Using Light to motivate a physically active lifestyle

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Executive Summary

The interest towards this kind of project originated with a goal to use light as an innovative method of solution space. Projects which used light as an avenue of novel ideas was sought after. Hence, Hola Studio, a lighting design studio based in Rotterdam, Netherlands was considered.

Hola Studio is known for its prowess in additive manufacturing and prototyping. This studio already had multiple projects under its belt which catered to varied needs and user groups. They had a successful project in collaboration with Den Haag Gemeente to use light as a personal trainer. Hola Studio has since then been on the hunt for projects which fit this umbrella topic.

Due to the generality of the topic of using light to make people move, extensive research was carried out. Literature research about light and motivation was carried out, while benchmarking studies were to understand how day-to-day products and art installations use light to instigate interaction. Based on all the research insights, user group, persona and general direction were defined.

The concept development stage was launched with a substantial amount of ideas generated. This brought into light the need for a scoped down design direction. Hence, a part of ViP method was used to define design direction. With renewed design direction, concepts were developed and evaluated. Evaluated concept was developed further and embodiment design took place.

This resulted in a desk accessory which motivates people to do micro-activities using light. The device uses two states of mirror state and light state to indicate the extent of physical activity and hence, motivates user to do physical activity by nudging the intrinsic motivation of the users.

A validation test was done to understand the perception of users towards the developed design, with respect to appearance, usability and desirability. With changes in the selling price and some minor changes, the design was overall very well received. This gives confidence in the market-readiness of the design trailblazing the health and well-being market.

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01

Introduction

Introduction

The Hola Studio is a young lighting design and prototyping studio, based in Rotterdam, Netherlands. Hola aims at providing 3D printed lighting solutions using the Emotional design approach *(What Is Emotional Design?, 2024b)*, by focusing on designing lamps which evoke various emotions, such as warmth, energetic, playfulness, etc. and provide the users with a positive experience. This approach creates added values like deeper connection, emotional resonance and enhanced user experience for the products used.

By working with biodegradable 3d printing materials such as PLA (polylactic acid) and having an on-demand production approach, Hola showcases its value of being an energetic yet, environmentally conscious production powerhouse. Hola promotes consumers to have a deeper emotional connection with everyday objects. Thus, elevating their interaction with these objects.

Hola studio gradually transformed into a one-stop-solution for all the prototyping needs for clients from varied fields and requirements. The studio took on projects in fields such as health and wellbeing, retail, accessories, event lighting production, etc. With this transition. Hola studio gathered expertise in various design methods, materials and production techniques.

Hola Studio was commissioned for a project in collaboration with the Den Haag Gemeente to create a fun, entertaining way to stimulate people's movement. Hola designed sculptures to tackle this problem brief by creating an installation called 'The Wave' at the Scheveningen beach which can act as a personal physical coach and stimulate people on the beach to perform various exercises. This installation has sensors which track human movement and has various light indicators to support progress through different exercises.

Fig. 01: The Wave - A 3D-printed smart sand sculpture *(Zuzia, 2021)*

Introduction

Based on the success of this project, Hola decided to continue making designs which engage people in physical activity and help them achieve the recommended advice by Beweegrichtlijnen.

To continue on their streak of light installations to help people perform physical activity, Hola made an umbrella project called ‘LightMoves’. This project aims to create further developments, variations and collaborations in this effort of increasing physical wellbeing amongst people. One of these design directions is ‘De Wind’, a smart, light-based, running coach device, motivating people of Rotterdam to inculcate running as a primary form of exercise in their lifestyle.

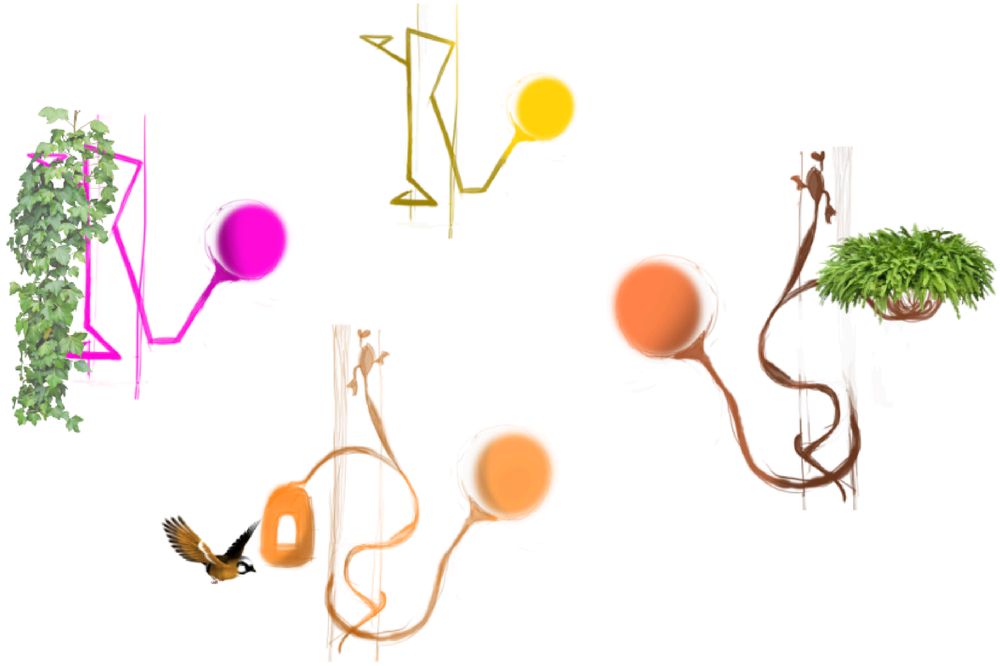


Fig. 02: Visualization of De Wind design *(Hola, n.d.)*

This graduation project starts on the basis of this design direction and develops further to target the issues leading to the decline in the physical activity across the population. The general framework of products aimed at stimulating movement and exercise in humans was the most important incentive for the project. "De Wind" project has a goal of enhancing physical well-being and hence, is an example of the kind of solutions aim to create in this project. The main goal of the project is to encourage physical activity through an engaging light product.

02

Research Phase

Introduction to Light

Basics of light

Visible light is commonly referring to Electromagnetic radiation that can be detected by the human eye. This electromagnetic radiation helps in perceiving objects and environment around us. Visible light is a narrow window of the electromagnetic spectrum, ranging from about 400nm to 700nm. Radiation shorter than 400nm (Ultra-violet rays) and longer than 700nm (Infra-red rays) cannot be detected by the human eye. *(Sustare, 2018)*

Visible light is used for illumination primarily through the use of natural sunlight, lightbulbs, LEDs, etc. to illuminate various indoor and outdoor spaces. Light is also used by plants to generate energy by photosynthesis. This biochemical process is essential as it is the foundation of the food chain. Humans synthesize vitamin D from cholesterol in their skin when exposed to sunlight, as the Sun is the best provider for UVB rays required to produce this vitamin. Sunlight helps in increasing the serotonin levels in the body, enhancing the mood and mental health. The internal biological clock of the body is influenced by the sunlight helping in regulating the sleep-wake cycle. Light is used in various scientific applications such as spectroscopy, UV sterilization and photography. *(Light and Life | Wrestling With LightHistory, Science and Applications | Books Gateway | AIP Publishing, n.d.)*

Light is derived from two categories of sources, namely natural light sources and artificial light sources. The Sun is the most significant natural source of light. The moon reflects the light from the sun as moonlight during nighttime. In specialized organs of particular species, there are bioluminescent tissues which synthesize light by chemical reactions or bacterial symbiosis.

Artificial light sources can be divided into three categories. Firstly, when temperature of certain objects gets to a high level, they begin to emit light. Such sources are called incandescent light sources, e.g. candles, incandescent lamp, etc. Secondly, luminescent light sources like fluorescent tube lights, electric bulbs, LEDs, etc., produce light when current is passed through them. Finally, certain gases at low pressures produce light when electricity is passed through them. Sources like neon lamps, low pressure sodium lamps come under this category of gas discharge light sources. *(Keiser, 2016)*

Introduction to Light

Perception of light

Light plays a profound role in our existence. It plays the fundamental part in optical perception, while doing more than merely illuminating our surroundings. Light shapes the way we interact with and experience the world. It actively influences our moods, behavior and internal physiological processes. *(Grütter, 2020)*

Absence of light presents a significant challenge for various organisms, prompting them to change their regressive traits, adapting them to dark environments. These adaptations usually manifest as weakening of visual sensory organs and compensatory enhancement of non-visual sense organs. This highlights how light shapes the evolutionary trajectory of various organisms, adapting different survival strategies in diverse environments. *(Friedrich, 2019)*

To discriminate between light and dark is a primordial trait shared by a vast array of living beings - from animals and plants to even some single-celled bacteria *(Purves, 2021)*. Hence, this distinction defines the perception of light in such organisms, including humans. Hence, interactions with light are complex with its perception having visual and physiological effects.

Image-forming effects of light

Eyes and Cameras carry a lot of similarities, as working principle for both of them involves projection of image on a sensor (retina, in case of eyes). The eyes collect light through lenses, projecting it on the retina and sending the image to the brain as electrical impulses. The brain interprets these signals, constructing a detailed image *(Tony, 2015)*. This image-forming process is the foundation of the visual perception attribute of light.

Perception of light leads to a bombardment of sensory information, but humans can only process a limited amount of this information. The brain organizes the information from the stimuli based on experience and knowledge, into patterns. These patterns are interpret by assigning meaning to them and hence, creating an understanding of the world *(Young, n.d.)*. Thus, perception is understood as a three-staged process: organization, identification and interpretation of sensory information *(Ou, 2017).*

All objects absorb and reflect varying amounts of light, The light reflected by an object makes the object visible to the eye. Mirrors, due to their smooth, reflective

Introduction to Light

surfaces are able to reflect most of the light incident on them, forming a virtual image seemingly behind the mirror *(Editor, 2015).* Hence, mirrors can be used primarily to create a visual experience through their virtual images.

Non-image-forming effects of light

Light subtly impacts our perception, physiology and behavior, even sometimes without creating an image. Light triggers a diverse range of responses in humans, such as changes in circadian rhythms as well as mood and alertness. Light exposure, particularly blue light, affects our internal clock regulating our sleep-wake cycles, by suppressing melatonin production, promoting wakefulness. Conversely, blue light during nighttime can disrupt the sleep pattern *(Vitaterna et al., 2001)*. Light significantly influences our mood and alertness levels as bright light exposure can improve mood, reduce fatigue, and increase alertness *(Lok et al., 2018)*.

Light and its reflection can affect our spatial perception as well. For example, mirrors can also be used to influence the perception of space, as large mirrors make a room feel bigger, as strategically placed mirrors can create illusion of depth. *(Yihuan, 2023)*

Another instance of such effects is in how we perceive faces. Our eyes focus on facial features in perception of various objects called pareidolia, where it covers the tendency to see faces or familiar patterns in random stimuli. Face perception in such instances of pareidolia influence the saccadic eye movements, drawing the observers attention instantly towards the stimuli. *(Kauffmann et al., 2019)*

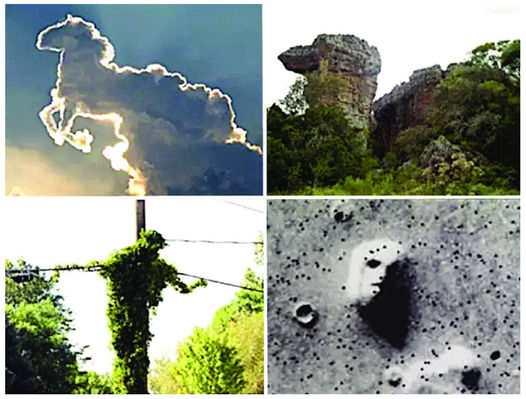


Fig. 03: Examples of Pareidolia *(Hodgson, 2023)*

Popular examples of Pareidolia are seeing faces in car's headlights, clouds, trees, etc. Thus, effects like pareidolia can be used in this project to attract attention of the observer by having a face or a pattern resembling a face in the design of the product.

Similarly, by incorporating other aforementioned effects, the product can implement directed yet, playful lighting to visually stimulate and motivate the users.

Lighting Atmospheres

Understanding of artificial light's effect on living organisms and ecosystems, such as ALAN was carried out in the research phase of this project. However, due to it not being directly applicable later to the project, this research can be found in the Appendix B.

Color

Color shows itself as the most potent element of light in its psychological influence. From warm to cool, different colors evoke distinct emotional responses in people. Hence, we notice warm lighting is used to create a sense of intimacy and encourage social interactions in restaurants or living rooms. Cooler lighting is ideal for workplaces or study areas, as they promote focus and concentration. *(AL-Ayash et al., 2015)*

The impact of color, however, cannot be narrowed down to simple ranges of warm and cool colors. The HSB (Hue-Saturation-Brightness) properties of a color help in altering the emotional connection of a space or object to a considerable extent. Highly saturated colors can be stimulating and even overwhelming, while unsaturated, muted color tones promote relaxation and comfort. *(Veitch et al., 2011)*

A correlation between the cultural context of a color can be beneficial to look into. For instance, red color is seen as good luck or new beginnings in some cultures while it is also widely associated color to danger. Hence, a careful consideration of the intended use of space and users is necessary for effective color selection. *(Wierzbicka, 1999)*

Color temperature

Warmness or coolness of the colors can be seen against the correlated color temperature (CCT) scale. Color temperature which is measured in Kelvins (K), helps to gauge the hue, light would have, leading to either alertness and focus (>5000K) or warmth and relaxation (<3500K). Hence, places which require concentration and productivity such as offices or libraries have cooler lights and places which need inviting and relaxing atmosphere such as restaurants have warmer lighting solutions. *(Lan et al., 2020)*

Thus, depending on the type, intensity and duration of the physical activity, light can be used to create specific ambiances and/or motivate towards performing certain activities. Color temperature can be used for different contexts of activities, like warm colors for activities like mediation. Dynamic color changes can be used to indicate the progress in the solution.

Lighting Atmospheres

Fig. 04: Representation of various color temperatures *(Sparks, n.d.)*

Light intensity

Light intensity, measured in lumens, refers to the observed brightness of a light source. Similar to color and temperature, intensity of light also affects our mood and behavior. Dimmed lights are often used to create an intimate and relaxed atmosphere, yet excessively low intensity lights can lead to fatigue, lethargy and staggered concentration.

On the other hand, bright lights can have an energizing and alerting effect. Hence, products, paintings and art installations are showcased in a strong light to create a stimulating environment around the object. However, extremely bright light can cause eye strain, headache and agitated mood. *(Hvass et al., 2021)* This effect of extremely bright light is contextual, depending on individual sensitivity, while bright light is considered to be above 3000lux indoors *(Vanagaite et al., 1997)*.

Hence, based on the intended programmatic of the concerned space, the optimal light intensity needs to be chosen. Task lighting should provide sufficient brightness for specific activities without creating eye strain or glare. Whereas, general lighting in common spaces like hallways can be kept at a lower level to create a welcoming ambience.

Light distribution

How light is distributed throughout the space plays an important role in molding the perception and mood of the space. Renowned American lighting designer Richard Kelly introduced the concept of ambient luminescence, focal glow and play of brilliants. According to this concept, light is distributed in various ways to create visual awareness.

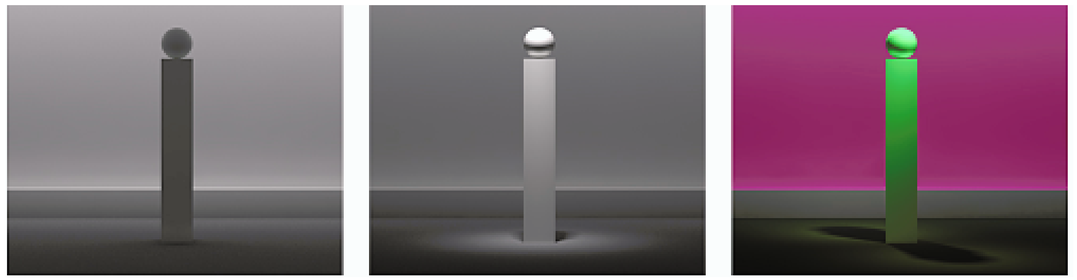


Fig. 05: Three tenets of Lighting Design (Ganslandt & Hofmann, 1992)

Ambient luminescence refers to an overall illumination that fills the space like diffused light in an art gallery. Focal glow is targeted lighting towards specific areas or

Lighting Atmospheres

objects to draw attention to a particular element. Spotlights or pendant light showcasing piece of art can be used as an example of focal glow. Play of brilliants is seen when sparkle and drama is added to a space using strategically placed lighting. A dazzling chandelier or strategically placed light sconces act as lighting systems which add visual interest and energy, simulating the visual senses. *(ERCO GmbH, 2024)*

By using these three lighting elements as 'grammar of light', one can create lighting solutions which not only illuminate a space but create a balanced lighting and guides the viewer's eye to stimulate ones attention. *(Three Forms of Light – Lighting Design for Spaces, 2022)*

Light frequency

A rapid fluctuation in light intensity leads to light flicker which can lead to negative impact on our well-being. It is often imperceptible by the human eye, but studies show that prolonged exposure to flickering light can cause headaches, eye strain and disruption of sleeping patterns. LED technology works differently than traditional lighting, and high-quality LED fixtures are designed to minimize flickering by providing uniform and consistent light output. Additionally, adjustment of light levels need to be done smoothly to maintain visual comfort and well-being. Hence, high-quality and continuous dimming systems are used instead of discreate dimming stages. *(Inger et al., 2014)*

By crafting lighting designs based on these multifaceted effects of various attributes of light mentioned earlier, designs are created which connect to the users on an emotional and physiological level. By applying these principles, the designs move beyond the basic functionality of illumination and can be used to promote well-being, productivity and a sense of connection with the design. Light can thus be used to transcend the basic use and influence thoughts and moods of the users towards a better living and health.

Evolution of Lighting

By understanding the historical context of lighting, the development of technologies which solved the core human need for illumination can be studied. This study helps in learning from the past innovations and their contexts, leading to creation of new ideas. This study also acts as a foundation to envision the emerging trends which will shape the future of the lighting industry. This section is the summarized version of the complete research in this topic. The in-detail research can be perused in Appendix C.

Three historical aspects

Here, the research is done to understand the historical context of various light sources, their change in color, temperature and similar properties and finally, the change in rules and regulations around these light sources. These three aspects are studied to gain valuable insights for this project.

By tracing the journey of artificial light from fire and candles to LEDs, one can look at how light was brought to every household and street. Technology was constantly developed to create luminaries which first mimicked light from the fire and gradually towards the complete control over the light properties such as color, color temperature, intensity, etc. by the user.

With the evolution of lighting technology, understanding of color temperature evolved as well. This led to the study of understanding the effect of light and its color temperature on human perception, along with the use of suitable luminaries for specific programmatic.

Lighting regulations and standards evolved along with the light sources to ensure safe and energy-efficient solutions available to the users.

This research section, thus, helps in understanding the historical shift in user needs while showing how color temperature demands have changed as well, to cater to the changing needs of the users. Finally, the familiarity with changes in lighting regulations gives the client company a head-start in making the final solution compliant with the safety and energy-efficiency standards kept in place.

Theory of Motivation

After understanding the evolution of lighting solutions, the next aspect which brings this project together is understanding motivation, its effects and methods of its implementation. This section helps in exploring the different reasons why people get motivated to do something, both intrinsically and extrinsically, and tap deeper into the reasons why motivation can make people enjoy doing physical activities.

Basics of motivation

Motivation can be described as the process where goal-directed activities are initiated and sustained *(Cook & Artino, 2016)*. It can also be seen as a process which helps in initiating, guiding and maintaining goal-oriented behaviors. The word 'motivation' is derived from the Latin term "motivus", meaning a moving cause. Thus, from a psychological standpoint, motivation is about the activating properties of doing the process.

Psychologists have been studying motivation and effects since the times of Aristotle, who theorized about 'Free will'. Yet, studying motivation proves to be difficult as it cannot be measured directly. To study motivation, the observer needs to study the changes in the behavior due to internal or external stimuli. Thus, we can label motivation as a performance variable indicating change in progress rate/performance. *(Petri& Cofer, 2024)*

By talking about internal and external stimuli causing a person to be motivated to perform a task is usually how motivation is classified *(Conner & Norman, 1998)*. This classification is seen as "intrinsic motivation" and "extrinsic motivation". Theses classifications are sometimes classified as "push" and "pull" motivation. The intrinsic motivation or 'push' is when an activity is performed for its inherent satisfaction, while extrinsic motivation or 'pull' shows behavior when an external reward or punishment is involved.

Psychologists are having an active debate whether intrinsic and extrinsic motivation are mutually exclusive. Conditions like 'psychic akinesia', where the patient would have difficulty in self-initiating an activity but can perform an activity without any difficulty when prompted, shows that intrinsic and extrinsic motivations are separated, at least at the neural level. Many psychologists believe that even though intrinsic and extrinsic motivations would be distinct concepts, to drive a behavioral change, there needs to be an amalgamation of these two drivers, as seen in a pre-decisional phase of behavioral change *(Morris et al., 2022)*

Theory of Motivation

No matter how abstract of a concept motivation seems to be, it can be factorized into three components which are highly interdependent, namely activation, intensity and persistence. *(Bandhu et al., 2024)*

Activation is the decision made by the person to initiate an action/behavior/change in behavior. This components is also known as direction, where initiation is done in pursuit of internal need or external stimuli. Intensity is the level of effort and dedication the person puts for the initiated action. The intensity may vary person to person. Yet, high or low intensity is not necessarily good or bad efforts from the person. It is just the degree of efforts the person must put in to complete the initiated task up to the desired effect. Persistence is the ability to stay consistent on the task initiated trough challenges or setbacks. Persistence requires the person to have a steady intensity for the task, even if things do not go according to plan. *(Simpson & Balsam, 2015)*

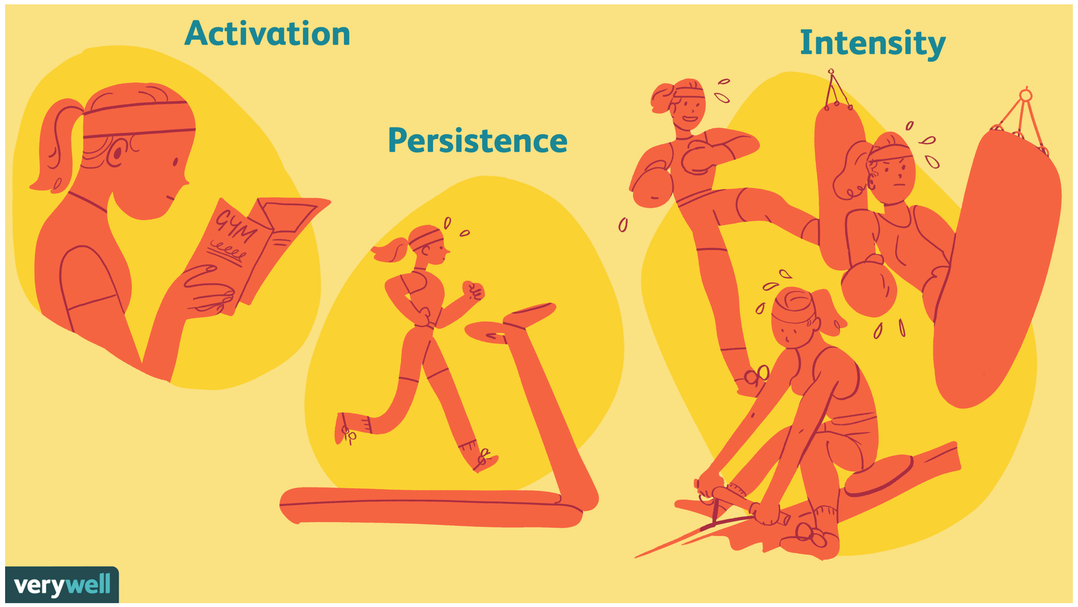


Fig. 06: Three components of motivation *(MSEd, 2023)*

Theories of motivation

To better understand motivation and its components, various theories involved with motivation need to be studied. These theories of motivation are categorized into two: content theories and process theories. Content theories focus on the needs or desires as the reason for human drive, whereas, process theories concentrate on how the psychological and cognitive processes shape human motivation. *(Rhee, 2019)*

There are multiple content theories of motivation, out of which we will be talking in detail about one of the most well-known theories. This theory is ‘Maslow’s hierarchy of needs’. This theory proposes that humans follow a hierarchy of needs and they are motivated based on the need to fulfill them, from the most basic needs, at the base to higher-level needs. *(Simplilearn, 2024)*

Theory of Motivation

Moreover, a person can be motivated towards a particular level of need only if the lower level needs are fulfilled already. In other words, only when the lower level need is satisfied, the next level needs are prompted for activation.

The downside of this theory is that it was proposed in 1943, after which there have been significant developments in understanding of human psychology and physiology. One of the limitations of this theory is the hierarchical structure of needs. It is seen that different level needs can be activated at the same time, e.g. people can strive for love, beauty, self esteem, etc. even when they do not have basic need such as food fulfilled. The hierarchy does not consider the social impact in affecting how intense a particular need is seen as. It also considers the needs to be either fully satisfied or unsatisfied. Such is not the case in real-life.

Another major downside of Maslow's theory is how the 'growth needs' i.e. needs related to self-actualization are theorized. This particular category of needs is not defined precisely and can be interpreted vaguely by the reader. The study to develop this theory was based on a very small demographic of white, educated males. Hence, this theory might not hold true in other societies.

Based on these limitations, Desmet et al created a design-focused topology of human psychological needs. This topology has thirteen fundamental needs and fifty-two sub-needs, giving a clear overview of the needs of the people. *(Desmet & Fokkinga, 2020)*

Fig. 07: 13 Psychological needs based on topology *(Desmet & Fokkinga, 2020b)*

Theory of Motivation

These fundamental needs, once fulfilled, lead to long-term well-being and happiness. Any kind of positive experience comes from the fulfilment of a psychological need. Hence, a product which through its interaction brings a positive experience, by fulfillment of a fundamental need needs to be created. The revised topology can be used to strengthen current needs of motivation tools for physical health and also to introduce new needs, not addressed before in this topic.

Another famous theory of motivation is the 'Self-determination theory' (SDT). It is a motivational theory shows how various contexts and individual differences affect various types of motivation. SDT theorizes that there are three basic psychological needs for purpose, competence, autonomy and relatedness which all human beings strive to satisfy. SDT can be studied when there is self-engagement a person feels, motivating them from the inside. This can also happen due to external factors in some cases. Purpose is seen to be the strongest SDT component. *(Owen et al., 2014)*

Alongside these theories, techniques like Behavioral Change Techniques (BCTs) are used to implement methods of action as a method of fulfilling the psychological needs. A BCT is a specific, observable and replicable component designed to influence a person's behavior. There are extensive studies done in understanding which techniques can bring in the desired changes. There are around 78 to 93 BCTs, depending on the study considered. These BCTs are categorized based on various factors. The categories are reward & threat, feedback & monitoring, social support, goals & planning, repetition & substitution, comparison of behavior and natural consequences. The study mentions the importance of combination of various BCTs and how these combinations can be used over a long period of time, consistently. Out of these broad categorizations, study recognizes repetition and substitution as the most effective BCTs. *(Fatima et al., 2023)*

By focusing on these combinations of BCTs, users can be motivated to inculcate changes in their behavior towards a more active lifestyle.

Benefits of motivation

With understanding the meaning and classification of motivation, the reasons which make motivation so important can be seen in the infographic seen on the next page: *(MSEd, 2023)*

Theory of Motivation

Fig. 08: Various benefits of having motivation in ones life (MSEd, 2023)

Low motivation

Even with so many proven benefits, lack of motivation is something which everyone experiences at some point in their life at varying levels. For some it may be occur as occasional “laziness”, for others it may be like Avolition, indicating an underlying serious mental health problem.

Hence, there are different causes of low motivation varying according to the person. One can beat lack of motivation by identifying these causes as a first step:

- All-or-Nothing thinking
- Believing in quick fixes
- Thinking one-size-fits-all
- Burnout
- Doubting yourself
- Unclear purpose
- Negative self-talk
- Mental health issues, e.g. depression

Once a person understands what is causing their lack of motivation, they can start finding ways to tackle it. One of these steps can be taken to get back on track:

- Adjust goals
- Break up tasks in smaller goals
- Improve one’s confidence
- Remove insecurities
- Surrounding oneself with motivating people
- Give oneself incentives or rewards for completing tasks

(Hardcastle et al., 2015)

Theory of Motivation

Gamification

With the ever-increasing influence of digital age on our lives, Gamification is taking the world by storm. The concept of gamification is successfully applied to many fields like marketing, fintech, social networking, learning, etc. Gamification can be understood as the application of gaming mechanics on non-game environments. Various gaming mechanics like role-playing, reward systems, badges, streaks, etc. can be used to increase engagement, motivation and enhance user experience. *(Rankstar, 2022)*

According to this 2022 study, gamified interventions are effective in increasing physical activity (PA). This study also points out that gamification mechanics help in maintain the behavioral change effects even a weeks after the mechanics are stopped, but the effect weakens over time. It also suggests that gamification can be a possible solution to reduce sedentary behavior. Hence, overall, gamification interventions are promising ways of increasing physical activities among people. *(Mazeas et al., 2022)*

There are numerous gamified solutions out there which aim to make people get more PA incorporated in their lifestyle. Yet, this 2023 study mention how very few of these solutions investigate various motivational elements using motivational techniques. This study recognizes the issues with behavior change and user adherence when various gamification techniques are applied. Hence, Fatima et al. suggest using specific motivational techniques such as purpose, autonomy (SDT) and gamification mechanics such as repetition, habit formation, daily steaks to increase behavior change and user adherence. *(Fatima et al., 2023b)*

As these studies suggest, various mechanics can be implemented to create effective solutions to include PA in daily lives. This project builds upon the results of these studies and aims to design a product which would maintain a level of user adherence suitable to make behavioral change in the users. These studies show how different age groups respond to these mechanics differently, hence, the design can be made suitable according to the target user group.

Fig. 09: Gamification seen as a method to reach ones goals *(McKenna, 2022)*

Theory of Motivation

Conclusion

Through this research subsection focusing on motivation, various insights are gathered which can be implemented in this design project. Insights which were found from this section, which need to be kept in mind while designing the solution for this project are as follows:

- Initiation & sustenance of goal-directed activities will be seen as motivation by the users
- Motivational mechanisms should be an amalgamation of intrinsic and extrinsic drivers
- The solution can consider indicating change in progress rate/performance
- The solution should provide the components of motivation, i.e., activation, persistence and intensity in its usage
- By fulfilling a fundamental need, a positive experience is created, which in turn creates conducive environment for motivation.
- SDT of Purpose and BCT of Repetition can be used to bring about increased motivation, as they are the most effective SDT and BCT
- Gamification methods can be applied to make the solution more user adhered and interesting for the users.
- The solution should be made suitable to target user group as different age group behave differently to various motivation mechanisms.

These values need to be considered with high importance while designing the solution, as the fundamental working of making a motivational product can be made through these insights.

Various agents can be used to further bring about change in a user's health behavior. Out of the ones mentioned by *Hardcastle et al. (2015b)*, creating tailored interventions, specific to the users, should be implemented in the solution to make the project motivate the users to the fullest.

Design needs to compliment the stage-based approach of progress in users. As habit-formation efforts take time and repetition through positive reinforcement, the design features should promote autonomy and sense of purpose through the design.

Benchmarking Study

In this section we look into a comparative analysis of existing efforts into making people move using various interaction mechanisms, with a focus on lighting mechanisms. By examining products, playground game installations, art installations and apps that utilize various methods to inspire PA, we gain valuable insights into established user experiences and their design strategies. This analysis will act as a foundation to identify shortcomings of existing solutions and potential opportunities in using light to enhance motivation and engagement towards movement.

Playground equipment

Playground in itself is associated with games and movement. There are multiple playground equipment used to elevate the play, such as swings, slides and seesaws. Recently, commercial playground equipment manufacturers are looking for ways to revitalize playgrounds and make it fun for not only children, but for everyone in the community,

Out of the variety of modern playground equipment, some of these equipment combine digital fun and physical play by incorporating electronics with multisensory components in them. These playground equipment aim to get kids moving, thinking and interacting in new and fun ways. Here, we consider two such interactive playground equipment developed by 'Playground Centre'. Such innovative, interactive playground products are not exclusive to this company and are slowly becoming a norm to make outside play more interesting in this digital era.

The two products considered are Speed and SPORT containing central panel and several posts with sensors, indicators, light, sound and haptics. They enable kids to race, play as teams and learn various cognitive and soft skills. The lights and speakers on the posts help children interact with the equipment as the game duration varies according to the game selected on the panel.

Fig. 10: Speed by Playground Centre *(Playground Centre, 2020)*

Benchmarking Study

Fig. 11: Speed by Playground Centre *(Playground Centre, 2020)*

Fig. 12: SPORT by Playground Centre *(Playground Centre, 2020a)*

Fig. 13: SPORT by Playground Centre *(Playground Centre, 2020a)*

Art installations

Art installations are three-dimensional works that transform a space to create a spectacular experience for the viewer. Interactive art installations are a form of art which break away from the conventional experience of “observe only” and invite the viewers to participate. These installations often amalgamate art and technology using sensors, cameras, projections, and similar digital elements to create responsive and dynamic experiences. The technology involved ranges from simple sensors to complex virtual reality setups enabling light, sound and even touch as interactive

Benchmarking Study

elements. Here, we are going to look at various art installations which have incorporated some level of interaction. This interaction can be with light or sight, prompting the viewer to act on some stimuli. Some of them also have sound to indicate changes or states. The most advanced installations even have haptics in them and can react according to the information provided by the viewer.

Fig. 14: Domino Effect *(ENG_Effetdomino — Ingrid Ingrid, n.d.)*

Here, ‘Domino Effect’ installation promotes observers to interact with the art pieces by pushing them and creating a chain of dominoes falling. These dominoes have lights in them to make the effect more lively in darkness and have musical effects when they are falling. The Dominoes are then lifted back up by a mechanism underneath. This ensures a repeated, quick but fun interaction with the dominoes.

‘Mini Pool’ is an interactive installation where swirling effects of light are created by the movements of people on it. The unlimited light effects prompt the children to skip around the installation to their fullest.

Fig. 15: Mini Pool *(Mini Pool – Jen Lewin Studio, n.d.)*

Fig. 16: Slimme Beweegroute *(NWST NeWSTories bv, n.d.)*

‘Slimme Beweegroute’ was a study done by TU/e and Fontys Hogeschool to develop a running track with more opportunities for exercise. Lights are placed on the ground across a 55 meters stretch, with light poles at every 10 meters. The lights are complimented with a LED matrix display at the starting of the stretch. These elements give feedback and guide the users towards measuring their speed across the track. This setup was tested three times with conclusions drawn indicating importance of personalization, goal-setting and understanding the system as motivators for the users.

Benchmarking Study

Fig. 17: Park of the Future by Nova Innova *(Living Light - Park - Living Light, 2024)*

'Park of the Future' is a park in Rotterdam, which has little lights powered by electricity generating plants which light up the walking path on both sides. This creates a mesmerizing view around the park and akes the walk a visual experience.

Fig. 18: Paper trails by Team Ignite, TU/e *(GLOW, 2023)*

'Paper trails' was an installation for the Glow Fest `22 in Eindhoven. Small artefacts resembling paper planes were connected together such that they would sense a person underneath them and they would light up in a sequence to lead them towards a particular spot in the festival. This interaction created curiosity for the observers and made them act on their feeling to follow the light.

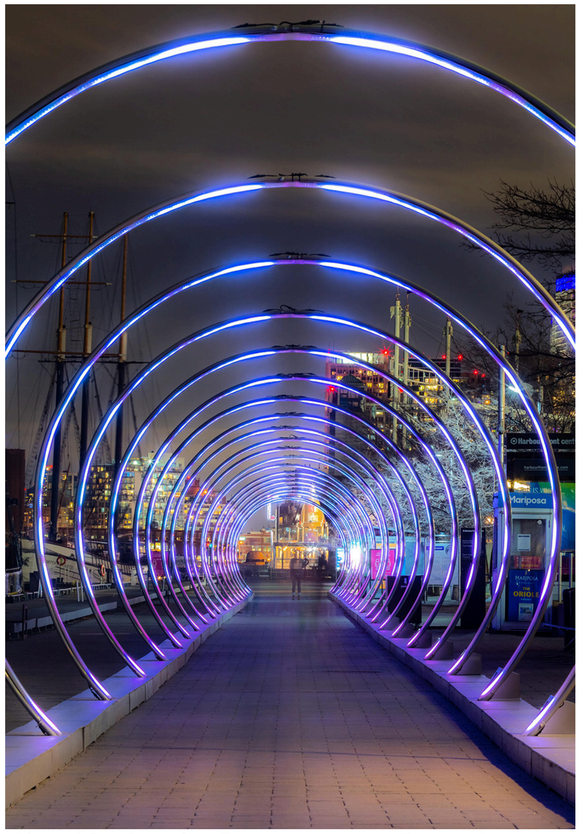


Fig. 19: Sonic Runway by Rob Jensen *(Gallery - Sonic Runway, n.d.)*

Sonic runway is an installation which contains arches placed at regular intervals and connected to each other. These arches create patterns of light based on the music/song they are playing on the speakers in the installation. This creates an effect where the observer can follow the light patterns, the beats or both when it is on. As per the creator, this installation plays on the familiarity of the observer with the song/music and makes them anticipate the patterns, providing excitement and contentment alike.

Benchmarking Study

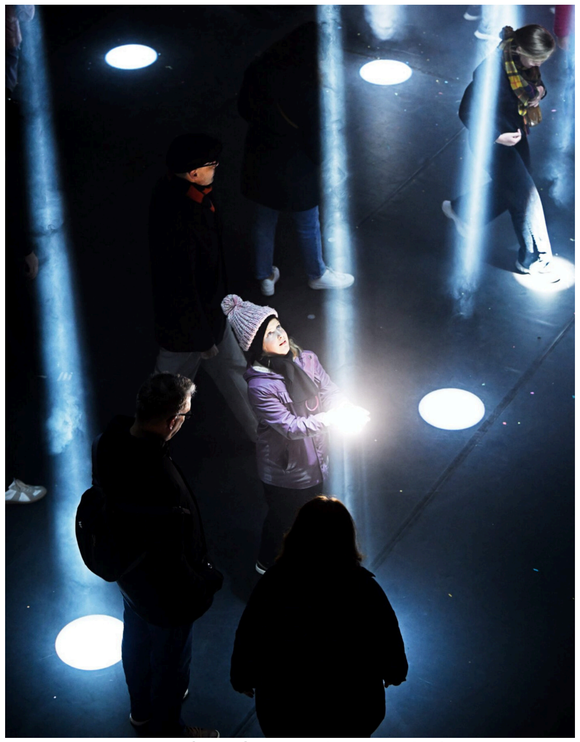


Fig. 20: A|RP|AY by Philip Ross *(GLOW, 2024)*

Airplay (stylized as A|RP|AY) was an installation at the Eindhoven Glow fest `22. This installation senses the observer and their hand movements to follow the light beam. This creates an effect where the observer feels that they can move the light beams around. This effect makes the intangible light seem to be tangible. Similarly, wind direction and speed is sensed by the installation as well, making the installation react to the surrounding . Here, the duration of the interaction is dictated by the observer, giving them complete freedom.

Fig. 21: Ice Break *(Lightworks 2022 UK - Copenhagen Light Fest, 2024)*

Ice Break installation implements visual stimuli as a basis of encouraging observers to move across the ice rink. This installation was featured in the Copenhagen Light festival. Here, overhead projectors project lights on the ice rink floor to imitate tiny living creatures which the skaters can follow. This installation constantly created patterns of movement across the ice rink and the skater can decide if they would want to projection or not. This installation makes a gamified version of the interaction, leading to all age group finding it fun and interesting.

Benchmarking Study

Commercial products

In today's age, staying healthy goes beyond just hitting the gym. Hence, there is an ever-growing market of variety of commercial products designed to empower individuals towards holistic well-being. By ranging from monitoring your PA to making healthy choices a breeze, these innovative products cater to various aspects of a healthy lifestyle. Here, we will be seeing various products which bring about a healthier and fun lifestyle.

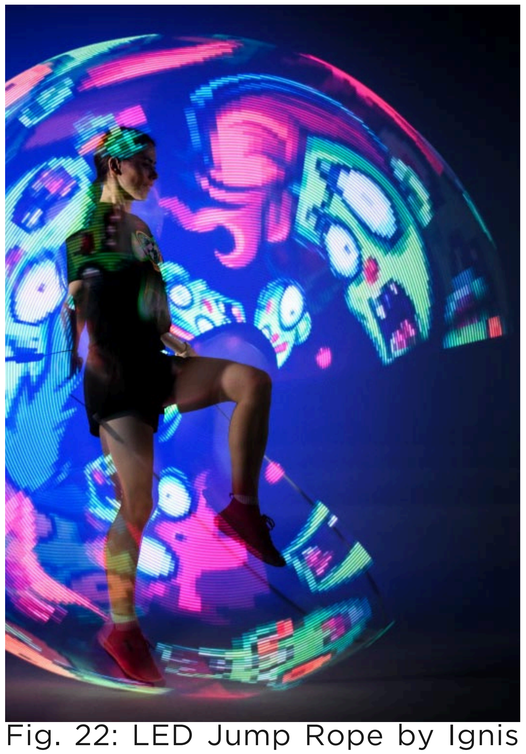


Fig. 22: LED Jump Rope by Ignis Pixel *(Ignis Pixel, n.d.)*

Fig. 23: LED Cube by Ignis Pixel *(Ignis Pixel, n.d.-b)*

Fig. 24: LED Hula Loop by Ignis Pixel *(Ignis Pixel, n.d.-a)*

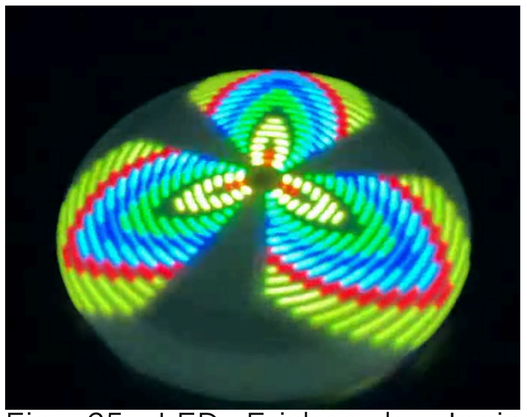


Fig. 25: LED Frisbee by Ignis Pixel *(Ignis Pixel, n.d.-a)*

This group of products are by company called Ignis Pixel. They specialize in making props which have lights embedded in them. These lights are controlled by sensors and depending on the orientation and motion of the prop, they create different user-defined patterns. This makes the props even more intriguing and fun to play with. Different props have different usage but they all have light systems which are activated when the props are in motion.

Benchmarking Study

This group of products here, use light, sound and/or haptics to engage the users into physical activities. The light-up dance mats can be used by users of any age group to follow the sequence of light and sound to dance on the mat, activating the pressure sensors embedded in the mat. This product features different difficulty levels and game modes.

Fig. 27: Light-up dance mats by Generic OEMs *(Amazon: Toys & Games, n.d.)*

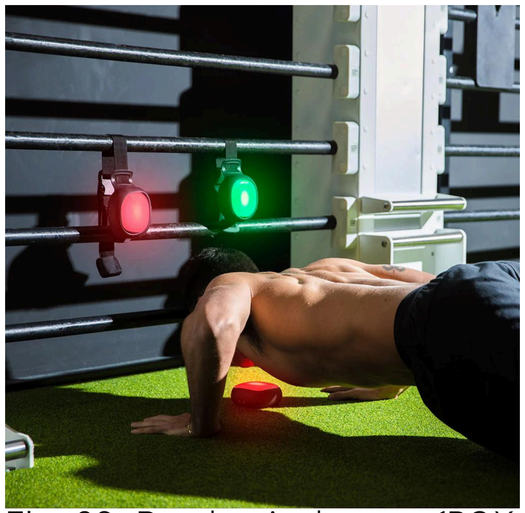


Fig. 26: Rox by A-champs *(ROX, n.d.)*

Fig. 28: Boxing trainer *(Amazon: Sports & Outdoors, n.d.)*

Rox are small training modules which offer various games focusing on physical activities and reaction time training. They use motion sensors and touch sensors to determine user data while indicating various information such as time, duration or status via lights or display. The users can use this device to make their training more gamified and track their progress effectively.

Boxing trainer uses light signals and sound to indicate the button to be boxed at for the user. This creates a system which uses lights and buttons to help users improve their reaction time. By incorporating timed light signals, the user can approach the system at various skill levels.

Benchmarking Study

Fig. 29: Just Dance game by Ubisoft *(Just Dance - IGN, 2009)*

These games here help users to perform various physical activities by motion tracking and the users follow the motion depicted on the screen.

Just dance is a multi-console rhythm and dance game with a focus on physical activity. This game incorporates a variety of music and on-screen choreography to guide user towards various dance routines. Catering to the broad audience, the game offers various difficulty levels and dance styles. Depending on the console, the motion tracking technology system also changes.

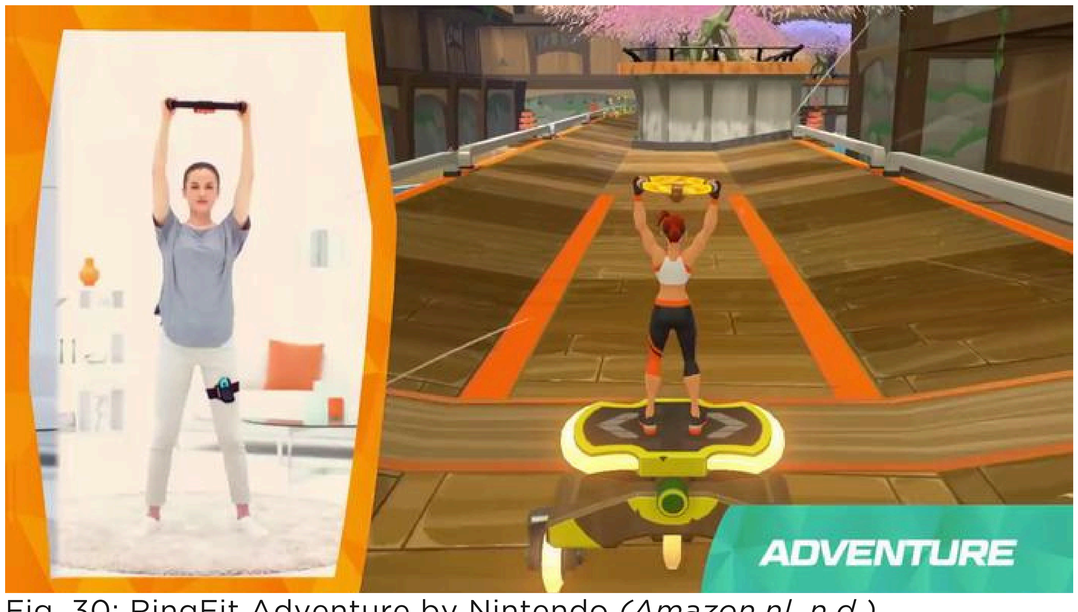


Fig. 30: RingFit Adventure by Nintendo *(Amazon.nl, n.d.)*

Ring Fit Adventure by Nintendo combines role-playing game elements with physical activity using a leg strap and a fitness band. Controllers are attached to the strap and the band, creating a feedback loop to monitor the player's movements. The game offers a storyline and tracks motion of the users to promote exercise in them.

Benchmarking Study

Fig. 31: Pokémon Go by Niantic, Inc. *(Schulz & Schulz, 2024)*

Fig. 32: Zombies, Run! by Six to Start *(Uk, 2022)*

These apps use gamification and worldbuilding aspect of a story to create an interactive and fun experience around the physical activity of running and walking. One of the primary reasons for their success is the use of social aspect of the apps to create communal goals and make users socialize through various tasks.

Pokemon Go app uses AR technology to overlay various Pokemon characters in real life, making users interact with them through their phone screens. This engaging gameplay successfully provides motivation to users to walk and explore the surroundings.

Zombies, Run! uses its interesting and in-depth storytelling to make the users run or walk to complete the missions and progress through the narrative. This app offers different running challenges at different difficulty levels, as well as communal challenges,

Benchmarking Study

Conclusion

In the playground equipment seen in this study, the equipment have several posts with tabs on top to have long interactions with. These tabs contain lights and sensors, making the gameplay interactive and fun. The importance of haptic feedback and competitive motivation is showcased in these examples, which can be addressed in this project as well.

The art installations are varied in their functioning as well as interactions, owing to the artistic freedom of the creators. Installations like Domino Effect, Park of the Future, Sonic Runway, Airplay and Paper trails rely on short interaction mechanisms like pre-programmed LED systems to create different effect. Exceptions in these installations are Domino Effect and Airplay which let the users interact directly with the installation making changes in the effects of the same.

Art installations like Mini pool, Slimme Beweegroute and Ice break have a variable duration of interaction depending on the user's interests. Mini pool and Slimme Beweegroute incorporate LED tiles which react to the user's movements, while Ice Break plays a looped, prerecorded projection to initiate motion in the observers.

These installation show how having variable interaction durations, catering to the user's needs are more favorable towards an impactful experience. These installations also prompt us to consider offering both pre-programmed and user-defined interaction effects in the product.

The commercial products are diverse and implement interactions via different systems. All the products by Ignis Pixel and various training aids mentioned in this study implement robust haptics and aftereffects are created through the LED systems in them. These LED systems can be either for feedback or for simple visual patterns. Nintendo Ring Fit shows how existing parts can be reimagined by appending them to new parts to give new set of interactions. Finally, the apps and games which incorporate screens like Pokemon Go, Zombies, Run! and Just Dance create on-screen mechanisms which can be interacted using motion sensing or touchscreen, integrating the solutions seamlessly in user's existing technology.

Hence, by incorporating insights from this analysis, the product created in the end can be used to create an environment which motivates sustained, enjoyable physical activities as a part of user's daily lives.

Interaction Mechanism Table

Based on the benchmarking analysis in the previous subsection, an Interaction Mechanism table is generated to get an in-detail and granular understanding of how their mechanisms work together leading to various effects. With this breakdown, factors such as primary modes of interaction (light, sound, haptics, etc.), nature of interaction (digital or analog), number of intended users, intended location, nature of activity, intensity of activity and duration of interaction are studied. Using this breakdown, informed design decisions can be made which help in tailoring the design to achieve desired level of physical activity in the most holistic way.

Sr. No.	Product/Installation name	Developer	Precedent Type	Lighting Element	Light interaction	Sound	Haptics	Screen/Panel	Digital/Analog Inter	Individual/group	Outdoors/indoors	Goal oriented/	PA Intensity	Duration
1	Speed	Playground Centre	Playground equipment	Light Posts					Analog	I + G	Outdoors	Leisure	Intense	Long
2	Sport	Playground Centre	Playground equipment	Light Posts					Analog	I + G	Outdoors	Goal oriented	Intense	Long
3	Domino effect	Ingrid Ingrid	Art installation	Motion-sensitive LEDs					Analog	Group	Outdoors	Leisure	Low	Short
4	Mini Pool	Jen Lewin	Art installation	LED tiles					Analog	I + G	Outdoors	Goal oriented	Variable	Variable
5	Park of the Future	Nova Innova	Art installation	Low power LEDs					Analog	I + G	Outdoors	Leisure	Low	Short
6	Slimme Beweegroute	TU/e & Fontys Hogeschool	Art installation	LED tiles					Analog	Individual	Outdoors	Variable	Variable	Variable
7	Sonic Runway	Ron Jensen	Art installation	LED arches					Analog	Group	Outdoors	Leisure	Variable	Short
8	Ice break	Morten Just	Art installation	Projection					Analog	Group	Outdoors	Variable	Variable	Variable
9	A|RP|AY	Philip Ross	Art installation	High intensity light beams					Analog	Group	Outdoors	Leisure	Low	Short
10	Paper trails	Team Ignite, TU/e	Art installation	LED strips					Analog	Group	Outdoors	Leisure	Low	Short
11	Zombies, run!	Six to Start	Commercial product	Screen					Digital	I + G	Outdoors	Goal oriented	Intense	Long
12	LED Jumprope	Ignis Pixel	Commercial product	Embedded LEDs					Analog	I + G	I + O	Variable	Intense	Variable
13	LED frisbee	Ignis Pixel	Commercial product	Embedded LEDs					Analog	I + G	Outdoors	Variable	Variable	Variable
14	LED hulaloop	Ignis Pixel	Commercial product	Embedded LEDs					Analog	I + G	I + O	Variable	Variable	Variable
15	LED interactive cubes	Ignis Pixel	Commercial product	Embedded LEDs					Analog	I + G	I + O	Variable	Variable	Variable
16	Physical Training aid	Rox by A-champs	Commercial product	LED Buttons					A + D	Individual	Indoors	Goal oriented	Intense	Long
17	Boxing Trainig Aid	Generic OEMs	Commercial product	LED buttons					A + D	Individual	Indoors	Goal oriented	Intense	Long
18	Nintendo Ring Fit	Nintendo	Commercial product	Controller indicators					A + D	I + G	Indoors	Goal oriented	Variable	Variable
19	Just Dance game	Ubisoft	Commercial product	Screen					A + D	I + G	Indoors	Goal oriented	Variable	Variable
20	Light up dance mats	Generic OEMs	Commercial product	Pressure-sensitive LEDS					A + D	I + G	Indoors	Goal oriented	Variable	Variable
21	Pokemon Go	Niantic, Inc.	Commercial product	Screen					Digital	I + G	Outdoors	Goal oriented	Variable	Variable

Fig. 33: Compiled analysis of all precedents, as an Interaction Mechanism table *(Author, 2024)*

Thus, with insights from this table, the properties of the product to be designed can be narrowed down. The product can be operated on an individual level while possibly having a mix of analog and digital interface. Yet, being analog-focused to minimize distraction and cluttering is preferred. Due to the constraints on the physical scale of the project, the product will be intended to be used indoors. As the users can be of varying health levels and would want to customize their experience, the intensity of the product can be kept variable and user defined. The product has to be motivating for the user to complete intended tasks in order to feel the intrinsic motivation of completing a task, hence, the product is goal-oriented.

Interaction Mechanism Table

The product also aims to provide a fun and engaging experience, hence, it should have the possibility to be used in leisure as well. Hence, the product can be goal-oriented or leisure-oriented, focusing on goal-oriented mode. The product can have primary interaction method as Light interaction, while secondary interaction can be haptics as a feedback mechanism. The study shows prioritizing of interaction elements and minimizing distractions to give a smooth and hassle-free experience. Hence, The product aims to be minimalistic. In order to implement minimalistic design language, the product can have no screens or display panels.

Hence, here, further definition to the features desired in the design were defined. The design is to prioritize interaction experience while maintaining user adherence to gain promising results.

Physical Activity

As indicated in the project introduction by Hola Studio, physical inactivity is a problem, increasing at an alarming rate across the Dutch population. However, physical inactivity or insufficient activity is becoming a global issue. According to WHO, 1 in 4 adults do not meet the global recommended levels of PA, terming it as a global pandemic of physical inactivity. There has been no improvement in global levels of PA since 2001, while insufficient activity increased from 31.6% to 36.8% in high-income countries between 2001 and 2016. *(World Health Organization: WHO, 2022)*

Lack of PA increases the risk of death by 20 to 30% as it increases risk of noncommunicable diseases (NCDs) such as cardiovascular disease, cancer, diabetes, etc. Thus, Lack of PA is the fourth leading cause of deaths worldwide. *(Kohl et al., 2012)*

A 2019 review shows how physically active older adults (>= 60 years) are at reduced risk of various NCDs *(Cunningham et al., 2020)*. Physical activity in old age is observed due to the habits related to PA formed in the earlier years. *(Meredith et al., 2023)*

These facts bring into focus the importance of PA as a part of the lifestyle in population below 60 years of age.

To bring about this change in lifestyle, Gezondheidraad set out the Beweegrichtlijnen, as mentioned in the project introduction by Hola Studio. Similar to Gezondheidraad, the WHO recommends minimum 75-150 minutes of vigorous physical activity throughout the week. The Gezondheidraad and the WHO recommend alike to limit amount of time spent being sedentary and to replace sedentary time with physical activity of any intensity. They also suggest that even light intensity PA provides health benefits.

This claim is further backed up by this 2017 study where it is recommended that inactive or insufficiently active people should engage in any intensity of PA, and that light intensity PA (LIPA) can lead to light-to-moderate benefits to begin the lifestyle change with. Thus, doing short bursts of LIPA helps in habit formation, health and well-being. *(Füzéki et al., 2017)*

Hence, from these insights we can conclude that target users of this design should roughly be adults, below 60 years of age. It is also concluded that users are to be motivated towards LIPA exercises, using lighting design as a tool to create fun, engaging and habit-forming experiences.

Target User Group

From the previous subsection, the target user group can be anywhere between 18 to 60 years old. To further narrow down the user age group, various statics and research insights need to be considered.

As per the numbers given by the Centraal Bureu voor de Statistiek (CBS), PA across the Dutch population starts decreasing from the age of 35 *(CBS, 2023).*

The adults from the age of 35 on, start feeling that their health is declining. This can be seen in a 2003 study where a survey asked people to rank their health status on a 5-point scale, with 1 being excellent health and 5 being poor. As seen in the graph presented by the study below, the bottom quartile (where people feel there are healthy) ends at 35 years of age. The health gradually declines until the old age of 60 years. Hence, taking care of ones health starting from mid 30s becomes of vital importance in aging well. *(Case & Deaton, 2003)*

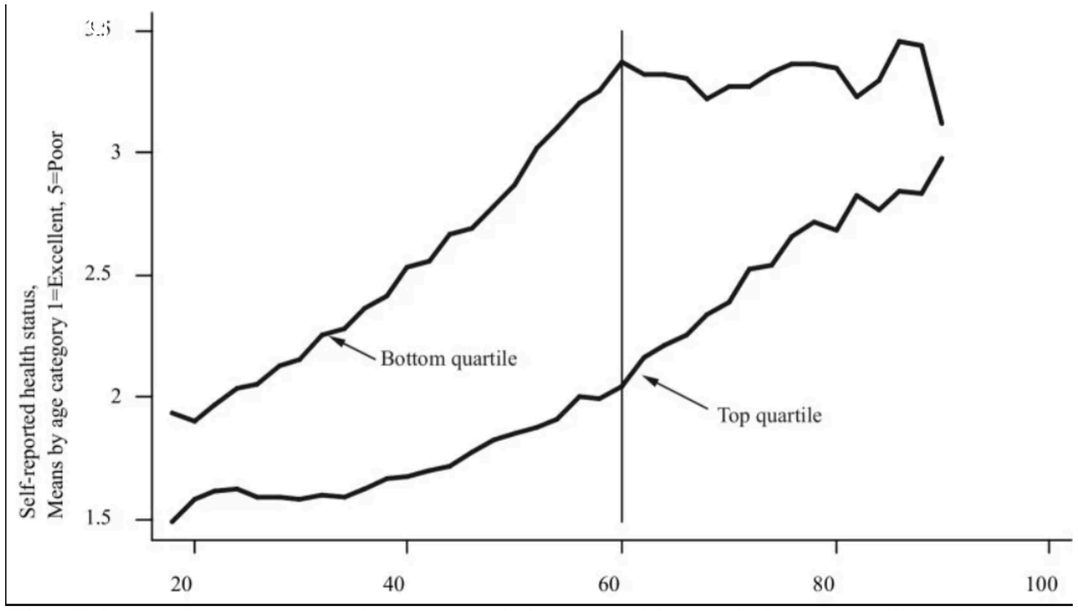


Fig. 34: Health status of the participants *(Case & Deaton, 2003)*

People tend to settle down in their lives and have added responsibilities between the age of 26 to 36 years. Hence, one finds themselves in a situation where they have less time for themselves. *(Burkhardt, 2021)*

Based on these insights, the design would focus on users of the age group from 35 to 45 years old. This age group will be the appropriate target group as this user group would inherently want to create habit-forming changes in their lifestyle towards health. However, to increase the market reach, the product can be kept open to use by users of other age groups as well.

This project can help the users fulfill their need for a motivating product towards achieving a healthier lifestyle, while not taking a significant chunk of time from their daily schedules.

User Personas

Following are the different personification characteristics of the target user. These characteristics are based on research and correlation between the characteristics themselves as well. The target user of the product:

- **Is a desk worker:** Working personnel who have desk jobs, spent most of their day sitting (87% of the studied participants) *(Ryde et al., 2020)*
- **Wants to incorporate Leisure Time PA (LTPA):** Occupational PA may not confer the same health benefits as LTPA, as higher levels of occupational PA also exhibit increased health risks. *(Prince et al., 2021)*
- **Lacks motivation to exercise at home/coming back home:** After work, individuals may lack motivation to exercise, leading to potential health risks and reduced physical activity levels. *(Bláfoss et al., 2019)*
- **Wants to break up sitting during the work day:** Cognitive benefits and decrease in monotony may be seen by breaking up long hours of sitting *(Tuckwell et al., 2022)*
- **Wants to increase focus using physical activities:** Regular PA is associated with increased brain function, improving memory, attention and focus. *(Gomez-Pinilla & Hillman, 2013)*
- **Wants to implement exercise as a coping mechanism for stress and anxiety:** Participants of this study emphasized on the importance of PA on their physical as well as mental health. *(Kaur et al., 2020)*
- **Is looking for engaging ways to bring about lifestyle changes:** A need for engaging ways to increase adherence and eventually bring lifestyle chances is shown in this study. *(Leung et al., 2017)*
- **Prefers products with small physical footprint on the desk:** Study suggests people require smaller products with smaller formfactor to optimize desk arrangement. *(The University of North Carolina at Greensboro, n.d.)*
- **Is bombarded with notifications by multiple devices:** Push notifications create an overload of information and may affect the well-being of the user. *(Kushlev et al., 2016)*
- **Prefers minimalistic design**: Minimalistic designs are favored as they convey essential information effectively. *(Gumber, 2023)*

From these points, we can better construct a target user group and take informed decisions about the features of the product.

Conclusion for Research Section

The research section has helped in understanding and deconstructing the nuances of various aspects like theories of motivation, evolution of lighting systems and chose target users. This section gave insights about how light can be used to create changes in behaviors, moods, feelings and thoughts. With the evolution of light, it was seen how various attributes of light can create various effects on the observer. It also showed the inherent need of humans to use light in more ways than just a tool for illumination.

The ‘motivation’ subsection shows that though motivation is multifaceted, it can be used to bring about lifestyle changes for the holistic well-being. Consecutively, benchmarking study showed how many precedents have used light and other interaction methods to motivate the viewer/user in doing a task. Through the interaction mechanism table, some features of the products have been narrowed down to give the product more user desirability.

By understanding various levels of PA and focusing on short bouts of PA, it is seen that PA done at regular intervals can prove to be beneficial and help in inducing a habit-forming change in the user. The target user group is defined to be (but not restricted to) between 35-45 years of age. Based on this age group, user characteristics were studied, as it helps identify and define the user group better.

By using the insights from the research section, the product got closer to becoming a solution which fulfills the needs of the users and proves to be a fit for the potential market.

03

Concept Development

Ideation - Phase 1

Keeping the insights from the research section in mind, the first phase of ideation underwent prematurely in the concept development stage and it explored the design direction given by the client company as the basis for the ideation constraints. This ideation phase was done before the finalizing of the research section and gaining its insights. This early ideation phase was to bring about an active approach in having preliminary exploration about which aspects of the design work for or against the project. This iterative approach showed the need for a dynamic adjustment in the project scope to align with the emerging insights from the research phase.

To aid the ideation process, questions were formulated as a guide to ideate solutions of these questions. The following questions were kept in mind while ideating and exploring the solution space:

- How can the solution create motivating interactions using light as an interaction mechanism?
- How can the solution indicate fun and interesting interactions to the users?
- How can the interactions be kept interesting for user adherence?

To further direct the ideation process, a word cloud was made from the research done across various topics. This world cloud helped in revealing the hidden connections and find key themes and concepts which need to be focused during the ideation process.

Fig. 35: Word cloud based on references in research *(Author, 2024)*

Ideation was carried out using ‘Crazy 8s’ and SCAMPER methods. Crazy 8s is a design sprint method, which removes overthinking by making the designer come up with 8 solutions in 8 minutes. Whereas, SCAMPER works by ideating by looking through different lenses of Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Rearrange. Using this method, one can generate ideas which have the potential to challenge the status quo and explore new possibilities.

By following these methods for a couple of times, various initial ideas were formed. A very primitive form

Ideation - Phase 1

of detailing is done to better define the initial ideas. 18 ideas are detailed in this phase of ideation. Out of these eighteen ideas, few are shown below. Rest of the ideas in phase 1 are in the Appendix D.

Fig. 36: Lit-up footprint paths

In this concept, the user walks on lit-up paths which indicate the pace and the speed of running with the help of footstep-shaped light tiles.

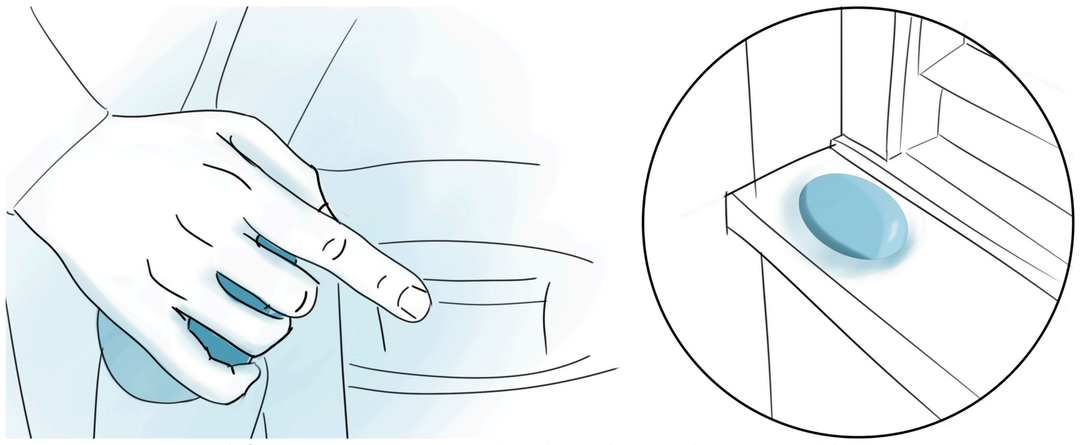


Fig. 37: Wearable suggesting activities based on weather

This idea is about a wearable which acts as a smart training buddy, indicating the weather using light and suggest activities accordingly.

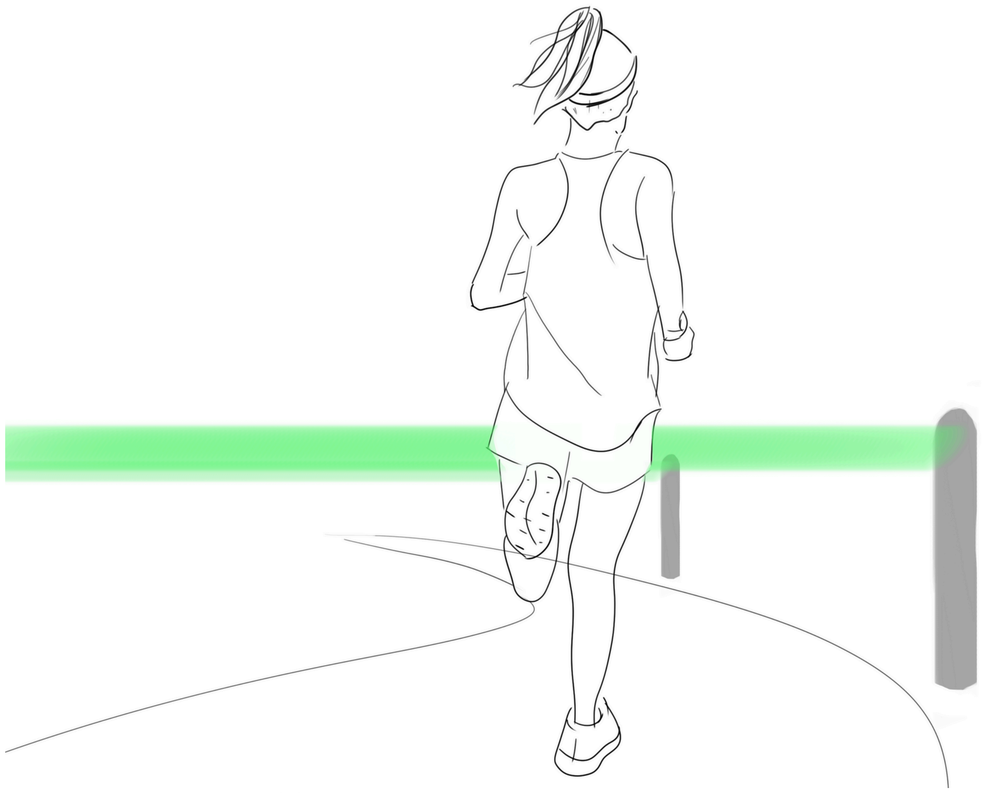


Fig. 38: Horizontal light beams acting as milestone

Here, the concept creates beams of light which are analogous to crossing the ribbon at the end of the race. Such beams at regular intervals can create a sense of accomplishment or achieving milestones to increase motivation.

Ideation - Phase 1

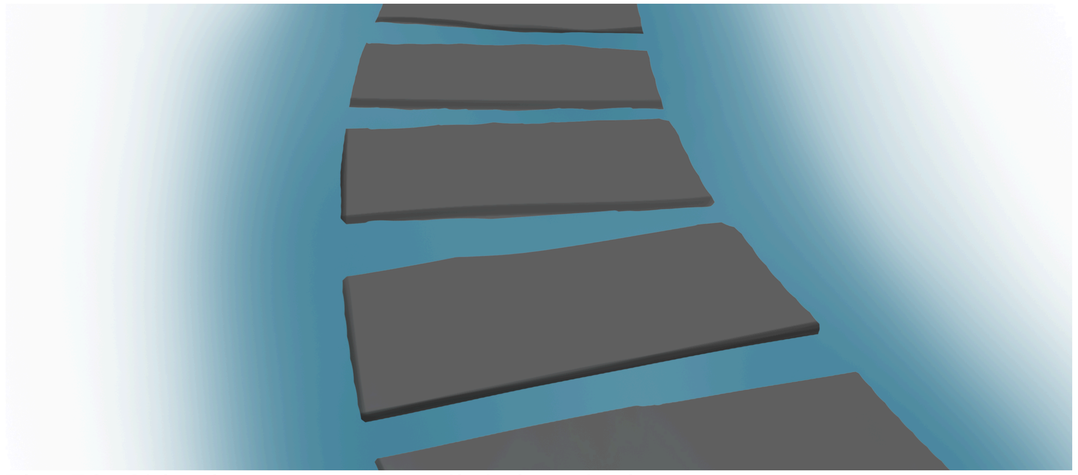


Fig. 39: Skipping stones as a lighting design

This concept bring the fun and excitement of skipping over stones in water by having light emanate from the sides of each stone, giving a water-like effect from light.

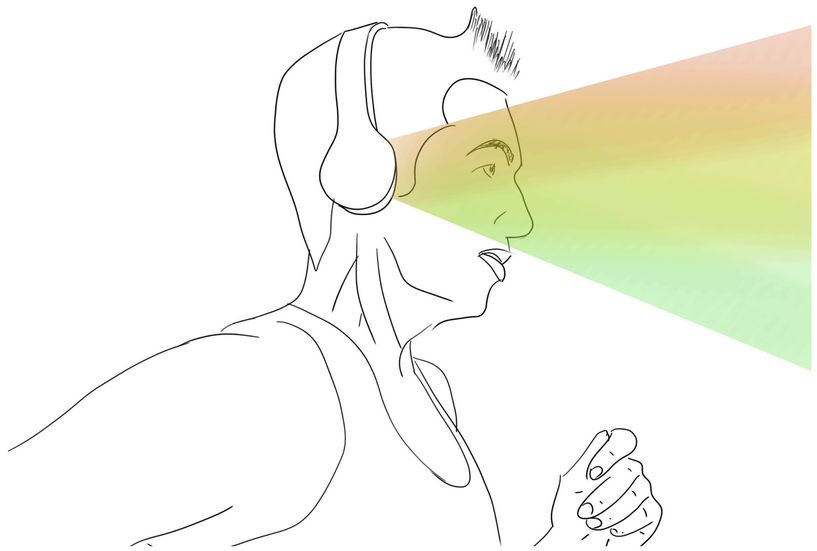


Fig. 40: Running headphones showing progress of route

Here, the concept helps in creating increased concentration, while maintaining safety for runners listening to audio while running. These ‘visual curtains’ provide indication of the route and can be used to give additional information.

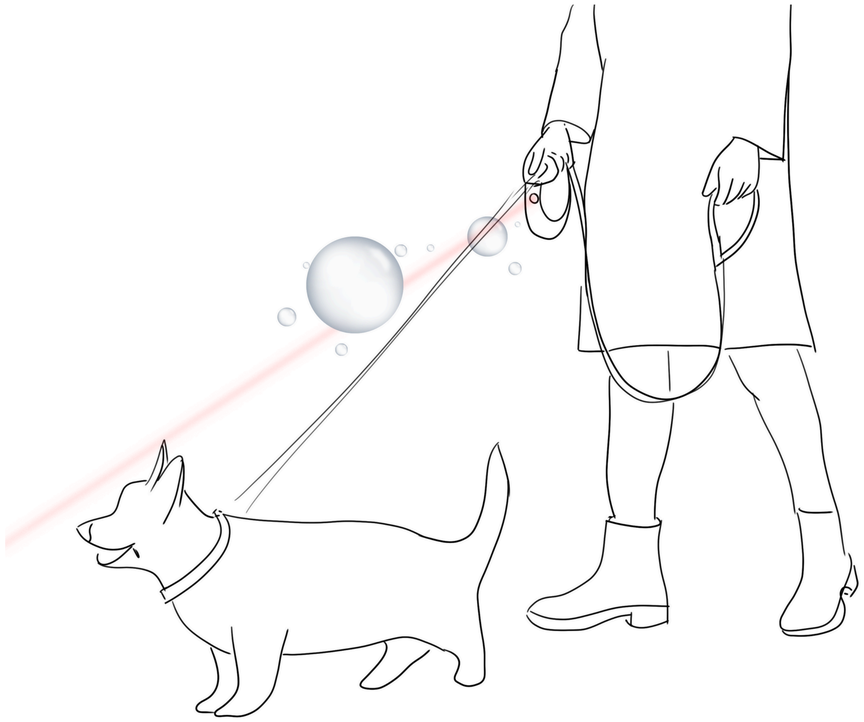


Fig. 41: Dog leash used an interactive toy for the dog

Being a fun concept, it creates an indirect motivation by having the dog leash have laser pointer and bubble machine to make the leashed dog chase them and in turn making the user run with the dog.

Design Direction

Constraints & ViP process

The subsection Ideation Phase 1 explored ways to boost motivation for running exercises, especially through large-scale installations similar to ‘The Wave’ project by the client company.

However, research revealed that physical activity typically declines around age of 35 years, leading to a shift from active to sedentary lifestyles. This decline in physical activity can be counteracted by performing any kind of activity at any intensity, as seen from the insights in the research section. People want to create a healthy lifestyle which makes it easier to incorporate exercise in daily life. These findings highlight the importance of addressing this issue at its core by creating the motivation to exercise in general, rather than focusing on running, as an exercise, alone.

Although Ideation Phase 1 generated interesting ideas, they did not completely align with the conclusions of the research insights. Hence this subsection critically evaluates the need to reestablish the design direction while having constraints in place which can steer the project in a particular direction. Here, we discuss how the design direction was formulated, keeping the insights from the research section in mind, some ideas were refined and reintroduced in Ideation Phase 2, after being modified based on the research insights and revised design direction.

In order create a holistic design, constraints need to be set in place such that they concentrate the progress towards a desired methodology and eventually, a desired solution.

Design constraints play a crucial role in shaping the design direction and guiding the scoping process. This project required a more holistic approach, going deeper into the mindset and barriers towards having a healthy and physically active lifestyle. To use light as a medium of creating a significant and long-lasting change in the user’s life, deconstruction of the existing products, their issues and current status quo of the exercise motivation market was studied in the research section.

To aid in streamlining this process and giving a solution more integrated to the users, the ViP method was followed. The ViP method focuses on having meaningful innovations which are not only user-centered, but holistic in their approach as well. To avoid having a repetitive design which the users discard after a few uses, the ViP method pushes the designer to analyze

Design Direction

the interactions and the contexts of the existing solutions.

By following the ViP method, the design brief is formulated and this drives the design process forward. This method is used here only to generate a design direction for the project, as ViP method is quite extensive and following the complete method would be beyond the scope of the project.

According to the ViP method, various insights from the research done for this project are presented as factors. These factors are then clustered to form core values of the design, leading to the formation of the worldview statement. This worldview statement is used as a problem statement for the design process and through this statement, analogies, characteristics and qualities of the design solution are articulated.

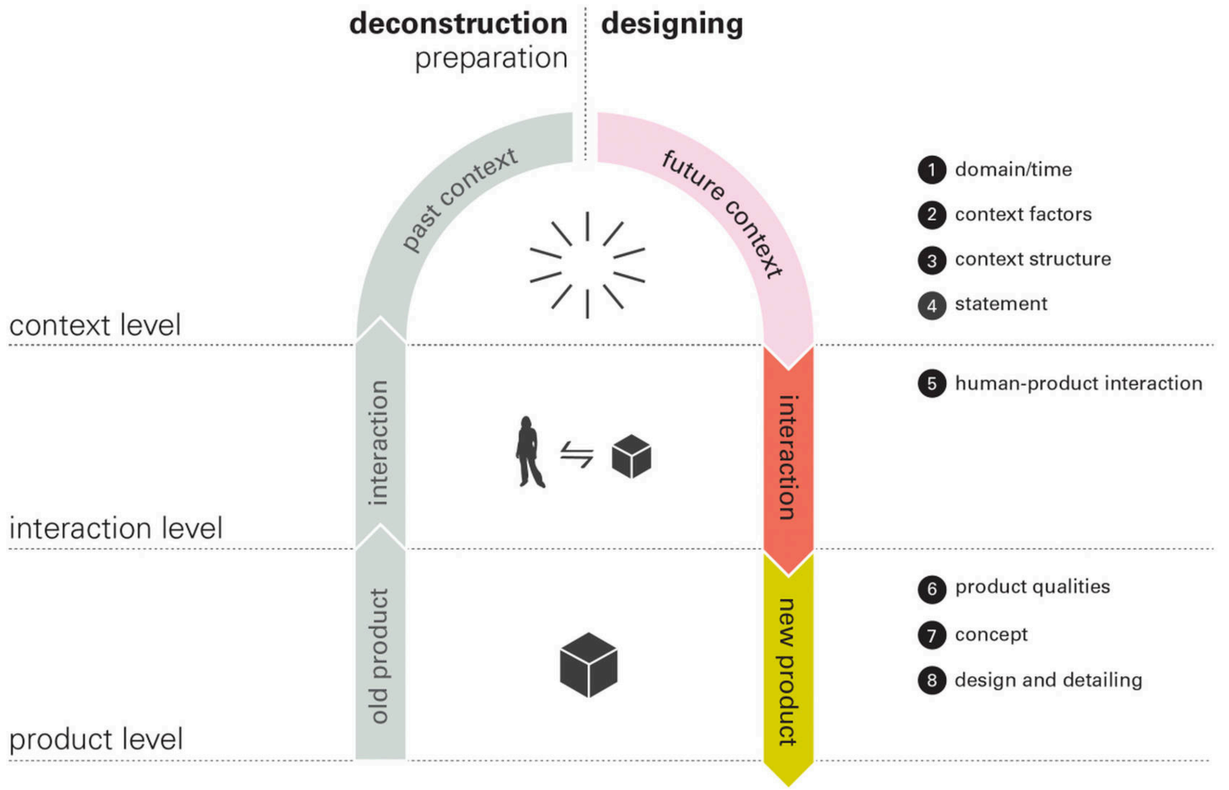


Fig. 42: The ViP Method by Paul Hekkert & Matthijs van Dijk *(Gomez et al., 2013)*

Design Direction

Factors, clusters & core values

Based on the research done, there are various factors which can be drawn from the different contexts. Some of these factors are shown below. Complete list of these factors can be seen in the Appendix E.

Physical activity can improve mental well-being

People rely on wearables to track activity and receive personalized health data

Many people have limited time for exercise

People respond better to positive reinforcement and playful interactions

Interactive surfaces and gamification elements can increase engagement

People are increasingly becoming aware of their health data

Different colors and light patterns can evoke emotions and influence behavior

People often struggle to initiate activity

Some users prefer internal rewards (feeling good) while others benefit from external motivators (badges, points)

Fig. 43: Selected factors from complete list

As the next step of the ViP methodology, these factors were categorized and related factors were grouped together to form clusters. These clusters are set as thematic groupings of the considered factors which help in informing different aspects of the design process. There were four clusters formed as follows:

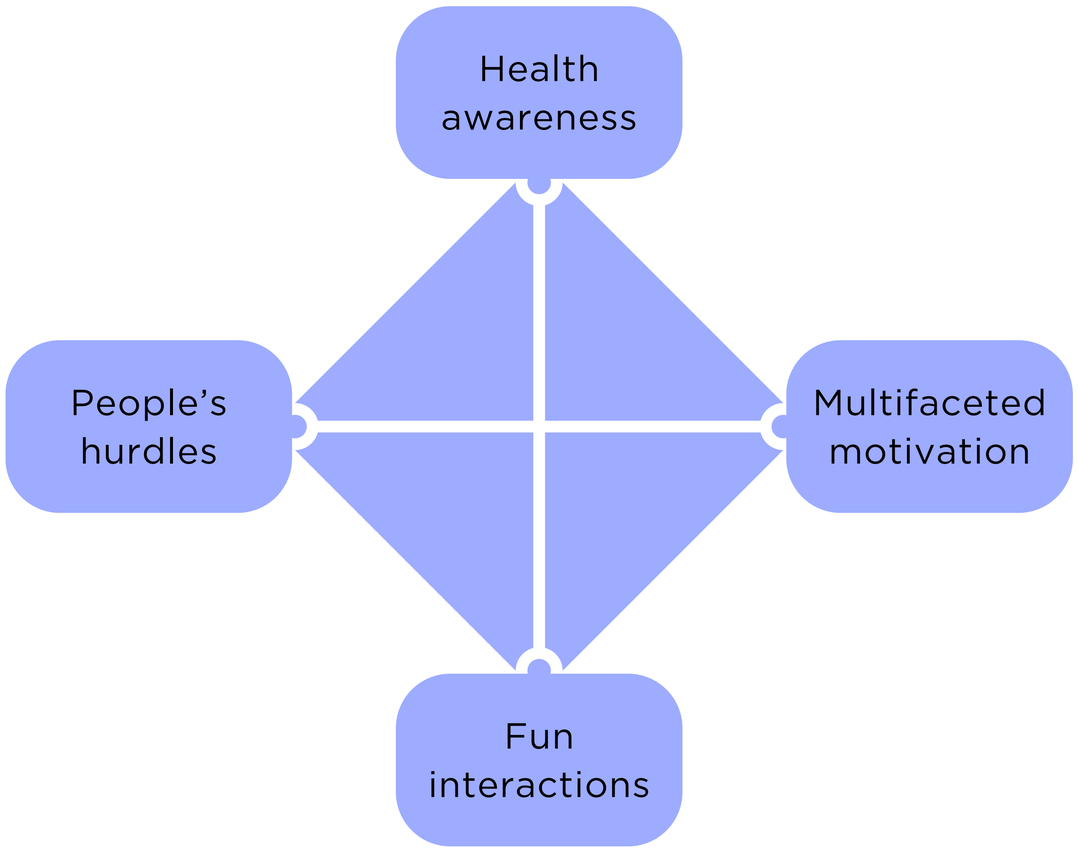


Fig. 44: Clusters formed from grouping of the factors

Design Direction

By delving into these clusters, the fundamental principles are formed as core values of the solution. These core values guide the design decisions and ultimately shape the character of the desired solution. Further exploration is done in order to understand the core values, the clusters, their recurring themes and their shared threads.

The core values for this design are as follows:

- Reducing barriers to starting activity
- Catering to diverse motivational factors
- Emphasizing the inherent connection between movement and well-being
- Making physical activity enjoyable and intrinsically rewarding

Worldview & its analogy

A worldview statement is an envisioned future context which develops as the design process moves towards the desired solution. Here, the worldview statement is made by catering to the research and the core values mentioned above. This worldview statement can be seen as the ‘Design vision’ statement of the project.

This vision statement emerged from a thorough exploration of various research findings and insights. The concept of nudging stems from studies into clusters of strategies from the above section, where subtle encouragements can effectively guide individuals towards positive actions. Additionally, the idea of micro activities is grounded in research such as the study of Light Intensity Physical Activity (LIPA), which suggests that even short bursts of activity can significantly contribute to habit formation and overall health and well-being. By combining these insights the vision statement is formulated and the project has worked towards fulfilling this statement:

> “I want to nudge people into acting on their inner awareness by motivating them to perform micro-activities using fun and interactive mechanisms”

To better describe the worldview statement, it is recommended to aid the statement with an analogy. This analogy acts as a reference to the intended future context of the solution. As seen in the analogy above, are sprinkling breadcrumbs on a trail. Each playful interaction and micro activity acts as a breadcrumb, that motivates the individuals along a path of discovery and engagement with their health and well-being. As they follow these ‘breadcrumbs’, they gradually build

Design Direction

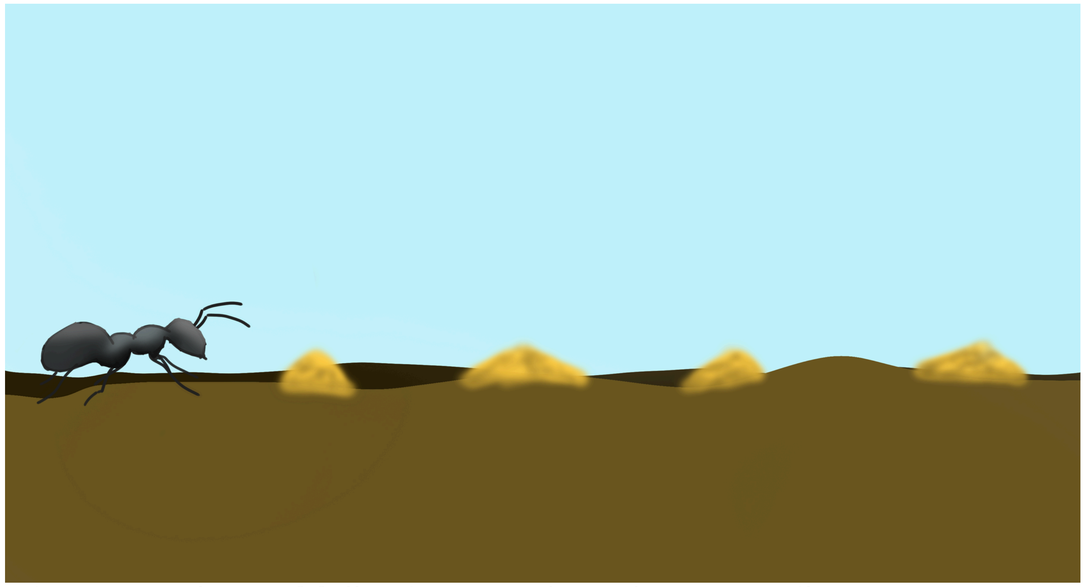


Fig. 45: Analogy of following Breadcrumbs on a trail

momentum and confidence, resulting in a gradual shift towards a healthy lifestyle. This shows how the user can make big changes based on the micro-activities done regularly over time.

Characteristics & Qualities

Based on all the insights gathered from various steps of the ViP method, the design direction took a more concrete form. Hence, this helped in devising the interaction characteristics which can be aimed for in the desired solution to fulfill the worldview statement. The interaction should embody characteristics like:

- stimulating
- short interaction
- positively reinforcing

The design qualities which should be evidently reflect in the design are:

- joyful
- engaging
- actionable

These qualities will, thus, align the solution holistically to the envisioned design direction.

Revised scoping

Hence, based on the research and the developed design direction, and after consulting with the client company, the project moved away from focusing on the design development of an outdoor installation for motivating people to run. The revised scoping outlined how the design ideation should concentrate on a personal product which makes users motivate towards generic movements as micro-activities, instead of running exercises. The design solution is brought down to being much smaller in scale to cater to the business needs of the client.

Design Direction

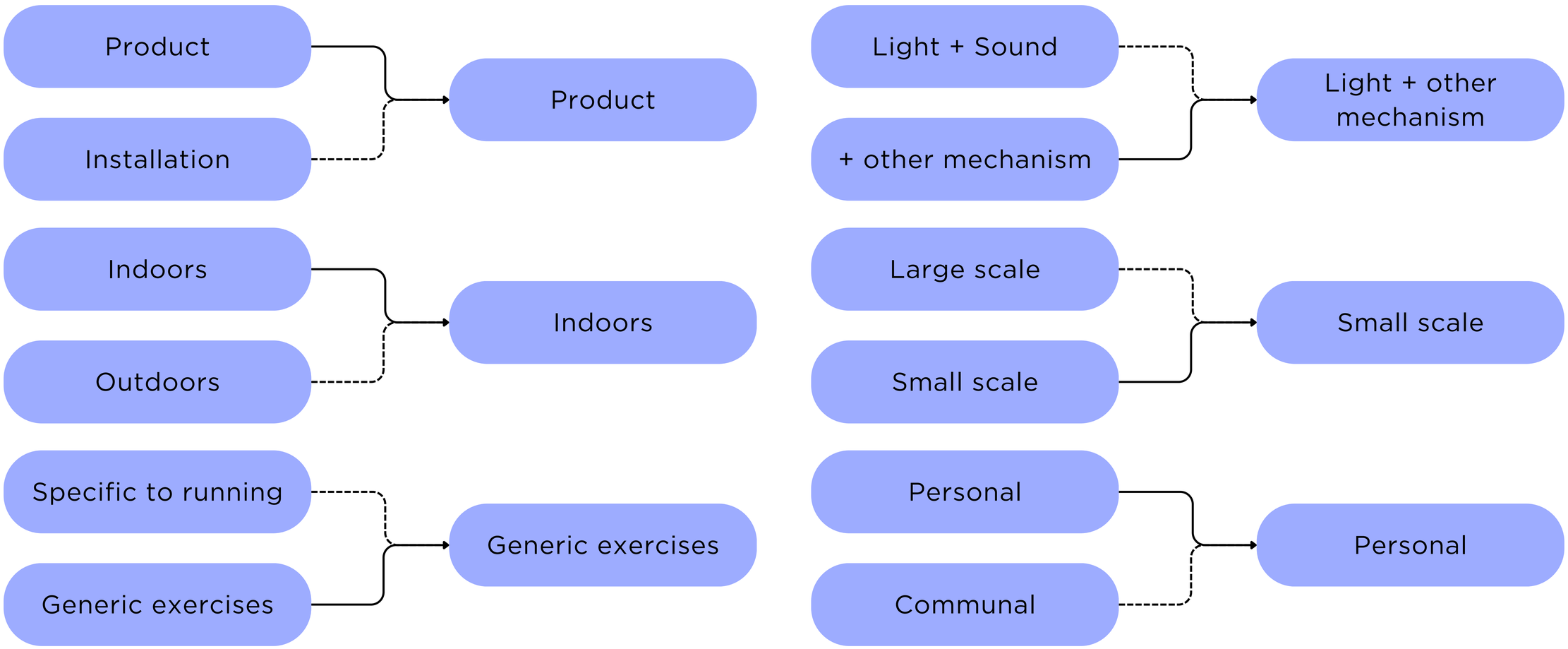


Fig. 46: Decision making for revised scoping, done for a more precise design direction *(Author,2024)*

Ideation - Phase 2

As mentioned in the previous subsection, due to the change in design direction, most of the ideas generated in phase 1 of ideation were set aside, while some were modified to fit the new design direction and were reintroduced into phase 2 of ideation.

Keeping the complete research insights, decided scope and design direction, second phase of ideation was conducted by incorporating a few different ideation methods. This was done to have diversity in the ideation process and make sure that adequate avenues are explored. SCAMPER as before, biomimicry and forced analogy ideation methods were used. Biomimicry uses nature as inspiration for problem solving. Forced analogy uses deliberate relations between unrelated objects to show new and creative perspectives. Multiple ideas are generated out of which, three concept directions are chosen to be considered as eligible for concept evaluation.

Concept A

In this concept, the idea of a health piggy bank is implemented. The conventional piggy bank indicates accumulation of small change of currency over time, filling the piggybank with a considerable amount of money. Hence, using similar principle for health, the piggybank updates after every physical activity done over a period of time, showing an accumulation of movement, leading to a healthier lifestyle. The time duration can be set by the user. This is a personalizing by focusing on micro-activity for daily goals or daily consistency for long-term goals and habit formation.

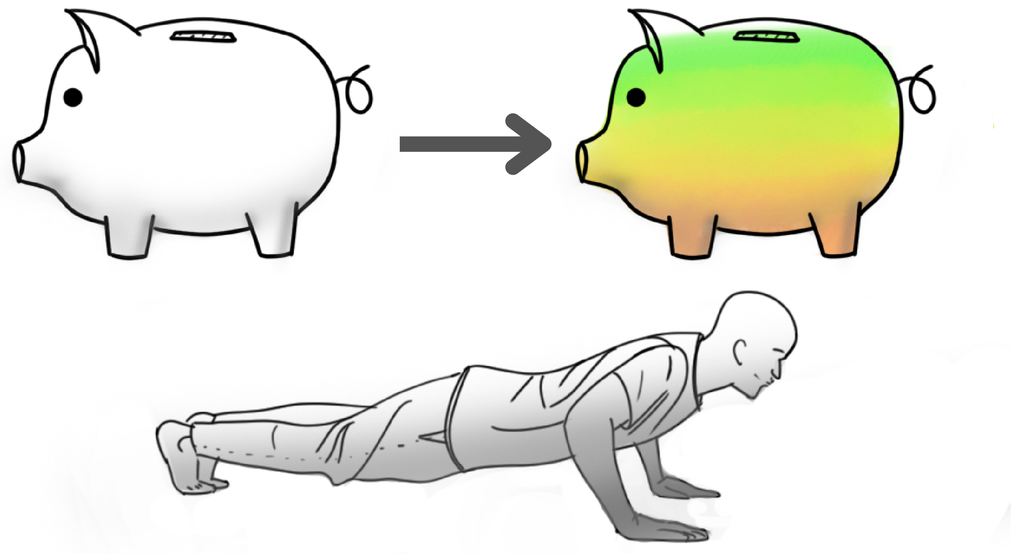


Fig. 47: Concept C- Health piggybank

Concept B

Concept B is a product concept called ‘Zen Ripples’, which aims at creating interest in the user to perform micro-activities by having various lively visual states. This concept incorporates a surface which acts like a mirror when still and gives interesting patterns when

Ideation - Phase 2

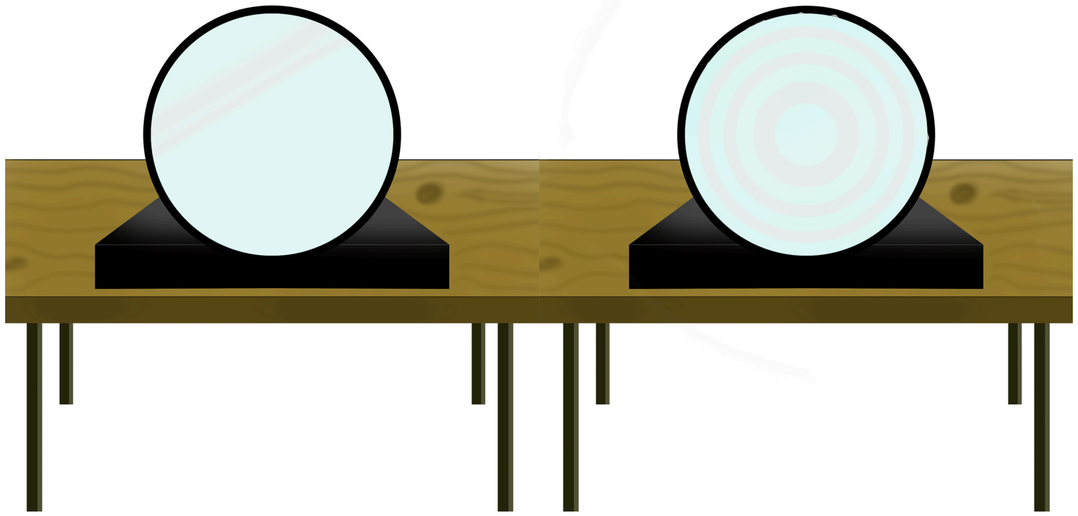


Fig. 48: Concept D- Zen ripples

movement is induced in it. Here, the movement is seen as concentric circles moving out, mimicking water ripples. In order to motivate a person to perform micro-activity, Zen ripples can be seen as long, sedentary periods making it look like a common mirror. This makes the user see their face in the mirror-like surface. As per pareidolia, the reflection of the face will garner the user's concentration towards itself. The user would want an aesthetic effect shown on the surface, hence would perform micro-activities. This will make the product have beautiful ripple effects instead of mirror effect.

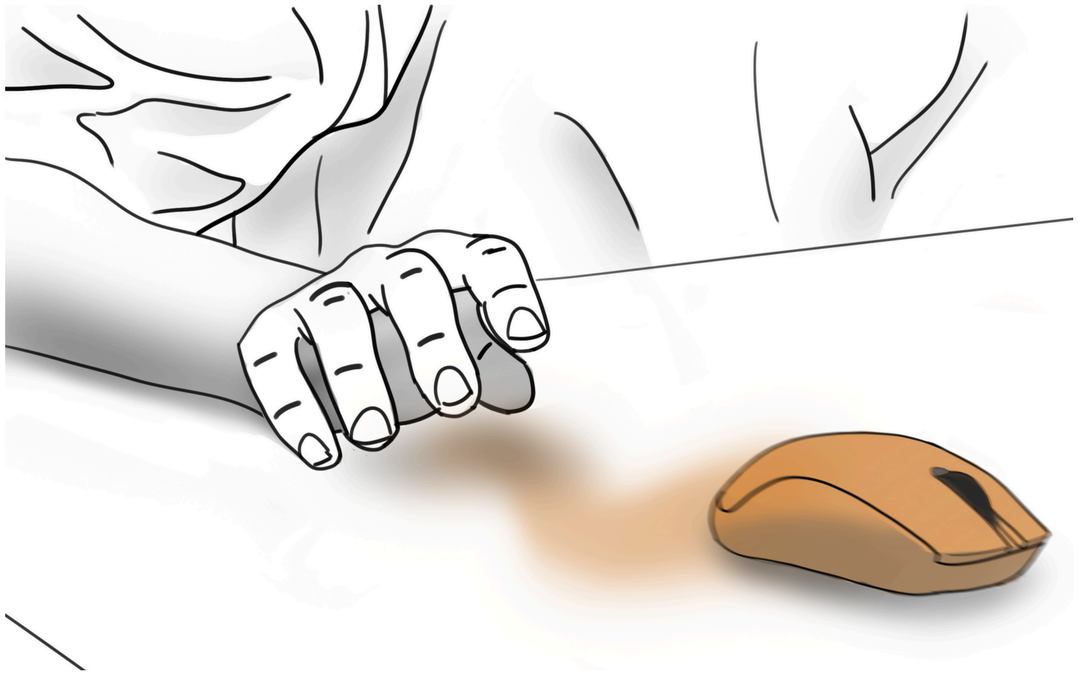


Fig. 49: Concept E- Catch-me-if-you-can

Concept C

This concept E is a form of 'catch-me-if-you-can' type of a product idea. In this concept, the product is a kind of a desk accessory which will be still for most of the time. Yet, after a certain amount of time the user is sedentary for, the product jumps or flies or runs to a place where the user cannot find it easily. This makes the user get up and do some kind of activity to catch the product. This product can be a mouse or a micro-drone made to perform the abovementioned tasks and increase the inclination of the user to perform more activities.

Ideation - Phase 2

drone made to perform the abovementioned tasks and increase the inclination of the user to perform more activities.

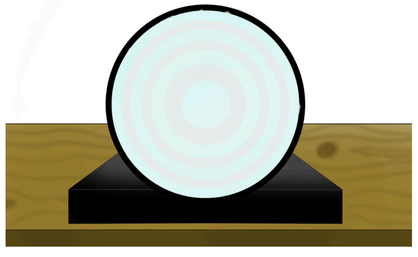
These five concepts were considered to be evaluated and were compared against each other through various parameters to see which concept fares well against the formulated design direction.

Concept Evaluation & Selection

After the ideation and conceptualization phases, the concepts presented in the earlier section were evaluated to find the best solution to go ahead with. The selected concept was to be developed further and go ahead the complete design process.

Concept A

Concept B



Concept C

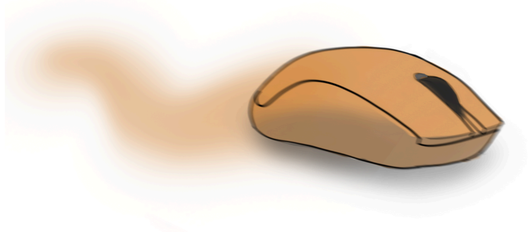


Fig. 50: Concepts to be passed through Harris profile

In order to select the best concept, the Harris Profile method was chosen as the evaluation method. To use this method efficiently, a list of values required for the comparison need to be listed. The considered concepts and the list of values for comparison are given below. These values are a combination of the interaction characteristic and design qualities found from the ViP method and values which were deemed important for this project, in accordance to the client company.

- Stimulating interaction
- Short interaction
- Positively reinforcing
- Joyful
- Engaging
- Actionable
- Fit to Hola's portfolio
- Ease of production
- Fit to target user group
- User adherence

Fig. 51: All values considered in the Harris profile *(Author, 2024)*

Concept Evaluation & Selection

Based on the values used to evaluate the concepts, the Harris profile was create. In this method, all the concepts are evaluated against a 4-point scale for each value. The values range from --, -, + and ++. The set of

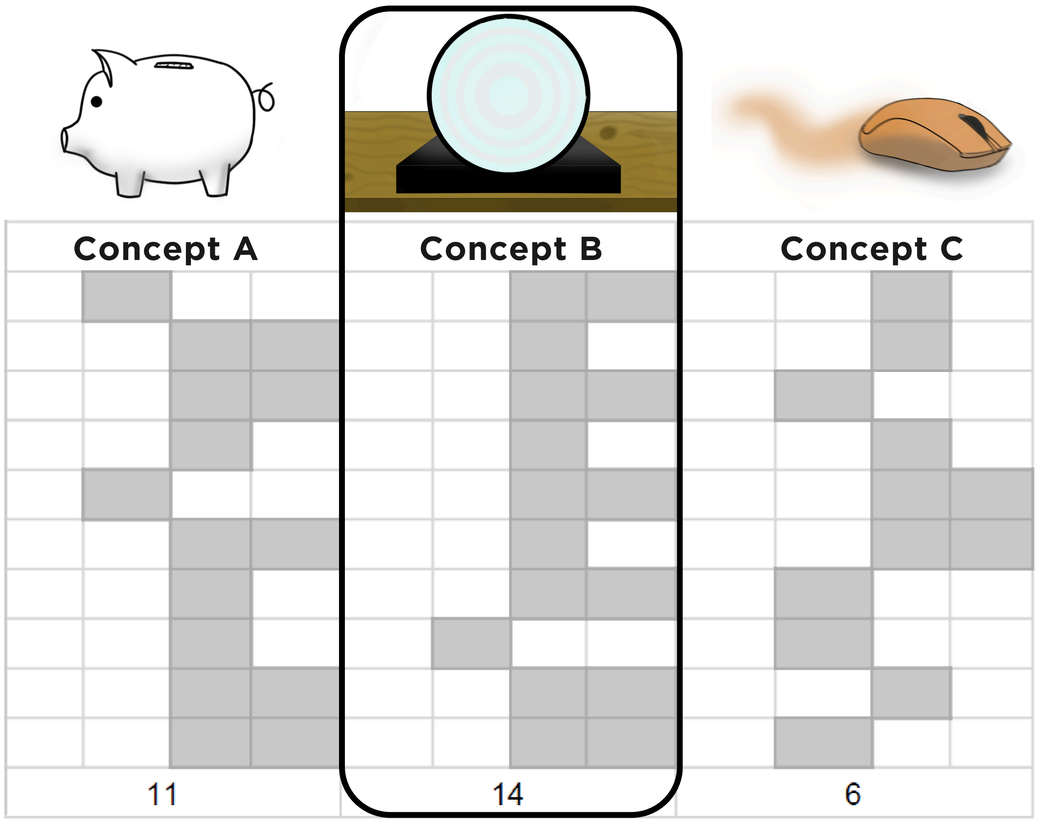


Fig. 52: Completed Harris profile indicating concept B as the best concept to detail out

columns for each concept can be seen as towers. A concept is said to be a good concept if the tower, if made in reality, then it would tip to right side, which has the positive side. Thus, helping one evaluate the concepts.

As it can be seen from the Harris profile above, concept B: Zen ripples turned out to the be the concept with highest potential. The supervisory team and the client company was informed of this result and they showed support. Hence, Zen ripples is finalized to detail further.

Concept Realisation

After the decision to go ahead with concept D, the next phase was to explore means to bring the concept into realization. In order to do so, the working of the concept and other products displaying working similar to the concept or parts of it needed to be studied. Through this study, expected material properties and structure of the design solution can be decided.

Working of the concept

As described in the ideation phase, the concept has two states, namely, one where the surface of the concept which faces the user, has a mirror-like surface to indicate that any kind of physical activity has not been performed in recent times. This state will be called the **mirror state**, from here on. Once any kind of physical activity, in this case micro-activity, is performed, the mirror-like state changes to a visually kinetic, moving effect which has appearance similar to the ripples created in a water surface, called the **light state** from here on. The concept works such that the light state acts as a motivator towards doing some form of physical activity. The mirror state brings to attention the lack of physical activity and the effects such as pareidolia incentivizes the user to perform micro-activity and gain the light state on the device.

These two states are shown in the analogy here.

The stillness of the water, indicates a still, undisturbed state. This can be seen as not doing physical activity. The ripples are formed in the water surface when there is some kind of activity in the water. This activity can be seen as similar to a person doing physical movements in their daily schedule.

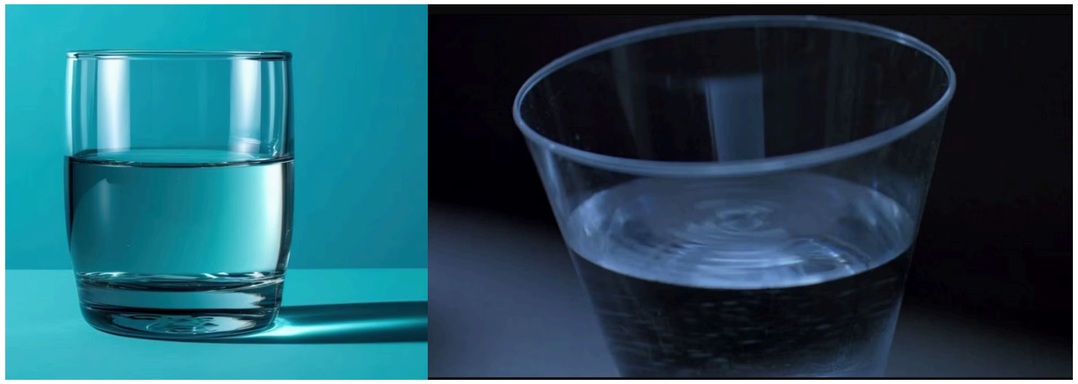


Fig. 53: Still water in a glass *(Jain, 2023)* & famous water cup ripples scene from the classic 1993 movie Jurassic park *(Dubiel, 2023)*

Benchmarking study

The mirror state and the light state must to be able to transition efficiently between each other. In order for this to happen, the level of reflectance and transparency need to be changed according to the appearance of the state.

While searching for products which have similar properties, glass panes which are made in such a way that they provide privacy while letting natural light in the room, were studied. Here, two products stood out

Concept Realisation

against the various solutions present in the market. Them being windows which have a semi-transparent film coated on them and are highly reflective or highly transparent depending on the surrounding light, and crystalline glass panes which are opaque or transparent depending on the electric current passed through them.

The window panes with semi-transparent coating work in such a way that when there is light on both the sides of the glass pane, it acts like an almost transparent glass pane. When there is light on only one side of the pane then it reflects light and hence, becomes a highly reflective, mirror-like surface. This working can be seen in the image below. Examples of such products are Reflectasol by Saint-Gobain and generic semi-transparent foils which need to glued to normal glass panes to achieve the desired effect.

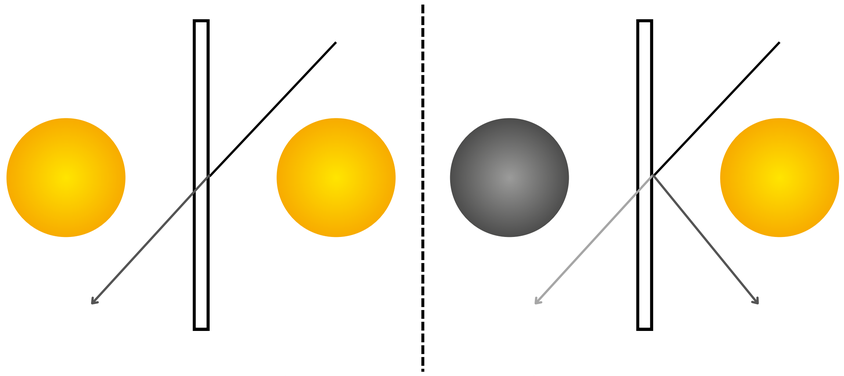


Fig. 54: Transparent & reflective states of semi-transparent windows *(Author, 2024)*

The crystalline glass panes, also known as electrochormic glass panes have a crystalline layer laminated between thin glass sheets. This crystalline layer has crystals which are randomly spaced in the layer by default. This random pattern of crystals makes the composite glass pane look cloudy and slightly opaque. When there is a current passed through the crystalline layer, the crystals align themselves making them transparent. Various companies provide these kind of glass panes, with its most common use in trial rooms and glass walls in buildings.

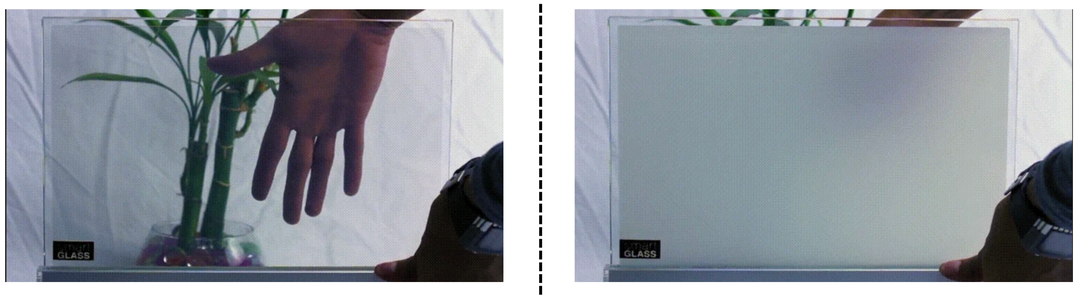


Fig. 55: Transparent & opaque states of electrochromic glass *(Pro Display, 2024)*

Due to factors like cost, availability and variety, the semi-transparent windows were considered to explore further. This was also one of the choice from the client company as they have prior experience working with these semi-transparent coating/film materials. Hence, the change of states proved to be a feasibile solution and can be efficiently produced.

Concept Realisation

For the light state, there were various options considered. The primary characteristics of this effect were random yet calming, actionable, stimulating and playful. In order to get these characteristics into the solution, products which had properties similar to iridescence were considered as a starting point. Various materials with iridescence were studied, along with natural occurrences of this effect in beetles, humming birds, etc.

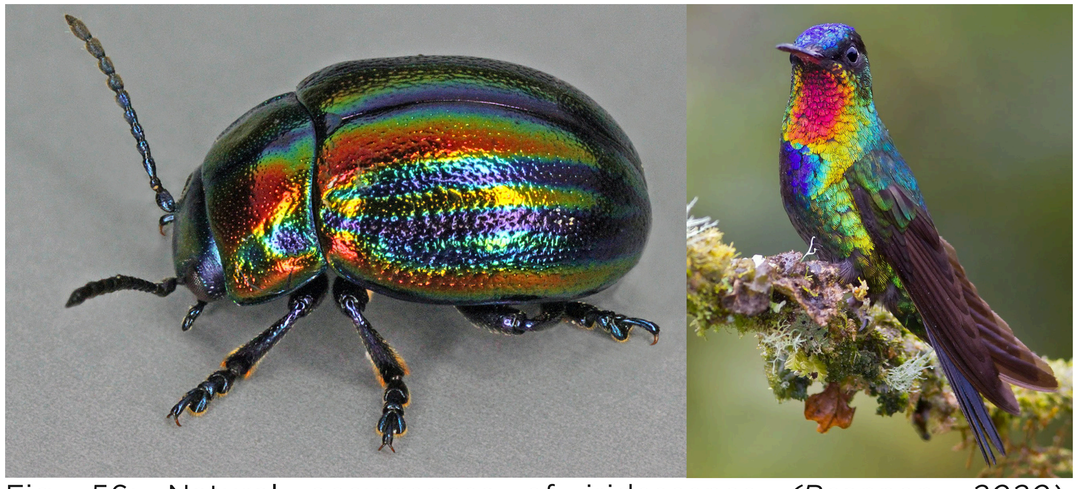


Fig. 56: Natural occurrences of iridescence *(Rcannon, 2020), (Campbell, 2023)*

Hence, iridescent products like lamps, clothing, accessories, desk accessories, etc were studied. Along with lamps and other lighting solutions, textiles were an interesting frontier to explore for interesting effects. Basic fabrics like tule were studied, but did not hold well for having the desired effect. Experimental fabrics which have composite materials on them were studied to check if they were a good fit. One of such textiles is the dichroic textile by Laser-atelier in Zurich. This material is laser cut in a such a way that the dichroic material can be flexible and used as a textile.

Fig. 57: Dichroic textile *(Laser Atelier, 2019)*

For these iridescent and dichroic effects, the viewing angle is of vital importance as the light rays are reflected in a random patterns and have the shimmering effect only if the viewing angle keeps changing.

This would mean that some kind of motion needs to be induced in the solution to get these effects. This motion feature would increase the complexity and wear and tear of the solution. Hence, other means of getting the light effect were explored, concentrating on ones which do not need movement or complexity for the whole solution to function.

Concept Realisation

Products with material properties like light projection, polarization of light, etc were considered. Dichroic cubes, polarizing garments and light lamps with interesting effect were studied. From the studied materials, a ‘water’ lamp gathered most similarities to the desired effect. Such a lamp was bought and studied to understand the working of the effect.

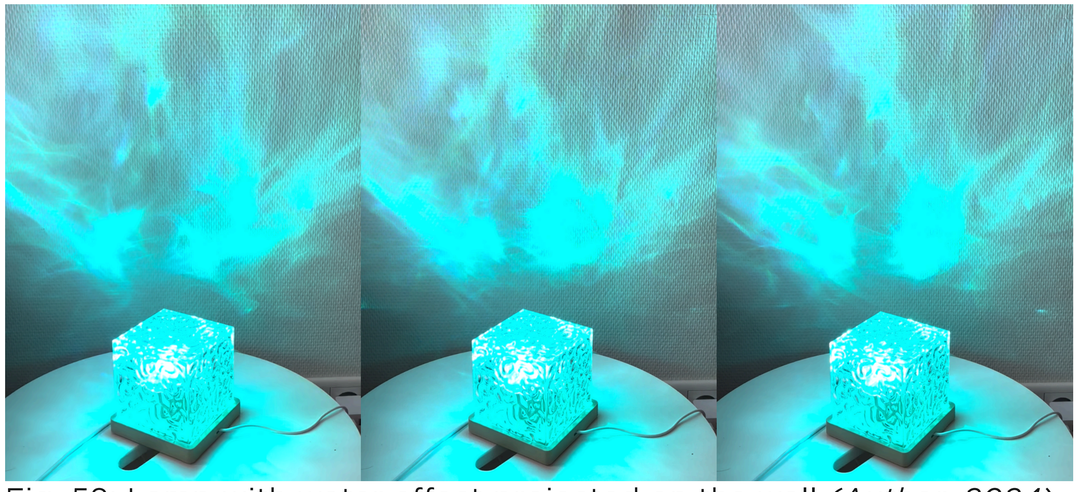


Fig. 58: Lamp with water effect projected on the wall *(Author, 2024)*

In this product, light is passed through two textured transparent materials, while one of the materials is spinning. The texture is similar to waves and hence, when the light passes through the material, due to variable thickness, it refracts the light in different directions and intensities. This effect is enhanced by making on of the textured materials move and create shimmering, ripple-like light on the walls.

These explorations helped in understanding the variety of materials which can be implemented in the solution. This study also emphasizes on how there are existing products which implement technologies achieving the effects needed in the solution. This gave confidence and assurance that the solution can reach the intended potential and work as envisioned.

Light Lab Explorations

Along with the benchmarking study in the concept realization step, physical material explorations were parallelly done in the Light lab. There were a myriad of materials available to explore in the light lab. Additionally, Hola studio, the client company provided with a lot of materials to explore as well. Collectively, this gave a good set of materials and possible combinations of those materials to be explored and chosen from.

To test out the semi-transparent film which client company had worked with before, they provided an infinity mirror which was developed in-house by them. This infinity mirror had the semi-transparent film on the front surface and LEDs behind it. When the lamp was in Off state, the front surface would be highly reflective. When the lamp was switched on, the Infinity effect created by the LEDs inside was clearly visible. This effect was shown to give a feeling that there is no backside to the mirror and continues infinitely inside its form factor.

This transition in states is exactly what the current design of the project envisions to achieve, specifically being able to change states between reflectance and transparency. Thus, with the help of the exploration using infinity mirror, it was decided that the front layer of the solution will be made from the same material as the semi-transparent film used in the infinity mirror.

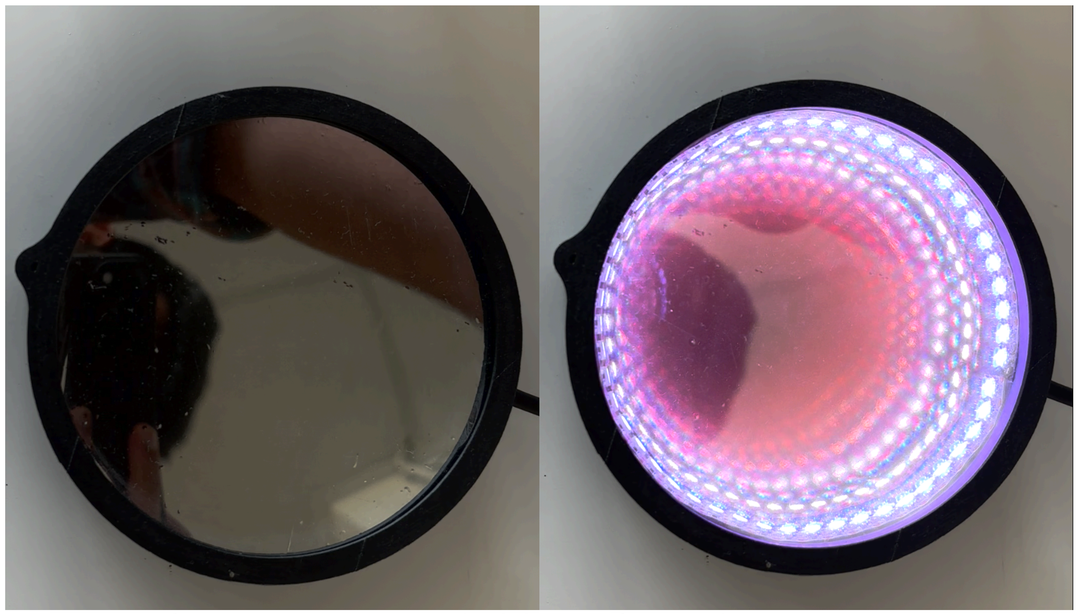


Fig. 59: Infinity mirror provided by Hola studio to experiment with *(Author, 2024)*

Now that the way to switch the lighting states was finalised, the contents of the states had to be finalised. The mirror-like state was there by default in the semi-transparent film when there was no/less light on one side of the film. Hence, during the mirror-like state, the lights in the solution would be switched off to create the mirror-like effect.

Light Lab Explorations

Coming to the light state, this state is the most crucial aspect of the design as it is the crux of the design solution. Hence, a lot of thought, exploration and time went into exhausting almost all the possible means of realising this effect. As this effect started with keeping ripples on a water surface in mind, the reflections of a water surface with ripples were observed and qualities which define the ripple effect with light falling on it were observed.

This lead to the understanding of caustics and how the waves/ripples in water affect the light which is reflected and refracted because of the light. One of the most interesting examples of this effect used on a large scale was seen on the sets of the 2017 movie ‘Blade Runner 2049’. In this movie, the light cinematographer, Roger Deakins had set up character lighting for the scene in advance. With the inclusion of the architectural design of the set where the scene was to be shot, there was a shallow, large water body all around the filming platform. This gave reflections of caustics all over the set walls, due to the overhead character lights. This caustic effect was very much liked by the team and Deakins manipulated the light to make the best of the caustics and give more character to the lighting. Similar caustics and ripple effect is desired in this project and hence, aspired towards.

Fig. 60: Director Denis Villeneuve on set of Bladerunner 2049, with the caustic effects seen in the background, Columbia pictures *(Maher, 2017)*

Since, in this lighting arrangement, a large water body was used to get the desired effect, it was not practical to be implement the same system into the product. Water would render the product vulnerable to leaks and could create complicated mechanism to use the exact same technique. Hence, alternative ways to achieve similar effect were explored, while keeping this effect from the scene as an inspiration.

Light Lab Explorations

In order to replicate the caustic effect seen in the image before, various methods were tested. Multiple materials were observed with different types of light shone on them in different parameters. Some of the explorations which were not continued in this project can be seen in the Appendix F.

One material which seemed to be interesting and was extensively tested was a two-tone iridescent fabric made out of green and red threads perpendicular to each other. This materials created mesmerizing effects when viewed from various angles, and when it deforms from being flat to having folds, creases or bumps.

Fig. 61: Two-tone iridescent fabric, flat and folded, creating iridescence on the folds *(Author, 2024)*

Seeing this interesting effect, the two-tone fabric was considered as an option to create the light state. Various mechanisms were explored to create the ripple-like effect through various motions.

Two mechanisms were found promising in bringing about this effect, namely, mechanical cam shaft mechanism and magnetic mechanism. The cam shaft mechanism is fairly common mechanism and hence, different arrangements of this mechanism were studied. A 3D printed version of the cam-shaft assembly was found online, to be working in making an effect which mimics a drop of water falling in a large water body.

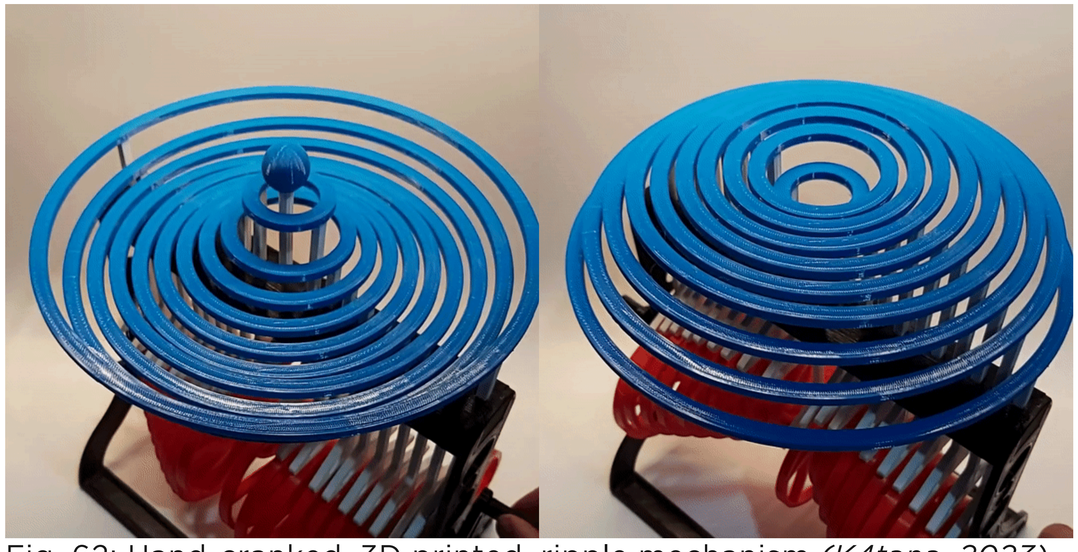


Fig. 62: Hand-cranked, 3D printed, ripple mechanism *(K4tana, 2023)*

To test this mechanism out, a rapid prototype was made. This prototype was made using the shoebox prototyping method. A crude prototype was made out of common items found around and built in order to answer the questions through the prototype. In this case, the feasibility of the cam-shaft mechanism was to

Light Lab Explorations

be tested.

Fig. 63: Shoebox prototype with the two-tone fabric on top *(Author, 2024)*

Here, the same mechanism was made as the online version of the cam-shaft assembly and the two-tone iridescent fabric was covered on it to create the ripple-like effect. The cam-shaft mechanism worked decently well, while showing the necessary modifications needed to make it work efficiently. Yet, when the fabric was covered over the top surface of the prototype, the fabric needed to be kept in place using some kind of fasteners. For the prototype, a rubber band was used to contain the fabric on top of the prototype.

During hand-cranking the prototype, it was observed that the fabric did show movements under it, but to show the effect properly, the fabric would need to be extremely taut at all times, throughout the motion of the mechanism underneath. This would require the fabric to be extremely precisely pulled and pushed according to the motion. This would complicate the solution by a large margin. Thus, upon discussing with the client company, they suggested to not go ahead with mechanisms which would have a lot of motion in them as they would wear out quickly and is not preferred by the company. Thus, the cam-shaft mechanism and the magnetic mechanism were not considered ahead, as they both included a significant amount of motion in their working.

Also, the technology for the ‘water’ lamp, shown earlier, was studied further. The lamp was disassembled and the internal working of the lamp was studied. The lamp, as mentioned before, has two textured transparent plastic parts covering the light. The light passes through the plastic pieces and refracts in different directions due to the varying thickness of the texture. One of the plastic parts, seen as the dome part in the images, is spun around the axis with the help of a motor. This rotation of the plastic part leads to a dynamic and lively light pattern on the wall.

Light Lab Explorations

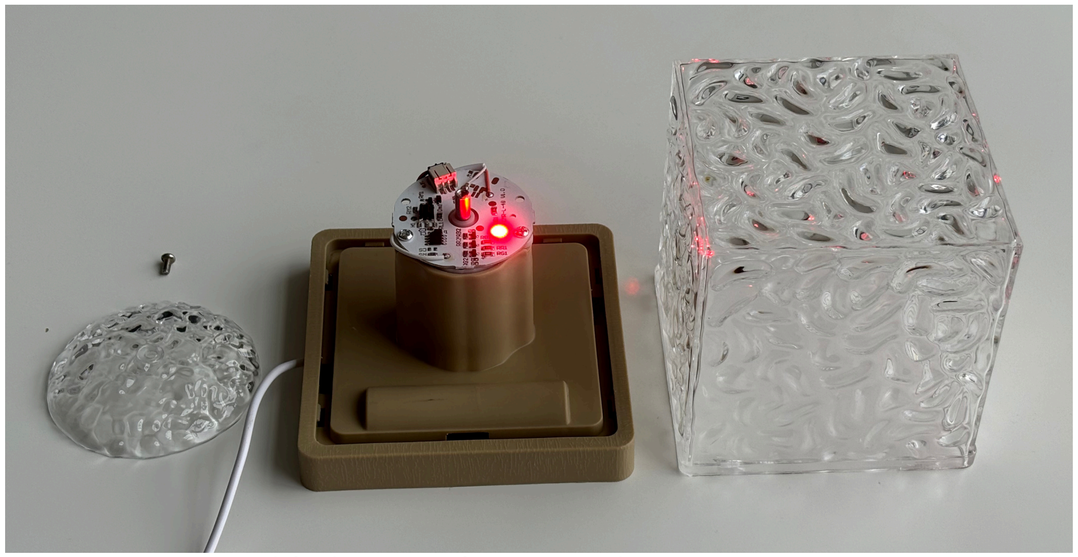


Fig. 64: Disassembled ‘water’ lamp *(Author, 2024)*

Based on this product, it was decided that implementing this technology in a completely novel manner would be an interesting approach in the desired direction. Hence, this product and its study proved that using this method of using textured transparent surfaces, the light effect can be achieved and it was backed up by the supervisory team and the client company as well.

Keeping this technology in mind, various means of achieving this effect were tested out. This testing will be further discussed in the concept detailing section.

Fig. 65: The dome plastic part which revolves around its axis *(Author, 2024)*

Conclusion

In this section, the design process was followed to find ideas, which moved the concept development forward. In order to do so, the design direction was formulated, which aligned all the efforts towards the desired solution. Various technologies, products and effects were explored to realize the envisioned effects. The semi-transparent film for mirror state and textured transparent surface for light effect were selected. From here, the design cycle takes a more converging role, where, the concept will be detailed further and fleshed out as a potentially market-ready product.

04

Concept

Detailing

Introduction

After the concept development phase, in which possible solutions were ideated, best concept was chosen and the working principle of the concept was finalized, the next phase is to hatch out the details for the concept. In order to detail the concept completely, various components of the concept were developed and elevated to a finer, more cohesive design.

In order to streamline the detailing of the concept, the concept was broken down into its components and grouped together to form categories (seen below), individually but worked upon, in parallel. This let the design be implemented up to the final phase of embodiment design and the final prototype.

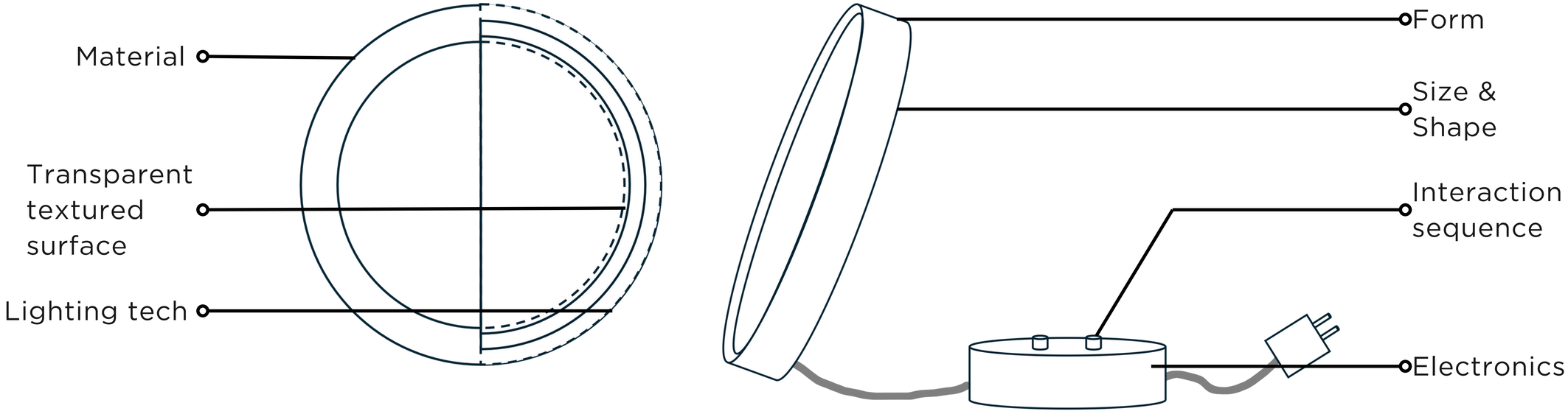


Fig. 66: Categorizing product components *(Author, 2024)*

List of Requirements

Considering the insights from the research phase, benchmarking studies and discussions with the supervisory team and the client company, a list of requirements was formed. This list of requirements was based on the Pugh's Criteria and categorized accordingly.

Pugh's criteria are extensive questions, which lead to the requirements necessary for the final design to solve the focused need. List of requirement is a living document and is constantly changed to aid the ever-changing demands of the design.

To sketch out these requirements, factors such as the target user group, the client company's portfolio and the interaction design of the product were considered. For the target user group, the use of the product by users with desk jobs and their inclination towards doing regular short duration PA were considered. The characteristics of client company's portfolio, such as 3D printed products, form-giving techniques and emotional design methods were considered as well. For the interaction design, principles of ergonomics such as use-cues, affordances and intuitiveness were considered to make the product convenient for the users to use and benefit from.

- **Performance**
  - The product must reliably translate micro-activity to the lighting effect
  - The product must trigger micro activities for the user on short and long terms
- **Size & Weight**
  - The size of the product should be appropriate for its intended use on a desk
  - The product should be lightweight and easy to handle, to move around the desk
- **Maintenance**
  - The product should withstand daily wear and tear, minor scratches and impacts
  - The product should be easy to clean and maintain
- **Aesthetics, Appearance & Finish**
  - The product should fit into client company's values and product portfolio
  - The product should be minimalistic
- **Ergonomics**
  - The product should be easy for the users to understand and interact with
  - The design of the product should guide the users on how to use the product
- **Safety**
  - The product should comply to the IP20 or higher value of IP protection class and to IK5 or higher

Size & Shape Analysis

To have a product which functions in the intended manner while giving the desired interaction with the users, the size and shape of the design needs to be studied and consecutively decided.

Here, some tests were done to find the shape and the size respectively which are most suitable to the design. The shape of the design was considered first. Once the shape was decided, the size could be adjusted by scaling it to the desired dimension.

Shape benchmarking

There were various shapes which were ideated to see the possible variations for this design. For the shape, the two light states of the product were considered, where the shape should compliment the mirror and the ripples-like-light states.

Common mirror shapes were studied to understand which shapes are already popular with the users. The similarity between existing mirror shape and the product's shape would help the users feel more comfortable with the product due to their familiarity bsis. Upon studying various mirrors, three shapes were found out to be most common, namely, circular, rectangular and organic shapes.

There are a lot of manufacturers and retailers for multiple shapes and sizes of mirrors. To simplify the benchmarking process, well-known furniture retailer, IKEA, was initially considered. IKEA has around 144 different types of mirrors. Hence, a variety of standing mirrors could be studied for the benchmarking from IKEA and few other retailers. IKEA mirror Lassbyn is the circular mirror, Lindbyn is the standing, rectangular mirror and this acrylic mirror is the organic shaped mirror sold by Amazon (Aesthetic Mirror, n.d.).

Fig. 67: Various shapes and orientations of mirrors *(Spiegels, n.d.)*

As seen here, the organic shapes do not have a defined restriction to them. They can be of any shape made from curves and does not restrict to the primitive shapes. While these shapes contain a lot of character, they gather a lot of attention on their own. Hence, it was understood that the organic shape would take more attention, rather than the effect. Since the product has a mirror-like effect rather than being an actual

Size & Shape Analysis

mirror, the complexity of producing organic shapes makes working with them difficult. Hence, the other two shapes, rectangular and circular were considered. From here, The rectangular and the circular shape were each tested. To perform the test for the rectangular, a photo frame was used with the semi-transparent film covering the background of the photo frame.

Fig. 68: Testing rectangular photo frame

Shape test

Upon studying the rectangular shape, there were various inferences which were formed. First and foremost, the corners in the rectangular shape would create overlapping of lighting effect, making them brighter than the other regions. This can also lead the design to direct the attention of the users towards the corners, rather than the overall central region. Lastly, the rectangular shape being familiar for users as a photo frame, would prompt them to associate their reflection with the stationary photos typically found in photo frames. Hence, possibly making them nonchalant about their reflections in mirror-like state.Finally, the circular shape was tested by covering the inverted portion of a square mirror available, to create a circular reflective side. The mirror setup was then placed at various locations to understand its effect.

The circular mirror shape immediately displayed a more soft and inviting aesthetic, due to no sharp corners. Most importantly, the circular shape gives an even light distribution, making it ideal for a smooth lighting effect. As the product can be placed on a desk or kept as a centerpiece, the circular shape allows the product to integrate well with the space.

Also, as circle is a universally recognizable shape, it helps in making the product inclusive, irrespective of cultural and societal differences. Moreover, the circular shape signifies continuity, reinforcing the idea of small, regular actions leading to a healthier and more active lifestyle.

Hence, the shape was decided to be circular and the form would be complemented with gentle arcs to give a coherent form design.

Size & Shape Analysis

Size test

After conducting the shape test, the size was immediately addressed for the circle. As seen in the images, various sizes were made to check the possible match. To begin testing with the range of the size which would be suitable for the design, circles of various sizes were drawn on the mirror. A range of suitable diameters was found out to be between 20 to 25cms. The extremes of this range were made out of cut outs and the reflections from the mirror in various conditions was studied.

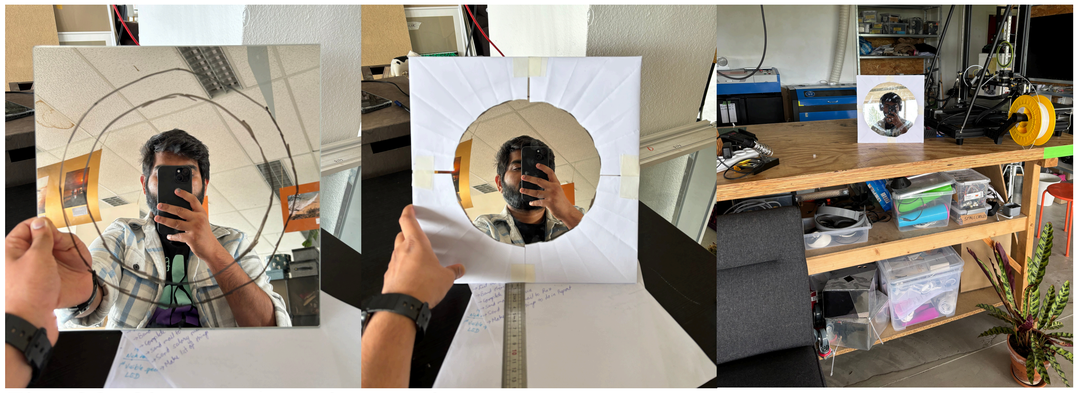


Fig. 69: Size exploration series

Upon studying the reflections, it was concluded that, in order to have optimal reflection, i.e. the user being able to see their entire face and neck, with a part of their shoulders, required setting multiple factors in place. The distance was one of the most crucial factors, as the closer the mirror was placed, the reflection got bigger and the user would not be able to see their complete face from that distance. While if it was too far then the user would not be able to see themselves amongst the reflected background. Hence both the scenarios, for desk top product usage, the product would be kept at a distance of around 40cms, while for product kept as a centerpiece would be around 5feets.

Once, the distance was finalized, the angle of the mirror surface was studied. Having the mirror surface of the product tilted upwards with an angle ranging from 20 to 25 degrees showed optimal reflection for desk top usage. The product would be best used when upright for the centerpiece usage. Therefore, further design was based on these parameters.

Fig. 70: Angle exploration series

Form Analysis

Once the shape of the crux of the concept was decided, a form around the shape needed to be implemented, i.e., a form which would be in the bezel of the product and the light effects will be in the region inside the bezels. This form translates the design concept with its decided shape, into a tangible, physical form. This helps in creating a product which is not only functional but also aesthetically pleasing and emotionally resonant.

Circular form

The most obvious forms to begin ideating after deciding on the shape of the main body as a circle, are disc and cylinder. The form was initially kept simple and mostly, a singular shape. Therefore, considering both cylindrical and disc forms, the complete product was conceptualized and evaluated. As seen below, one of the inspirations for the flat cylindrical form ideation was a minimalistic record vinyl player called Black Wheel 2 by a Dutch company Miniot B.V. This minimalistic form proved to be extremely simplistic and lacked character of its own. The Black Wheel 2 compensated for this lack of character in the form by having an ingenious technology nested inside the form. Hence, upon discussion with the supervisory team, it was decide to search for ways to introduce more character into the flat cylindrical form. In order to do so, keeping the flat cylindrical shape in mind, ideation process was carried forward.

Fig. 71: Black Wheel 2 *(Miniot bv, n.d.)*

The client company emphasized on the requirement for the final product to fit the company's portfolio during the ideation process. In order to understand the form giving technique of the client company, client company's portfolio was studied and insights were inferred from. Below, one of the studied products can be seen, while others can be seen in Appendix G.

Fig. 72: Lampet's family- Ombra *(Hola Studio, 2019)*

Form Analysis

Voluminous form

The Ombra lamp, similar to other lamps in the Hola Studio's portfolio use the basic shapes (primitive shapes) and repeat them to create a voluminous form, giving the product warm, friendly yet, steady characteristics. By having recognizable shapes and form, the product gets a minimalistic attribute to itself, which can be evidently seen in the portfolio.

While studying the portfolio, the client company suggested an interesting read, which served as one of the primary inspirations for their form-giving workflow. This book describes the form of primitive shapes present in various instances in Nature, man-made objects and around us. The book which was pertaining to the project was The Circle, one of the 3-part encyclopedia, (Square and Triangle as other 2 parts) by Italian designer Bruno Munari. This book helped in understanding the volume giving properties of primitive shapes and how using a particular primitive shape, a form of another shape can be created. This insight piqued lot of interest and led to exploration of primitive shapes in order to arrive at a minimalistic but characteristic form design.

As seen in the examples from the book here, spheres are stacked on each other to create a pyramid shape, while in the other example, circles are used in the negative space to give it volume, making the sculpture 3-dimensional, even though it consists of only flat shapes.

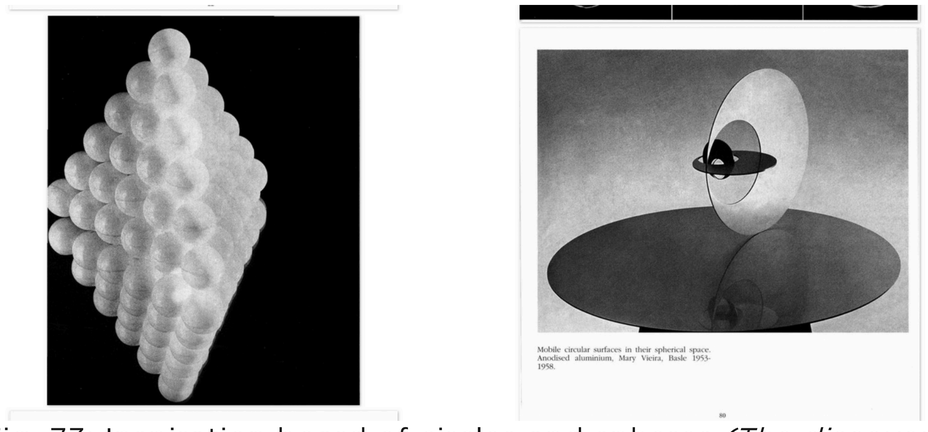


Fig. 73: Inspiration board of circles and spheres *(The discovery of the Circle, n.d.)*

Hence, taking inspiration from the portfolio study and the book, various primitive shapes, especially spheres were considered to give more volume, character and emphasis to the form of the product.

Form Analysis

Primitive shapes

Various products with primitive shapes such as cylinders, cubes, pyramids, spheres, etc. were studied. These shapes were usually intersecting with other shapes or were cut in various planes to give a more detailed form. Below, an inspiration board can be seen which was created while studying these shapes.

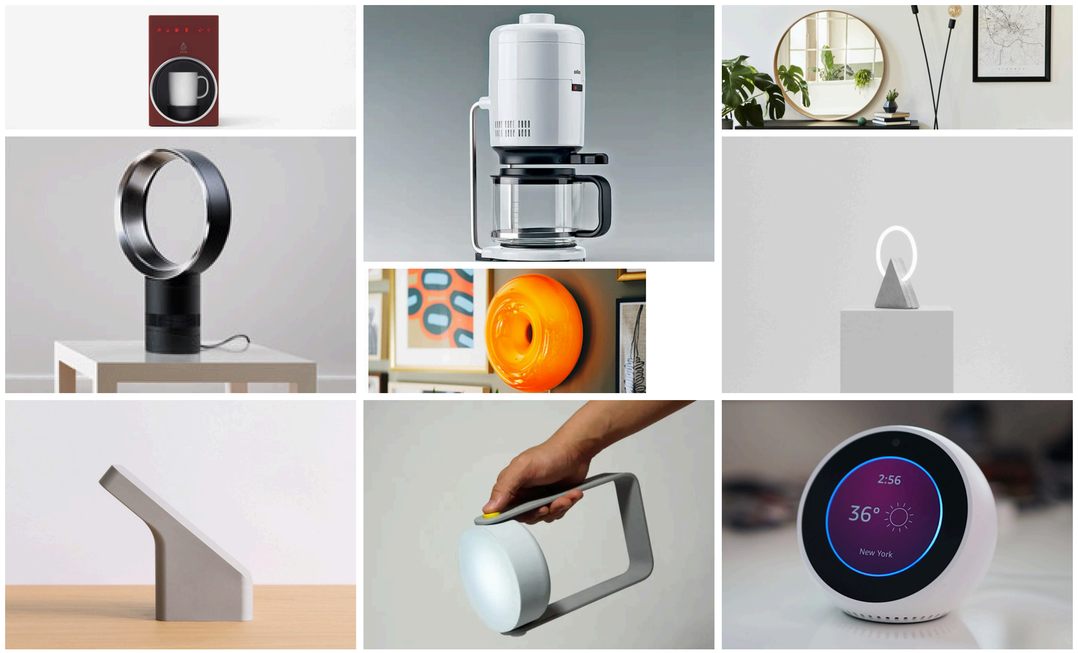


Fig. 74: Primitive shape inspiration board

Looking at these products with primitive shapes as the basis for their form, their minimalism and fusion of various shapes to create interesting forms provided a good direction to move forward the form giving process. This approach was similar to the form giving technique of the client company as well.

Ideation was carried out to generate forms using the previous insights. From all the generated ideas, a few of them can be seen below. These sketches helped in developing a quick CAD design which was done in Gravity Sketch (in VR) and refined in SolidWorks. This design was then seen true to scale in a Mixed reality (MR) environment to inspect the form. This was also recorded in the VR device and shown to the supervisory team and the client company to get their input.

Fig. 75: Primitive shape ideation sketches

Form Analysis

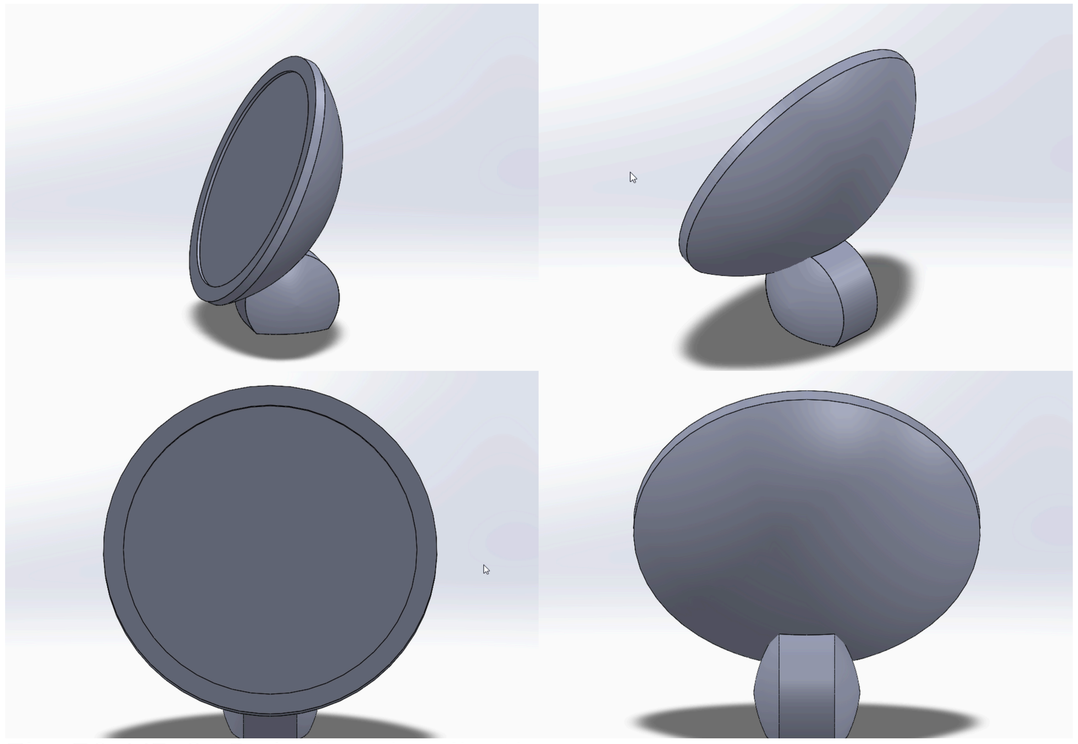


Fig. 76: VR CAD design visualization

These designs were ideated keeping the dimensional parameters in mind. Thus, the designs were keen on being implemented under the constraints of the size, angle and the distance from the user. Hence, during the evaluation in mixed reality, the design was made to scale as the sizing decided, the form had the angle incorporated into the design and the design was kept at the desired distance in the mixed reality environment from the viewer. Hence, MR environment mimicking real life scenario.

Fig. 77: Product visualization in Mixed Reality

Upon reviewing the design, the imbalance in the form was very prominent. The form gave a feeling that the product could tip over any moment. The volumes of the main body and the stand were not cohesive, making the attention drawn towards the stand. The intersecting volumes of the design made the form look stubby and rigid, giving it an unpleasant demeanor.

Form Analysis

This was seconded by the supervisory team, as well as the client company. Hence, the form giving process needed to be reworked and a better form giving method needed to be implemented. In order to do so, a lecturer from the Visualization department was contacted to get their help and expertise in making the form more inline with the intended characteristics.

Form analysis by observation

Susie Brand-de Groot, an expert in form giving and visualization was approached and the entire project, with the emphasis on the form giving process was explained to her. She agreed with the findings from the review of earlier form design and hence, suggested to rework the form giving process. She also suggested to redirect the analysis of the form by doing form analysis by observation, rather than using various methods like Gestalt's laws and golden ratio, which were implemented in the earlier design.

Hence, various products were observed to understand their form, cohesiveness and the overall silhouette created by the form of the product. Various lamps were given more emphasis as the product properties were somewhat similar. Based on these leads, the form analysis was done and another moodboard was created.

Fig. 78: Mood board from Form analysis

Based on this mood board, inferences were carried out. Use of stands to give the product a stable base, use of thin cylindrical structure to support the main body gives the appearance of lightweight-ness, connections between shapes through cylinders can indicate affordance of motion and proportional difference between the stand and the main body were important insights gathered from this mood board. Based on these insights, further ideation was generated.

Form Analysis

main body was kept as it is, due to it being the main focus of the form design and the base had to be cohesive to the main body. The ideas were then presented to the supervisory team and client.

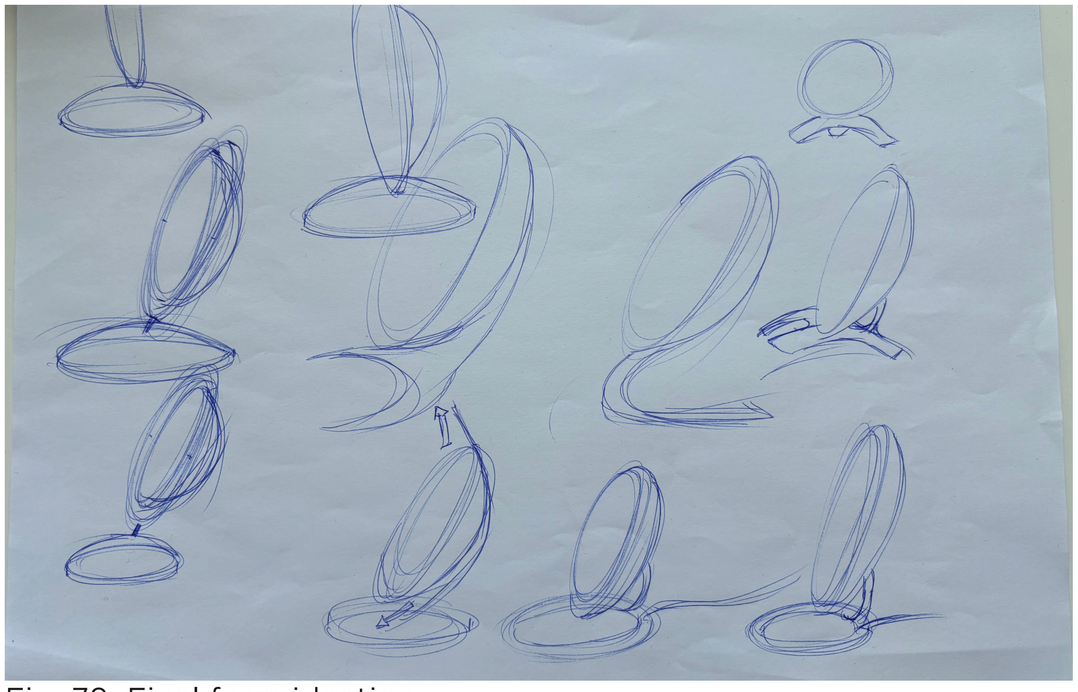


Fig. 79: Final form ideation

From the results of the ideation process such as, including a connecting cylinder and using a stand-like structure to form a stable base for the main body, discussions with the supervisory team and client company were done. The final form was selected as seen here.

The final form has a steady base which holds most of the electronics and is connected to a ring structure. This base is made to have a flat top in order to achieve the most optimal printing orientation during the production process. A ring structure is in turn connected to the main body. This gimbal-like design allows for the product to be set according to the user's preference and can be placed at an angle when placed on a desk or upright when placed as a centerpiece on a desk.

Fig. 80: Final form for the product *(Bozhko, 2017)*

Material & Color Analysis

Along with the form, the material and color options of the design were explored. The client company wanted to explore conventional subtractive manufacturing processes along with additive manufacturing, which they possess expertise in. Upon doing process and materials research, initial cost estimation and fabrication company research, it was understood that the conventional manufacturing processes would incur a big capital investment and would increase the base price by a considerable margin. Along with the increased cost, the subtractive manufacturing processes do not allow for easy changes to tweaking in design.

Hence, to keep this design project in line with the client company's tested manufacturing processes, the design was developed further to suit additive manufacturing. This also helps the client company to use their existing network of fabrication companies to find the best path forward in making the design a reality.

There are pros and cons to every manufacturing process and hence, with the additive manufacturing processes, the down sides were to be considered as well. As this design is to be produced using additive manufacturing (3D printing), the downsides of this technology need to be considered.

The load-bearing structures in the design would be compromised as the 3d printed parts would start failing when the load is applied in the same direction as the layer lines. *(Erokhin et al., 2023)* Hence, the load-bearing structures in this design are to be printed using metal 3D printing techniques.

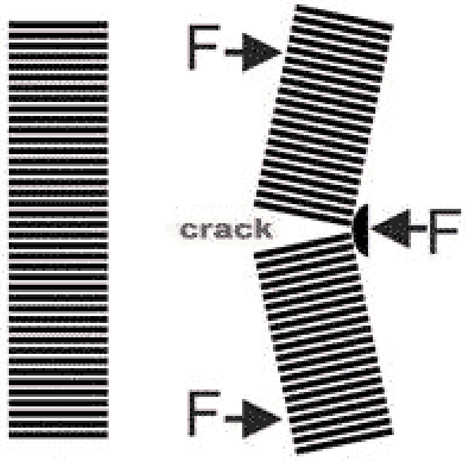


Fig. 81: Cracking of 3d prints *(FACFOX,INC., 2019)*

Hence, the product will be made with FFF (Fused Filament Fabrication) 3D printing technology. Such 3D printers are available in-house at the client company, leading to readily available production process. The metal 3D printed parts would be manufactured by fabrication companies which are already in their network and experience working with.

One of the requirements for this design mandate the design focuses on minimalistic aesthetics and thus, various color palettes which gave a minimalistic aesthetic were studied. Out of the studied colors, various 3D printing filaments were studied to match the

Material & Color Analysis

requirement. Out of the filaments considered, FormFutura's Galaxy PLA - Space Grey matched the criteria and was used to 3d print the final prototype. This space grey color has high content of silver aluminum particles which give the print a sparkling effect.

Fig. 82: 3D filament used *(Formfutura, 2024)*

This sparkling effect is further enhanced by changing the slicer software settings to fuzzy texture as that would hide the layer lines as well as give an uneven surface to the 3d print, providing an added effect of uneven reflection of light from the particles.

Fig. 83: Comparison between normal and fuzzy texture *(Print, 2024)*

Thus, minimalistic colors like black, space grey, white, navy blue are complimented with the metal 3D printed parts of connector and ring to form a regal contrast in the complete design.

Transparent Textured Cylinders

The idea of using textured diffracting elements similar to the ‘water’ lamp was aimed to be implemented in the concept. As the concept developed, the diffracting elements were looked into as well.

In the ‘water’ lamp, the two diffracting elements bend light in such a way that there is water-like, ripples-like light effect created on the wall near the lamp. To mimic this effect, similar textured, transparent, plastic diffracting sheets were bought from Hornbach, a home development and hardware superstore.

Fig. 84: Two textured Polystyrol sheets bought from Hornbach

Two sheets, each with a different texture were bought and experimented with. These sheets were meant to be cut and used in a way that the ripple-like light effect seen in the ‘water’ lamp can be seen in the center of the region surrounded by these sheets.

After some ideation and research, two methods were decided as possible means to get the desired effect. These two methods were then prototyped to test the effect created by them (as seen in fig. 86). First method was having the textured sheets parallel to the semi-transparent foil, with the light incident from the edge of the textured sheet.

Another method was where two layers of the textured sheet would be bent in a concentric cylindrical shapes and then light would be behind the texture sheets, completely surrounding them. In the ‘water’ lamp, one of the two textured sheets is in motion, giving the dynamic effect. To mimic that dynamic effect, the light source would be coded in such a way that there are pulsating lights which mimic motion of the light source.

The first phase of prototyping was done to test these methods, along with their complexities. The overall lighting effect of the first method needed to be

Transparent Textured Cylinders

observed. For the second method, the feasibility of the method and the apparent motion of the light source being similar to the movement of one of the texture sheets needed to be observed. The inspirations for both the methods can be seen in the images below.

Fig. 85: Visual representation of two methods to be tested *(moslash, n.d.)*

Prototyping phase 1

In the first phase of prototyping for the diffracting elements, simple 3d printed structures were created to test both the methods.

For the first method, a 3D printed part which would hold the textured sheet upright was made. It had space for the LED strip to pass through without restriction. This LED strip was then moved along the length to see the effect created by this arrangement. The two types of textured sheets were interchanged to see their respective effects. The images form this test can be seen below. For the sake of convenience, the LED strip was taped to the table top while the whole arrangement was moved to mimic the dynamic effect. Two different kinds of LED strips were used, one having warm white-yellow color and another being a RGB LED strip.

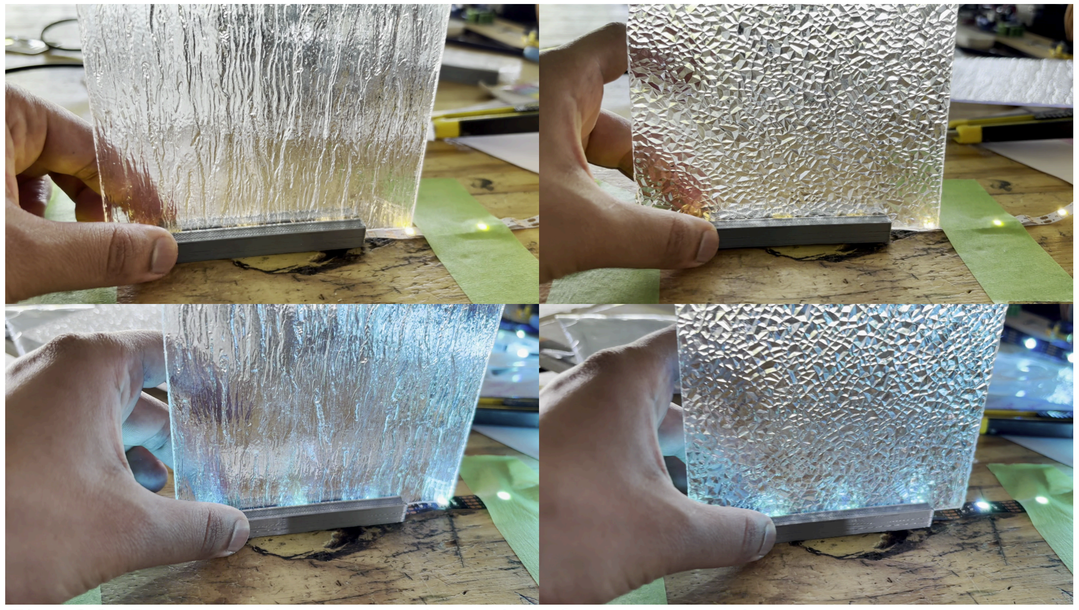


Fig. 86: Prototyping phase 1 testing for method 1

After testing the first method, the second method was test. For this purpose, thin strip of the textured sheets

Transparent Textured Cylinders

were cut from the entire board and they were fit inside a 3D printed part. This part was used to stack two textured sheet strips, with the LED strip able to move along its length. The 3D printed part was stuck on a sheet of white paper on its side, to give a surface for the light effect to be displayed upon.

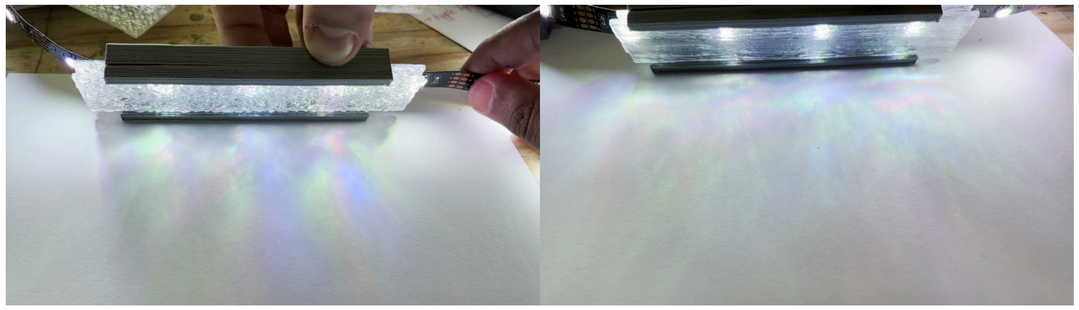


Fig. 87: Prototyping phase 1 testing for method 2

Through this test, the project aimed to study the difference between the effect by changing the incidence angle of light, arrangement of the components and necessity for inclusion of a backdrop. Both the methods were tested to see which method produced light effects similar to the dynamic light effect seen in the water lamp, which is the desired light effect in the light state of the product.

Results of Prototyping phase 1

The prototype for the first method showed little effect and this did not translate the manner of light effect as the ‘water’ lamp, The lack of prominence of the effect was evident. The static textured sheet which is visible to the user, makes the complete lighting effect pretty lack-luster. Hence, the first method was not considered as a viable option for the diffracting elements.

The second method showed promise as the light effect very was very clearly seen on the white paper and the whole lighting mechanism was obstructed from view, hence, maintaining its level of wonder. The LED strip was observed to have diffracted into its constituent colors, giving the effect more randomness and novelty. Yet, depending on the requirements of the design, this feature of the effect proved to be desirable.

Moreover, out of the two textured sheets which were tested, the one with geometric patterns showed very sharp diffractions and gave a very sudden transition in the effect. This was against the soft ripples seen in the water lamp, and thus, the wavy patterned texture sheet was selected.

Hence, the second method was considered as means of mimicking the lighting effect. However, this testing was done with the stack being comprised of straight strips. The change in effect when this setup was transformed to be fit in a circular shape, needed to be studied. Hence, another phase of prototyping was undertaken.

Transparent Textured Cylinders

Prototyping phase 2

To continue testing the second method, the infinity mirror prototype provided by the client company was used to be alter the design needed for this project. In the infinity mirror, the reflective back surface is used to create the ‘infinity’ effect. This was an undesirable effect for the product. Hence, the reflective surface was replaced by a white blackout paper which acts similar to the white paper used in the phase 1 of prototyping.

As a programmable LED strip was already placed inside the infinity mirror, this LED strip was reprogrammed to get a moving wave pattern of colors to mimic the movement of the LED strips. This reprogramming was supposed to depict dynamic changes in the lighting effect, while the whole setup remained stationary.

To be able to incorporate the textured cylinders in the circular form factor of the infinity mirror, which is the desired shape for the product as well, the textured sheets were cut into thin strips and bent to create cylindrical bodies. The complete process, along with the aspects which failed and worked can be seen in appendix H. The cumbersome nature of producing these bent textured cylinders begged for a change in approach towards production of the cylinder.

After multiple iterations (which can be seen in detail in Appendix H), the finalized transparent textured cylinders were developed using FDM 3D printers for prototyping and will be 3D printed using clear resin SLA 3D printing. The cylinders were given a thin formfactor as they are not load bearing structures and do not require strength. The thinness of the cylinders offers improved transparency.

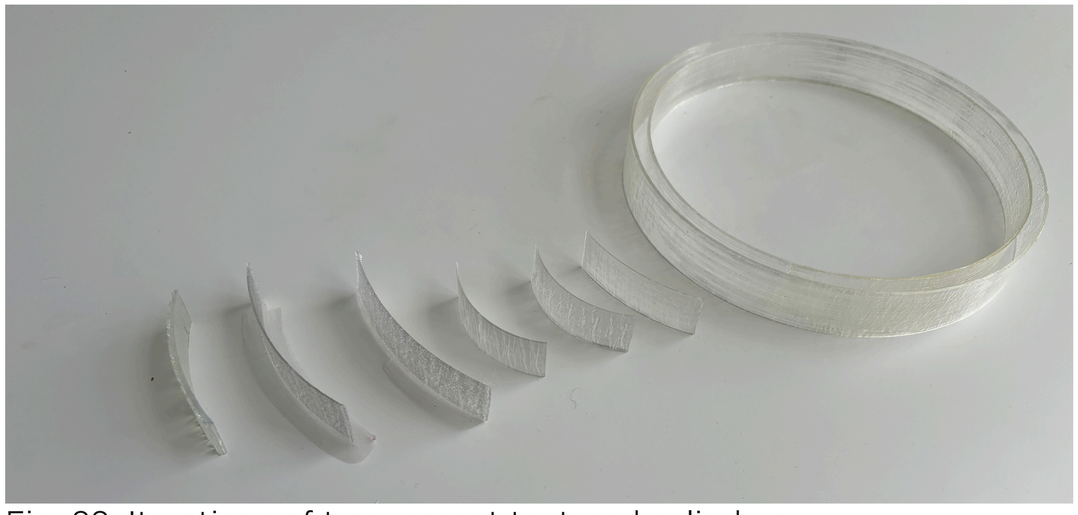


Fig. 88: Iterations of transparent textured cylinders

These cylinders were then placed inside a prototype frame of the main body and tested. The test results displayed the light effect reaching to about

Transparent Textured Cylinders

Results of prototyping phase 2

The test results displayed the light effect reaching to about one-fourth distance of the diameter of the face of the main body. The effects created by these cylinders were similar to the water effect, yet because they are projected on a smaller space with lesser distance as compared to the water effect in the ‘water’ lamp, the effect seen in the testing seems to be closer together. Though the effect is slightly different, the effect seen here still gives the precursory indication, such that, the absence of such an effect would motivate the user to change the state.

Fig. 89: Testing of transparent textured cylinders

Fig. 90: Testing of transparent textured cylinders in prototype

Hence, from this testing the transparent textured cylinders and their effect was tested and finalised.

Lighting Technology

As seen in the prototyping phase of the diffraction elements, various LED strips were tested. The warm white LED strip did not create an effect which was contrasting enough to give a beautiful lighting effect. While the non-programmable RGB LED strip did not provide the flexibility to create customized lighting and color patterns. Moreover, the preset color states were for basic color combinations (16 preset color states), which did not give a higher level of customization.

Hence, programmable LED strip was chosen to have complete control over the lighting conditions of the product. Two types of programmable LEDs, RGB and RGBW LED strips were considered. As the direct white light in the RGBW LEDs is not used in this product, RGB programmable LEDs were decided to go ahead with.

Electronics

To control the programmable (a.k.a. addressable) LED strip, a microcontroller is needed which acts like the brain of the whole circuit. In this project, common microcontrollers like Arduino boards or ESP boards are capable of doing the job. The microcontroller communicates with the chip inside the LED strip to control the light of the LED strip. WS2812 is a common chipset found on the LED strip and can be seen in the LED strip used for this project as well.

The power supply comes as 5V DC power supply, while the amperage rating (current capacity) should match the LED strip's requirements. This requirement is primarily based on the number of LEDs which are connected to one power supply. The higher the number of LEDs, higher the current drawn.

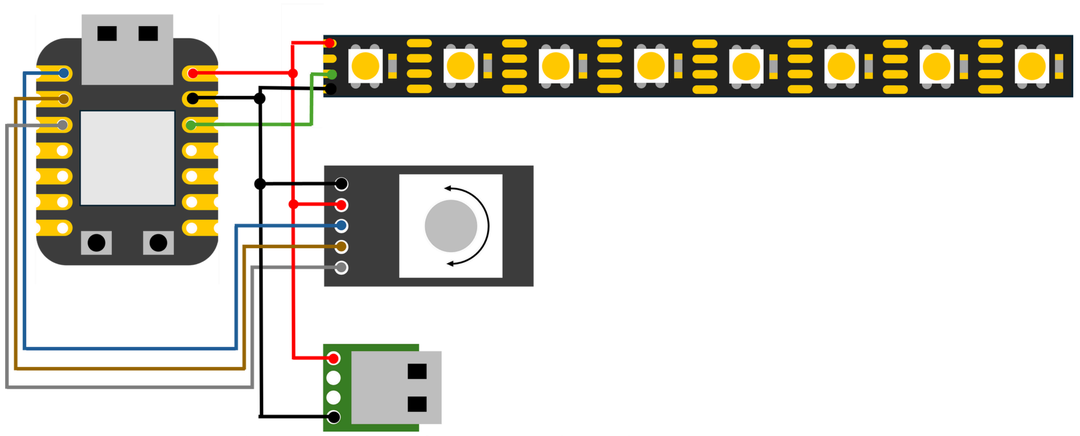


Fig. 91: Circuit diagram implemented in the project

Code

To control the LED strip via microcontroller like Arduino, libraries are used, which simplify the communication between the microcontroller and the LED strip. A popular library for controlling LED strips is FastLED. FastLED handles the low-level communication with the LED strip letting one control the color, timing,

Lighting Technology

patterns and loops in the LED strip. For this project, FastLED was used as there are extensive projects and documentation available for this library. The code was initialized on a very basic level to simply control the colors of the light. Gradually, the code was expanded to handle various patterns, timings and eventually even input devices such as switch buttons.

Control systems

Various kinds of physical control systems can be implemented into the circuit to create more customizable and user-specific product performance. Dials, pushbuttons and momentary switches are common types of control systems very readily available. These control systems can help the user change the brightness, adjust the color, choose different preset pattern or even switch on and off the product.

Some products have complex control systems implemented in their design to minimize the number of control systems to interact with. This in turn increases the complexity for the singular control system, as it has to perform one or more functions. Usually, such complex control systems require their custom PCBs and codes which can easily get complicated for such setups.

The dial control system in Black Wheel 2 is a custom made system with custom PCB and custom dial mechanism. As seen in the image below, the control system becomes increasingly complex and expensive. It might also be confusing for the users trying to figure out which gesture does which task.

Fig. 92: The dial-buttons module in Black Wheel 2 *(Miniot, B.V., n.d.)*

Conclusion

As the requirements for this design are basic, the circuit is not complicated and can be made using readily available components. To have ease of interaction, the control system used are pushbuttons.

Conclusion

In this section, the concept was detailed out and the sections mentioned in the introduction were addressed.

List of requirements gave a basis for the final design to be scrutinized against. These requirements are not completely defined yet, as the LoR is a living document and constantly changes based on the development of the product. Yet, this acts as a good starting point for the company to go on from.

The size and shape test helped in deciding the physical constraints of the product which was further translated into the form and the final design.

The form and material analysis gave way to the realization of the concept in terms of making it a tangible product. The insights from these subsections can be used by the client company to evaluate the final design.

Diffraction elements, lighting technology and the user scenario sketch out the finer details of the concept, bringing it closer to actualization.

05

Embodiment Design

Technical Information

Based on the final design and the components to be included in the design to make it functioning, the embodiment of the design was carried out. This embodiment process can be seen across this section.

For convenience, the complete design is divided into multiple bodies. These bodies together form a functioning design which can be produced by the client company. As seen here, there are three bodies, namely, base, ring + connector, and main body. By assembling these three together, the complete product can be made.

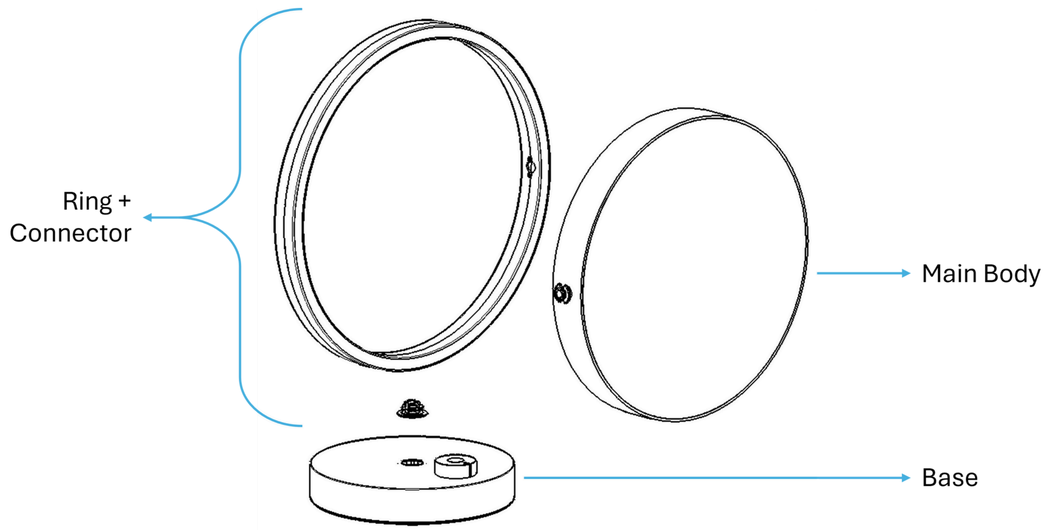


Fig. 93: Exploded view of the complete design

Here, the dimensions for the base can be seen along with exploded view of the base showing the base body, base plate and encoder knob.

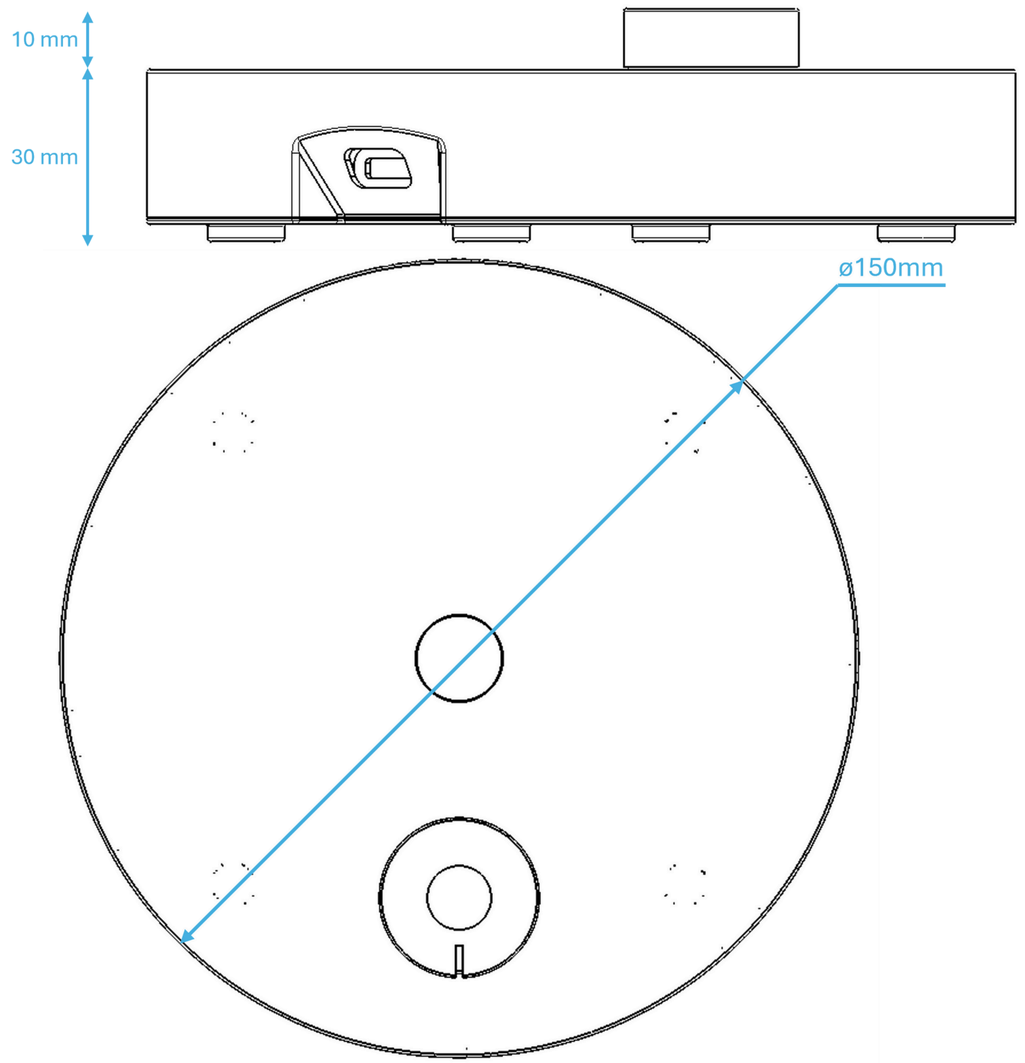


Fig. 94: Back-left and Top view of the base along with its dimensions

Technical Information

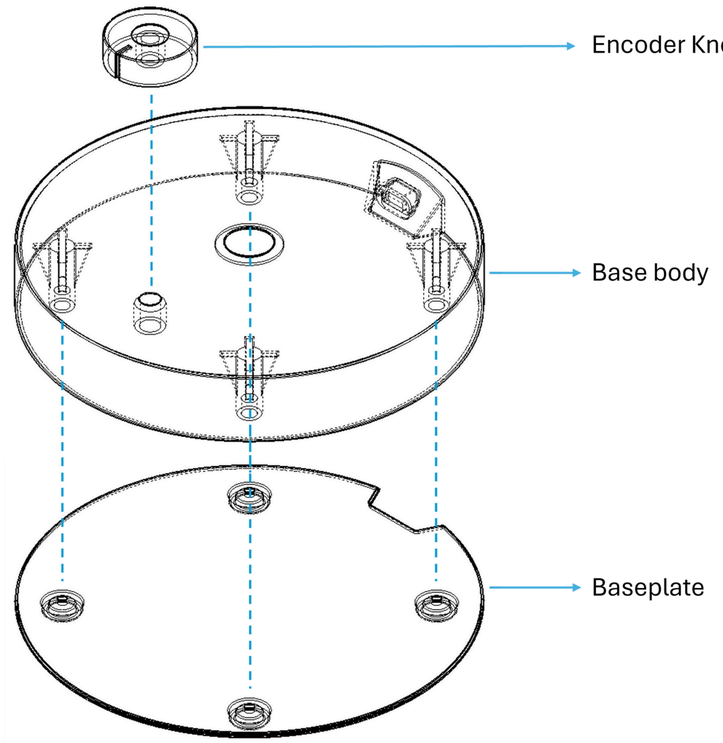


Fig. 95: Exploded view of parts of the base

The base plate is to be secured to the base body by four m3*8 bolts and there has been space provided in the design to fix m3 brass inserts in the ribs in the base body. The electronics will be secured inside the base body and wires for the LED strip will pass through the hole in the middle of the base body.

Following to the base, the ring is connected to the base by a connector. The ring will hold the main body, allowing for tilting of the main body at various angles. As the ring and connector are load-bearing parts, they are meant to be manufactured using metal 3D printing technologies. The connector and the ring use pin and slot mechanism to control the rotation of the main body.

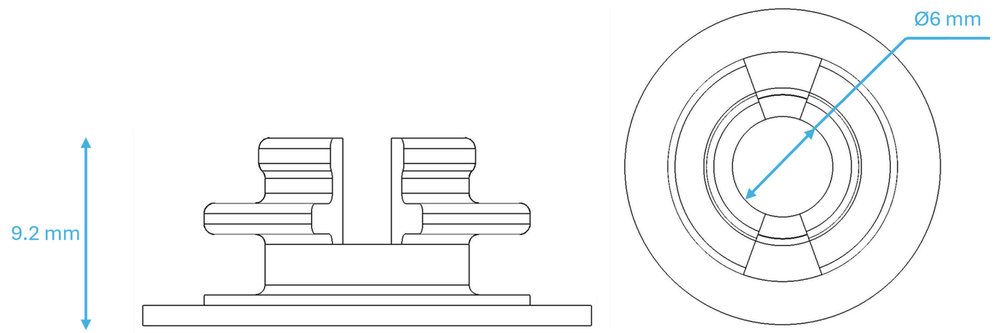


Fig. 96: Front and Top view of the Connector along with its dimensions

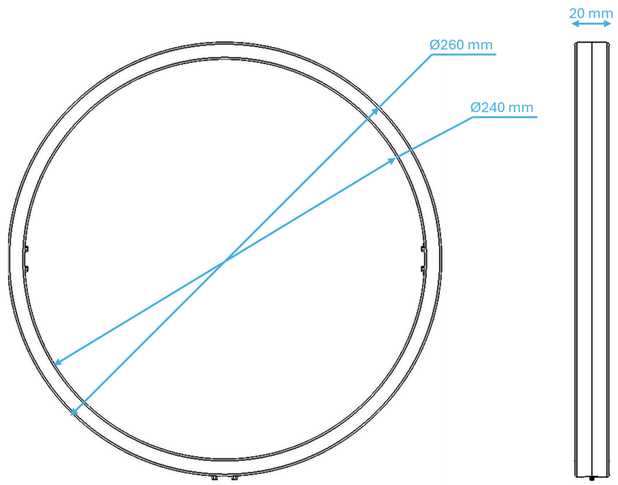


Fig. 97: Front and Side view of the Ring along with its dimensions

Technical Information

The wires for the LED strip would pass through the connector and then follow the hollow ring towards the side, where it will pass through the ring to reach the LED strip in the main body. The ring is split in 2 parts to facilitate hollow geometry of the ring.

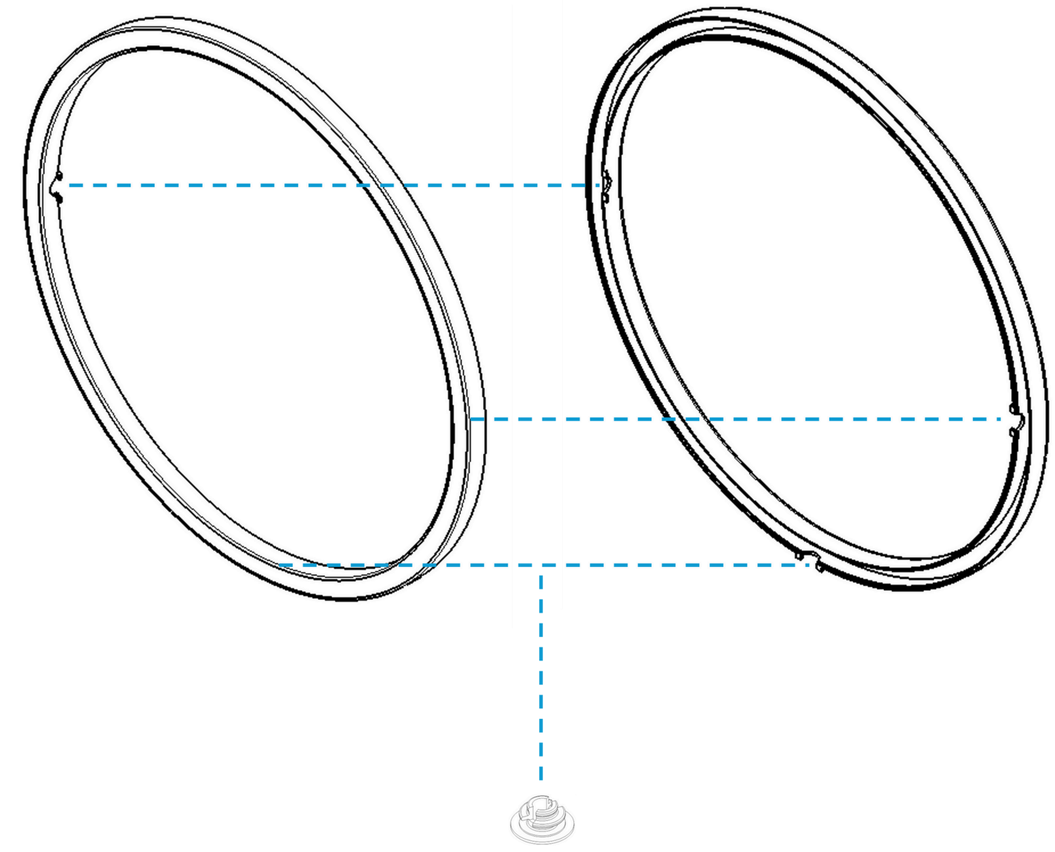


Fig. 98: Ring and Connector to be assembled together as shown

The main body houses the crux of the design, by housing all the optics for the design. These optics along with the LED strip lead to the ripples effect. Here, the exploded view of the main body can be seen. The LED strip were placed on the near end of the inner shell. The transparent sheet would be placed in between the two parts of inner shell, which is in turn press-fit in the outer shell. Following to this, the MDF backdrop and the semi-transparent sheet were press fit to the shells.

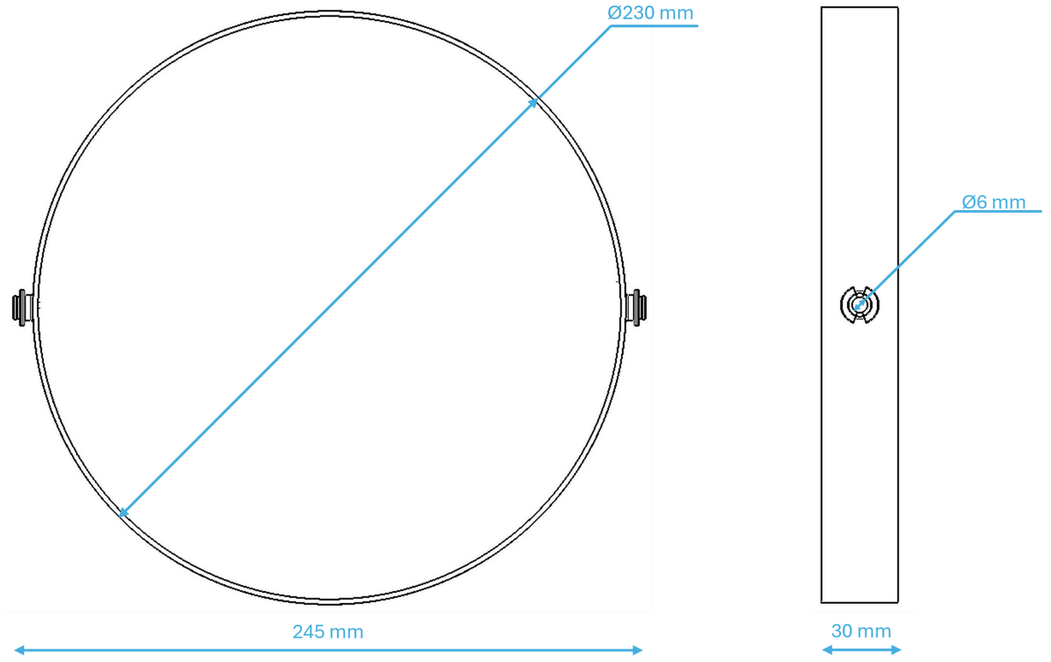


Fig. 99: Front and Side view of the main body

The order of assembling the complete product would be as follows:

- Stick the LED strip to the Inner Shell_1
- Fix textured cylinders to the Inner Shell_1

Technical Information

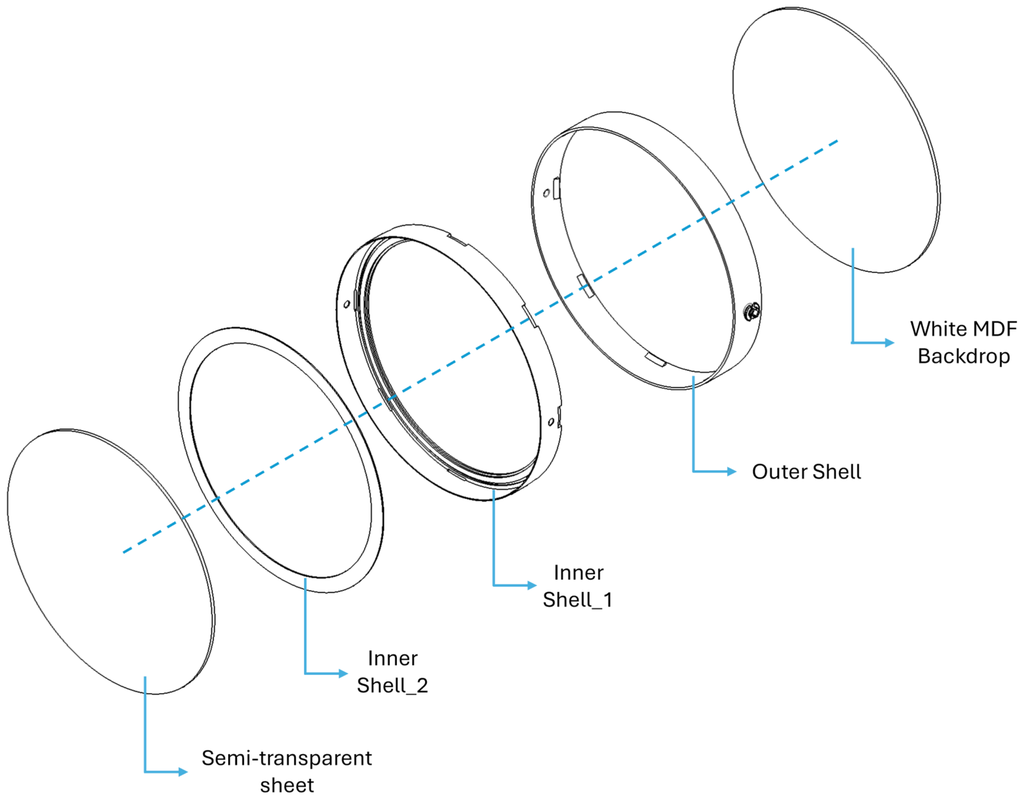


Fig. 100: Ring and Connector to be assembled together as shown

- Cover them with Inner Shell_2
- Press fit the Inner Shell in Outer Shell after aligning the tabs to each other
- Take out the LED wires through the holes in the shells
- Press fitting the MDF backdrop to the backside of the main body

- Press fitting the semi-transparent sheet to the front side of the main body
- Fix the lower side of Ring to the tabs on the sides of the main body
- Pass LED wires through the cavity of the ring and cover the top half of the Ring
- Stick the Connector to the Base Body
- Pass the wires through the Base Body and the Connector, and press fit the Connector to the bottom of the Ring
- Assemble the electronics in the Base Body
- Connect the LED wires to the electronics
- Press fit Encoder Knob to the knob shaft of the encoder
- Close the Base with the Baseplate

By following these steps, the assembling can be done without coming across any potential issues in the production.

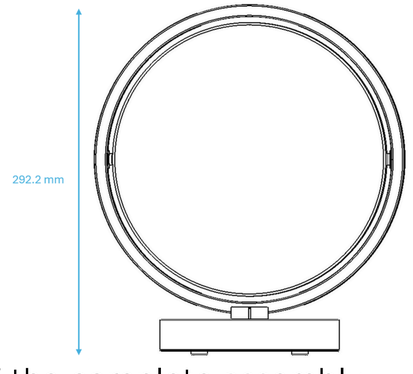


Fig. 101: Front view of the complete assembly

User Scenario

- The user of this product starts their work day and as they switch on their workstation, they switch on the device as well.

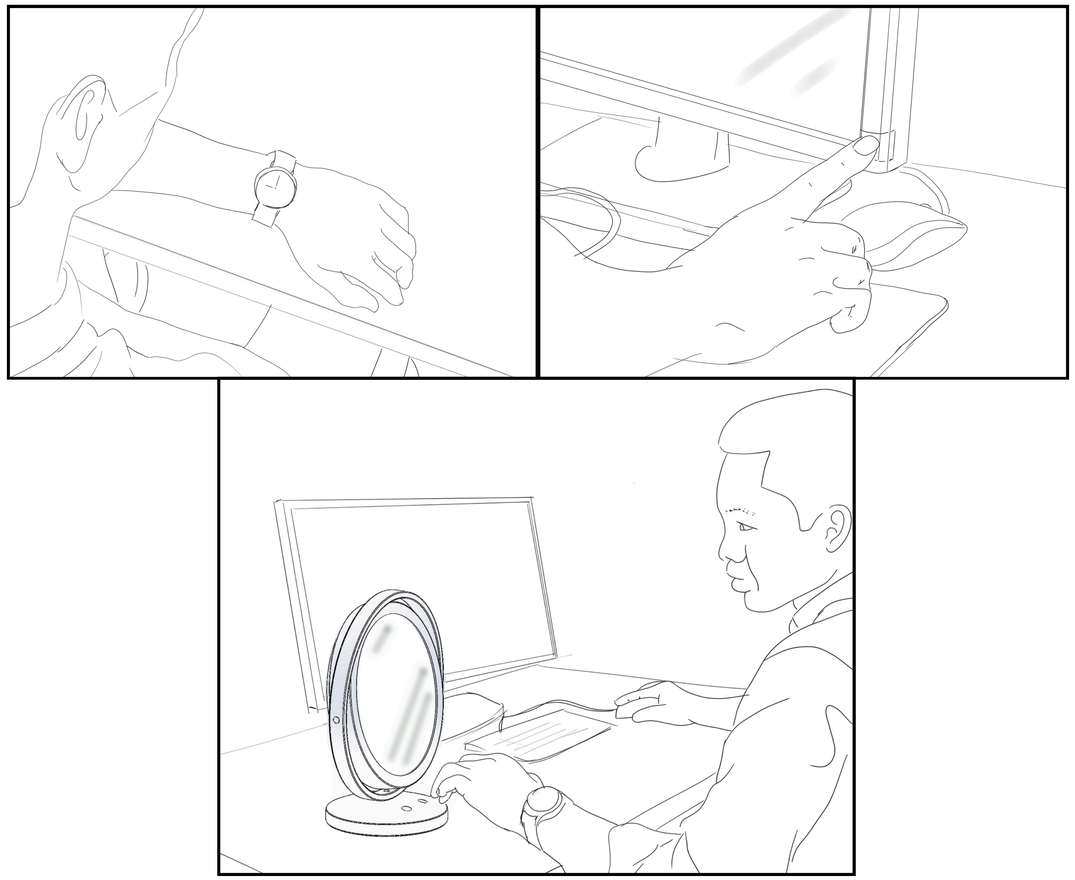


Fig. 102: Switching on the workstation and the device

- The user looks at the backside of the device for the Charging port. Here, the user connects any of their high wattage charging cables to power the device as shown here.

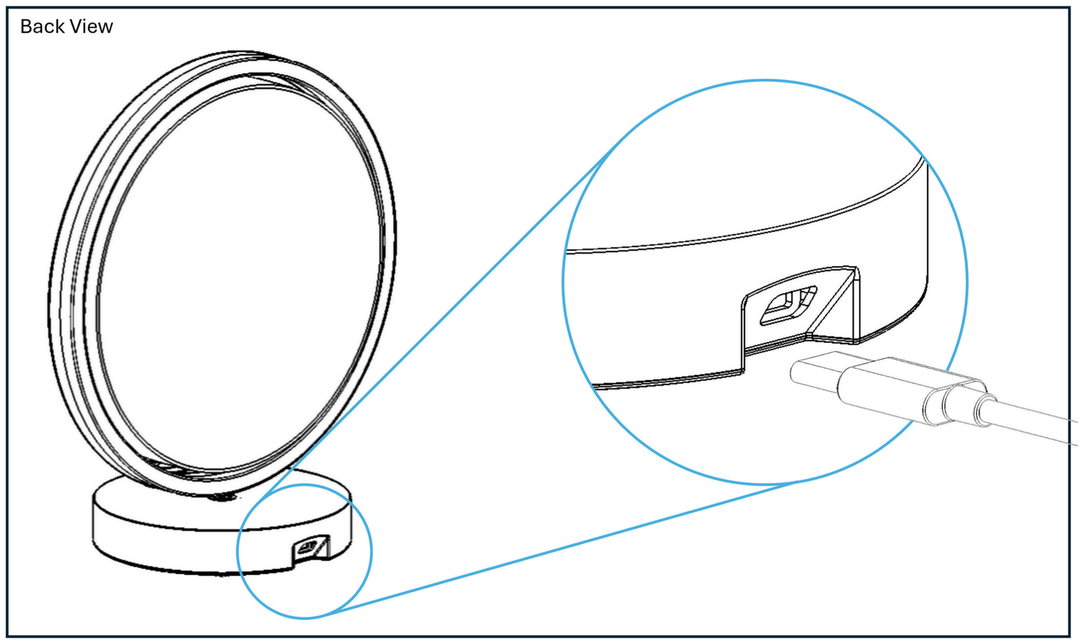


Fig. 103: Charging port of the device

- The user long presses on the center of the knob on the front side of the base of the device to turn on the device as shown.

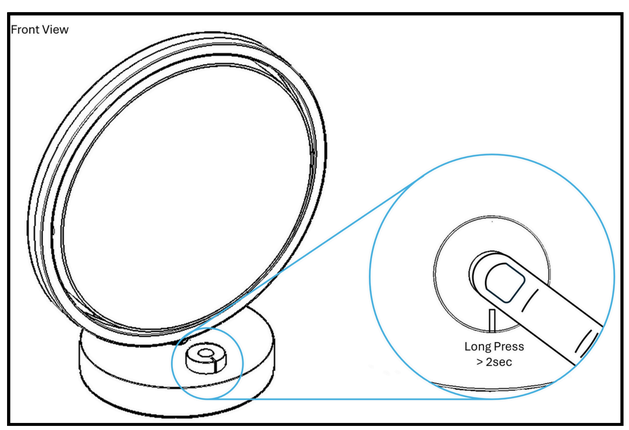


Fig. 104: Long pressing the knob to switch on the device

User Scenario

- After the device turns on, the device goes through a startup sequence which indicates functioning of the lighting system. This sequence can be seen as a rapid filling of the complete front face of the device with light, followed by clearing of the light in a similar motion. Then the device shows the standby/mirror mode by the light being shone from the topmost part of the front face in intervals.

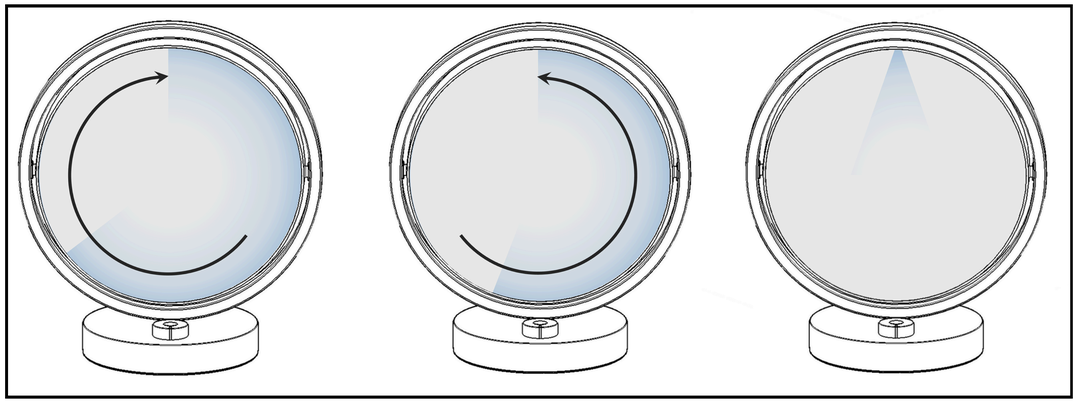


Fig. 105: Startup sequence

- The user makes sure that there are no gaps in the light effect and if so, then necessary maintenance interventions need to be followed.
- To set the timing, the user presses once on the center of the knob to move to the configuration mode. This is indicated by blinking of four light sources like a clock's 12 o'clock, 3 o'clock, 6 o'clock and 9 o'clock positions.

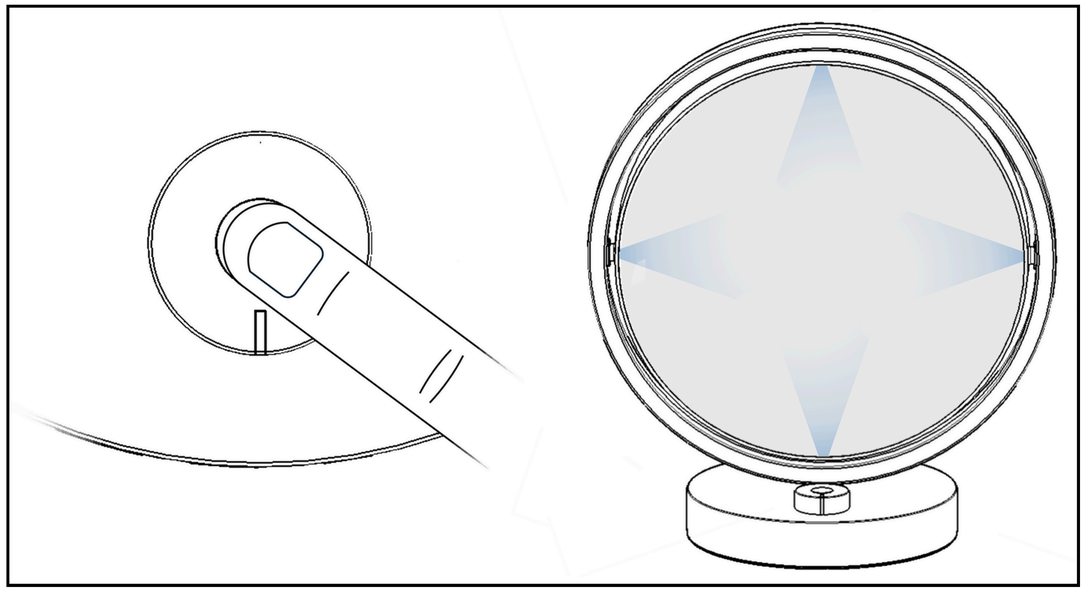


Fig. 106: Entering the configuration mode

- In the configuration mode, the timing works on a 1-hour cycle. The total time for micro-activity and the cool-off time will always be an hour. The user turns the knob clockwise to set the time for micro-activity they desire to do in each cycle. The front face acts as a clock and hence, for e.g., at the 2 o'clock position, the micro-activity time will be set to 10 minutes. The device will automatically calculate the time for the cool-down activity. The user turns the knob clockwise or counterclockwise to increase or decrease the time for the micro-activity respectively. The user presses the center of the knob once to confirm the setting.

User Scenario

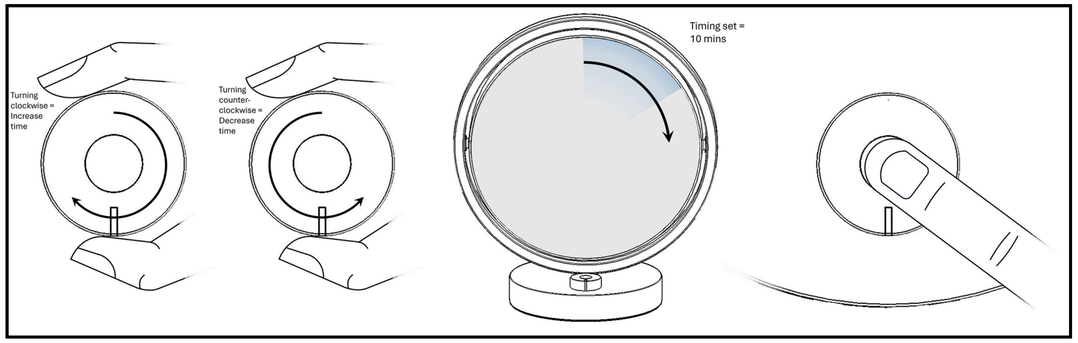


Fig. 107: Setting the timing in the configuration mode

- Following the configuration mode, the device will again moves to the standby mode, until prompted to move to the micro-activity mode, which is done by double clicking the knob. This starts the micro-activity.
- The user performs any kind of physical activity they like during the preset time.

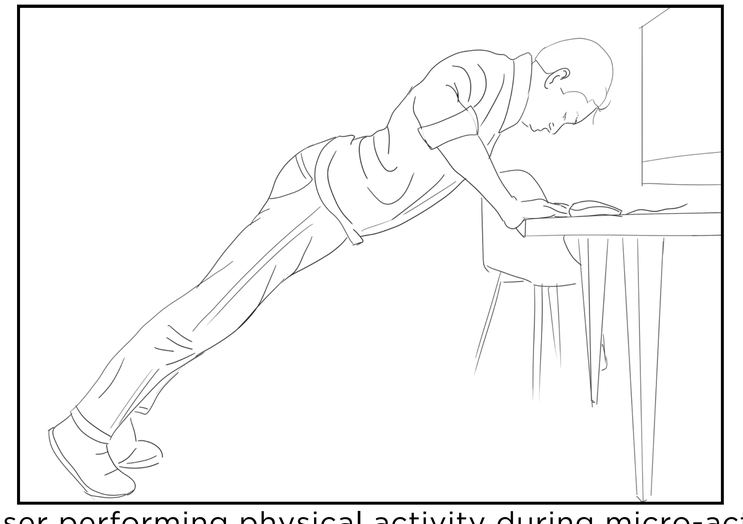


Fig. 108: User performing physical activity during micro-activity time

- During this sequence, the front face of the device is slowly light up with pulsating waves of light to indicate the passage of micro-activity time. For e.g., if the micro-activity timing is set to 10 minutes, then it takes 10 minutes for the front face to be entirely lit up.

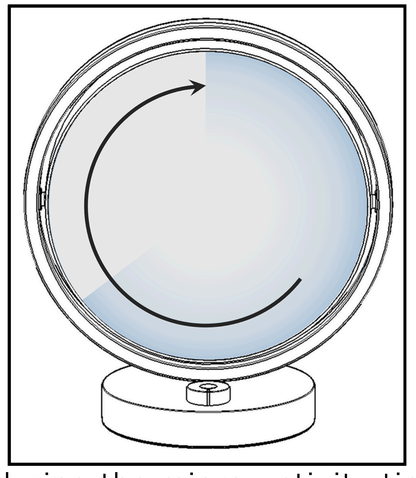


Fig. 109: Effect seen during the micro-activity time

- As the micro-activity sequence proceeds towards completion, the entire front face is lit up. Consequently, after the end of the micro-activity period, the entire front face blinks for a duration of 5 seconds to indicate the end of the micro-activity sequence

User Scenario

- After the indication of the end of the micro-activity sequence, the cool-down sequence starts where the front face of the device slowly turns down with pulsating waves of light to indicate the passage of cool-down time. This proceeds until the entire front face has been turned off, indicating the end of the cool-down sequence and one complete cycle as well.

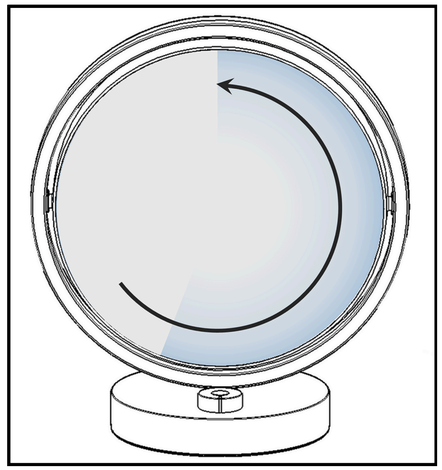


Fig. 110: Effect seen during the cool-down time

- Upon completion of the cool-down sequence the front face will blink for a duration of 5 seconds to indicate the end of the cool-down sequence and the cycle.
- Now, the device goes back to the stand-by/mirror mode to indicate the opportunity to start another cycle of micro-activity, which can be done by the user by following steps after turning on the device.

Manufacturing Process

To manufacture the product, many conventional manufacturing processes were considered. Sheet metal bending, welding and cold-cutting were seen as viable options to form the parts of the product. However, based on the cost structure, client company's values and business plan, the final production technique chosen was 3D printing technologies.

For this project, the cost structure had to match with the target user group. As the target user would be an earning individual, yet, requires motivation towards making investments towards a health lifestyle, this made the margin for markup as a non-luxury product. Hence, the production of the design needed to be as cost-effective as possible. Since metal working is fairly expensive as compared to 3D printing, client company preferred, similar to their past projects, to use 3D printing method as primary mode of production.

The client company boasts extensive knowledge in 3D printing technologies. Hence, 3D printing aligns perfectly with their expertise, allowing them to leverage their experience in delivering high-quality, innovative products. As discussed in the introduction, the client company uses characteristics of 3D printing such as on-demand production, minimizing waste and resource consumption.

These characteristics are further complimented by considering a staggered launch of the product. It is recommended to the client company, to release a kit which contains CAD files of the 3D printed parts along with non-3D printed components such as electronics, semi-transparent glass, MDF, etc.

This approach, also known as 'Peer production' can be used to create a low-budget solution which implements individual resourcefulness to bring the product in usage throughout the community (Benkler, 2016). In this project, a Kickstarter campaign can be used to create initial traction for the product in the market. Here, the peer production kit can be used. This 'print-yourself' kit will further highlight the company values of importance of conscious production techniques, while widening the market reach as the kit will be comparatively inexpensive to the complete product.

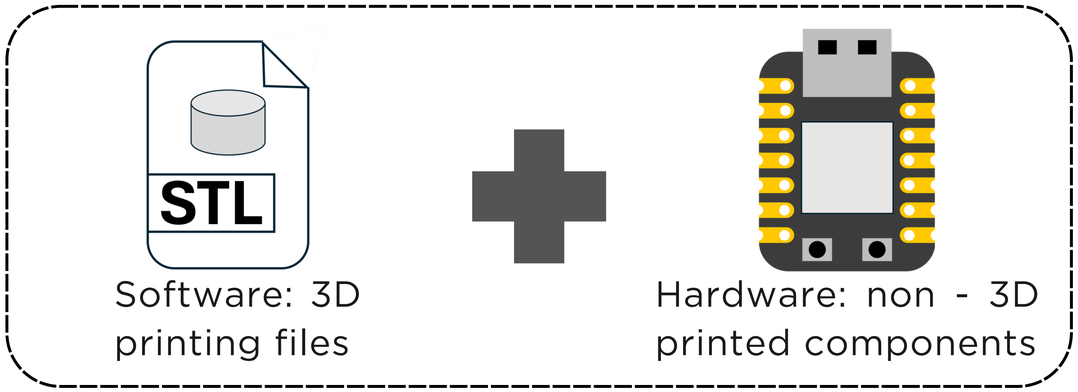


Fig. 111: Print-Yourself kit for Kickstarter campaign

Manufacturing Process

This peer production technique cannot be done on a large scale by any other conventional manufacturing techniques. Hence, 3D printing is the chosen method for this project. Further explanation regarding the staggered launch of the product can be found in the next subsections.

Here, for the conventional product sales in the form of online website sales, the manufacturing of the 3D printed parts will be carried out in-house. The specific methods for the components of the product are:

- Base and base plate can be produced using a good quality FDM 3D printer, without much hassle of supports or complication, thanks to the simple design.
- Connectors of base to the ring and ring to the main body can be outsourced by external fabrication companies which can 3D print metal and produce the parts accurately.
- Ring structure which holds the main body can be 3D printed in-house as well. The ring does not fit in regular size 3D printers and hence, would require to be printed on a bigger printer.
- Main body can be produced on regular 3D printers and give good results. Necessary components can be fit inside the main body by designing using the known tolerances for FDM printers.
- Textured cylinders need to be outsourced as they are made on SLA resin printers using transparent resin and post processed to make them completely transparent. Companies like JLC3D can be approached to get these components ready.
- Custom glass panes can be procured from various glass retailers. A sheet of such glass is usually 1 sq.m. which makes the cutting of the custom glass pane as 16 panes per sheet and these panes can then be coated with the self-adhesive semi-transparent foil. This coating process will be carried out in-house.
- White MDF sheets can be similarly used to create circular backdrops and from a single sheet on an average about 12 to 16 backdrops can be created. This can be made by laser cutting white MDF sheets in-house.

Using these simple and sustainable production techniques, the client company can realize a product which forms instant connection to the users and brings a high value proposition.

Cost Estimation

By accurately estimating the costs associated with the product development, manufacturing and market entry, financial viability of the product can be understood. This subsection outlines on developing a cost estimate, which will provide a foundation for budgeting, financial forecasting and investment planning for the client company.

To create a comprehensive cost estimation, the project needs to be broken down into its constituent categories and costs need to be assigned to each of them. The constituent categories to identify costs are:

- Research & Development (R&D)
- Product development
- Marketing and sales
- Technology and infrastructure
- Personnel costs
- Operational costs

As per the scope of the project, the cost of the production of one unit of the final design is calculated to be approx. €113. The part-wise calculation can be seen as follows (detailed breakdown is shown in Appendix I):

Sr. No.	Component	Price
1	Base body	~€6,20
2	Baseplate	~€3,20
3	Connector 1	~€7,35
4	Connector 2	~€7,35
5	Ring P1	~€7,30
6	Ring P2	~€7,30
7	Mainbody	~€12,40
8	Outer Cylinder	~€11,50
9	Inner Cylinder	~€10,90
10	Glass top	~€4,00
11	MDF bottom	~€1,50
12	LED strip	~€16,45
13	Control circuit	~€17,00
14	Nuts and bolts	~€0,50
	Total	**~€112,95**

Fig. 112: Part-wise cost calculation

Cost Estimation

The complete cost per unit is the sum of production cost and additional costs such as operational cost per unit. As these additional cost are highly variable and cannot be estimated at this stage of the project, the total cost per unit is assumed to be €150, considering the calculated production cost and currently unknown additional cost.

Considering the total cost per unit is €150, upon adding the markup on cost, the selling price of the product can be estimated. Keeping factors like production technique, target market and product value proposition, the markup is set to be on the higher end of the standard product markup range. For standard products, markup range is from 25-50% of the cost price of the product. Hence, the selling price is calculated to €225, keeping a 50% markup over the cost price of €150.

Hence, to summarize:

- Production cost per unit = €113
- Total cost per unit = €150
- Selling price per unit = €225 or €224,99

As mentioned earlier, the staggered launch of the product can be done by implementing peer production. Hence, the initial funding can be done by releasing a Kickstarter campaign which has a print-yourself kit, containing 3d printing files of various parts and non-3D printable components.

The print-yourself kit can be advertised as an inexpensive alternative to the conventional product sales mechanisms and increases the individualistic properties of the product according to the user as well.

Removing the 3D printing and operational costs of the 3D printed parts, the print-yourself kit would have a total cost price of around €110 and hence, the selling price of this print-yourself kit can be €129,99 straight.

Business Model

Developing a comprehensive business plan is essential in translating the innovative product concept into a viable, sustainable and profitable business venture. Here, the Business Model Canvas (BMC) document used a basis to formulate the business plan. The BMC acts as a more agile and visual approach to outline the business strategy. By filling up the BMC, the client company ca focus on key building blocks like customer segments, value propositions and revenue streams. This canvas can also help the client company to understand the core elements of the business model and identify potential areas for improvement, as the BMC is a living document and can be modified in tandem with the product development.

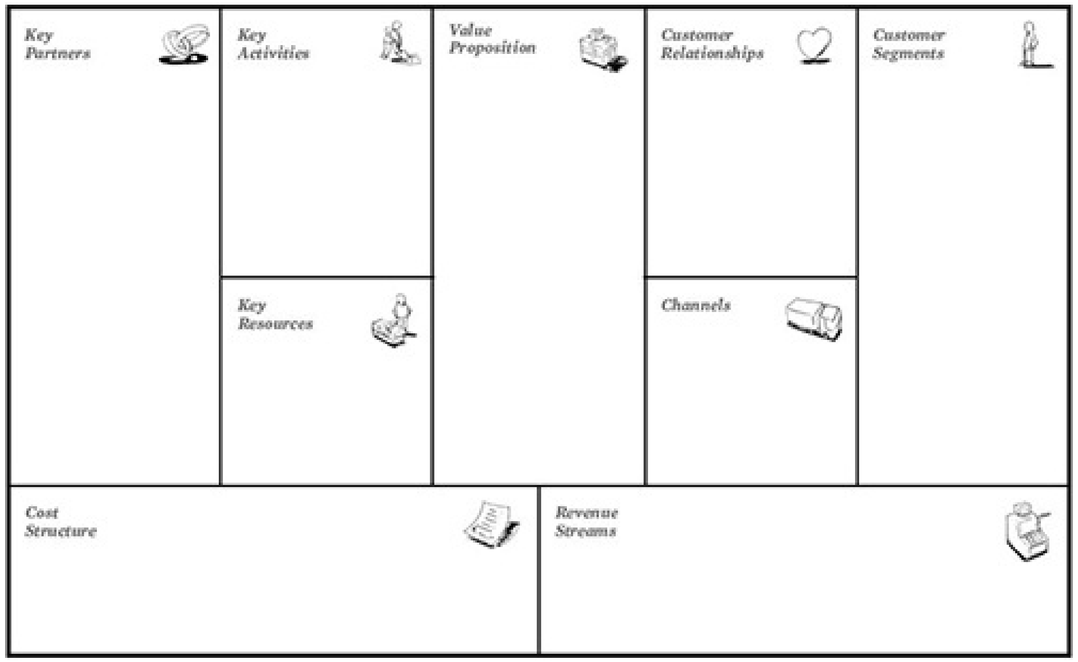


Fig. 113: Business Model Canvas *(Monsaert, 2018)*

Here, each block of the BMC is being filled out with the details mentioned as follows:

- **Block 1: Customer Segments:**
  - Office workers as primary customers
  - Individuals seeking to increase physical activity
  - Companies wanting to implement more productive practices
- **Block 2: Value Propositions:**
  - Increased physical activity through engaging in micro-activities
  - Improved cognitive functions such as focus and well-being
  - Customizable and adaptable to individual needs and schedules
- **Block 3: Channels:**
  - Direct sales through online stores as primary method to sell to the customer segment
  - Partnerships with office supply stores or wellness companies
  - Kickstarter campaign as a starting point to create traction for the product in the market

Business Model

- **Block 4: Customer Relationships:**
  - Customer support through the digital communication channels
  - Community building through social media presence and workshops
- **Block 5: Revenue Streams:**
  - Initial funding through Kickstarter pledges
  - Product sales through online store
  - Large number subscription model for companies
- **Block 6: Key Resources:**
  - Technology (hardware, software)
  - Intellectual property (copyrights)
  - Human resources (engineering, marketing, finances)
- **Block 7: Key Activities:**
  - Product development
  - Manufacturing
  - Assembly
  - Packaging
  - Marketing and sales
  - Customer support
- **Block 8: Key Partnerships:**
  - Technology providers like 3D printing and fabrication companies, PCB manufacturers
  - Components suppliers
  - Distributors and distribution channels
- **Block 9: Cost Structure:**
  - Detailed cost structure for producing a single unit of final design was discussed in the earlier subsection
  - Additional finalization costs such as design refinement
  - Production costs
  - Marketing and sales costs
  - Administration costs

This approach gives an overview for a strategic foundation for the product. By identifying key customer segments, defining a compelling value proposition displaying the USP, and outlining revenue streams, a solid groundwork has been established to developing a business around the product. The integration of a Kickstarter campaign into the model offers a way to secure initial funding and building a customer base. This business plan serves as a dynamic tool, allowing for adaptability, growth and refinement as the project progresses.

Conclusion

In this section, the concept was developed towards being more viable and congruent with the market. The target user group was kept in mind and business strategies were developed. The product was estimated to have a selling price of around 225 euros. To have a business plan which works around the client company's core values, a planning for a Kickstarter campaign was sketched out where the product would be sold in 'print-yourself' kits and thus, a larger market can be addressed through this approach.

Final Prototype

Final Prototype

Final Prototype

Components

The production process for the final prototype started with 3D printing the Base. Cura slicer was used to create gcode files for the 3D printer. Various settings in the slicer software were tweaked to get optimal print, such as concentric layer fill, smaller layer height and fuzzy texture. The 3D printed parts were then heated with a hairdryer to melt the imperfections away and get a clean surface. The base body, baseplate and the encoder knob were 3D printed respectively. All the electronics, except the LED strip were fixed in their designated positions at the base.

Ring and base connector were to be 3D printed as well. Yet, as they are load-bearing structures, their strength capacity were to be tested. Upon printing and testing them, it was found that using PLA filament to print these parts would not be provide enough strength and hence, for the final prototype, a secondary structure was created which replaced the connector and the ring. This structure gave greater support to the main body while providing allowance to tilt the main body forward or backward. However, in order to gain more support, the structure did not allow for the turning of the main body left or right. These changes in the design were considered in the validation process as well.

Here, you can see the CAD file for the structure used.

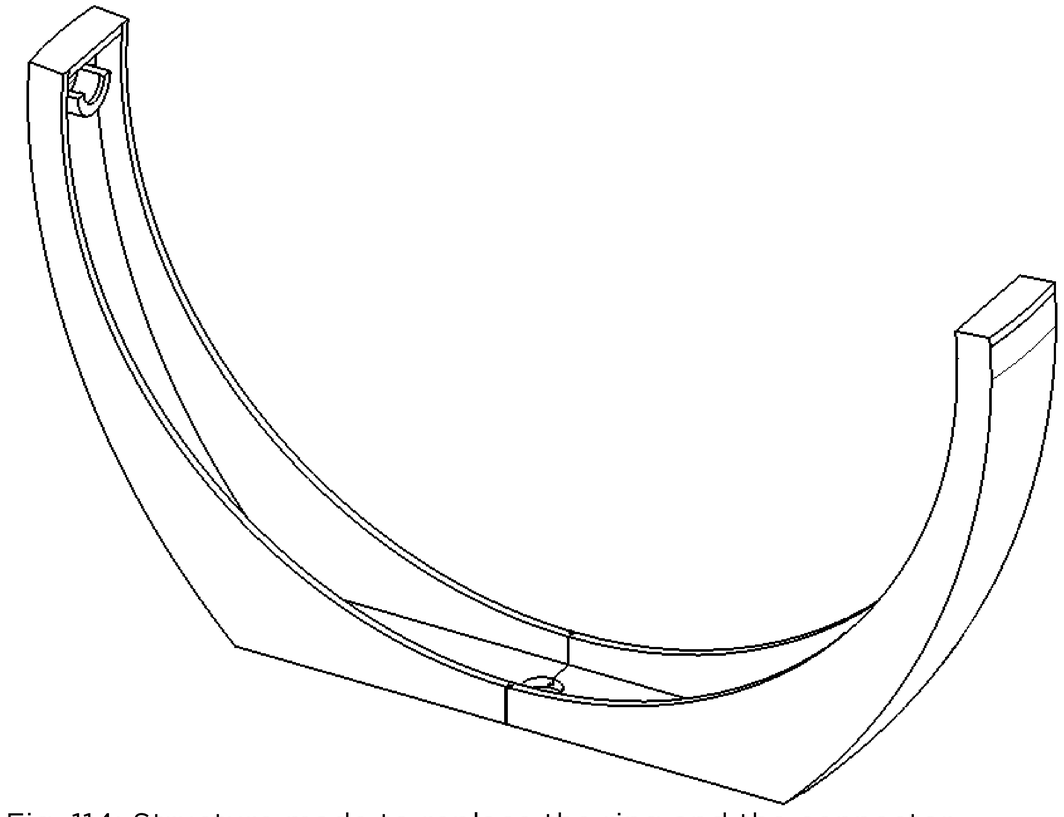


Fig. 114: Structure made to replace the ring and the connector

Due to limited resources for the time being, at the client company, the parts which were bigger than the print bed of the in-house 3D printer had to be split into smaller parts and were aligned together using lip and groove method. Hence, big parts, like ring, support structure, main body were split in smaller parts and printed.

Final Prototype

As seen over here, for e.g., the Outer shell of the main body is shown to be split along with lip-&-groove arrangement along the seam.

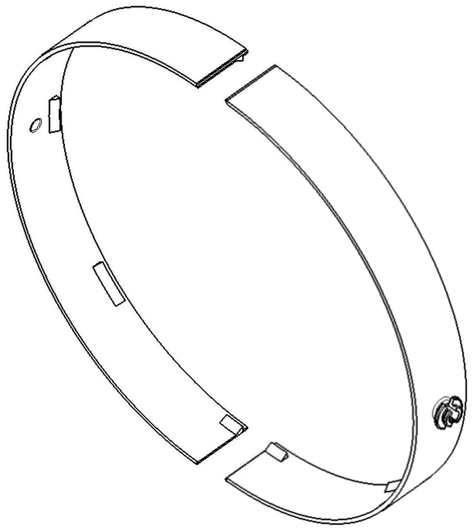


Fig. 115: Parts split to fit the 3D printer

For the final prototype, various LED strips were experimented with. Out of which, RGBW addressable LED strip having WS2813B chipset was used. This LED strip had 144 LEDs spaced out in a span of a meter. This high density of LEDs was used to get a smooth transition of effects between the LEDs and to prevent a jagged visual due to the change of light from one LED to another.

To control this LED strip, a microcontroller was used. The microcontroller used was the XIAO ESP32-C3. This board has a very small form factor, allowing for more space to add hardware to the circuit, while handling the required programming of the LEDs effortlessly.

Fig. 116: XIAO ESP32-C3 & KY-040 Encoder *(Getting Started With Seeed Studio XIAO ESP32C3 | Seeed Studio Wiki, 2024) (KY-040 Rotary Encoder Module, n.d.)*

To help in interacting with the product and accept user input, the circuit was connected with a rotary encoder. This encoder detects turns in clockwise and counterclockwise directions, as well as has a switch integrated into the shaft of the rotor. Hence, this encoder works as a knob and a switch. Arduino IDE was used to integrate the circuit and program the XIAO board.

Final Prototype

The LED strip was programmed using the FastLED library and the preset commands in this library made it easier to set effects in the LED strip. The library also has preset color functions and the one chosen out of them was the Aqua color as that preset color gave the closest effect to the water-like ripples effect. This aqua color comprises of 50% Blue and 50% Green and hence, when passed through the textured sheets, these LEDs would give a mesmerizing pattern of varying intensities of blue and green, within the limit of 50% saturation for each.

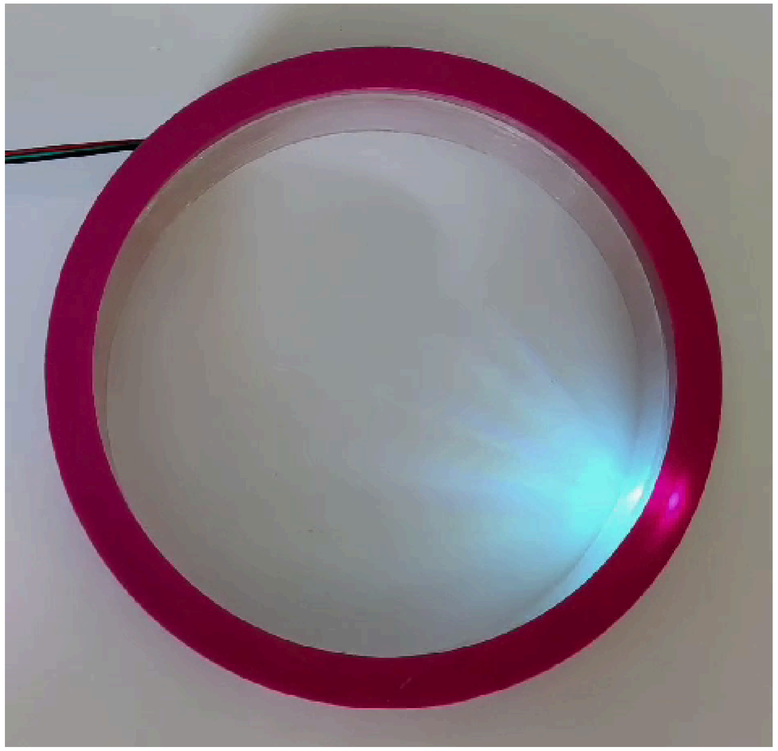


Fig. 117: Aqua color in LEDs as 50% Blue and 50% Green

Various hues and shades of colors were not extensively explored as the visual language would then not remain minimalistic and clear. This would lead to undesirability in the users. Hence, one shade of hue was considered here, as shown.

Along with this, the input from the encoder was used to form the visual feedback between the device and the user. This was done using these LEDs, as with clockwise turning of the knob, the number of LEDs lit would increase and vice versa. Thus, having a single color pattern would indicate consistent information transfer.

7 Validation Test

Validation

Product validation was carried out using the final prototype and additional documents. The method used for the tests was a combination of questionnaire, discussion and observation.

The validation test addressed three topics, namely, appearance, usability and desirability. As the limited scope of the project only allowed for short-term validation tests, the topics addressed by the validation were limited to these three.

Five participants around the age of 35 participated in the validation. These participants had at least 15-20 hours of sedentary work through the work week. Informed consent was sought from the participants before starting the validation through consent forms and user data was gathered.

The validation was done at a mutually convenient place and the prototype was kept on a desk along with a usual workspace setting of a laptop, keyboard and mouse, with some space for notebook/papers. This setting was consistently used throughout the validation to get data which is not influenced by the environment. The tests were done in daytime, near a window to gauge the necessary intensity of the LEDs required for optimal functioning. The participants were shown the prototype, along with visualization (renderings) of the final design, instruction manual and validation form [Appendix J]. The validation form gave instructions so as to how to use and when to use each element presented to the users. The setup of the validation and images of users validating the prototype can be seen here below:

Fig. 118: Validation test set up

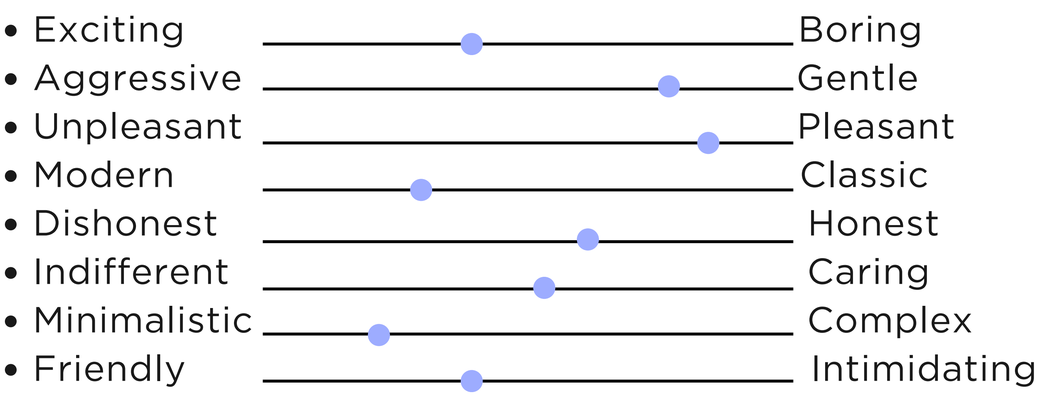
Fig. 119: Validation test conducted with 5 potential users

Validation

Here, the results from the test can be looked into. For the appearance section, users were initially asked to have a look at the prototype in Off state along with the visualizations of the final design. They were then asked to answer the questions in the Appearance section.

The first question was to name a few objects which they are reminded of while looking at the design. The most frequent answer was the bathroom mirror (all 5 users), while answers such as globe, spinning top and satellite dish were also mentioned. As the form design also relied on the existing bias of users towards a known object, having users identify it as an existing object gives them confidence in interacting with the product.

In the second question, users were asked to personify the design and rate various characteristics. These characteristics and their results are as follows:



In the usability section, the users were given time to follow the instruction manual and then were tasked to perform activities based on the instruction manual. After all the steps were completed, the were asked various questions regarding the usage of the product. \major insights from this section were:

- Charging port at the back is not ideal
- It is easy to set the timing because it works exactly like a clock
- Might create difficulty in remembering the various modes without instruction manual/experience
- The main body should not interfere with the knob

For the statements with Likert scale, the results showed that users found the functionality easy to learn (4.2), intuitive to use (4.6), comfortable to handle (3.8), has adequate number of use cues to understand the functioning of the product (4.2) and feels that it does not take a lot of time to operate the product (4.6). Hence, this shows that the product fared fairly well for the users in terms of usability.

For the desirability section, 3 out of 5 users imagine themselves using this product. Users with strict schedules or non-sedentary work would not prefer this. 4 out of 5 users would be willing to buy it, as it offers

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Validation

necessary reminders. The a few users wanted more prominent notifications as they are used to active/push notifications, while some would like to reuse this product for productivity, like for Pomodoro technique. Portability was a recurring theme in the things they would want to change about the product. One user suggested the ability to connect it to their mobile fitness app.

On an average, users found the product expensive and would want to buy it for 125 euros. One user suggested that if it looked as clean as in the render, then they would not mind paying the estimated 220 euros. All the users showed positive feedback in suggesting it to their loved ones.

Thus, the validation proved that the user would be accepting the product but with lower selling price and a higher product quality.

08

Conclusion

Conclusion

The project aimed to design a lighting solution which motivates people towards inculcating a more physically active lifestyle. The project need was extremely broad and hence, a myriad of design directions and solutions were possible. Most importantly, motivation being an intangible concept, bringing it to a tangible dimension and making strides towards making solutions which users adhere to, proved to be a difficult yet, rewarding challenge.

Extensive research was done to understand the theories, mechanisms and steps taken regarding motivation. This research led to multiple possible addressable needs, design directions and eventually solutions.

The major landmark for this project was during the phase of design direction selection. Choosing a toned-down, specific design direction gave the project a new definition.

The result was a desk accessory designed for people having sedentary lifestyle. The product motivates people to do small bursts of exercises at regular intervals to get the necessary health benefits from having a physically active lifestyle. These small bursts of exercise, also known here as micro-activities are the crux in motivating people towards an holistic and healthy lifestyle. Daily, even hourly achievements provide the necessary engagement and motivation to continue the streak of these micro activities. Light provides the necessary excitement to this process and makes the urge to see beautiful light patterns a motivator towards fulfilling those micro-activities.

Users can customize the duration of these micro-activities to their liking and use the specifically designed interface to do so. The validation for this project showed positive reviews for the product and a willingness in the users to adopt this minimalistic fitness companion. The few changes indicated by the validation test are with respect to the price point.

This indicates that with an attractive price point for the market, the client company can launch this product to trailblaze the health & well-being market.

09

Recommendations

Recommendations

Well-maintained 3D printers

Since most of the manufacturing of the final design will be carried out on a FFF 3D printer, it is of utmost importance to have the in-house 3D printers at optimum performance and they are kept well maintained and precise. There are tight tolerances in this design to cater to easy assembly and smaller BoM, hence, steps like press fitting during assembly warrant a precise 3D printing facility by the client company.

Transparent textured cylinders

As the light effect (caustics) are created by these cylinders. they are the heart of this design. There already has been extensive research and testing done in manufacturing of these cylinders, yet, if the client company desires to test out different effects for the cylinders, they can explore various thickness patterns of the cylinders to get varying effects.

Sizing

As mentioned in the validation section, users prefer a product with a smaller size. Yet, as shown in the size analysis, there would be a trade-off between the size of the product and the reflected image which is created in the front face. For smaller sizes, the reflected image generated would cut portions of the face, which would lead to unpleasant reflections, defeating the core purpose of the design. Hence, it is advised to the alter the size of the product while considering the reflected image

Connectivity

Though the design features emphasize on the device being standalone and not going towards the over-digitization of accessories, users indicated interest in IoT based product. Thus, the client company can further develop the design to host capabilities of data sharing and connectivity.

Charging port

The charging port in the final design is on the backside of the base. This position was not well received by the users and hence, the client company can change the position of the port to be more ergonomic in nature.

10

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Appendices

Appendix A: Project brief

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Rakesh Patel **Student number** 5,776,732

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title An interactive light installation stimulating people to become more active and enjoy the outdoors

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

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

In 2022, around 44% of Dutch adults complied with the guidelines on getting enough physical exercise by the Health Council of the Netherlands (CBS, Netherlands, 2023). While the Dutch government wants 75% of people to meet these guidelines by 2040 (Ministerie van Algemene Zaken, 2019), thus bringing a need to create a change in people's lifestyle. With the help of this design project, an exterior interactive light installation will be used as an intervention to bring about this required stimulation to increase physical activity.

This design project will aim at ideating, conceptualizing, and evaluating (with the help of an initial prototype/proof of concept) the role of light, the light installation and its interaction with the city dwellers of the Rotterdam city. These light installations will promote people to move, enjoy their surroundings and the urban landscape and eventually become more physically active.

The target audience for this design are teenagers, young adults, and adults, i.e. people from the age (but not limited to) 12 to 35. Along with these people being the primary stakeholders, the Rotterdam Municipality, similar governing bodies, and various sports associations might play an important role as the project progresses. Various associations concerning sports, like Sportbedrijf Rotterdam might be involved in the project as well to provide with the necessary insights for the solution's desirability and feasibility.

The primary opportunity presented by this project is in creating a stimulating environment, with the use of light, for the people of Rotterdam to appreciate and explore the surroundings and become more active while doing so.

➔ *space available for images / figures on next page*

introduction (continued): space for images

image / figure 1 Sketch of a former design by Hola Design Studio. Source: Hola Design Studio.

image / figure 2 Rendering of former design on 'Broken Light' installation by Rudolf Teunissan. Source: Hola Studio

Appendix A: Project brief

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

People in an interactive and welcoming atmosphere are encouraged to interact with their surroundings, even in a poorly designed space (Akpan et al., 2013). While lack of interactive elements results in them being focused on moving from one place to another without paying attention to the space (Project for Public Spaces, n.d.). Hence, with interactive elements in their environment, people would be more motivated to explore their physical surroundings and in turn, lead a more active lifestyle (Zhong et al., 2022). This project aims to motivate people in being more active by using interactive light installations in their surroundings, as interactive lighting can have a positive effect on the motivation to perform physical activity (Van Renswouw, 2020).

The primary conflicting requirement would be to create an interaction which does not follow the conventional passive, reaction-based lighting mechanisms. The light installation would have to be active for the users to interact with and get motivated to perform some kind of physical activity. A knowledge gap here is in designing a positive, active interaction which works in a public space using lighting design principles. Potential opportunity by implementing this project can be an holistic upliftment of the society by the increase in physical activity of the people. It might lead to more social engagement and communal harmony as these physical activities can also be seen as community building activities.

Assignment

*This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the **green text format**:*

Design an interactive lighting installation to motivate people living in Rotterdam to perform more physical activity, in the form of a scientific proof of concept.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

To make sure people interact with and are motivated to be more active by the light installation, following research and design methods will be worked on:
- Researching and narrowing down the area to a locality/neighbourhood;
- Researching into user behaviour around a particular urban area;
- Researching into design for behavioural change & means of stimulating physical activity;
- Ideating towards interactive means of motivation using light;
- Ideating on light installations with more active interaction rather than being a reaction to the user's actions;
- Developing concepts based on promising interaction ideas;
- Creating models and testing them to reach a conclusive design;
- Creating a final Proof of Concept (PoC) prototype for the studio to take further;
- Performing various analysis such as cost-benefit, sustainability, technical feasibility, ergonomic and aesthetic implementation on the concept as a basis;
- Preparing media to help explain the concept to users.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	6 Feb 2024
Mid-term evaluation	2 Apr 2024
Green light meeting	31 May 2024
Graduation ceremony	8 Jul 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

My objective for this project is to become an all-round designer, while keeping my technical background and skills strong. The lighting design field inspires me, and I would like to make a career into lighting design and hence, want to gain industry experience. I have gained knowledge and skills in user research, prototyping, user testing and technical development over my career. Through this project, I want to:

- gain more confidence in my ideation process
- add more experience in the conceptualization phase of designing
- learn high-quality visualization skills for my ideas
- acquire knowledge, skills, and experience in Lighting design field

By fulfilling these objectives, I want to prove my calibre as a competent Industrial Design Engineer.

Appendix A: Project brief

	6-Feb Kick-off								2-Apr Midterm								31-May GreenLight						8-Jul Graduation
Academic calendar week	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Project week	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date	5-Feb	12-Feb	19-Feb	26-Feb	4-Mar	11-Mar	18-Mar	25-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr	6-May	13-May	20-May	27-May	3-Jun	10-Jun	17-Jun	24-Jun	1-Jul	8-Jul
Working days	3	5	5	5	5	5	5	4	4	5	5	5	5	3	5	4	5	5	5	5	5	5	1
Off days	2	0	0	0	0	0	0	1	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0
Kick-off Meeting																							
Company introduction																							
Initial research																							
Research for locality																							
Research for user behaviour																							
Research for behavioural change																							
Research for physical activity stimulation																							
Interaction ideation																							
Form-giving ideation																							
Ideation evaluation & selection																							
Midterm report preparation																							
Midterm Evaluation																							
Implement midterm insights																							
Conceptualization																							
Concept evaluation																							
Concept detailling																							
Modelling & rendering																							
Prototyping																							
Prototype testing																							
Green light report prepapration																							
Green Light Meeting																							
Implement green light insights																							
Prototype finalization																							
Prototype user testing																							
Final presentation preparation																							
Final report preparation																							
Final showcase preparation																							
Graduation Day																							

Appendix B: Introduction to Light

Artificial light

The need for artificial light was evident since prehistoric times with the urge to seek vision and safety during the nighttime *(Ayres, 2021)*. Over the years, artificial light sources changed and evolved to cater growing needs and keep up with the technological advances.

Artificial light sources, generally referred to as lighting, are being used to accentuate features in objects or buildings, create various ambiences such as cozy, sci-fi, warm, etc. Moreover, these lighting fixtures are also seen as style statements, opportunities for people to express their styles and aesthetic tastes.

Artificial light is increasingly being used in medical applications such as phototherapy for certain medical conditions. By recognizing the immense potential light has in influencing people's moods, perspectives, and thoughts, people can make conscious choices with respect to the lighting around them to optimize their productivity, sleep and overall health *(Kuijsters et al., 2015)*. Thus, light can be alternatively used as a tool to increase one's mindful awareness towards their health.

Artificial light at night (ALAN)

Artificial light is being used extensively to fulfill its diverse functions. The increasing presence of these man-made lights during the nighttime is called ALAN, or 'Artificial Ligth At Night'. ALAN is having a growing impact on the human health, as well as the environment. Thus, acting as a concern against which measures need to be taken. *(Hartley, 2023)*

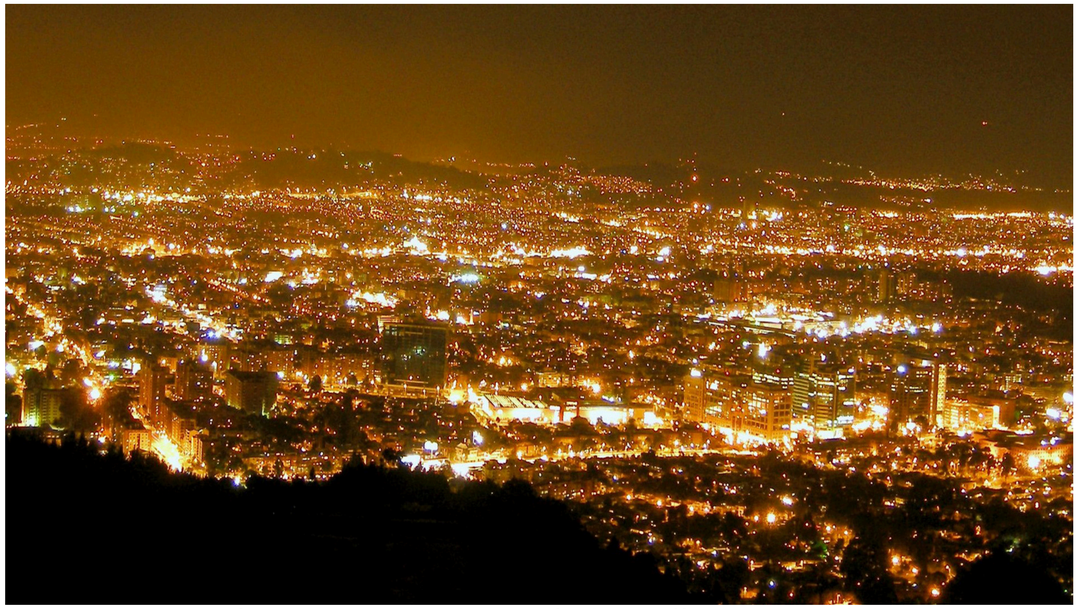

Fig. 04: Hazy glow over city due to light pollution *(Kadaba, 2020)*

Appendix B: Introduction to Light

Exposure to ALAN can affect various organisms in a deteriorating manner. Hence, it is good to be aware of the ill effect of light on various organisms during nighttime. ALAN decrease the production of melatonin hormone which regulates the sleep cycles. Thus, sleep problems, fatigue, and generally an increased risk in health issues are some complications due to disrupted circadian rhythm of the body. It also causes disruption of light-dark cycle for the wildlife as well. Due to this disruption, prey-predator interactions, migrations patterns, etc are affected. The influence of artificial light on plant life is already known by use of light in the greenhouses. Yet, unregulated artificial light can harm the wild plant life as well. There is a hazy glow over the cities due to the excessive artificial lights which obscures the night skies and hinders people's ability to see the stars, such as the milky way. *(Hartley, 2023)*

Light pollution is a growing problem as artificial light are estimated to increase globally by 1.6-9.6% annually. Whereas, more than 80% of the human population experiences the effects of light pollution, urban cities are impacted the most. This can be seen in the graph-map below, where the Randstad region of Netherlands can be seen as a hotspot for light pollution. *(The New World Atlas of Artificial Sky Brightness, n.d.)*

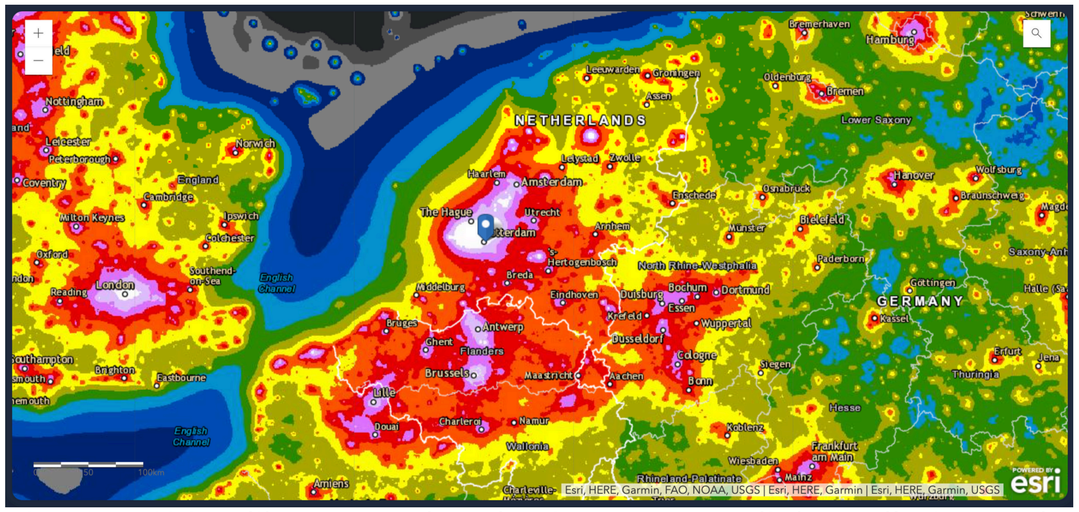

Fig. 05: Cities like Rotterdam having extreme light pollution. *(The New World Atlas of Artificial Sky Brightness, n.d.)*

Impact on flora & fauna

Plants rely on the day/night cycle as well for regulation of their internal processes. Thus, ALAN disrupts the processes which are dependent on light such as growth patterns, flowering, and seed/fruit production. Excessive light can trigger stress responses in plants which can leave less energy for growth and reproduction. Plants and trees around the street lamps have comparatively stunted growth and longer leaf life. This leads to irregular seasonal cycles for such plants. ALAN might aid some plant species which thrive under extended light periods, thus, disrupting the competitive balance within the flora ecosystems. *(Ellis, 2021)*

Appendix B: Introduction to Light

ALAN can alter the leaf chemical composition and pigment formation process, which alters the photosynthesis process for the plants. Due to the confusion created by artificial light for the nocturnal pollinators of plants, about 62% of decrease in seen nighttime visits by these pollinators, reducing pollination and fruit generation. *(Knop et al., 2017)*

As most of the pollinators fall under the fauna category, the effect ALAN on the animal wildlife is also studied and seen as a major issue. Similar to humans, the animals too follow the diurnal light cycle which gets altered due to artificial light. This leads to irregular sleeping cycles or a shift in their active periods completely (24-hour lifestyle). Melatonin hormone production is affected in animals as well, leading to declining overall health. *(Grubisic et al., 2019)*

Lack of visibility of the night sky can lead to issue in migration process of birds and flying insects, as they mostly rely on celestial cues like stars and moon to determine the direction. This leads to them veering off-course, take longer routes, getting exhausted and colliding to objects such as buildings. *(Lao et al., 2020)*

Nocturnal animals and insects usually rely on darkness for camouflage. Due to ALAN, their prey vulnerability increases to a great extent, making them easy targets for the predators. It also disorients the fauna such that they end up being far away from the breeding grounds, food source, etc. These disoriented animals and insects could mistake the artificial light for moonlight and come out of their hiding spots even though it would not be favorable circumstances. Such situations lead to various dangers for their species, while the disrupted circadian rhythm can lead to decrease in reproductive success, leading to population decline. *(Moyse et al., 2023)*

Impact on humans

As mentioned before, ALAN affects humans by altering the circadian rhythm and suppressing melatonin production. Prolonged usage of products can cause ALAN if not considered accordingly. Hence, clients need to consider ALAN in this project during product testing.

Studies suggest a connection between ALAN and increased risk of getting certain cancers, like breast or prostrate cancer *(Al-Naggar & Anil, 2016)*. Disrupted circadian rhythm is shown to act as precursors to lifestyle diseases such as obesity, Diabetes type 2. Research suggests correlation between ALAN and cognitive issues like depression *(Harb et al., 2014)*.

Appendix B: Introduction to Light

Light is more than just illumination; it is a powerful tool which shapes our environment and subtly influences our moods, thoughts and behavior. By understanding the psychology of light, one can evoke various desired emotional responses using different attributes of light.

Appendix C: Evolution of Lighting

By understanding the historical context of lighting, the development of technologies which solved the core human need for illumination can be studied. This study helps in learning from the past innovations and their contexts, leading to creation of new ideas. This study also acts as a foundation to envision the emerging trends which will shape the future of the lighting industry.

Early lighting era (<19th C.)

Even before the beginning of human history, light was seen as a purely natural occurrence by pre-humans. Eventually, natural fire was domesticated, when they discovered making their own fire. With this momentous feat, pre-humans were able to provide light and warmth for themselves even during nighttime. To make this fire more accessible, the fire was made to be portable by taking the aflame wooden branches away from the fire pit. This gave rise to the most primitive form of artificial lighting. *(How Was Fire Discovered?, 2020)*

This led to advancements in the use of torches as light source. Through the years, the wooden branches were swapped for more flammable woods like pinewood and the lighted end would be dipped in a flammable liquid like oil to create a stronger flame. *(History of Torches - Torches Work?, n.d.)*

To obtain light for the general masses and have a more compact form of lighting solution, candles and oil lamps were developed during the medieval ages. In ancient Rome, oil lamps were used to illuminate houses at night. In 1417, London, it was mandated by law to hang lanterns during the night leading to first public organized street lighting. *(Adminolivia & Adminolivia, 2023)*

Fig. 08: Candle makers workshop, 1765-72, Wellcome Library, London

With passing years, the materials used for the candles and oil lamps matured, leading to small increments in desired lighting. Yet, with the invention of Argand oil

Appendix C: Evolution of Lighting

lamps in 1780 provided light equivalent to 10 candles, paving way for use of oil lamps at a large scale. *(English Heritage, n.d.)*

Fig. 09: Argand oil candle lamp, Ministere De La Culture, France

Gas lighting era (19th century)

In the end of 18th century, light produced by igniting coal gas was discovered as a possible commercial lighting solution. The Scottish engineer William Murdoch discovered and started experimenting with coal gas lighting systems as early as 1770s and 1780s. Shortly after his experimentations, William Murdoch installed multiple coal gas lights in his residence in Cross street, Redruth by 1802. *(William Murdoch, First Man to Use Gaslight, n.d.)*

This technology was further commercialised by Friedrich Albert Winzer, a German entreprenuer who patented the Coal gas lighting system and implement them at the Pall Mall street of London on June 4, 1807. This marked with London being the first city in the world to have a street-wide gas lighting arrangement. *(Long, 2008)* This technology travelled to USA as, in 1816, Baltimore become the first city in USA to have gas-lit street lamps *(Samford, 2018)*.

Following the success of Coal gas lighting around various cities in the world, Paris adopted gas lighting as the primary source of artificial lighting in 1820. This lead to gas being seen as the main source of illumination across many cities in the world. *(Abraham, 2020)*

Appendix C: Evolution of Lighting

Fig. 10: Lamplighter lighting gas street lamp, Sweden

Fig. 11: First street illuminated by gas light, Pall Mall, London

Electric lamp era (19th-20th c.)

While the gas lights were being increasingly used to light up streets and other spaces, parallelly, inventions in the domain of electric lighting were taking place. Before the electric bulbs we know were invented, arc lamps were invented and experimented with. These arc lamps laid the foundation for the development of the electric lighting we know. Russian physicist Vasilij Vladimirovič Petrov successfully developed a persistent arc lamp in 1802. This lamp was further developed to be used on a larger and thus, in 1846, the Opera Theatre in Paris became the first public building to implement these electric arc lamps. *(Technologies, 2024)*

In 1876, Yablochkov candles were invented by the Russian electrical engineer Pavel Yablochkov. He implemented around 4000 Yablochkov candles across Europe over the next few years, starting from major landmarks in Paris. This spread of Yablochkov candles across cities like Paris, London, etc. created a global sensation bringing electric lighting to the forefront. *(Ethw, 2017)*

Fig. 12: Yablochkov candle

From 1850 to 1860, Joseph Swan, an English physicist invented the first incandescent electric light bulb. Yet, the electric bulb was not efficient due to lack of technologies providing stable vacuum and electric supply. In 1879, an American inventor named Thomas Edison developed the first commercially practical electric bulb which could be used for up to 1200 hours. These inventions led to the advent of the era of electric lighting all over the world. *(History of the Light Bulb | Lighting Basics | Bulbs.com, n.d.)*

Appendix C: Evolution of Lighting

Over the decades, there were modifications and improvements made to the tungsten based incandescent electric bulbs. Yet, seeing that these bulbs would create light, along with plenty of infrared energy, they produced a lot of heat. A form of lighting solution which will provide illumination without excessive heat was researched. Eventually, in 1927, scientists and inventors Edmund Germer, Friedrich Meyer and Hans Spanner co-patented the fluorescent lamp. With the use of these fluorescent lamps, a more efficient and economical lighting solution was developed, which produced far less heat. *(1900 - 1930: From Electricity to Fluorescents - Interior Design, 2022)*

Fig. 13: CFL bulb, a type of fluorescent lamp famous for its energy efficiency

Development of these fluorescent lights was under the family of various low pressure lamps used for illumination. One such popular low pressure lamp is the Sodium low pressure lamp. This lamp was used extensively throughout Europe starting from 1930s as street lighting. *(Eaton, n.d.)*

Development in the direction of increasing the lumen output per watt brought forth the High-Intensity Discharge (HID) lamps. These lamps are similar to fluorescent lamps but they produce more light, heat and pressure. Due to increased output, relatively smaller size and long life, these lamps were extensively used during the 20th century.

However, they had disadvantages such as restrike time, making them unsuitable for areas needing intermittent illumination. HID lamps are used till date to illuminate streets, large warehouses, stadiums, etc. *(Types of Lighting: High-intensity Discharge | EGEE 102: Energy Conservation and Environmental Protection, n.d.)*

Fig. 14: Stadium lighting using HID lamps

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LED era (21st century)

Based on the extensive research the scientific community had on electroluminescence, the emission of light by semiconductors when applied a strong electric current was studied. The first visible light LED was created by Nick Holonyack from General Electric in 1962. For this invention, he is called the ‘father of LEDs’ and contributed to the development of LED lighting.

The first LED developed by Holonyack was a low-intensity red LED. Based on this work, Yellow LEDs with higher light intensity were developed in the next decade. In early 1980s, green LEDs were developed which helped in creating white LEDs by combining green and ref LEDs, making them a viable replacement for incandescent and fluorescent lighting. *(A Short History of LED Lighting, n.d.)*

The creation of blue LEDs was however elusive for major part of the semiconductor lighting history. Japanese engineer and physicist Isamu Akasaki started working on making blue LEDs in early 1970s. Along with his student Hiroshi Amano, Akasaki developed the the first blue LED around 1985. Shuji Nakamura from Nichia Corp. improved upon the quality, brightness and efficiceny of blue LEDs was able to make with LEDs in 1996. *(Hecht, 2022)*

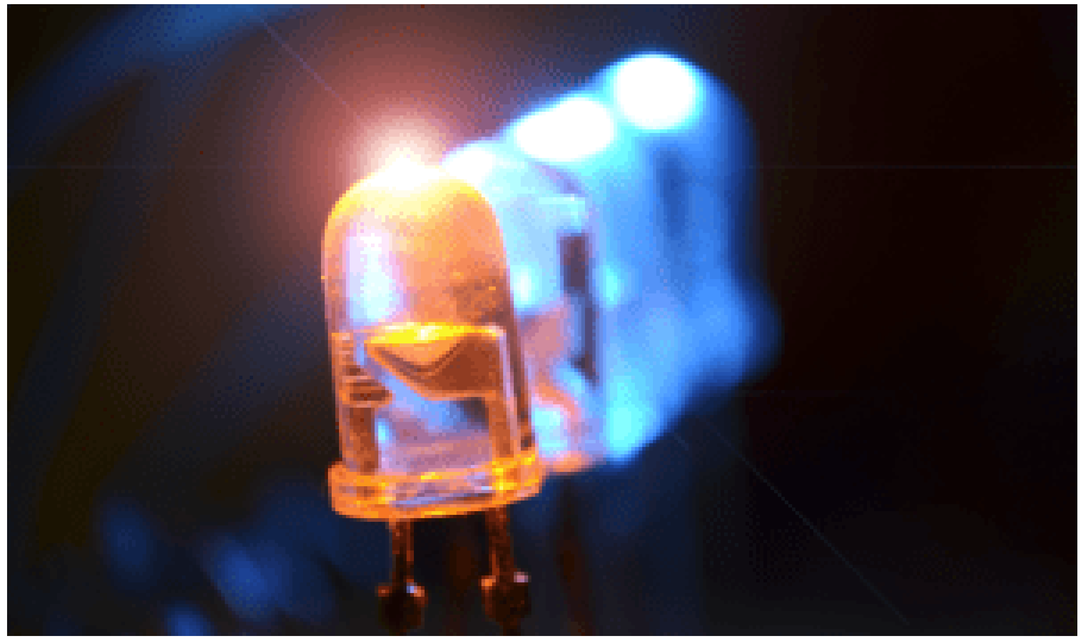


Fig. 15: Through-hole LEDs used in indicators, displays, etc.

Present & future

Over the years, LEDs have evolved to cover the lighting market, mainly due to their efficiency and versatility. The global LED market was valued at approx. $76 billion in 2022 showing its hold over the lighting market. With the advancements in technology, this market share is estimated to grow further.

The emerging trends seen in the LED technology are especially due to the focus of manufacturers to increase

Appendix C: Evolution of Lighting

the overall efficacy of the LEDs, including the luminous efficacy.

With already expanding market, Smart LED lighting solutions are becoming a norm in newly developed living spaces. The smart LEDs are controlled by advanced control systems which make these lights control-able wirelessly by smartphones or voice.

With the introduction of OLEDs (Organic LEDs) and MicroLEDs in the display and screen industry, we are seeing major improvements in the way visual content is delivered to the users. They are increasingly being used in smartphones, TVs and even advertising for large display boards.

illumination of public spaces by street lighting and automotive lighting using LED technology is being used increasingly. LED streetlights provide brighter illumination while 40-60% reduction in energy consumption compared to other light technologies. Hence, municipalities and automotive companies are shifting towards LEDs.

The domain of Human-centric lighting is an emerging trend which focuses on the psychological and physiological effects of light on humans. LEDs have the ability to mimic daylight and produce different color temperatures to mimic different times. LEDs can also produce various shades and hues of colors, with some LEDs being able to produce up to 16.7 million different colors. This leads to use of LED lighting to impact moods, sleep and overall wellbeing. Thus, LEDs are being used in homes, workplace, healthcare, etc to increase comfort and productivity.*(Energy, 2023)*

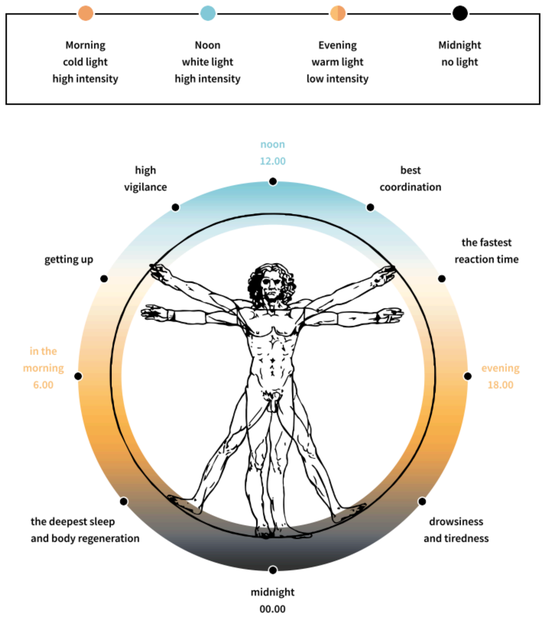


Fig. 16: Human-centric lighting affecting circadian rhythm

Evolution of color temperature

During the early lighting era, the light produced by those light sources of fire, torches, oil lamps and candle light ranged from 2000-1700K color temperature. These light sources were from yellowish white to reddish color. These primitive light sources did not have any color temperature control and were used for basic

Appendix C: Evolution of Lighting

visibility alone. *(Editor Engineeringtoolbox, 2023)*

As the luminaires developed and started becoming more advanced, they tried to mimic the feeling provided by fire but with more efficiency and convenience. Hence, the gas lights were warm white with ranging from yellowish to reddish. These lamps were used to provide illumination and add character to the place by having different designs. The flickering flame would also give a lot of character to these lamps. By changing the gases used in the lamp, the color temperature of the light could be controlled. *(White, 2023)*

Moving to the Electric lighting era, the use of incandescent, fluorescent and HID lamps allowed people to incorporate more daylight mimicking capabilities. The lights could now be used to even simulate the cooler daylight. Most incandescent, HID and fluorescent lamps have color temperature of 2700K, 3000K and 3500K respectively. These lighting solutions started incorporating electronic control systems to make them more personalized. This introduced the world to Human-centric Lighting, increasing their functionality. *(What Is Colour Temperature? | General Lamps, n.d.)*

LEDs majorly took over the lighting space in the world by the beginning of 21st century. LEDs, due to their solid-state nature, are able to go to cooler color temperatures efficiently as compared to its lighting predecessors. LEDs can be from 2000K to 5000K, providing the complete range. Hence, LEDs help arranging lighting according to the programmatic of the space, for e.g., studying, reading, working, leisure, etc. Precise control systems can be incorporated easily with these lighting solutions to give complete control over color, intensity, color temperature, etc. *(Weil, 2021)*

Evolution of rules & regulations

For primitive lighting solutions, there were not specific rules in place, to ensure safe and standardized use of lighting. People were tasked with refilling the oil in the lamps during ancient days and eventually professional lamplighters were tasked with lighting the lamps at dusk and extinguishing them at dawn. They were also tasked with the maintenance and safety of the gas lighting street lamps. A number of gas leaks led to strict legislation around the standardization of gas piping and general safety and maintenance. Other technologies were considered even more to mitigate these risks. *(Dillard, 2017)*

Appendix C: Evolution of Lighting

As electric lighting became more accepted throughout the world, the priorities for regulations changed. The standardizations focused more on ensuring consistent lighting at important spaces such as street lights. More illumination for each lighting used was prioritized and minimum lighting efficacy was decided at various spaces. With more light available to everyone, newer challenges of light pollution and its ill effects came into picture.

Sustainability rightfully found its way into almost every legislation of every institution by the starting of 21st century. LEDs already aid in achieving sustainability, by being energy efficient and having high luminous throughput. Reparability and reusability laws demand the luminaire fixtures to have retrofitting capabilities. By following this, newer energy efficient lights can be placed in already existing hardware. With such kind of modern regulations, the lighting industry is progressing in a holistic manner.

Conclusion

The understanding of evolution of lighting solutions over the centuries provides very helpful insights for this project. By learning this development process, the importance of user needs and how they shaped the lighting industry becomes more evident. This emphasizes the importance of user needs for success of this project as well. All the lighting solutions were made the way they were to create a desired effect, ranging from illumination to moods and feelings. Various attributes of light and lighting solutions will provide various effects. These effects can be incorporated in this project as required. This research section also helps in determining the choice of light source, colors, temperatures and control system for this project. All of these components will result in a complete product.

Appendix D: Ideation - Phase 1

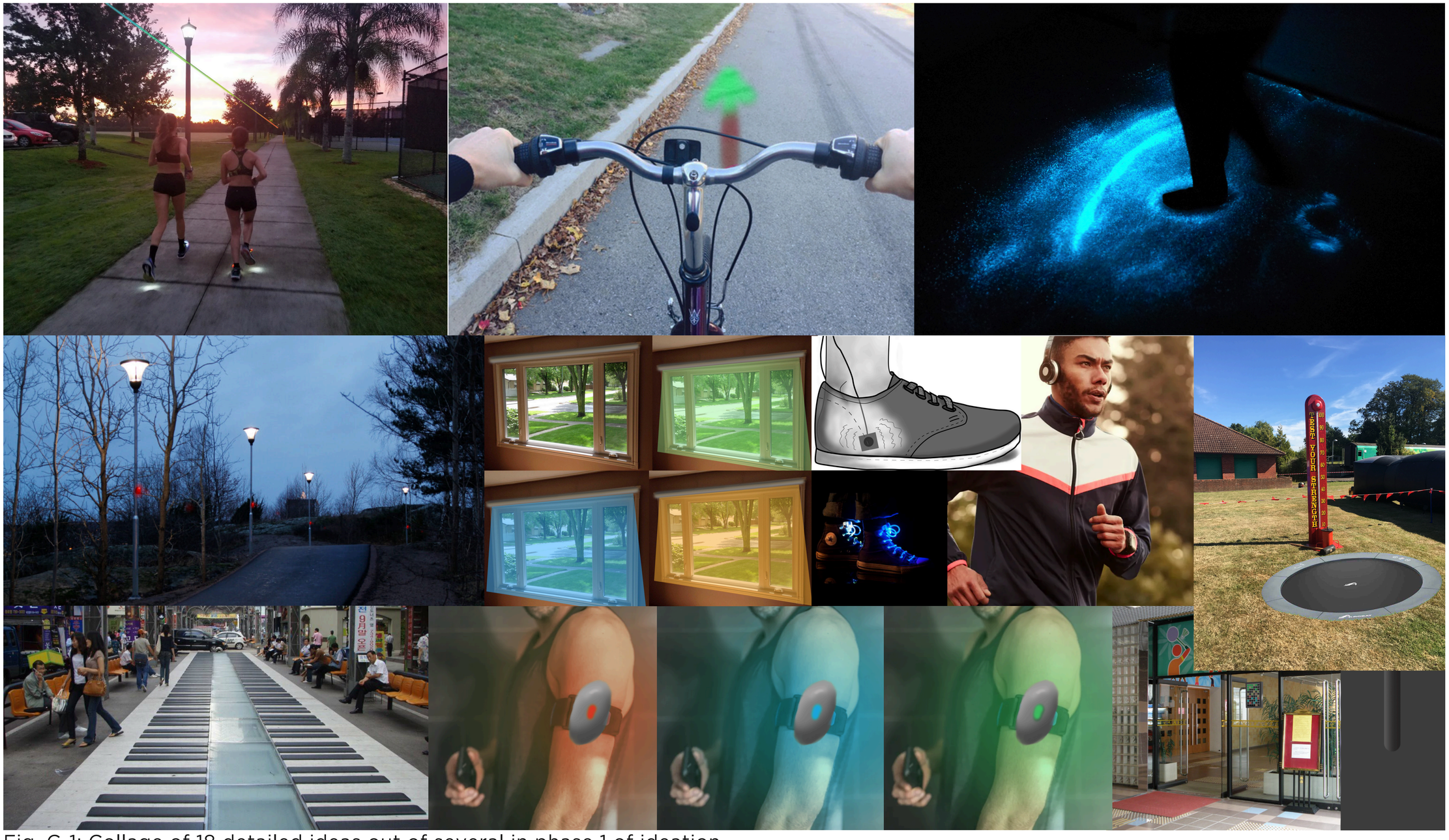


Fig. C-1: Collage of 18 detailed ideas out of several in phase 1 of ideation

Appendix E: Factors in ViP

- People respond better to systems that allow them to customize settings.
- Some users prefer internal rewards (feeling good) while others benefit from external motivators (badges, points).
- Many people have limited time for exercise.
- People often struggle to initiate activity.
- Visualizing progress is motivating.
- Physical activity can improve mental well-being.
- Outdoor activities should be adapted based on weather conditions.
- Safe and well-maintained walking/cycling paths can encourage movement.
- Accessibility features are crucial for a wider user base.
- Users are conscious of the environmental impact of their choices.
- There's a growing desire for social connection and shared experiences related to health goals.
- People rely on wearables to track activity and receive personalized health data.
- Interactive surfaces and gamification elements can increase engagement.
- Music and ambient sounds can improve mood and motivation.
- Different colors and light patterns can evoke emotions and influence behavior.
- People respond better to positive reinforcement and playful interactions.
- People of all ages want to focus on maintaining mobility and well-being.
- There is a growing desire for connection with nature and community-based activities.
- People are increasingly becoming aware of their health data
- People are further motivated by personalized goals.

Appendix F: Lightlab Explorations

One of such materials was the dichroic foil. This foil Refracts different wavelengths of light in different angles, scattering it. Thus, an interesting effect is created when light is cast upon this foil. This foil was given a kind of a texture by crumbling it, to see how it behaves when light hits its surface at different angels.

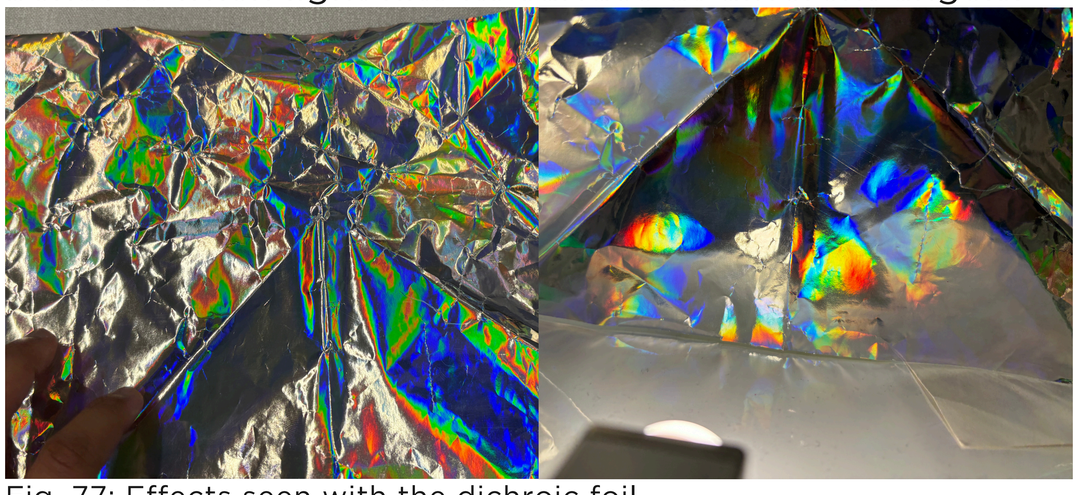


Fig. 77: Effects seen with the dichroic foil

The dichroic film was a decent alternative to the austic effect, but the effect was extremely random and seem to give a very chaotic feeling to it. On top of that, the foil is extremely susceptible to creases and folds. This makes it difficult to handle, as every fold or crease would create reflections around it, changing the effect over time.Hence, it was not taken forward.

Another material which was interesting to test was the iridescent film. This film had an adhesive layer on the back for hassle-free coating. The film incorporates the phenomenon of iridescence well in its structure. One can make interesting visual patterns using this material. Similar to this film, there are various textiles which have the same surface properties. Such materials are great to create objects/clothing with very energetic character.

Fig. 78: Iridescent film provided by client company for testing

Even after removing the adhesive layer, the film was too thick to be able to move it freely. The film tends to roll out or fall flat as its original shape, creating restrictions in its usage. Hence, this material was side aside as well.

Appendix F: Lightlab Explorations

Similar to the dichroic foil, dichroic cubes were studied to consider their effects and visual character. The dichoric cubes showed a more structured effect and based on the angle of the light and the side it is being cast on the cube, the effects were different and it create various polygonal patterns around it. While researching more about the dichroic effect, an artist named Stephen Knapp and his artwork stood out for me. His art work incorporate dichroic effect to create stunning art. Various kinds of light and various dichroic materials stuck to the wall create beautiful effects on the wall.

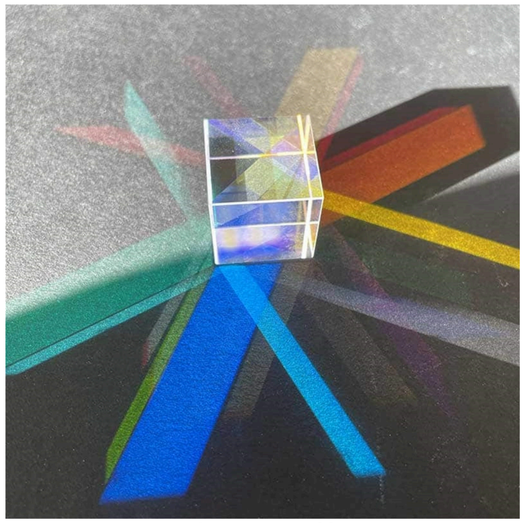


Fig. 79: Dichroic effect seen in the dichroic cube

Such similar effects were tested if they would give similar character and feeling as the water caustics. These effects by the dichroic materials were too polygonal and straight. This led the effect to be somewhat systematic, organized and not organic. The desired effect is that of somewhat random, organic movements which depicts a calming character. The dichroic cubes show a more straight and utilitarian character to them. Hence, these cubes were not considered as a possible means of getting the envisioned effect.

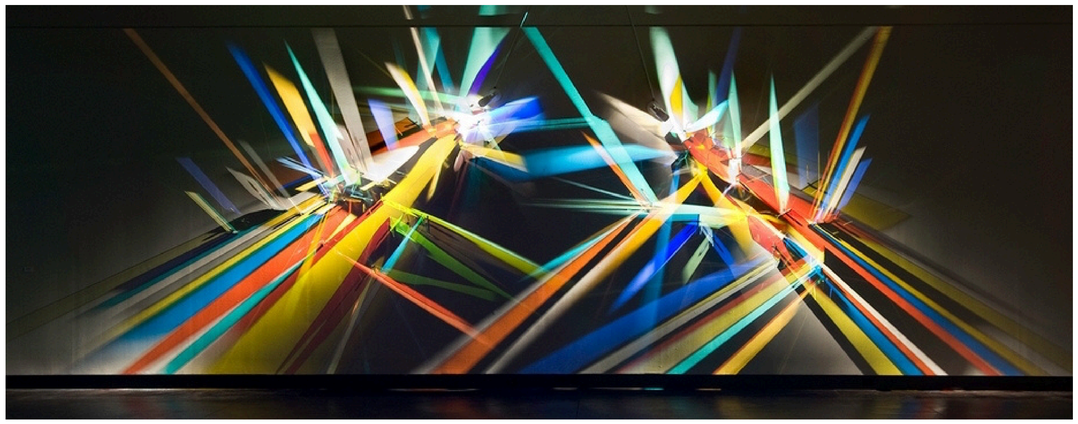


Fig. 80: Artwork by Stephen Knapp using dichroic materials

Appendix G: Form-giving at Hola

Fig. G-1: Lamps by Hola Studio

Appendix H: Diffracting Elements

Prototyping phase 2

To continue testing the second method, the infinity mirror prototype provided by the client company was used to be alter the design needed for this project. In the infinity mirror, the reflective back surface is used to create the ‘infinity’ effect. This was an undesirable effect for the product. Hence, the reflective surface was replaced by a white blackout paper which acts similar to the white paper used in the phase 1 of prototyping.

As a programmable LED strip was already placed inside the infinity mirror, this LED strip was reprogrammed to get a moving wave pattern of colors to mimic the movement of the LED strips. This reprogramming was supposed to depict dynamic changes in the lighting effect, while the whole setup remained stationary.

To be able to incorporate the textured sheets in the circular form factor of the infinity mirror, which is the desired shape for the product as well, the textured sheets were cut into thin strips and bent to create cylindrical bodies. These strips were initially cut using a saw, yet, to save up on time, these sheets were laser cut in the next steps.

To aid in precise bending of the strip, simple 3D printed jigs were made, against which heated and softened strips would be lightly pressed to give the strips a curve. Fours of these curved strips would make the entire cylinder. To make two concentric cylinders of the textured sheet, eight strips, four of each two measurements were cut, heated and bent. The jigs used to form the precise curvature of the strips can be seen below.

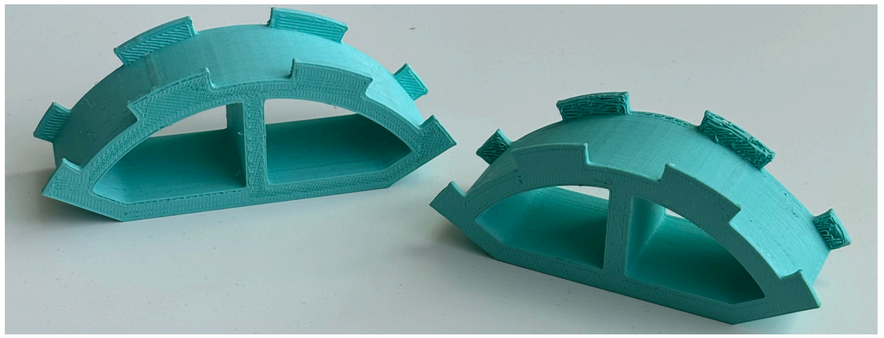


Fig. 89: 3D printed jigs used to bend the textured strips *(Author, 2024)*

To bend these textured strip, initially, a high power heat gun was used. This proved to be providing the strips with extra heat and the strips were shrinking and curling in size. To prevent this shrinking, the strips were then put in a domestic oven which was heated to around 50 degree Celsius to provide uniform heat to the strip placed in the oven. Yet, not knowing the exact time or temperature at which the sheet softens but does not curl, lead to the same result in the oven as with the high power heat gun.

Appendix H: Diffracting Elements

Eventually, after many failed attempts, the strips were softened by using a combination of a heat gun at its lowest setting and a hairdryer. The strips were first heated all over using the lowest heat setting of the heat gun.

This softened the strips to make them bend as per the design. Then, a hairdryer was used at its highest heat setting which was still way lower than the lowest heat setting of the heat gun, leading to retention of the softness of the strip, without it curling or shrinking completely. Yet, as this was a trial and error method, with respect to the timing of the heating, the bent strips were not perfect and created continuity issues to have a uniform cylinder.

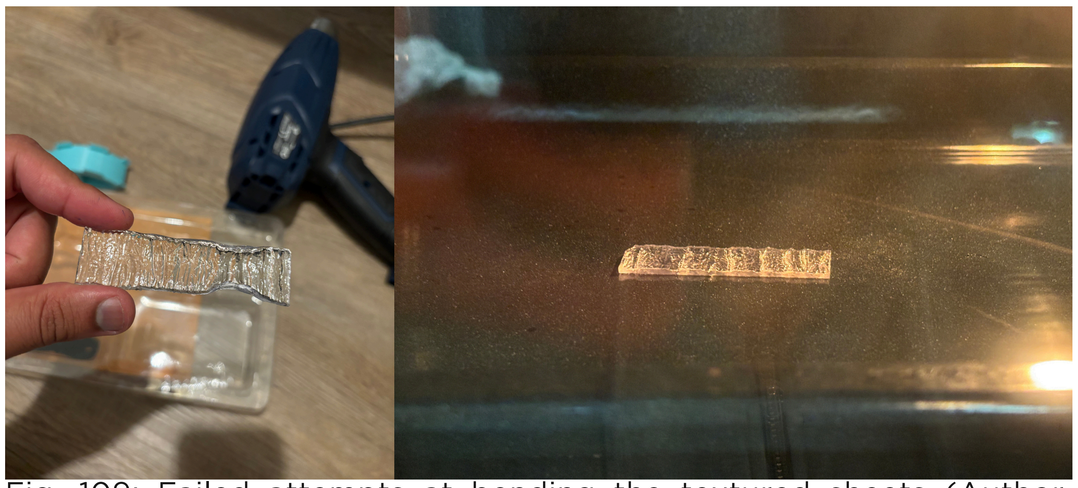


Fig. 109: Failed attempts at bending the textured sheets (Author, 2024)

The strips were then placed in a 3D printed frame which would hold the strips in position, forming a cylinder. The electronics used in the infinity mirror was reverse engineered to be able to reprogram the LED strips to suit the desired design. With this setup, the prototype, which acts the proof of concept (PoC) for this design, was tested.

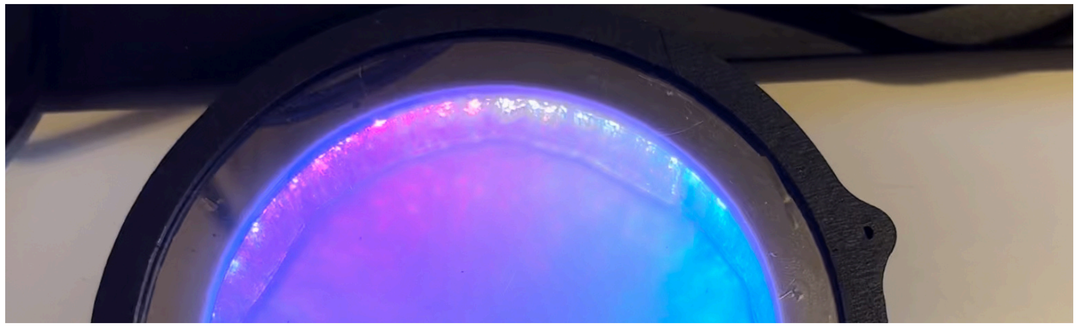


Fig. 110: Part of Infinity mirror used as PoC for prototyping phase 2 (Author, 2024)

Results of Prototyping phase 2

The lighting effect in the PoC was not as strong as expected. This was due to two reasons. One of the main reasons for this lack of strength was the orientation of the strips. In the PoC, the strips were cut without paying attention to the orientation of the texture. Thus, the texture was parallel to the white backdrop, making the diffraction effect very weak. Second reason was the programming of the LEDs, where the LEDs were transitioning smoothly from one color to the other, such

Appendix H: Diffracting Elements

that it created a cyclic wave of colors. Yet, as there was no off state for the LEDs such that one LED is on while its neighboring LED is off and after certain amount of time, the neighboring LED switched on, while the earlier LED switches off. This creates the desired dynamic effect of light inside the circle. As this effect was missing, the code was rewritten for the next phase of testing.

Overall, the bending of the textured strips to create the desired cylinder proved to be a very unreliable, non-reproduceable and time consuming task. Hence, an alternative to form these cylinders with textures on them was of paramount importance. These cylinders act as the crux of the lighting effect, hence, quite some testing and time went into refining it.

LED programming

As discussed earlier, the programming in the LEDs needed to be changed as the lighting effect was not as evident. Hence, the code was changed according to the suggestion presented above. This modified programming was implemented on the PoC and tested. As expected, the change in the code increased the contrast between the states of the LEDs and thus making the effect more prominent, making the PoC prove the viability, feasibility and merit of the design

Resin 3D printed texture strips

As mentioned earlier, the bending of the textured strips was difficult and inefficient. Hence, efforts were put into finding other means of making these textured cylinders. One of the methods considered was resin molding using silicone. This is tried and tested method of generating intricate objects with various applications. For this project, a clear resin which is suitable for casting would be needed. The concentric cylinders would need to be made in order to form a mold out of them. Once the mold would be formed, the resin would then be poured in the empty mold and let to be cured and harden. This would give uniform cylinders which can be reproduceable over and over again.

Another approach considered was breaking down the cylinder into parts, similar to the strips and resin 3D printing those parts. These parts would then be glued together to form a complete cylinder. When the client company was updated about these approaches, they immediately wanted to go ahead with the resin 3D printing approach. As they have an in-house SLA (resin) 3D printer and have experience in handling such materials, they wanted to streamline the design by including one of their existing machinery into the

Appendix H: Diffracting Elements

production process. However, the reason the cylinders were split into parts was because the in-house SLA printer available at Hola Studio has a printing surface of 115mm*65mm. This surface is considerably smaller than the size of the cylinders and hence, the cylinders were decided to be split and printed.

However, seeing the advantage in resin 3D printing the cylinder, the client company suggested of using external manufacturing companies which specialize in 3D printing to outsource the cylinders in SLA resin printing. Hence, one of their external outsourcing partners for large scale 3D printing, JLC3DP was selected to send the outsourcing of the cylinders to.

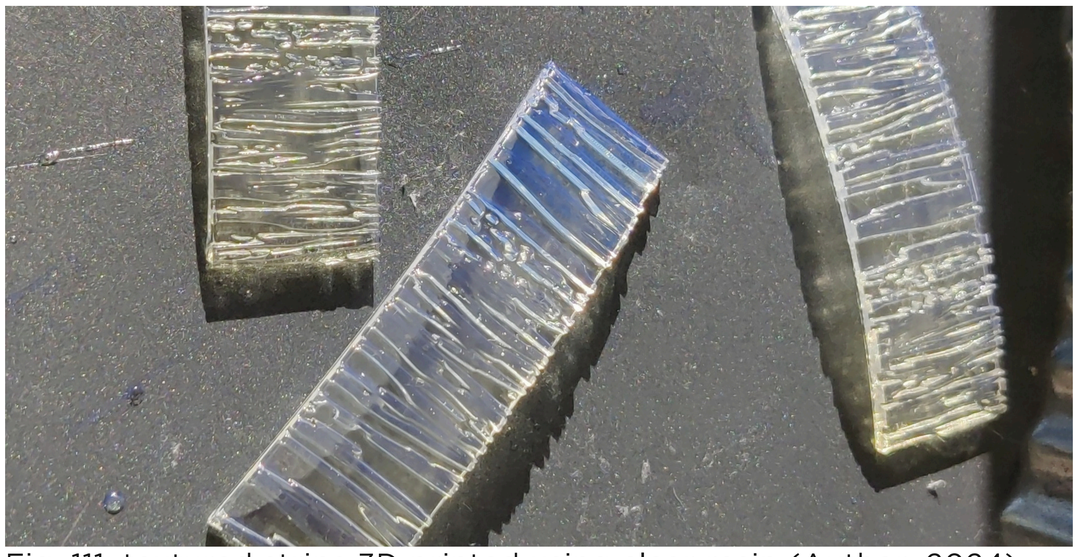


Fig. 111: textured strips 3D printed using clear resin (Author, 2024)

In the meanwhile, the original idea of splitting the cylinder and printing it in the in-house SLA 3D printer was considered for prototyping purposes. These 3D printed diffraction elements can be seen in the image above. These 3D printed parts were then used in the Quarter Prototype for testing.

Hence, the diffracting elements proved to be difficult to produce and hence, it was decided to get them outsourced by a large scale 3D printing company called JLC3DP.

Quarter prototype

Based on the final shape and size decided, dimensions of the PoC were smaller as compared to the intended design. Hence, the PoC only confirmed the proper functioning of the effect. However, the PoC did not show how the effect would be like when scaled to the desired dimensions. In order to answer this question, a part of the final design was produced. This prototype was a quarter portion of the main body of the final design. By making this prototype, the lighting effect true to the scale of the final design could be tested. Along with the scaling, the resin 3D printed strips needed to be designed and tested. Hence, they were prepared to be printed in-house and tested by fitting

Appendix H: Diffracting Elements

them in this Quarter prototype.

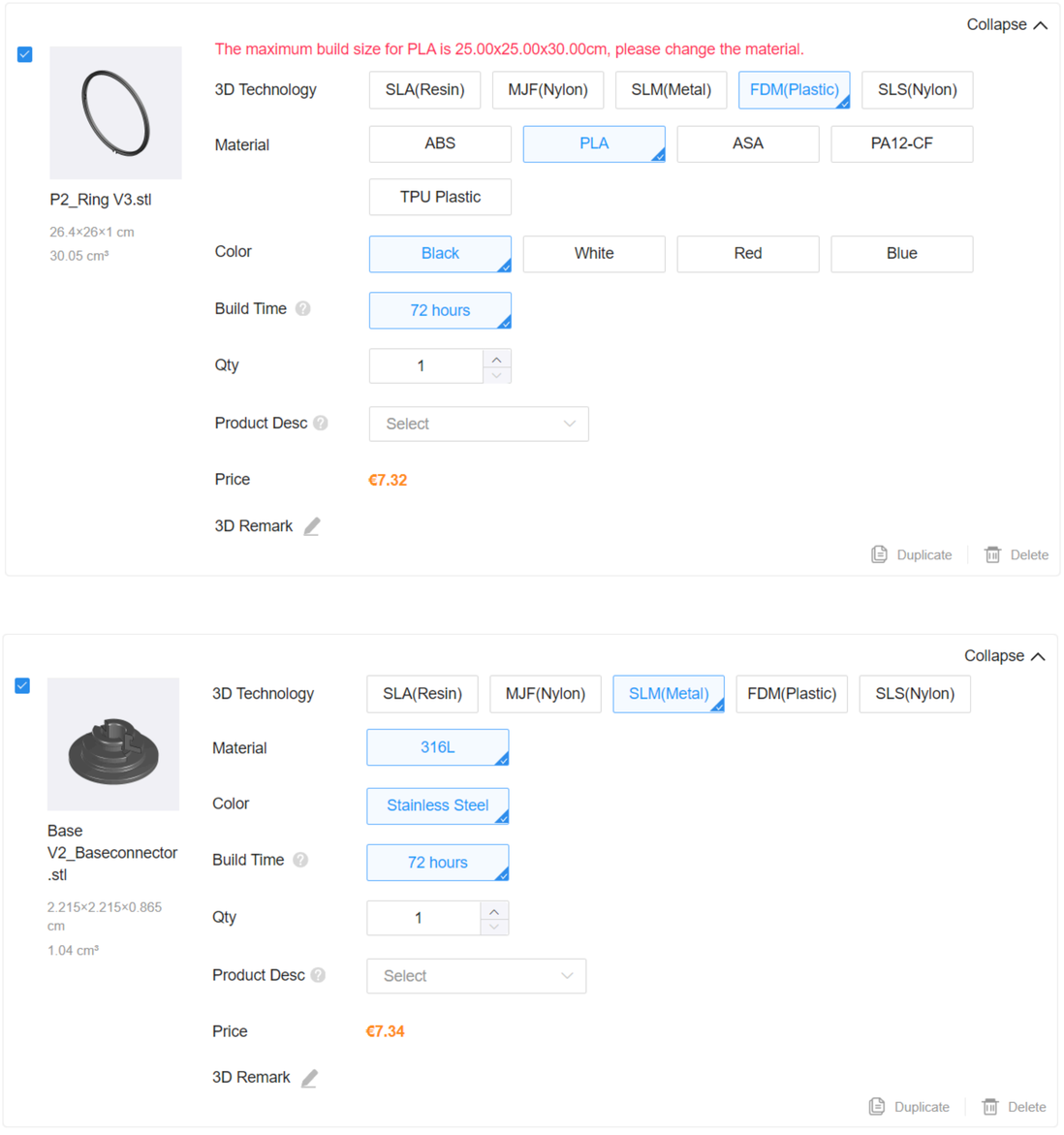
A frame was 3D printed in a FDM printer to give the prototype its structure. The top surface of the semi-transparent foil was applied on a laser cut piece of acrylic sheet. As a white backdrop surface, a white acrylic sheet was used to experiment the effect caused by this material. The sides of the prototype were made from laser cut MDF sheets. Thus, a complete setup which could act as a representative of the final design was made and tested.

There were a few insights which were found out from the testing of the quarter prototype. The white acrylic sheet was not the best solution to achieve the intended effect. This was due to translucent and glossy properties of the white acrylic sheet. The translucency did not provide enough darkness in the mirror-like state. The glossy surface finish of the white acrylic sheet created further reflections making the effect go haywire and lose its prominence and feeling of uniformity in the effect.

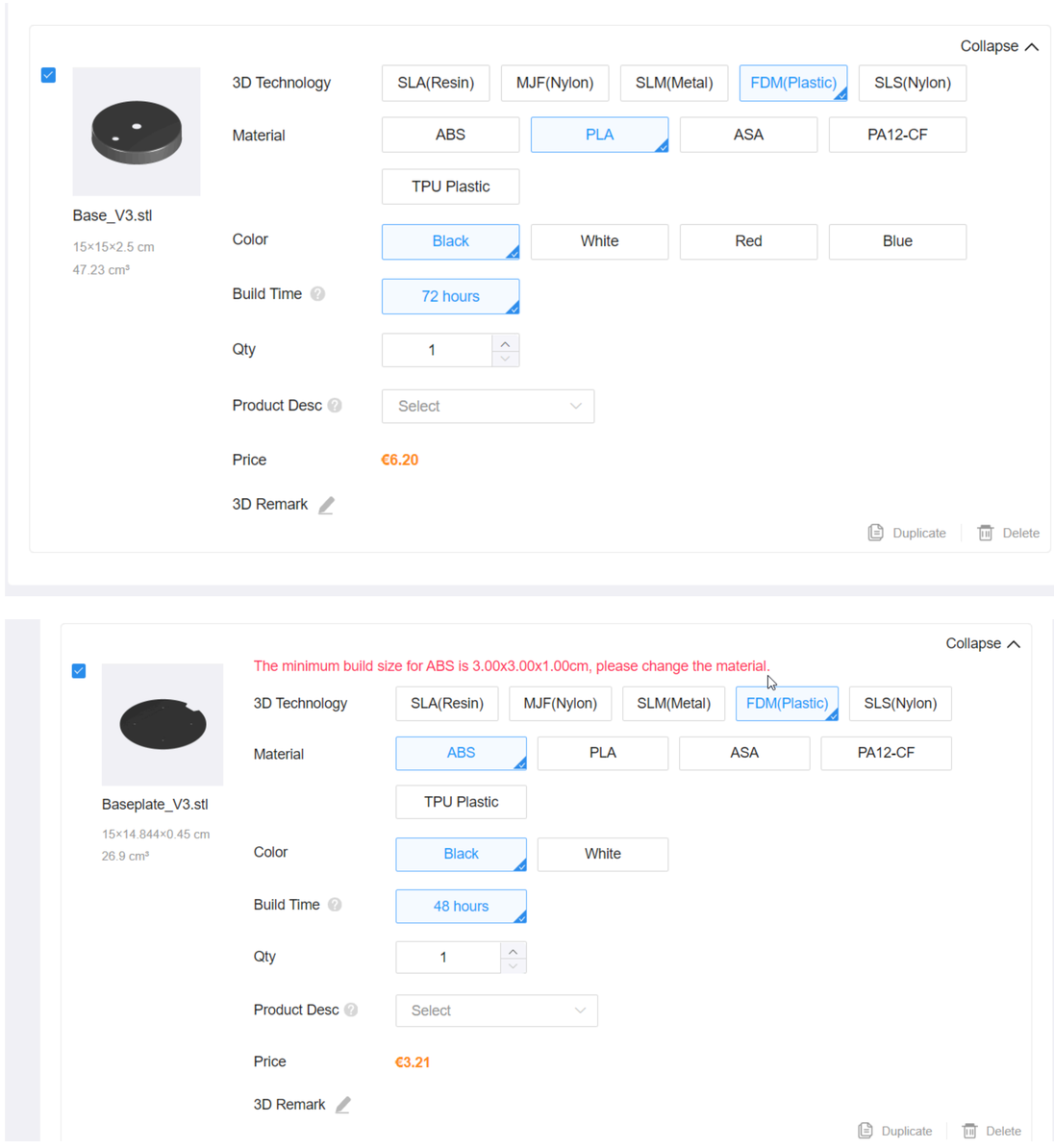
The resin 3D printed strips worked similar to the textured sheets and hence, were efficiently replaceable. The strength of the LED strips was seen to be sufficient when enough number of LEDs were on. During the initial use cycle, with part of the LED strip switched on, the effect might be too dull to be noticed. Hence, increasing the brightness from 50% (current state of brightness) to a higher value could be considered.

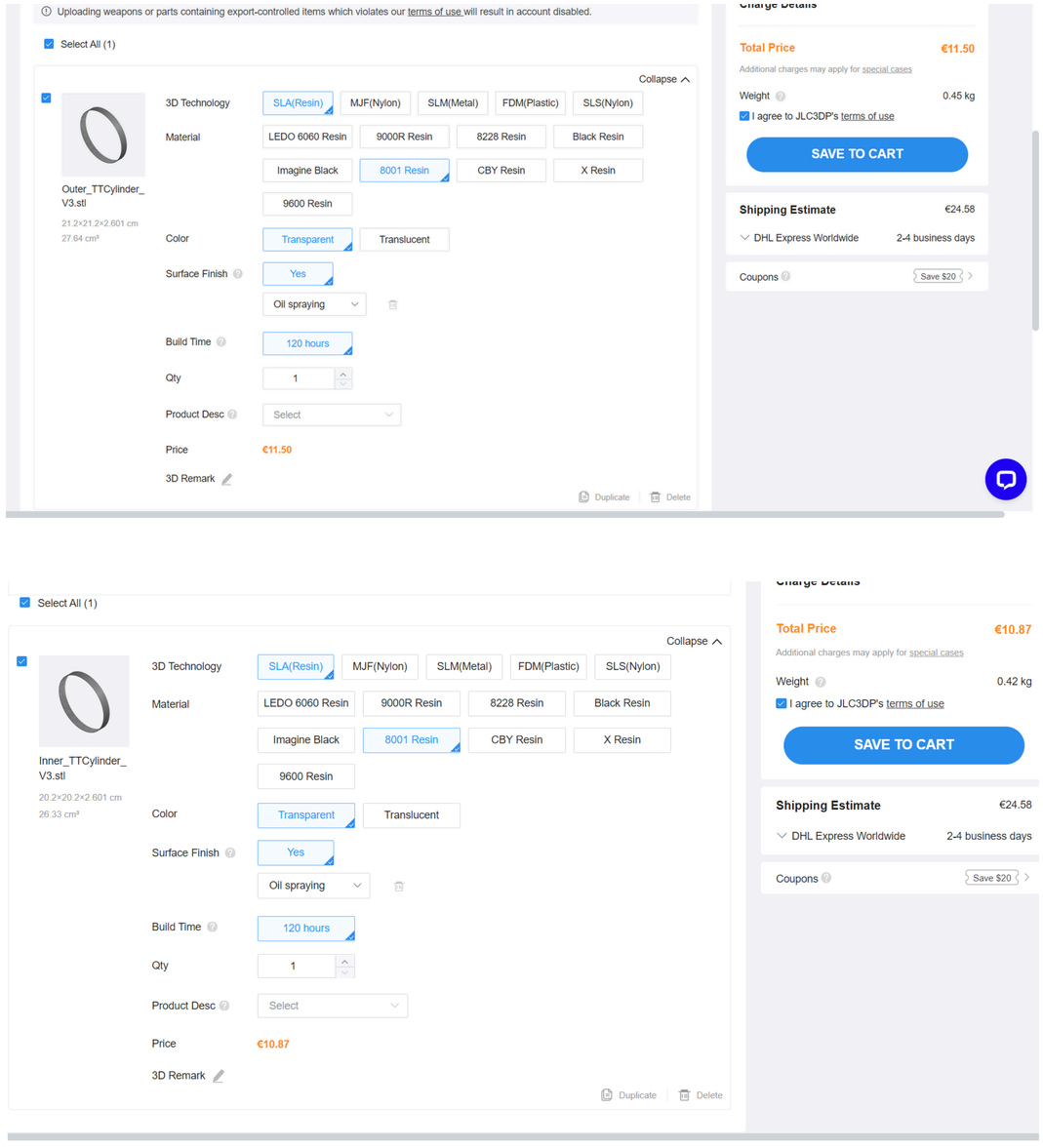
In conclusion, the diffracting elements were successfully developed using the SLA 3D printing and the true to scale diffracting elements would be outsourced by the client company.

Appendix I: Cost structure



Appendix I: Cost structure





Appendix J: Validation Test

TU Delft

Faculty of Industrial Design Engineering — Delft University of Technology

CONSENT FORM

You are being invited to participate in a validation test for project titled "Using Light to motivate a physically active lifestyle". This validation is being done as a part of the graduation thesis of Rakesh Patel, MSc. Integrated Product Design, from the Department of Industrial Design Engineering, Delft University of Technology, in collaboration with a client company, Hola Studio, Rotterdam, NL.

The purpose of this validation test is to gather feedback and data regarding the design, its intended purpose and identify opportunities for increased user adoption. A prototype of the design will be demonstrated along with additional information and/or instructions. The participant will then be asked to fill a form which contains various questions regarding the design. This can be followed by a discussion regarding the answers written by the participant and/or follow-up questions.

The test will take approximately 30 minutes to complete and will take place in a mutually convenient, safe location, offline. The data will be used for academic purposes and for initial validation by the client company. I will be asking you to share your thoughts on the complete design, interaction and experience.

Your answers in this validation test will remain confidential. I will minimize any risks by not collecting any personal data except name, email address and age; these data will be stored temporarily in a secure university drive and will be destroyed after the completion of the project. With your consent, interviews will be audio/video-recorded; once the recording has been transcribed and verified, the audio/video recording will be destroyed. Data will only be accessible by me and the client company. Furthermore, in any instances where photos are used in the final thesis, faces will be blurred to ensure the anonymity of the participants. Additionally, participants' responses, view or other input can be quoted anonymously in research outputs.

Your participation in this validation test is entirely voluntary, and you can withdraw at any time. You are free to omit any questions.

If you have any concerns, please contact me:

Rakesh Patel (r.m.patel@student.tudelft.nl)

_____ _____ _____

Name of the Participant | Signature | Date

Please take a minute to go through your answers and discuss them.

Usability Section

In this section, you are provided with an infographic manual explaining the intended way of using the prototype (which is same as the final design). Please take your time to go through the manual and ask queries if necessary. You are then given the following instructions to be carried out as shown in the manual.

1. Turn the knob, clockwise and counterclockwise
2. Press the knob
3. Move the device to place it in the most comfortable position
4. Connect the power cable to the device
5. Follow the startup sequence
6. Set the timing in the configuration sequence
7. Follow the Micro-activity sequence
8. Follow the Cooldown sequence

Please answer the following questions based on your experience of using the product:

Q1. Did you encounter any difficulties while using the product? If so, please describe the difficulties and at which step did you encounter them?

Ans. _____

Q2. How did you feel about the process of setting the timing of the micro-activity?

Ans. _____

Q3. What are your thoughts on the interface of the product?

Ans. _____

Q4. Are there any actions you wanted to perform but couldn't?

Ans. _____

Validation Form

Dear participant,

Please fill out this validation form according to the instructions given. There are three sections to this form and must be completed in the given order. For any queries, please feel free to reach out.

Name:
Email address:
Age:

Appearance Section

In this section, a prototype of the design is presented to you along with visualized images of the final design. The prototype is off and should be observed without interacting with the prototype for this section, to not develop any bias.

(Please think out loud all your thoughts regarding the design.)

Q1. Observing the prototype and the final design visualizations, which objects does the design remind you of?

Ans. 1. _____
2. _____
3. _____
Additional comments: _____

Q2. While observing the product and personifying the design, rate the following characteristics on this five-point scale:

(Please think out loud the reasoning being the rating)

Ans. Exciting	|_____|_____|_____|_____|_____|	Boring
Aggressive	|_____|_____|_____|_____|_____|	Gentle
Unpleasant	|_____|_____|_____|_____|_____|	Pleasant
Modern	|_____|_____|_____|_____|_____|	Classic
Dishonest	|_____|_____|_____|_____|_____|	Honest
Indifferent	|_____|_____|_____|_____|_____|	Caring
Minimalistic	|_____|_____|_____|_____|_____|	Complex
Friendly	|_____|_____|_____|_____|_____|	Intimidating

Additional comments: _____

Please rate the following statements based on this 5-point (Likert) scale:

1. The product's functionality is easy to learn.

Ans.	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
	O	O	O	O	O

2. The product is intuitive to use.

Ans.	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
	O	O	O	O	O

3. The product feels comfortable to handle.

Ans.	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
	O	O	O	O	O

4. There are an adequate number of use cues to understand the functioning of the product.

Ans.	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
	O	O	O	O	O

5. The product does not take a lot of time to operate.

Ans.	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
	O	O	O	O	O

Please take a minute to go through your answers and discuss them.

Desirability Section

Please answer the following questions:

Q1. Can you imagine yourself using the product on a regular basis? Why or why not?

Ans. _____

Q2. Would you be willing to buy this product? Why or why not?

Ans. _____

Q3. What features would make you more likely to purchase the product?

Ans. _____

Q4. The approximate selling price for this product is estimated to be around €220. Would you still be willing to buy the product? Why or why not?

Ans. _____

Q5. Would you recommend this product to your friends and family? Why or why not?

Ans. _____

Please take a minute to go through your answers and discuss them.

Thank you for participating in this validation test and giving your valuable insights.

_____ _____ _____

Name of the Participant | Signature | Date

Appendix J: Validation Test

User #	1	2	3	4	5	Total	Averag
Age	36	33	37	35	35		
Q1_1	Bathroom mirror	Bathroom mirror	Gyroscope	Toilet Spiegelen	Bathroom mirror		
Q1_2	Satellite dish	Globe	Bathroom mirror	Ball	cup holder		
Q1_3			Spinning top				
Q2_1	3	3	2	3	3	14	2.8
Q2_2	4	5	5	3	4	21	4.2
Q2_3	4	5	4	4	5	22	4.4
Q2_4	2	3	3	2	3	13	2.6
Q2_5	4	5	3	3	3	18	3.6
Q2_6	3	3	4	4	3	17	3.4
Q2_7	2	4	2	2	2	12	2.4
Q2_8	4	2	3	3	2	14	2.8
Q1	I don't like having to look behind the product to put the charging cable	No, but moving part can be slightly higher	The base needs to be held to push the charging cable inside, It gives me a fragile feeling	Not with the product but I would like a separate charger for this device. I don't like to mix chargers	I would want the charging slot near front, because by the time I see the front of the product after connecting, the starting is already gone		
Q2	Easy because it is like turning the needles of a clock	Feels very easy because it is relatble on how a clock works	It is easy	It feels intuitive	It is fairly easy, might need to go through the instruction manual, otherwise no one understands/likes it out of the box		
Q3	Nice to have a visual representation of the time with the clock. That's intuitive	There is no many buttons to understand, the 2 chosen moves are easy to understand	I like the knob and the button is the same, but I am guessing for older people it will be confusing	I had to remember all the long pauses and clicks, maybe after a few uses I will easily set timing	I like how the light shows the minute hand, and knob gives nice physical touch. We are used to displays so this is interesting		
Q4	No.	No.	No.	Yes. I started using a running app recently, it would be nice to add this product's data to my apps or app data to this product	No.		
Q5_1	4	4	4	5	4	21	4.2
Q5_2	5	4	5	4	5	23	4.6
Q5_3	4	4	3	4	4	19	3.8
Q5_4	4	4	4	5	4	21	4.2
Q5_5	5	4	4	5	5	23	4.6
Q1	Yes, as a freelancer I spend a lot of time behind the computer and this product would remind me to take breaks	I don't feel like I will use it on a regular basis cause I am a person usually working in different spots and environments, the design doesn't allow for moving	Being a young mom, I like how it will remind me to do some movement here and there, so yes, but I want to give me a bigger notifications as compared to just blinking	Yes, definitely. To think about it, I can use it for other things as well. Like for pomodoro technique	I don't think so I will. I like keeping my schedules tight and get done with work in one-go. I have started gyming regularly and prefer doing that for 1.5-2 hours at the end of the day. Also, I think it will be embarassing to do exercise in the office		
Q2	Yes, but it is a bit big at the moment	Yes, It is nice to have a product that reminds you the required physical activity per day	Yes, I can see myself buying something like this. It is easy and looks nice as an interesting lamp	Yes, I	No, my lifestyle choices are different than the product, so I don't want to buy it, but I can see it working for people who find it difficult to exercise		
Q3	More aggressive reminders Add a feature to remind people to look far awa every 20 minutes to reduce headaches	I would make it smaller, more portable	Maybe adding sound, but I also understand about passive notification	I think more timing and size options	I don't think so		
Q4	100 to 150	No, I would say it is a bit pricey for the activity its performing. In between 60-100 sounds more reasonable	120 to 150	If it is 3D printed then I would not like to pay so much, I think anywhere around 150 should be good	I think it is pricey, maybe around 100		
Q5	Yes, if I try it for some time and see the benefits	Yes, because it will be a way to stay in shape	I would want to try it properly first, but I would like to show it to my husband anf friends	Yes, it looks fun	Yes, the idea for the product sounds very interesting		