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This paper explores the natural characteristics of a light phenomenon, Sun Glitter, through Biophilia to recreate it as a Biophilic Play of Brilliants light solution for the built environment. The motivation strives from both Play of Brilliants light concept defined by Richard Kelly (1952) and the justified benefits of Biophilia (Kellert & Wilson, 1993) as it fundamentally presents our tendency to connect with nature and helps to revitalise our bond with nature through Biophilic Design methodology. The process demonstrates a design approach that is applicable for such an attempt to adapt a natural light phenomenon into indoor use by preserving the feelings it evokes due to its natural context.

Mainly four particular fields are investigated concerning each other; the Sun Glitter phenomenon, Play of Brilliants, Biophilia and Biophilic Design. According to the results, light experiments are conducted to draw a guideline for a final concept. The results of Theory and Light Experiments promises many possible design directions while the proposed concept illustrates only one of them.

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A Biophilic Play of Brilliants

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Sun Glitter

Lighting Design Master Thesis

Elif Öngül

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Institute for Architecture and Media Technology

Abstract

Nowadays, we try to reintegrate nature into our daily lives in various ways; it is important to reconsider the context of light in this matter.

This paper explores the natural characteristics of a light phenomenon, Sun Glitter, through Biophilia to recreate it as a Biophilic Play of Brilliants light solution for the built environment. The motivation strives from both Play of Brilliants light concept defined by Richard Kelly (1952) and the justified benefits of Biophilia (Kellert & Wilson, 1993) as it fundamentally presents our tendency to connect with nature and helps to revitalise our bond with nature through Biophilic Design methodology. The process demonstrates a design approach that is applicable for such an attempt to adapt a natural light phenomenon into indoor use by preserving the feelings it evokes due to its natural context.

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CONTENTS

1 INTRODUCTION

1.1 MOTIVATION

"The nature in us must have some relation to Nature outside of us; moreover, Nature outside of us must be unveiled to us by the Nature that we are."

— Maurice Merleau-Ponty, Nature: Course Notes from the Collège de France

The lighting concept of Play of Brilliants was defined by Richard Kelly in 1952. In his words, it is a light that 'excites the optic nerves and stimulates the body and the spirit' which tackled my curiosity to go further to have a genuine understanding of the essence of it. The more I looked into Play of Brilliants(PoB) in nature, the more I realised the contrast between outdoor and indoor examples. Indoor examples of PoB such as candlelight, chandeliers etc. could not trigger the same feelings as it does in nature. It is undeniable how they are still mesmerizingly sparkling, yet it did not occur to me as something from nature. There is something that got lost in translation in the process of recreation of a light phenomenon which makes it more from nature and acts as a reminder of our connection to it.

Separating PoB from the other two light elements described by Kelly may not seem right in consideration of the holistic approach, however, as Kelly points out, even though the three elements exist together, one is constantly dominant (Kelly, 1952). As a result, in the context of this project Play of Brilliants will be the sole aspect.

After a comprehensive research that questions the importance of described nature connection led me to Biophilia. A hypothesis that suggests humans' tendency to seek a connection with nature and other life forms (Kellert & Wilson, 1993). Biophilia clarifies its benefits as improved psychological well-being, reduction in stress level and enhanced mood and creativity (Kellert et al., 2008). These findings strengthen the motivation for this project in a quest of a lighting design concept with a strongly highlighted nature connection. After Biophilia, Biophilic Design emerged as a method for designing our built environment in such a way that embraces Biophilia. The Biophilic Design methodology ensures that the natural characteristics of a nature-inspired design are preserved.

Lastly, a light phenomenon called Sun Glitter had chosen for this project to be replicated as an indoor lighting solution. It is one of the simplest PoB that can occur on a cloudless day on the surface of the water. Copenhagen, the city where this thesis was written, is the source of inspiration for thiis decision with its watery nature.

1.2 Vision

Imagine if the sun glitter phenomenon can be recreated as an indoor lighting solution following the concept of Play of Brilliants together with Biophilia to preserve its natural characteristics and hence evoke our connection to nature.

This thesis takes a new look at the essence of Play of Brilliants to identify its core nature in pursuit of an interpretation of Sun Glitter with artificial light to revitalize our bond with nature as a result of using Biophilia as the base and consequently support psychological well-being.

1.3 Research Question

How can Play of Brilliants and Biophilic Design be combined to mimic the natural sun glitter phenomenon through lighting to strengthen our connection to nature?

Fig. 1: Close-up photo of Sun Glitter on the surface of the sea.

1.4 Methodology

Move-Testing Experiments and Biophilic Design are the two key methodologies used in this process. Four Move-Testing Experiments are undertaken to achieve the vision by answering the RQ, and the results are used as input in a Biophilic Design process.

1.4.1 Move-Testing Experiments

The paper is structured mainly based on Move-Testing Experiments described by Schön(1983) as any deliberate action taken with an end in mind. The move is affirmed if the result coincides with the intention, negated when it does not. Although it is the main method applied in 4 steps, it has different methods within different steps.

For this study, 4 different Move-Testing Experiments have been conducted; (1) to investigate within the Theory, the Play of Brilliants and Biophilia comparison; (2) the analysis of 8 different PoB examples in relation to Biophilia; (3) Sun Glitter analysis through observations supported by comparative photo registrations and post-processing methods referring to Biophilic Design attributes; finally (4) Light Experiments have been conducted on light and material concerning design criteria. The first three experiments guide the process to clarify the design criteria and the last test is conducted in an attempt to an affirmation of the design concept.

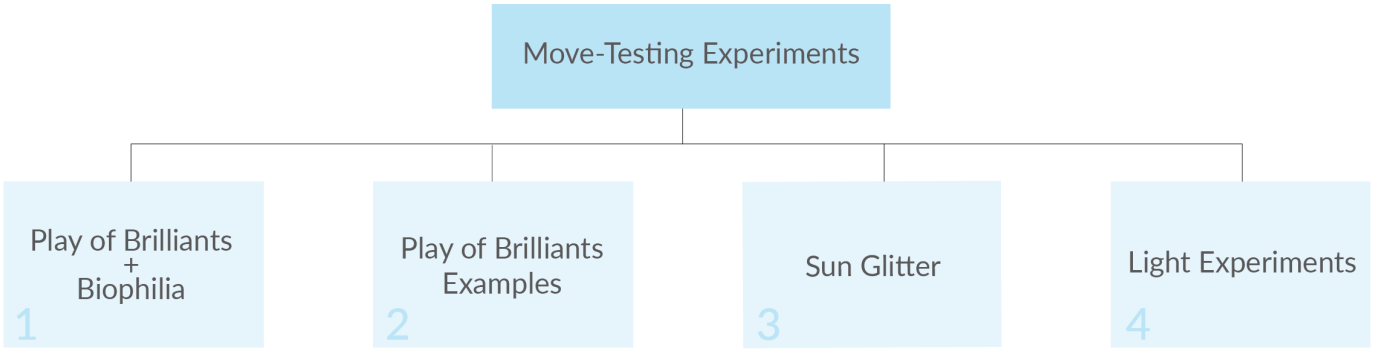


Fig. 2: Four different Move-Testing Experiments in order

Play of Brilliants + Biophilia

A study was done to understand both concepts fully in order to expose the common attributes. The analysis of Play of Brilliants offers a closer look to the concept including its definition, benefits and examples. Since the vision is revitalizing the bond with nature, Biophilia plays an important role to define the benefits and characteristics of nature. Findings of both concepts coincides in the core values regarding the nature characteristics. One is inspired and mesmerized by natural light phenomenon and the other introduces the very reason behind this feeling in connection to nature, thus presents a set of criteria for the next move-testing experiment; analysis of Play of Brilliants examples.

Play of Brilliants Examples

Eight Play of Brilliants examples are examined using predetermined criteria in the previous experiment of PoB+Biophilia. Comparing 4 outdoor PoBs to 4 indoor PoBs reveals how big of an impact the nature component has in the feelings that the light evokes in us. This analysis, together with the first experiment, forms the basis of the Theory conclusion and design criteria.

Sun Glitter

Personal observations have been made aiming to conduct a comprehensive study in addition to the research on the physics of the light phenomenon. The location is by the canal in Sydhavn, Copenhagen. Photo registrations and hand sketches benefited in the analysis of Sun Glitter's visual characteristics. Photo registrations, taken between 08.15-09.35 AM on a clear day, later post-processed in Illustrator software by the Image Tracing technique to eliminate distractive colour from the images. Additionally, hand sketches help to create a visual simplification of the natural phenomenon to understand its visual patterns.

Light Experiments

A series of light experiments was conducted in a personal living space where the environment gives the opportunity to have a complete darkroom. The set-up consists of one WIZ RGB light bulb, a mouth-blown glass vase with a textured surface and a glass jar. Photos were taken with a Nikon D3300 DSLR camera, an Opple Light Master lux meter was used for necessary light measurements. The light source is shielded with a reflective opaque filter to adjust the light distribution towards the test object.

Simulating a dynamic brightness, colour temperature and coloured illumination on the tested material was expected to be sufficient regarding the experiment goals defined within the design criteria.

Fig. 3: The experiment setup and the adjustment to the light bulb with the opaque filter.

1.4.2 Biophilic Design

Kellert(2018) describes the transition from Biophilia to Biophilic Design as the difference between a demonstrated cause and a method for designing for that cause. Biophilia guides the research in this paper to keep the goal of evoking our connection to nature in focus while Biophilic design facilitates the application of the findings into the design process. The process continues with the concepts and aspects of Biophilic design, as shown in fig. 4, which is also utilized as the final technique to accomplish Biophilic Design, yet they will not be explored further to keep the focus on the design.

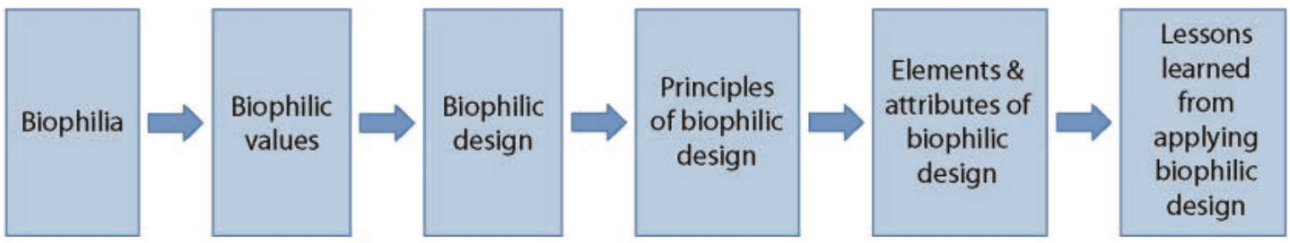


Fig. 4: Transtiion from Biophilia to Biophilic Design.

2 THEORY

The Theory will deliberate published material in the particular topics of this thesis, with the intention of establishing a foundation of knowledge that can contribute to supporting the design research experiment and thereby answer the Research Question. It starts with presenting the starting point of this thesis; Play of Brilliants followed by Biophilia in an attempt to match characteristics with PoB which will build design criteria in relation to light. Biophilic Design will be the second section of the Theory to demonstrate a method in order to exploit the findings.

The final part will be devoted to the analysis of the fields investigated in theory in relation to each other, followed by the analysis of Sun Glitter, the cascading light pattern on the surface of the sea due to the sun rays meeting the waves and creating numerous reflections, sparkles; supported by the scientific reasoning of the phenomenon. Dissecting the fundamental elements of Sun Glitter through the analysis will provide the design elements together with the findings of the previous analysis and answer the Research Question at last.

2.1 PLAY OF BRILLIANTS

In his article Lighting as an Integral Part of Architecture, Richard Kelly defined three types of light: ambient luminescence, focal glow, and play of brilliants (Kelly, 1952). These features have now become one of the most important aspects of lighting design. Kelly was a renowned expert on architectural lighting design in the middle of the twentieth century, according to Petty (2007). Neumann et al. (2010) claim that he gave a “large vocabulary” to the profession, and 3 elements of light are only a small fraction of that vocabulary, but it is one of the most important and consequently the basis of this paper. In this section, PoB will be deciphered to its cores to recreate the Sun Glitter phenomenon from nature as a daylight solution.

Focusing on the Play of Brilliants brings the necessity to understand the other two elements as well. Because the differences unveil the true importance and characteristics of Play of Brilliants. To begin with here Kelly's own words about three elements of light;

'...three kinds of light, (1) Focal glow, (2) Ambient luminescence, (3) Play of brilliants, respectively (1) make it easier to see (2) make surroundings safe and reassuring (3) stimulate the spirit.'

— Kelly, 1952

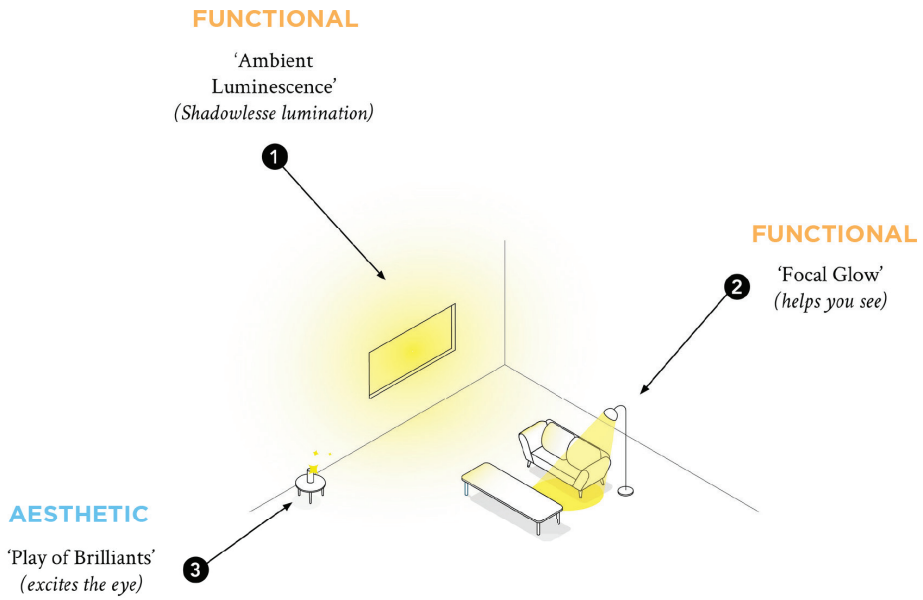


Fig. 5: All three elements of light defined by Kelly (1952).

From his explanation of all three elements, one stands out differently than the other two in terms of functionality. While Ambient Luminescence and Focal Glow mainly provides enhanced vision for both ambient and accent lighting, Play of Brilliants stimulates our 'spirit'. The etymology of the word 'spirit' is from Latin 'breath', further meaning as; 'the non-physical part of a person which is the seat of emotions and character; the soul' (Oxford English Dictionary, 2015). For such a delicate manner a philosophical point of view can lead to a deeper understanding of the word. Hegel describes the spirit as follows;

'...the "nature" of individuals, their immediate substance, and its movement and necessity; it is as much the personal consciousness in their existence as it is their pure consciousness, their life, their actuality.'

— (Friedrich & Rauch, 1983)

Based on the definition of spirit by Hegel, Play of Brilliants can be defined as "a light that stimulates the 'nature' of individuals, quickening their substance, emotions, consciousness, and life" using both above-mentioned definitions of the word "spirit". It is a tremendously powerful light element with immeasurable potentials.

Furthermore, Play of Brilliants excites the optic nerves, stimulates the body and the spirit, sharpens the wit as being distracting and entertaining (Kelly, 1952). He continues with examples; 'it is a sunlight on a fountain, a rippling brook, a cache of diamonds in an opened cave, the rose window of Chartres, the tree outside your window interlaced with the beams of spotlights, a night city from the air.'. A simplified modern contemplation can be that it is a decorative light that results in awe and curiosity through light patterns or projections used to create visual attractiveness (Casciani, 2020).

The majority of the examples are light phenomena from nature, basically interference of the sun with a natural element in its own order is a Play of Brilliants. However, this is not particularly surprising given the fact that the sun is our first light source followed by human-made interpretations of light. Every light we invent or imagine must have its inspiration from natural light. In this case, the light aforementioned is sunlight, moonlight or starlight in nature while the patterns are the results of this light being scattered, reflected or refracted through an object and consequently stimulates excitement, fascination as well as wonder. Still, there is a difference between outdoor and indoor examples. This difference plays a crucial role in the process of adaptation of light phenomena, especially with a vision of conserving the benefits of nature context. Therefore, in order to understand nature and its attributes that have to be preserved, the concept of Biophilia was used in further analysis.

2.2 BIOPHILIA

Biophilia means 'love of life' (Fromm 1964). It is a practice to understand deeply what nature really is and acknowledge its vitality. Therefore, it is inevitable to ignore its potential contribution into a case where nature is under the spotlight. Heerwagen and Gregory (Kellert et al., 2008) states that nature has seven attributes;

(1) *Sensory Richness* which refers to variations in different aspects of nature such as brightness, the colour of the sun, different growth patterns of flowers etc., **(2)** *Motion* as in Nature's constant change and move; **(3)** *Serendipity* meaning ephemeral events like coming across to an animal in the woods for a moment or a ray of sun coming through clouds; **(4)** *Variations on a theme* is similarities but not duplications in patterns, can be summarized as 'rhythmic visual growth patterns' which can be summarized as fractal structuring in waves, clouds, trees; **(5)** *Resilience* is the toleration that Nature has towards disturbances and the persistency through adaptation; **(6)** *Sense of freeness* points out not having physical boundaries in nature which can create both psychological and physical sense of freedom; and finally, **(7)** *Prospect and refuge* simply refers to being able to see without being seen gives a feeling of protection.

The relevant attributes for this project (1) Sensory Richness, (2) Motion, (3) Serendipity and (4) Variations on a theme will be taken into consideration through a deeper analysis with the analysis of Play of Brilliants examples and due to their relevance to light.

The four attributes of nature can be boiled down to *Dynamism* in the lighting context. While Sensory Richness is the dynamic brightness, colours, patterns etc., Motion can be summarised as dynamic movements whereas Serendipity is the dynamic presence of light and lastly Variations on a Theme is the dynamic shapes and forms of light. All four attributes are resolved into light-related aspects separately keeping dynamism as the basis and presenting *dynamic light*.

2.3 BIOPHILIC DESIGN

Biophilic Design is a methodology to apply Biophilia into the built environment defined by Kellert (2008). He has divided the Biophilic Design elements into six categories (fig. 6), which are **(1)** Environmental features, **(2)** Natural shapes and forms, **(3)** Natural patterns and processes, **(4)** Light and space, **(5)** Place-based relationship, and finally, **(6)** Evolved human-nature relationships. These elements have 70 attributes in total, each defining different specific parameters in relation to the built environment.

Environmental features	Natural shapes and forms	Natural patterns and processes
Color	Botanical motifs	Sensory variability
Water	Tree and columnar supports	Information richness
Air	Animal (mainly vertebrate) motifs	Age, change, and the patina of time
Sunlight	Shells and spirals	Growth and efflorescence
Plants	Egg, oval, and tubular forms	Central focal point
Animals	Arches, vaults, domes	Patterned wholes
Natural materials	Shapes resisting straight lines and right angles	Bounded spaces
Views and vistas		Transitional spaces
Façade greening	Simulation of natural features	Linked series and chains
Geology and landscape	Biomorphy	Integration of parts to wholes
Habitats and ecosystems	Geomorphology	Complementary contrasts
Fire	Biomimicry	Dynamic balance and tension
		Fractals
		Hierarchically organized ratios and scales

Light and space	Place-based relationships	Evolved human-nature relationships
Natural light	Geographic connection to place	Prospect and refuge
Filtered and diffused light	Historic connection to place	Order and complexity
Light and shadow	Ecological connection to place	Curiosity and enticement
Reflected light	Cultural connection to place	Change and metamorphosis
Light pools	Indigenous materials	Security and protection
Warm light	Landscape orientation	Mastery and control
Light as shape and form	Landscape features that define building form	Affection and attachment
Spaciousness		Attraction and beauty
Spatial variability	Landscape ecology	Exploration and discovery
Space as shape and form	Integration of culture and ecology	Information and cognition
Spatial harmony	Spirit of place	Fear and awe
Inside-outside spaces	Avoiding placelessness	Reverence and spirituality

Fig. 6: Elements and Attributes of Biophilic Design.

Even though it is comprehensively guiding, the kind of light described in these sub-elements are referring to functional light in a space, which can be seen as Ambient Luminescence and Focal Glow (Kelly, 1952) as they are mentioned in the first section of Chapter 2.

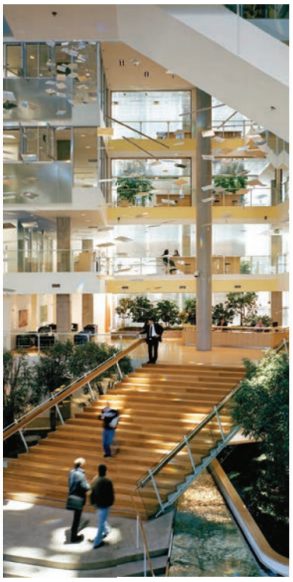
However, another book was written by Kellert 10 years later to simplify the existing framework. This time instead of 6 design elements with 70 attributes, there are 3 design elements with 25 attributes to use as a guide for a biophilic design. These three elements are (1) Direct Experience of Nature, (2) Indirect Experience of Nature and (3) Experience of Space and Place (2018). In consideration of his latest book, it is much easier to drag clear Biophilic Design guidelines to recreate a nature-inspired Play of Brilliants for the built environment.

Direct Experience of Nature

- Light
- Air
- Water
- Plants
- Animals
- Weather
- Natural landscapes and ecosystems
- Fire

Indirect Experience of Nature

- Images of nature
- Natural materials
- Natural colors
- Simulating natural light and air
- Naturalistic shapes and forms
- Evoking nature
- Information richness
- Age, change, and the patina of time
- Natural geometries
- Biomimicry



Experience of Space and Place

- Prospect and refuge
- Organized complexity
- Integration of parts to wholes
- Transitional spaces
- Mobility and wayfinding
- Cultural and ecological attachment to place

Fig. 7: Experiences and Attributes of Biophilic Design.

Indirect Experience of Nature

Considering the aim of recreating Sun Glitter in an indoor environment, it is the Indirect Experience of Nature that has to be followed as a guideline. All sub-categories of it can be seen in the table above, however, only the relevant ones will be discussed further. For a comprehensive understanding, it is recommended to review the source itself.

Natural materials are important to stimulate dynamic and natural properties. Kellert suggests using stone, wood, stone-like natural materials in order to highlight their change over time to showcase their adaptive response to the stress over time. Other dynamic and natural properties in relation to light can be considered to choose a natural material.

Natural colours; he refers to colours' role in our evolutionary process to find resources and responses to daylight. Therefore it can be interpreted into both the colour of the material and the light.

Simulating natural light and air is about simulating the dynamism in both properties. The air mentioned is the quality of it as in airflow, humidity, ventilation etc. Therefore it is not necessarily relevant for the design guidelines. On the other hand, natural light is dynamic natural light. Laganier and Van der Pool state that "[…] subtle changes of light that have a calming effect on people. These dynamics are close to natural light" (2011).

Naturalistic shapes and forms is simply mimicking the patterns from nature due to their ability to transform a static space into one that maintains the dynamic and ambient qualities of a living system (Kellert, 2018).

Natural geometries is addressing the hierarchical organizations in nature. For every pattern we encounter within nature, there is a mathematical equation as an explanation such as 'Fibonacci Sequences' or 'Golden Ratio'.

All in all, even though some other categories have not been mentioned, it is not due to their lack of relevance for the case but the level of it. The other five criteria mentioned above are taken as design criteria in the Design section.

3 THEORY ANALYSIS

3.1 PLAY OF BRILLIANTS + BIOPHILIA

This section presents first two Move-Testing Experiments together as they are connected to each other. The criteria derived from the first mote-testing experiment; Sensory Richness, Motion, Serendipity and Variations on a Theme are used to define the qualities of comparison between eight examples in the second move-testing experiment.

Being in nature and watching the movement of light creates a distinctive experience for us than what a chandelier offers. The study of this distinction leads to the delineation of natural qualities. For this reason, indoor and outdoor examples of Play of Brilliants will be compared to each other within the Nature attributes defined by Biophilia. The selected examples can be seen below (fig. 8).

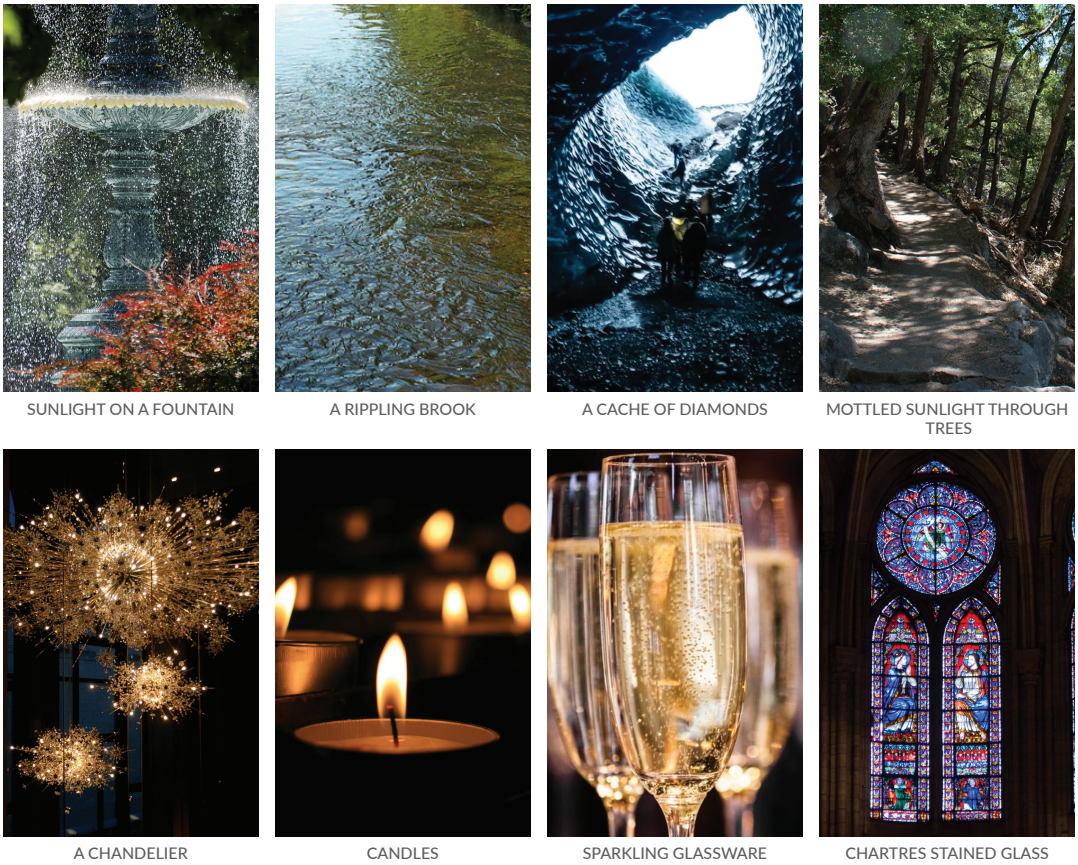


Fig. 8: Outdoor (top row) and indoor (bottom row) Play of Brilliants examples to be analysed in this section.

Sensory Richness

Sensory Richness refers to variation in nature such as the change in light or different weather conditions like the calmness after a storm which basically reminds us that nature is alive and constantly changing. It is easy to see it in ‘a sunlight on a fountain’ or ‘a rippling brook’ since either the water or the sun is constantly changing and creating a high contrast with its environment, which results in the sparkles. High contrast is a common attribute for both situations where it is dynamic outdoors due to sensory richness, yet static indoors considering the examples listed above. A chandelier or a group of candles offers sparkles of high contrast as well but it is often a static light what we observe. To conclude it is important to create a dynamic high contrast.

Motion

Kellert describes motion through a simple experience of taking a walk in the woods. Watching the birds stirring, the wind breezing, the water gurgling while the light is shifting is a pure example of motion in nature (2008). He also cites from Katcher that it is a ‘‘Heraclitean movement as it is always changing, yet remaining the same.’’(1993). In a lighting perspective, the motion of either the light or the material shows the spectacle as it is dynamic. In this case, the motion of nature results in alive, fluctuating changes in light effects. It is one of the core characteristics of nature which is naturally a part of outdoor Play of Brilliants examples while it is missing in indoor examples. Therefore, Motion, as another big difference between them, should be taken into account for the design criteria.

Serendipity

Serendipity can simply be seen as the unexpectedness of nature which is again not a part of indoor examples. Built environments are goal-oriented, functional places that serve as planned. Kellert points out light related examples of serendipity in the rays of light that enter a building at a certain angle and create ephemeral patterns (2008). Therefore, it is unlikely to expect serendipity in such planned circumstances unless it is again daylight that interferes with the space without our control over it. It is simply the excitement of the new, unknown that happens unexpectedly. Experiencing surprises inspires us to look for new perspectives (Solly, 2018). Seeing the sun shining upon a waterfall after a cloud passes by and shimmers as the falling water drops is a pure example of unexpectedness in the Play of Brilliants. On the other hand in indoor situations, lighting a candle is an action that includes the consequence of the action in itself which is the opposite of unexpectedness. As a result of both dynamic lighting and a dynamic environment, Serendipity becomes an essential part of nature’s characteristics.

Variations on a Theme

The last attribute highlights the rhymes and changes in nature, for instance, growth patterns in trees, clouds, waves etc.. Similarities but not duplications of patterns. Within the lighting context, these patterns are the glittering lights we experience in nature and see as the Play of Brilliants. The sparkly effect of light happens through reflection among the water particles in a rippling brook, sunlight on a fountain or in glassware. The light travels inside of a diamond, through refractions and reflections happening numerous times and finally leaves the mineral while creating a Play of Brilliants for us. All these numerous, uncountable times of light deformations create a randomly placed repetition of various, similar patterns. Finally, as this attribute is presence in both outdoor and indoor examples of Play of Brilliants, it is important to preserve it as the light pattern for design criteria.

Fig. 9: Play of Brilliants attributes in relation to Nature attributes defined within Biophilia.

In summary, primarily Motion and Serendipity are part of the 7 Attributes of Nature, yet missing in indoor Play of Brilliants examples presented in this section which can clarify the main dissimilarity between the outdoor and indoor cases. Furthermore, Sensory Richness and Variations on a Theme will be addressed in connection with the contrast and repetition as they are the core attributes of the Play of Brilliants in all examples investigated in this section.

3.2 SUN GLITTER

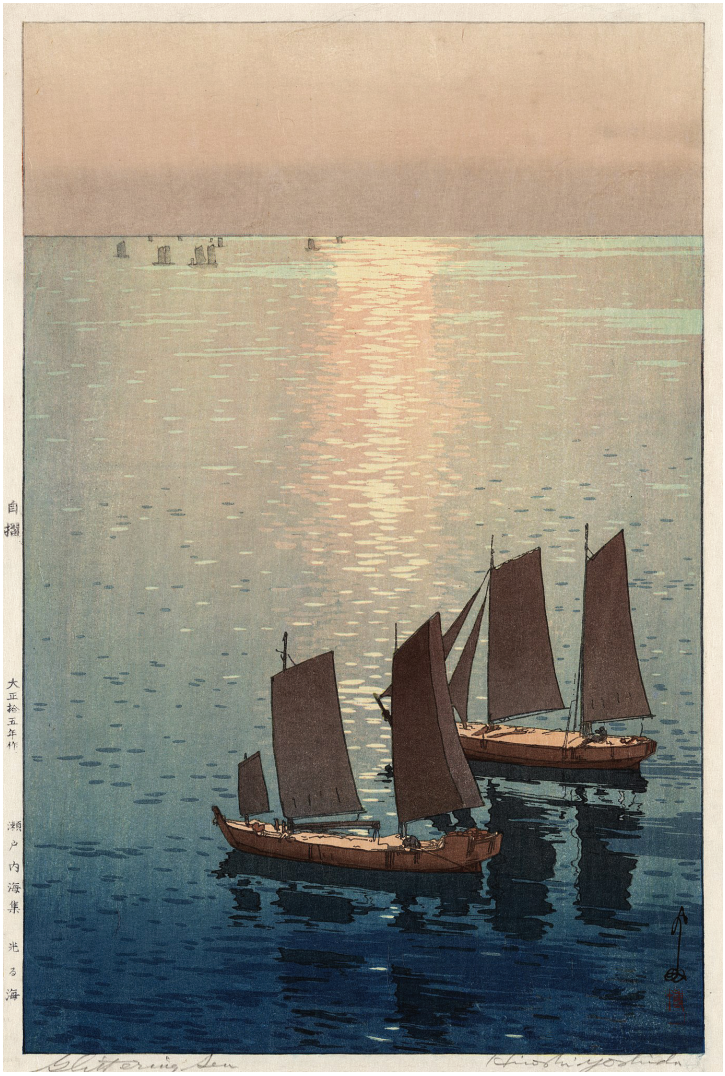


Fig. 10: Hikaru Umi - ‘‘the sparkling sea’’

‘Water, whether still or in motion, has so great an attraction for the lover of nature, that the most beautiful landscape seems scarcely complete without it. There are no effects so fascinating as those produced by the reflections in nature’s living mirror, with their delicacy of form, ever fleeting and changing, and their subtle combinations of colour.’

— Pollock, 1903

The Sun Glitter phenomenon has been poetically described as “the road to happiness” (Shuleikin, 1941) and “the golden bridge” (Stelenau, 1961). It is the coruscating sea, sparkles on the surface of the ocean caused by the sun’s reflection in the shape of a long elongated line of light. Even though it is quite obvious to see on a clear day and happens quite often, the physics behind it is far more complicated.

Understanding why Sun Glitter occurs is critical to determining the nature of the phenomenon. It's the specular reflection of the sunrays on the sea surface that reaches the observer's eye and creates the shimmering sun path. The more the sea is ruffled by the wind, the more the glitter appears as a result of the deformation of the sun's image (Jerlov, 1976). When the sky gets gloomy, the glittering of a rippling water surface vanishes (Minnaert, 1993). As a result, the principles of the phenomenon can be summarised as the sun rays colliding with the rippling water surface. At solar altitudes of 30-35°, the phenomenon is most vivid (Jerlov, 1976).

Fig. 11: Sun glitter photo

3.2.1. Observations

Fig. 12: Sun glitter photo registration

Photo registrations show that the shape of the light line differs as the sun rises and reaches higher degrees of elevation. As indicated by Lynch et al. in a visual study of Sun Glitter supplemented by long and short exposure images with high rate movies, while the line is straight, it becomes conical over time (2011). Despite the fact that the study attempts for a scientific explanation, it clarifies several key components of the occurrence that is helpful for the present project.

A visual simplification was created on the spot through hand sketches in order to analyse the spectacle's qualities. The pattern can be observed shifting while the effect remains constant. When the waves move faster, the sparkles become more vivid as well, which creates the literal glitter. The light pattern shifts from linear to pointed forms.

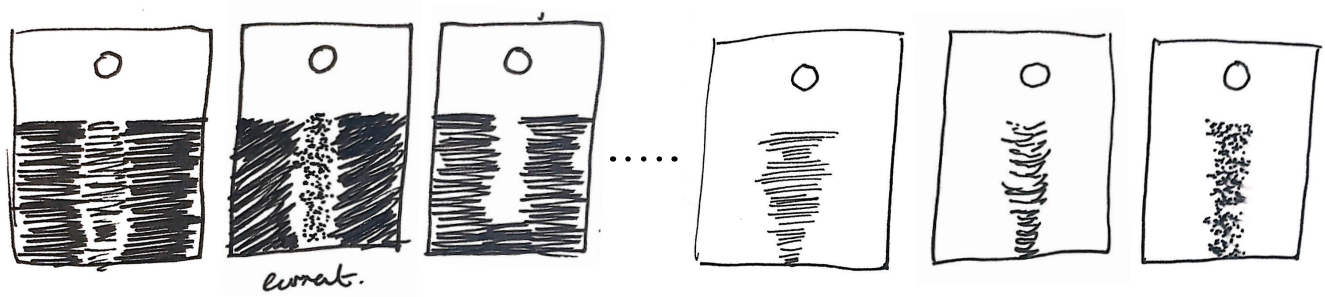


Fig. 13: Hand-sketches made during the observation.

3.2.2. Analysis

As the third Move-Testing Experiment a scientific and visual analysis of the Sun Glitter phenomenon were carried out in order to better comprehend it in distinct ways. To begin with, there are two main elements that create a sun glitter;

The sun **(1)** is reflected from the water surface **(2)** and finally creates the effect on the sea surface as a combination of glitter and the light surrounding it. If these two elements boil down to a physical recreation they can be translated into a light source **(1)** and a reflective surface **(2)** which are both dynamic and consequently create this dynamic effect of glitter on the surface. Based on the personal observations and research it is concluded that the changes in both elements affects the colour, brightness, pattern and shape. While the light is dynamic in colour temperature, angle and brightness; the water, reflective material, is dynamic in the pattern.

1. Colour Temperature → Colour

The Colour temperature of the sun affects the colour of the waves. While the colour of the glitter remains the same as white, the waves appear to be warmer in colour during early times of the day compared to later hours. It shifts from warm to cold hues with the sun rising up.

Fig. 14: Sun glitter photo registration with the indicator of the change in colour temperature.

2. Solar Elevation → Path Shape

The shape of the glitter path depends on the solar elevation. The more the sun rises, the more conical the path becomes. It is a straight path with the same width as the sun when it is near the horizon.

Fig. 15: Different path shapes due to the elevation of the sun.

3. Cloudiness → Brightness

A decrease in sun brightness due to the cloud cover leads to a less bright glitter which appears to be less glary. It disappears completely on a cloudy day.

4. Water Roughness → Pattern

A change in current results in a rougher water surface. This leads to different angles for light to be reflected in many more angles at the same time and creates a more pointy pattern rather than a linear one. The study below clearly shows this change in time through a post-processing technique.

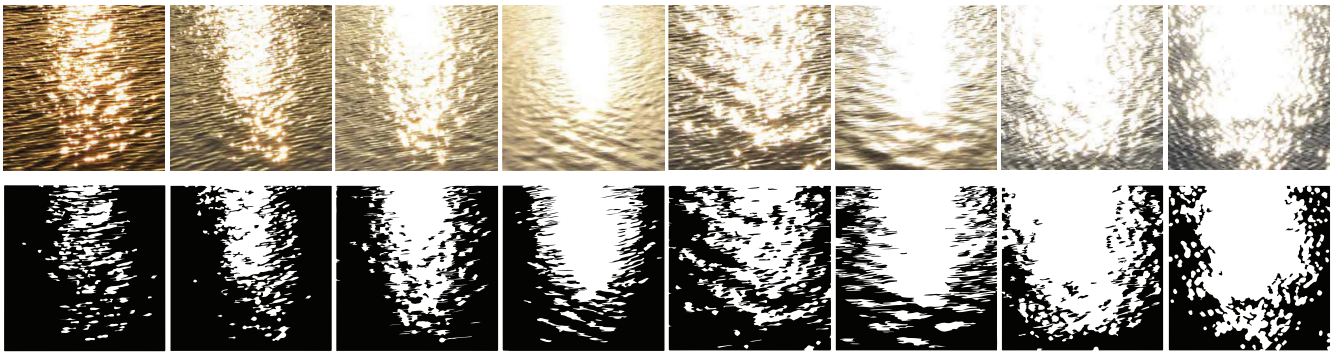


Fig. 16: Change in the pattern of glitter due to water surface roughness(first row). The Images are post-processed with the Image Trace technique (second row)

3.3 Conclusion

Play of Brilliants has been analyzed through indoor and outdoor examples based on Biophilia in order to detect nature attributes in both of them to unveil the missing attributes in indoor examples in comparison to outdoor examples and later recreate the Sun Glitter phenomenon in the built environment by preserving them. These attributes are Sensory Richness, Motion, Serendipity and Variations on a Theme which all will be translated to the design application through *dynamic lighting*.

Moving on with Sun Glitter analysis based on observvations and research result in unfolding the fundamental elements that create sun glitter, a *dynamic light source* and a *dynamic material*, and the outcome which they affect in different aspects such as; brightness, colour, shape and pattern. Although the material has been featured as dynamic, as the scope of the thesis is on lighting design, the dynamism of the material will be sorted out through lighting by keeping the material static.

Lastly, Biophilic Design elements considered in relation to Sun Glitter analysis; natural colours, natural materials, naturalistic shapes and forms, simulating natural light and natural geometries will be guiding the design process in the following chapter.

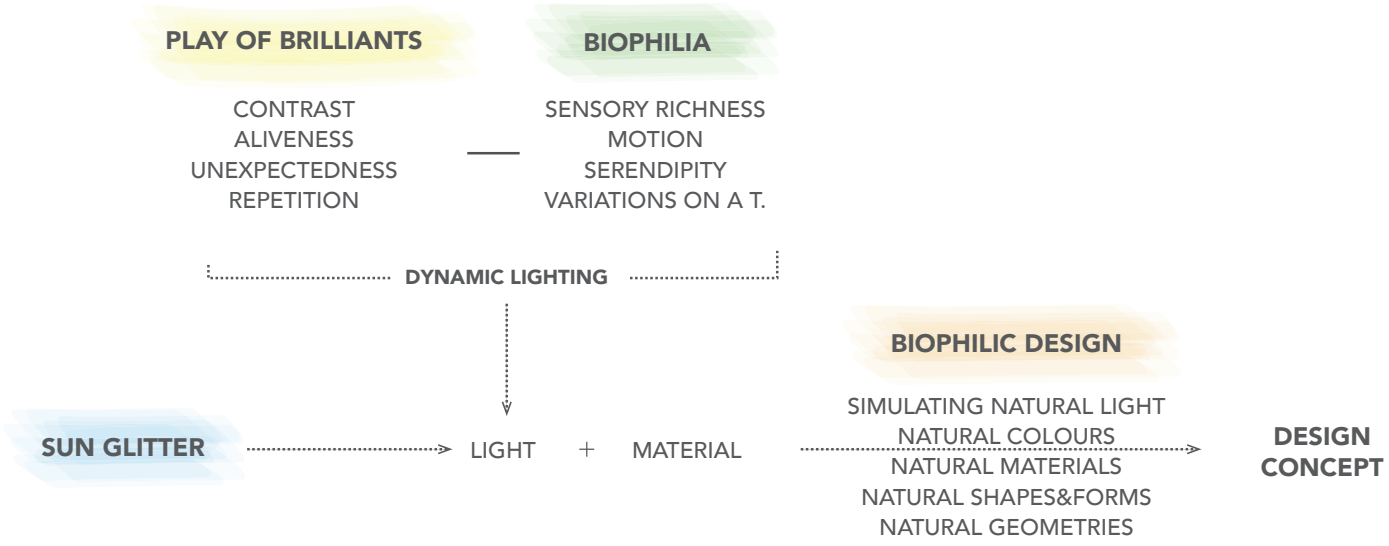


Fig. 17: Model illusrating the process of combining different knowledge throughout the theory and its analysis. Finally using the knowledge in Biophilic Design process to reach a design concept.

4 DESIGN DEVELOPMENT

To comprehensively handle all design criteria, Design Development carried on primarily in two different categories; Material **(1)** and Light **(2)**. Following that, ideas are generated based on the contemplated criteria for both categories as a whole for an immersive design solution.

Material

Criteria: Natural materials — Natural colour — Natural Geometries — Natural Shapes and forms

The aim is to mimic water's most distinctive properties; transparency and reflectance. Glass is a reasonable option considering these two properties. Different compositions of plastic material could be used as well, but considering the criteria of Natural Materials, it is better to avoid any kind of plastic. Also, the Refractive Index(RI) of water is 1.33 while glass has a RI of 1.52 which is quite similar to water. Therefore, glass is chosen as the material.

Natural colours criteria can be tackled as the colours from the nature of water. These colours will be tested in the following section to finalise the design decisions on material and light.

Fig. 18: Colour palette of water generated from the photo.

Natural Shapes and Forms/Geometries will be used to determine the surface properties of the glass. Considering the conditions for glitter to appear is undulated water, this pattern of wavy water surface will be simulated in an attempt to recreate Sun Glitter in a similar way as in nature. The wavy texture might result in refracting light in random spots and therefore create sparkles on the surface. Finally, the natural pattern of waves can already be an example of the Fibonacci Sequence in nature, thus it would be enough to preserve organic wave patterns to fulfil the criteria of Natural Geometries.

Light

Criteria: Simulating Natural Light → Sensory Richness — Motion — Serendipity — Variations on a Theme

In order to simulate natural light in the sense of mentioned Nature attributes (Chapter 2) through Colour Temperature, Brightness; these qualities of light will be tested. The light source should simply follow the rhythm of the day. As Mende states; "Light is first perceived by having a shadow, and the shadow does not exist without light" (2018). It is a play of light and shadow that transforms a static object into a dynamic one. With the help of dynamic light, a play of light and shadow, an illusion of dynamic material can be accomplished through dynamic lighting.

4.1 LIGHT EXPERIMENTS

Light experiments are the last Move-Testing Experiments performed to test four different variables. The nature of water is the repetitive pattern of waves coming one after another that inspires a repeated structure of glass material. To create dynamism through lighting; a light setup is considered in close proximity to the glass structure from both sides which will benefit from light and shadow as well as the surface qualities of the glass.

Light experiments conducted to explore the interaction between glass material and light with different qualities; Brightness, CCT and Colour based on the earlier analysis of Sun Glitter and Biophilic Design.

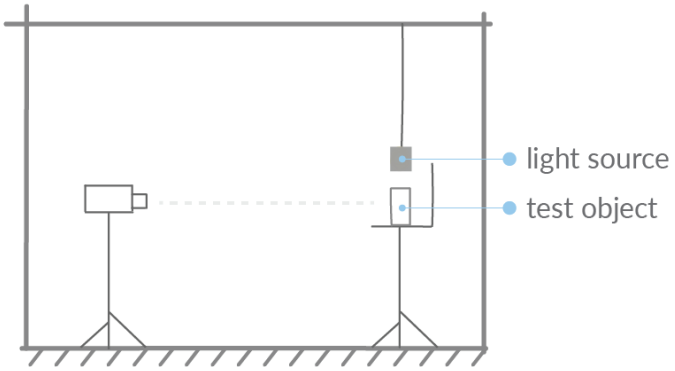


Fig. 3: The experiment setup.

4.1.1. Material

Aim

The first test was carried out to experiment with different surface qualities of glass. Two completely different surfaces were used to observe their interaction with daylight to achieve various reflections.

Test

A non-textured glass jar and textured glass vase are placed next to the window on a black background.

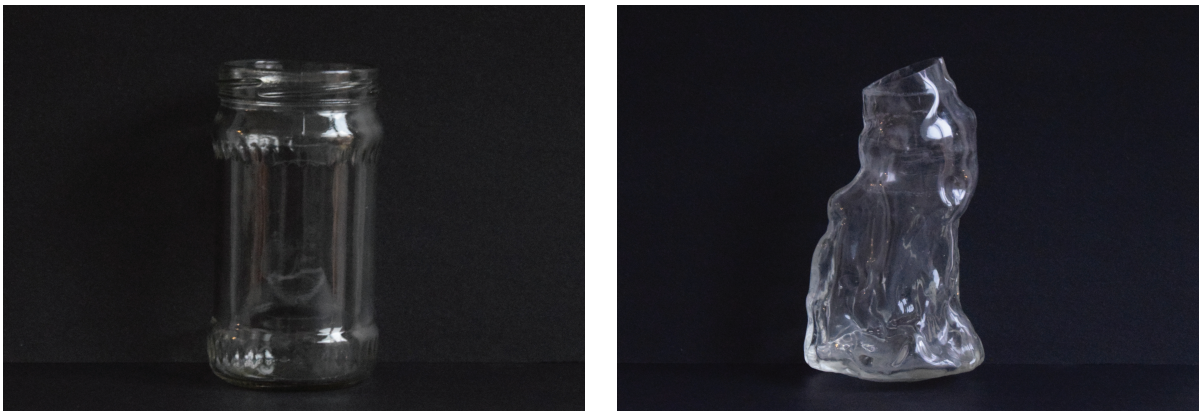


Fig. 19: Test objects for the material experiment.

Findings

As it is clearly visible in the pictures, non-textured glass is much weaker in catching the light compared to textured glass. By cause of offering various angles for light to get reflected and refracted, textured glass displays much more contrast of light patterns on the surface which is much similar in quality to the water surface that displays glitter. Thus, the vase will be used as material in the following light tests, and chosen as the material for the conceptual design.

4.1.2. Brightness

Aim

Creating a dynamic look of waves can be possible through a dynamic brightness in different light sources. Yet, it depends if the light reaches the bottom of the material regardless of brightness levels. If it succeeds to stay on different levels on the surface of the material then it will be possible to mimic the dynamism of the waves.

Test

The same rough-surfaced glass piece was examined under 4 different brightness levels while keeping the colour temperature fixed at 2700 K.

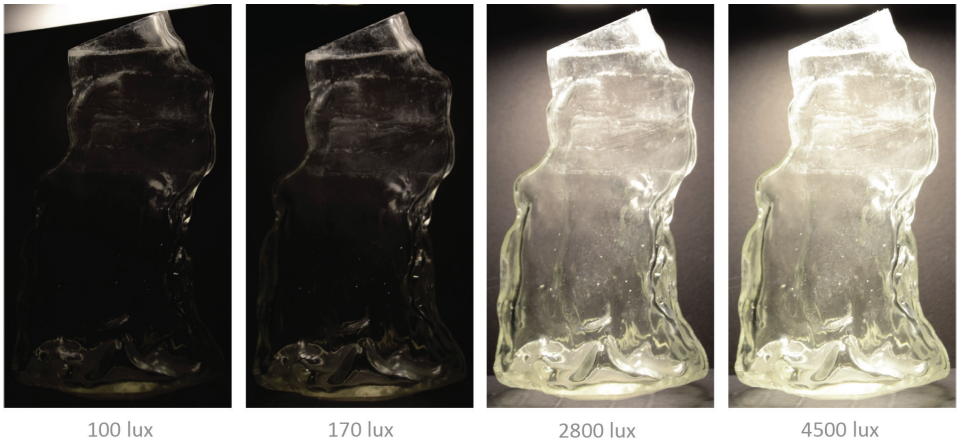


Fig. 20: Textured glass vase under different brightness levels.

Findings

Even though there is a huge difference between lower and higher levels of intensity, it is still possible to perceive the light at the bottom of the material. However, the contrast between the highest and lowest can be enough to recreate a dynamic wave movement. 100 lux has a very little effect in comparison to 170 lux, whereas the material is overly lit under 4500 lux which is reducing the contrast in the area close to the light source and thus excluding the sparkles.

4.1.3. Colour Temperature

Aim

To see how different colour temperatures acts in regards to the colour difference between the actual sparkles and the waves. Sun glitter is always white in colour due to the nature of glitter as a pointy light high in intensity (Chapter 2), still, the colour of the waves are changing according to the colour temperature of the sun based on the time of the day. This test will show if two different light sources are needed to create two different coloured light effects.

Test

The object has been tested under the same brightness of 2800 lx and 3 different CCT levels; warm, intermediate and cool to mimic daylight(EN 12464-1:2021).

Fig. 21: Textured glass vase under three different colour temperature of light.

Findings

The Colour of sparkles on the surface is all the same as white. Therefore, it can be concluded that even a low CCT level of light can achieve both warm waves and cold glitters at the same time. One light source per glass piece is enough.

4.1.4. Coloured Illumination

Aim

To investigate the ‘Natural Colours’ criteria, the object was explored under different colours.

Test

Light in different colours of water taken from the colour palette study introduced earlier with the same level of brightness of 2800 lx.

Fig. 22: Textured glass vase under different colours of light.

Findings

It is aesthetically appealing and creates a water-like look due to the surface qualities of glass in addition to the colours. Although the vision aims to create a Sun Glitter interpretation which occurs in the day, this experiment promises a different scenario where the light mimics the waves at night. Yet, it can be evaluated for further scenarios.

4.1 EXPERIMENT RESULTS

Regarding the material, the test results can be summarized as textured glass functions better than non-textured glass. The reason is that the surface properties can mimic water properly compared to non-textured glass. It reflects the light in random order and creates the intended glitter. Also, Biophilic Design elements Natural Material, Natural Shapes&Forms, Natural Geometries can be fulfilled through the choice of glass and its surface qualities. Although 'Natural Colours' criteria was tried to be fulfilled through a water colour palette in the fourth test, it is not satisfactory in terms of a daylight scenario where the sun reaches high levels of CCT (6500-above) which is cool light but not as blue as in the 4th test. Yet, it still can be used for another scenario for the night hours.

The fact that only one light source is enough to create both light effects for the waves and the glitter is one of the most important findings of the light experiments. Through a dynamic play of Brightness and CCT levels, it is possible to create dynamic waves as well as a dynamic glitter at the same time. While the CCT levels should be adjusted according to daylight which means lower levels around sunset/sunrise and higher throughout the day, Brightness should be dynamic on a smaller scale to create a dynamic simulation of waves. The findings can be summarised as below;

- The glass material will be textured to simulate the wavy pattern of the water surface
- Light sources will follow daylight in terms of CCT changing gradually from 2800 K to 4200 K, sunset to sunrise;
- A smooth movement of waves will be created by increasing and decreasing the brightness levels from 170 lux to 2800 lux.
- A night scenario can be considered through different wavelengths of light below 550 nm as it is hues of blue.

5 CONCEPTUAL DESIGN

The conceptual design reflects the findings of the four light experiments. The study attempts to illustrate a design approach more than a finalized design, therefore it is important to mention that the design presented in this section is left in the concept phase with various possible design opportunities for the future.

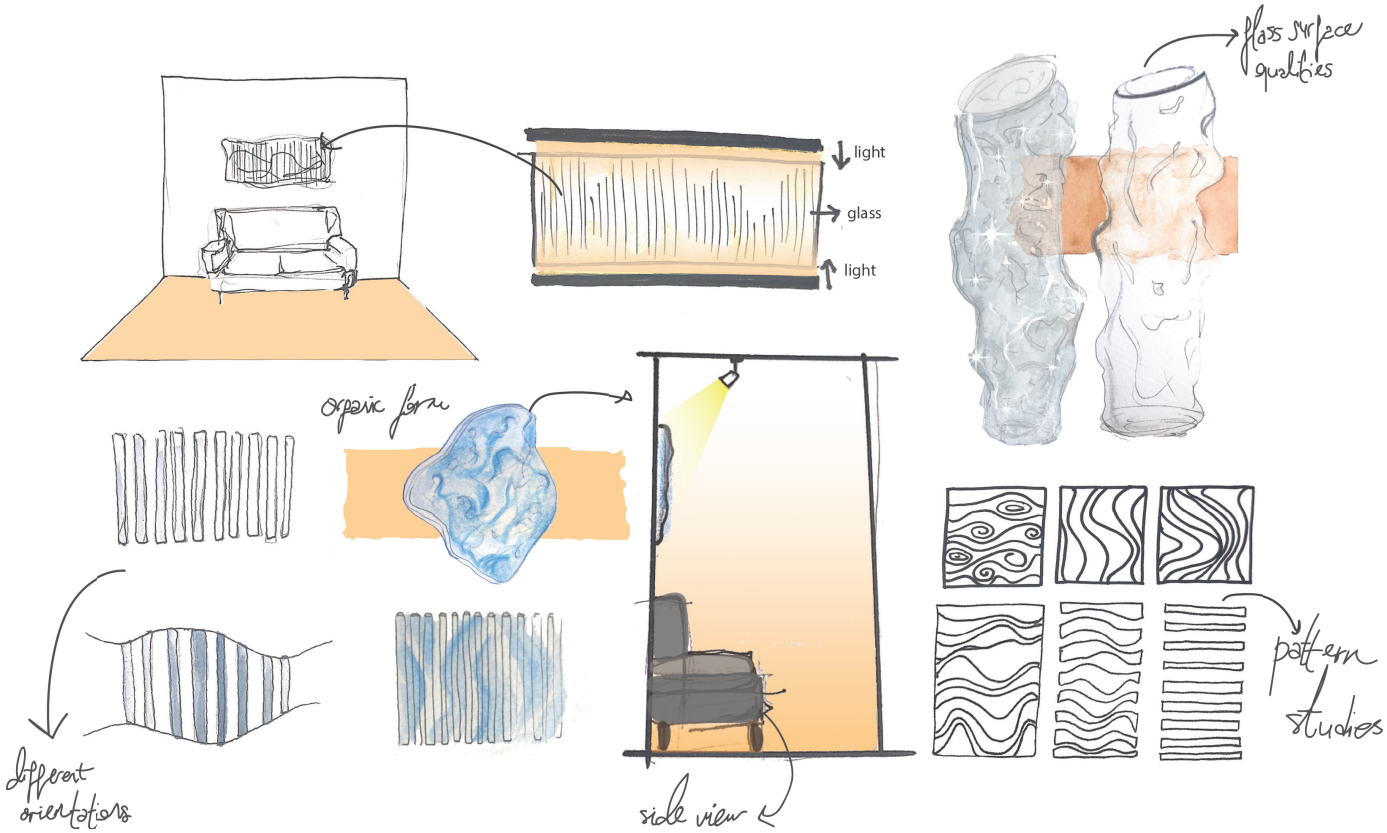


Fig. 23: Initial idea sketches.

The design concept will be explained in two parts; first the installation and second the design scenarios of light.

Fig. 24: Final concept 3D modeled in Rhino, rendered in Keyshot and post-processed in Photoshop.

The installation consists of textured glass cylinders where the textures are inspired from the waves, as the test object. They are located right next to each other to represent the repetition of the waves. The lights are installed right above the glass cylinders, not below so that the light will not be directly visible and thus glary for the observer.

The light scenarios have three variables changing in time according to the weather forecast; colour, brightness and colour temperature. While the brightness is the constantly changing variable in order to provide the wave effect, colour temperature and colour perform slower changes for longer periods of time.

5.1 BRIGHTNESS

Dynamic brightness will implement the dynamic change in the waves. Therefore it will be increasing and decreasing in a pattern of waves between the light fixtures. Yet to follow the dynamic light outdoor it will be changing within a predetermined scale. For instance during a clear sky it will be the brightest, appr. 2800 lux. The movements of the clouds will be considered as well; when they covered the sun, the brightness will decrease dramatically to the minimum illuminance level of appr. 170 lux until they move again. It wont be always active so that the design criteria of Serendipity will be covered. On a complete overcast day the lights will be off.

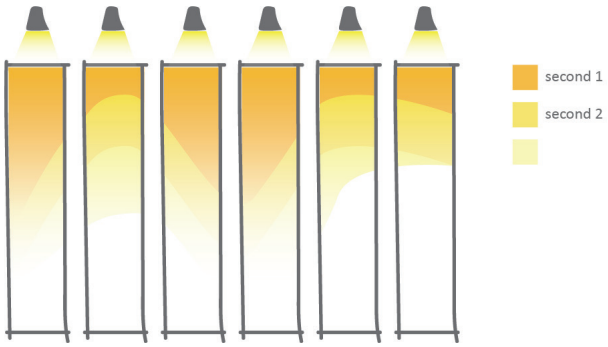


Fig. 25: Change in brightness on the glass pieces.

5.2 COLOUR TEMPERATURE

Colour temperature is changing during the day depending on the time. Starting with the sunset it starts with 2800 K and rise until 4200 K during the afternoon. The reverse cycle is carried out from afternoon till sunset.

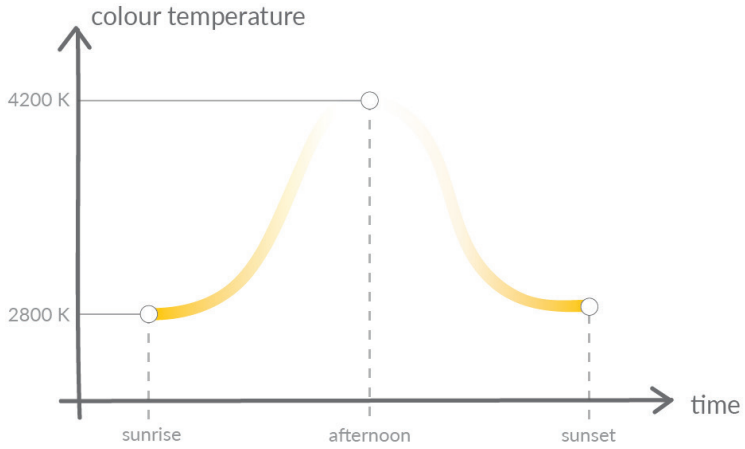


Fig. 26: The change in colour temperature of the light following daylight.

5.3 COLOUR

As an add-on, change in colours can be used to simulate specific scenarios. For instance, during night hours keeping the colour below than 550 nm results in a water colour palette and hence offer a different experience than the day. This can be a playful feature with the execution of a gradual change in colour in between different hues of blue.

6 CONCLUSION

Now that the design concept has been introduced, it is possible to open a discussion whether the Research Question has been answered;

How can Play of Brilliants and Biophilic Design be combined to mimic the natural Sun Glitter phenomenon through lighting to strengthen our connection to nature?

The combination of Play of Brilliants and Biophilic Design was only possible through a bridge of Biophilia. Comparing PoB to Biophilia provided a set of criteria in order to design accordingly and hence facilitate the engagement of Biophilic Design to the process which ensures the vision of 'strengthened nature connection'. Furthermore, this comparison justified the importance of preserving nature within a natural phenomenon in the process of recreating the experience and the values it provides. Moving on with the analysis of the Sun Glitter phenomenon provided the essential design elements and their qualities regarding the light effect they induce. These design elements were studied according to the design criteria using Biophilic Design as a method. Therefore, the design concept reflects a proposal of a piece of Sun Glitter in a built environment as a Biophilic Play of Brilliants light experience that can revitalize our bond with nature as a reminder of the dynamic nature.

To conclude, the conceptual lighting design is accomplishing the vision of recreating Sun Glitter as an indoor lighting solution by keeping PoB and Biophilia as the core to preserve the nature in it, hence our connection to nature.

6.1 FUTURE WORKS

The presented work flow expands the possibility to benefit nature-inspired lighting design by preserving the real essence of nature. It can be a guideline to mimic natural light phenomena in the built environment. A light phenomenon can be replicated through a scientific and visual analysis nourished by preserved natural qualities of light within the Biophilic Design framework.

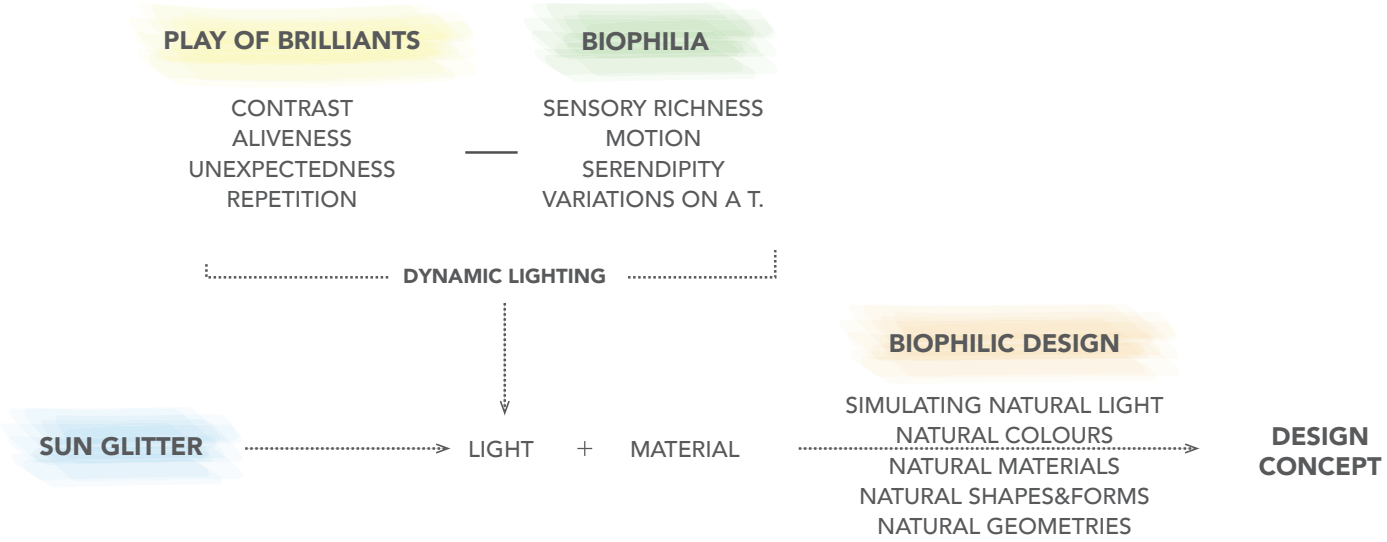


Fig. 17: Model illusrating the process of combining different knowledge throughout the theory and its analysis. Finally using the knowledge in Biophilic Design process to reach a design concept.

Modern life, unfortunately, does not offer lots of exposure to nature. In fact, we begin to forget what it means to be in nature, how it feels when we encounter an animal in its own element. Under these circumstances, it is valuable to be able to design our environment so that it will provide a glimpse of this nature feeling and bring attention to its absence. We should not completely sacrifice the meaning of nature experience just because we are living in a modern world. It is possible to bring hints of nature to our current element through design. It would be too assertive and unrealistic to expect to experience the same as we do in nature through a well-considered design, yet I think it is valuable enough if it is possible to experience a reminder of it.

This study demonstrates a guideline to carry a natural experience to the built environment as a reminder of the real experience, all in all, the dynamic, constantly changing nature. I believe perceiving the constant change is a reminder of time and hence, life. This study should be seen as an attempt to bring this effect of remembrance back into our everyday built environment that is often forgotten in modern life.

'The deeper the blue becomes, the more strongly it calls man towards the infinite, awakening in him a desire for the pure and, finally, for the supernatural... The brighter it becomes, the more it loses its sound, until it turns into silent stillness and becomes white.'

— Kandinsky

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FIGURES

Fig. 1: Close-up photo of Sun Glitter. Self produced

Fig. 2: Four Move-Testing Experiments. Self produced

Fig. 3: Light experiment setup. Self produced

Fig. 4: Transition from Biophilia to Biophilic Design. Retrieved from
Kellert, S. R. (2018). Nature by design: The practice of Biophilic Design. Yale University Press.

Fig. 5: Three elements of light. Adapted visual from
https://www.blairmcintosh.com/blog/2018/2/21/richard-kelly

Fig. 6: Elements and Attributes of Biophilic Design. Retrieved from
Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (2008). Biophilic Design: The theory, science, and practice of bringing buildings to life. Wiley.

Fig. 7: Experiences and Attributes of Biophilic Design. Retrieved from
Kellert, S. R. (2018). Nature by design: The practice of Biophilic Design. Yale University Press.

Fig. 8: Outdoor and indoor Play of Brilliants examples. Links:
First row-left to right:

(1) Sunlight on a fountain, https://static.vecteezy.com/system/resources/previews/001/368/446/non_2x/water-fountain-in-sunlight-photo.jpg

(2) A rippling brook, https://live.staticflickr.com/2088/5787636676_35476c31eb_b.jpg

(3) A cache of diamonds, https://res.klook.com/images/fl_lossy.progressive,q_65/c_fill,w_1620,h_1080,f_auto/w_80,x_15,y_15,g_south_west,l_klook_water/activities/obdorwvrvmblmtj5qvpu/CrystalIceCaveTourfromJ%C3%B6kuls%C3%A1rl%C3%B3nGlacierLagoon.webp

(4) Mottled sunlight through trees, https://live.staticflickr.com/65535/48217583701_733f18a4e3_b.jpg

(1) MET Opera Chandelier https://i.pinimg.com/originals/3b/21/2c/3b212c91604cbb57e3262119582620ec.jpg

(2) Candlelight http://3.bp.blogspot.com/-dgHvigPy8tY/VYUzyj8W67I/AAAAAAAAAec/z7V-LyXIxCE/s1600/Candles.jpg

(3) Sparkling glassware https://www.bbc.com/future/article/20181217-the-chemistry-that-gives-champagne-its-famous-fizz

(4) Chartres stained glass https://upload.wikimedia.org/wikipedia/commons/3/39/Cath%C3%A9drale_Notre-Dame_de_Paris_-_18.jpg

Fig. 9: Play of Brilliants attributes in relation to Nature attributes defined within Biophilia. Self produced

Fig. 10: Hikaru Umi - ‘‘the sparkling sea’’. Hiroshi Yoshida, 1926.

Fig. 11: Sun glitter photo taken in Sydhavn, Copenhagen. Self produced

Fig. 12: Sun glitter photo registration, Sydhavn, Copenhagen. Self produced

Fig. 13: Hand-sketches made during the observation. Self produced

Fig. 14: Sun glitter photo registration with the indicator of the change in colour temperature.

Fig. 15: Sun glitter photos showing the change in glitter shape. Self produced

Fig. 16: Sun glitter photos showing the change in glitter patterns. Self produced

Fig. 17: Illustration of the model of the process. Self produced

Fig. 18: Colour palette of water generated from the self-taken photo.. Self produced

Fig. 19: Test objects for the material experiment. Self produced

Fig. 20: Textured glass vase under different brightness levels. Self produced

Fig. 21: Textured glass vase under three different colour temperature of light.. Self produced

Fig. 22: Textured glass vase under different colours of light. Self produced

Fig. 23: Initial ideas hand-sketches. Self produced

Fig. 24: Final concept 3D modeled in Rhino, rendered in Keyshot and post-processed in Photoshop. Self produced

Fig. 25: Illustration of change in brightness on the glass pieces. Self produced

Fig. 26: The change in colour temperature of the light following daylight. Self produced