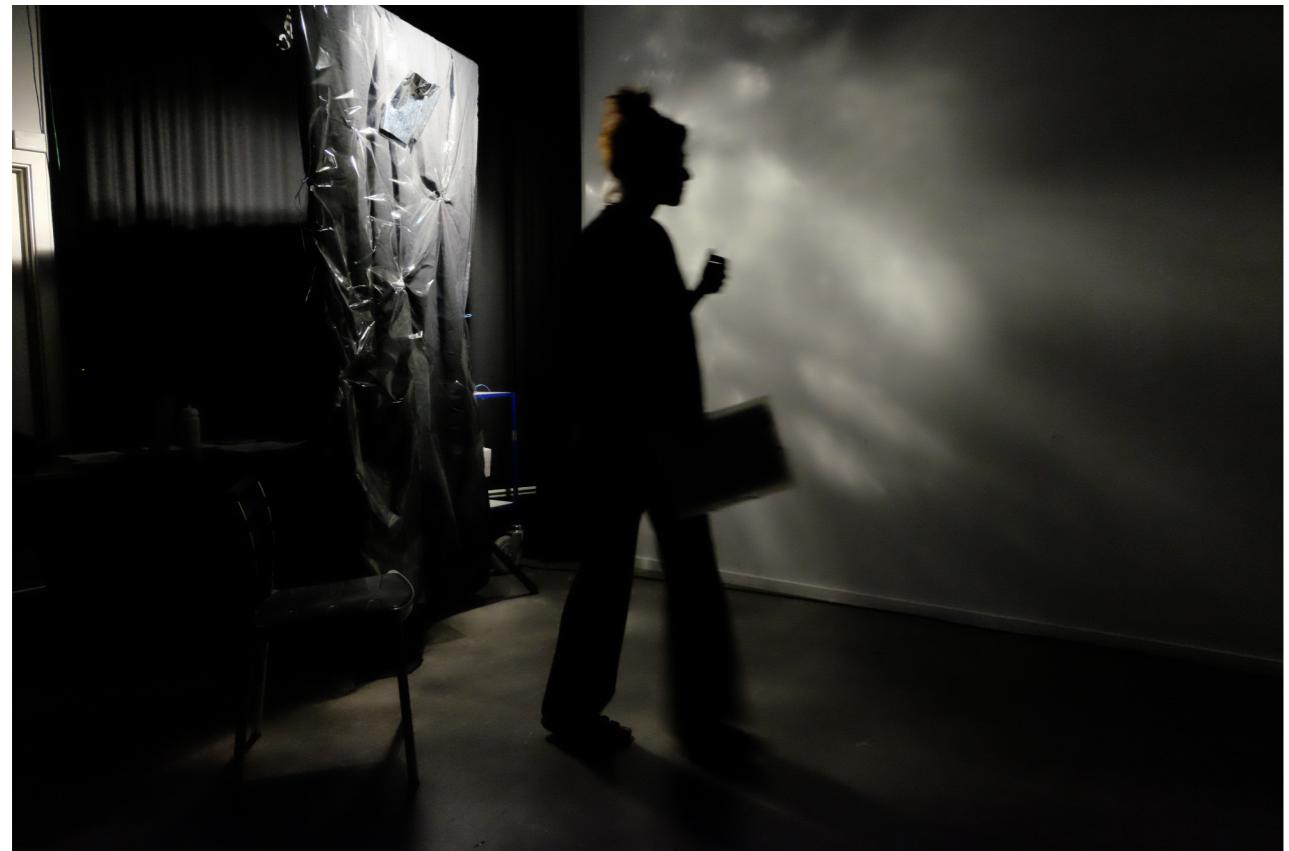
- Butterfield, J. (Ed.). (1993). *"Douglas wheeler," the art of light and space*. New York: Abbeville Press.
- Celant, G. (2019). *Doug wheeler*. New York: David Zeirner Books.
- Chilvers, I., & Glaves-Smith, J. (2015). *Light art* Oxford University Press.
- Chulvi, V., Agost, M. J., Felip, F., & Gual, J. (2020). Natural elements in the designer's work environment influence the creativity of their results. *Journal of Building Engineering*, 28, 101033.
- CIE. (2019). *CIE 234:2019 A guide to urban lighting masterplanning*CIE.
- Clark, R. (2011). *Phenomenal. california light, space and surface*. Berkeley: University of California Press.
- Clarke, M. (2010). *The concise oxford dictionary of art terms* Oxford University Press.
- Coplans, J. (1968). *Doug wheeler. exhibition brochure* Pasadena: Pasadena Art Museum.
- Crispolti, E. (Ed.). (2006). *Lucio fontana: Catalogo ragionato di sculture, dipinti, ambientazioni, vol 1*. Milan: Skira.
- Csikszentmihalyi, M. (1997). *Creativity : Flow and psychology of discovery and invention*. New York: Harper Perennial.
- Debord, G. (1992 [1967]). In Rebel Press L. (Ed.), *Society of the spectacle* . London: Rebel Press.
- Deleuze, G., & Guattari, F. (1987). *A thousand plateaus : Capitalism and schizophrenia*. London: Athlone.
- Descottes, H., & Ramos, C. (2011). *Architectural lighting: Designing with light and space*. New York: Princeton Architectural Press.
- Dobson, C., & Christoff, K. (2020). Chapter 12 - productive mind wandering in design practice. In D. D. Preiss, D. Cosmelli & J. C. Kaufman (Eds.), *Creativity and the wandering mind* (pp. 271-281) Academic Press. doi:<https://doi.org/10.1016/B978-0-12-816400-6.00012-2>
- Ebbengaard, C. L. (2015). Illuminights: A sensory study of illuminated urban environments in copenhagen. *Space and Culture*, 18(2), 112-131.
- Eliasson, O., & Sans, J. (2010). *Olafur eliasson & ma yansong: Feelings are facts*. Beijing: UCCA Publication Series.
- Eliasson, O., Behmann, S., & Engberg-Pedersen, A. (2016). *Studio olafur eliasson. unspoken spaces* . London: Thames & Hudson.
- Encyclopædia Britannica. *Light - reflection and refraction*. Retrieved May 15, 2022, from <https://www.britannica.com/science/light/Reflection-and-refraction>
- Fox, M. (2002). *Optical properties of solids* (Oxford University Press ed.)
- Franceschini, C. (2021, March 02). *Five illuminating facts about dan flavin*.<https://perfectpicturelights.com/blog/dan-flavin>
- Friedel, H. (2017). *Heinz mack: Licht / light / lumière* Hirmer.
- Fromm, E. (1955). *The sane society* . New York: Premier Book.
- Gabel, V., Maire, M., Reichert, C. F., Chellappa, S. L., Schmidt, C., Hommes, V., et al. (2013). Effects of artificial dawn and morning blue light on daytime cognitive performance, well-being, cortisol and melatonin levels. *Chronobiology International; Chronobiol Int*, 30(8), 988-997.
- Ganslandt, R., & Hofmann, H. (1992). *Handbook of lighting design* (ERCO ed.) Verlag Vieweg.
- Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., et al. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology*, 45, 22-29.
- Govan, M., & Kim, C. Y. (2013). *James turrell: A retrospective*. CA, United States: Los Angeles County Museum of Art.
- Govan, M. e. a. (2004). *Dan flavin: The complete lights, 1961-1996* (New York: Dia Art Foundation ed.) Yale University Press.
- Griffin, J. (2015, 1 November). *Light years ahead: Interview with robert irwin*.<https://www.apollo-magazine.com/apollo-artist-interview-with-robert-irwin/>
- Groot, W. T., Bonaiuto, M., Dedeurwaerdere, T., & Knippenberg, L. W. J. (2015). *A theory of committed action for nature: Key outcomes of the BIOMAT project*Nijmegen : Institute for Science Innovation and Society, Faculty of Science, Radboud University Nijmegen.
- Heinz mack sculptor and painter - desert and arctic*. Retrieved 03/13, 2022, from <https://www.mack-kunst.com/en/Desert-and-arctic.htm>
- Hunter, M. D., Eickhoff, S. B., Pheasant, R. J., Douglas, M. J., Watts, G. R., Farrow, T. F. D., et al. (2010). The state of tranquility: Subjective perception is shaped by contextual modulation of auditory connectivity. *NeuroImage (Orlando, Fla.)*; *NeuroImage*, 53(2), 611-618.
- Jackson, D. (2015). *Superlux : Smart light art, design and architecture for cities*. London: Thames and Hudson.
- Jahncke, H., Hygge, S., Halin, N., Green, A. M., & Dimberg, K. (2011). Open-plan office noise: Cognitive performance and restoration. *Journal of Environmental Psychology*, 31(4), 373-382.
- Janson, H. W., Davies, P. J. E., & Janson, H. W. (2011). *Janson's history of art : The western*

- tradition* (8th ed.). Upper Saddle River, NJ: Prentice Hall.
- Kandel, E. R. (2016). Reductionism in art and brain science: Bridging the two cultures. *Columbia University Press, New York, NY, U.S.A.*
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective.* (Cambridge ed.) University Press.
- Kaplan, S. (1995). The restorative benefits of nature: Towards an integrative framework.. . *Journal of Environmental Psychology, 15*, 169-182.
- Kaplan, R., & Kaplan, S. (2011). Well-being, reasonableness, and the natural environment. *Applied Psychology : Health and Well-being, 3*(3), 304-321.
- Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning, 86*(2), 115-125.
- KCET. (2020, 1 October). *S11 E1: Light & space.* <https://www.youtube.com/watch?v=Aho-zYz2fGU>
- Kellert, S. R., Heerwagen, J., & Mador, M. (2008). *Biophilic design : The theory, science, and practice of bringing buildings to life.* Hoboken, N.J: Wiley.
- Kellert, S. R., & Wilson, E. O. (1993). *The biophilia hypothesis.* Washington, DC: Island Press.
- Kostelanetz, R. (1991). *Moholy-nagy : An anthology.* New York: Da Capo Press.
- Lam, W. M. C. (1977). *Perception and lighting as formgivers for architecture.* New York: McGraw-Hill.
- Le Parc, J. *Lumières.* Retrieved 03/18, 2022, from <http://julioleparc.org/lumieres.html>
- Lee, H., & Lee, E. (2022). Effects of coloured lighting on pleasure and arousal in relation to cultural differences. *Lighting Research & Technology (London, England : 2001), 54*(2), 145-162.
- López-Martínez, F. (2017). Visual landscape preferences in mediterranean areas and their socio-demographic influences. *Ecological Engineering, 104*, 205-215.
- Louisiana Channel (Producer), & Louisiana Channel (Director). (2022, January 19). *We are in space | artist Lita Albuquerque.* [Video/DVD] YouTube:
- Lynch, D. K., & Livingston, W. (Eds.). (1995). *Color and light in nature* Cambridge University Press.
- Lynch, K. (1960). *The image of the city.* Cambridge MA: M.I.T. Press.
- Mack, H. (2015). *Heinz mack - ZERO and more.* London: Ben Brown Fine Arts.
- Mansfield, K. P. (2018). Architectural lighting design: A research review over 50 years. *Lighting Research & Technology (London, England : 2001), 50*(1), 80-97.
- McCoy, J. M., & Evans, G. W. (2002). The potential role of the physical environment in fostering creativity. *Creativity Research Journal, 14*(3-4), 409-426.
- Mehrabian, A., & Russell, J. A. (1976). *An approach to environmental psychology* Cambridge, MA: M.I.T. Press.
- Menezes, C. (2014, January 07). *Julio le parc: Light and movement.* <https://www.studiointernational.com/index.php/julio-le-parc-light-and-movement>
- Metzger, W. Optische untersuchungen am ganzfeld. 1930, (Psychologische Forschung 13), 6-29.
- Mikkelsen, T. (2009). *Kreativitetens psykologi : Hvad du som kreativ bør vide om dig selv og din Psyke* (1st ed.). Kbh: Nyt Nordisk Forlag.
- Morgan, A. L. (2018). *The oxford dictionary of american Art and Artists* (2nd ed.) Oxford University Press.
- Münch, M., Linhart, F., Borisuit, A., Jaeggi, S. M., & Scartezzini, J. (2012). Effects of prior light exposure on early evening performance, subjective sleepiness, and hormonal secretion. *Behavioral Neuroscience; Behav Neurosci, 126*(1), 196-203.
- Neuteleers, S., & Deliège, G. (2019). Does nature experience matter? why not to care too much about the link between nature experience and valuing nature. *Biological Conservation, 231*, 49-50.
- Orgeman, K. (Ed.). (2017). *Lumia, Thomas Wilfred and the art of light* Yale University Art Gallery.
- Pasini, F. (2008). "It is not a lasso, an arabesque, nor a piece of spaghetti". <https://www.tate.org.uk/tate-etc/issue-14-autumn-2008/it-not-lasso-arabesque-nor-piece-spaghetti>
- Petersen, S. (2018). *Lumia: Thomas wilfred and the art of light.* New York: College Art Association, Inc.
- Piemontese, M., Malina, R. F., & Mourasson, V. B. (1993). Les artistes et la lumière: Artists and light. *Leonardo (Oxford), 26*(1), 70-72.
- Piene, O. (1969). *Otto piene: Elements.* New York: Howard Wise Gallery.
- Pilotti, M., Klein, E., Golem, D., Piepenbrink, E., & Kaplan, K. (2015). Is viewing a nature video after work restorative? effects on blood pressure, task performance, and long-term memory. *Environment and Behavior, 47*(9), 947-969.
- Plambech, T., & van den Bosch, Cecil C.Konijnendijk. (2015). The impact of nature on creativity – A study among danish creative professionals. *Urban Forestry & Urban Greening, 14*(2), 255-263.
- ProaTV (Producer), & ProaTV (Director). (2019, October 12). *Dan flavin por katharine J. wright.* [Video/DVD] Youtube: ProaTV.
- Rodriguez, T. (2012). Open mind, longer life. *Scientific American Mind, 23*(4), 18-18.
- Russ, S. W. (2020). Chapter 10 - mind wandering, fantasy, and pretend play: A natural combination. In D. D. Preiss, D. Cosmelli & J. C. Kaufman (Eds.), *Creativity and the wandering mind* (pp. 231-248) Academic Press. doi:<https://doi.org/10.1016/B978-0-12-816400-6.00010-9>

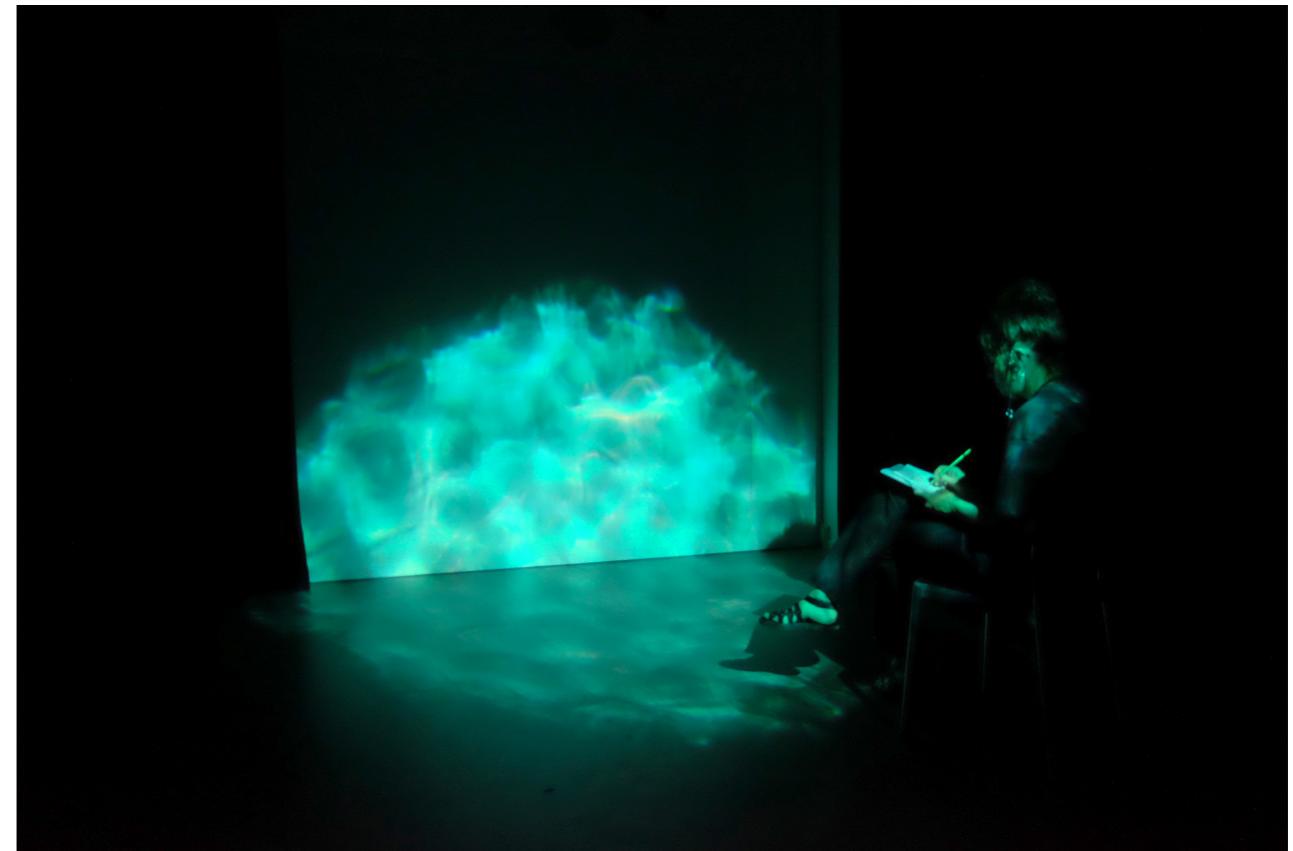
- Rutkoff, R. (2017). *Thomas wilfred*. NEW YORK: ARTFORUM.
- Schavemaker, M., & Poerschmann, D. (2015). *Zero - let us explore the stars* Walther König Books.
- Singh, S. (2018). Why is creativity so important anyway? *Gulf Marketing Review*,
- Soga, M., Gaston, K. J., Koyanagi, T. F., Kurisu, K., & Hanaki, K. (2016). Urban residents' perceptions of neighbourhood nature: Does the extinction of experience matter? *Biological Conservation*, 203, 143-150.
- Stein, D. M. (1968). Thomas wilfred 1889-1968. *Members' Newsletter (Museum of Modern Art (New York, N.Y.))*, (2), 4-4.
- Szolosi, A. M., Watson, J. M., & Ruddell, E. J. (2014). The benefits of mystery in nature on attention: Assessing the impacts of presentation duration. *Frontiers in Psychology; Front Psychol*, 5, 1360-1360.
- Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology*, 15(1), 77-85.
- Tiffany, R. (2008). Seeing oneself seeing "The weather project". *Anamesa*, 6(The perception issue), 78–99.
- Tregenza, P., & Loe, D. (2014). *The design of lighting* (2nd ed.). London: Routledge.
- Turrell, J. *Introduction*  
 . Retrieved 20 May, 2022, from <http://jamesturrell.com/about/introduction/>
- Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science (American Association for the Advancement of Science); Science*, 224(4647), 420-421.
- van Rompay, T. J. L., & Jol, T. (2016). Wild and free: Unpredictability and spaciousness as predictors of creative performance. *Journal of Environmental Psychology*, 48, 140-148.
- Walch, J. M., Rabin, B. S., Day, R., Williams, J. N., Choi, K., & Kang, J. D. (2005). The effect of sunlight on postoperative analgesic medication use: A prospective study of patients undergoing spinal surgery. *Psychosomatic Medicine; Psychosom Med*, 67(1), 156-163.
- Weibel, P., & Jansen, G. (2006). *Light art. artificial light: light as a medium in 20th and 21st century art* Hatje Cantz.
- White, M., Smith, A., Humphries, K., Pahl, S., Snelling, D., & Depledge, M. (2010). Blue space: The importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *Journal of Environmental Psychology*, 30(4), 482-493.
- Wirz-Justice, A., Skene, D. J., & Münch, M. (2021). The relevance of daylight for humans. *Biochemical Pharmacology*, 191, 114304-114304.
- Yu, C. (, & Hsieh, H. (2020). Beyond restorative benefits: Evaluating the effect of forest therapy on creativity. *Urban Forestry & Urban Greening*, 51, 126670.
- Zelenski, J. M., Dopko, R. L., & Capaldi, C. A. (2015). Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behavior. *Journal of Environmental Psychology*, 42, 24-31.
- Zemánek, J. (1999). *Zdeněk pešánek, 1896-1965* Prague: National Gallery & Gema Art.
- Zielinska-Dabkowska, K. (2014). Critical perspectives on media architecture: Is it still possible to design projects without negatively affecting urban nighttime environments and will the future remain dynamic, bright and multi-colored? pp. 101-108.

# APPENDIX

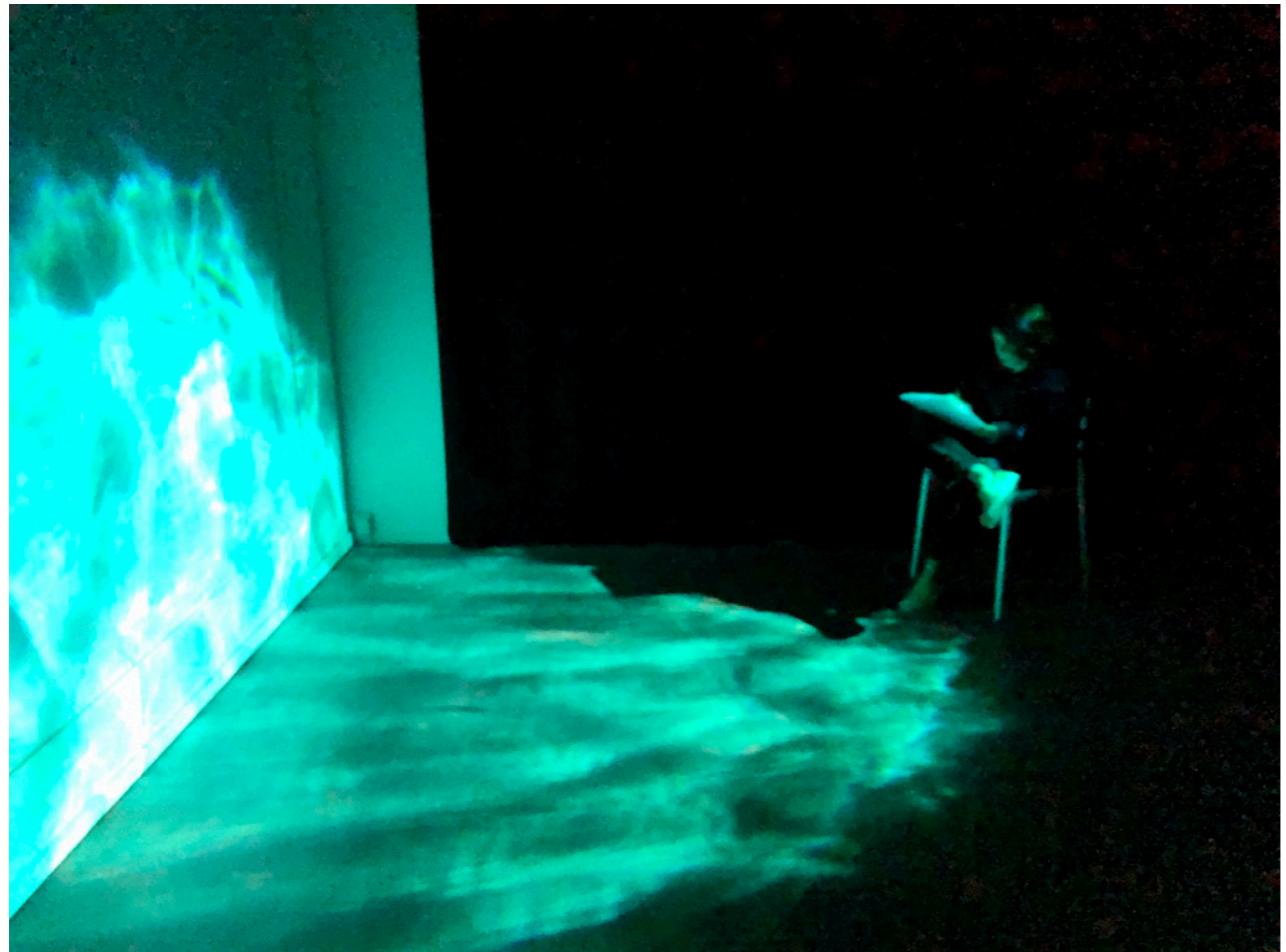
The following are picture from the test at the Light Lab at Aalborg University Copenhagen campus.



92



93



94



95

