Lichtdruk

A kinetic artwork

Master thesis

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This thesis is written as part of the masters program of Integrated Product Design (IPD) at the faculty of Industrial Design Engineering, Technical University Delft.

Acknowledgements

These past months have been some strange ones, with many ups and downs. Due to personal circumstances, it was not always easy to stay motivated. Nonetheless, my supervisors, Sylvia Pont and Susie Brand-de Groot, both kept believing in me, and taught me that having faith in the process is the best thing you can do. For this I will be ever grateful. Next to that they gave a ton of useful advice, nudges (and sometimes strong pushes) in the right direction and were understanding of my situation. Thanks for the time you have spent with me, helping me complete this project. I would also like to express my appreciation towards my client, Arjen Witteveen, who has been very open towards new ideas, but also provided inspiration and new inputs when I needed it. It has been very pleasant working together once again, in a casual, informal way.

I would like to thank my parents, for being there for me, always willing to listen when I was both up and down, and checking in on me every once in a while. I would like to thank my sister, who has been graduating art school at the same time. It was nice to talk about both our projects together, exchanging ideas and getting and giving new angles on both our topics.

Next I would like to thank my friends at Slopend, for making me laugh every once in a while, reminding me not to take life so seriously. It was great to forget everything else those evenings, and just enjoy each other's company. In particular, I would like to thank Matthias Groenewolt for his enthusiastic energy, for dragging me out of the slumps when I didn’t know where to go with the project anymore and for his help creating the video.

I would like to thank Carlo Faulquier, for letting me borrow his camera equipment, and helping me out with shooting the video, and Jochem Wichers for his performance in that video.

Finally, I would like to thank Jessica Overdiep from the department's secretary, who always received me with a warm smile to book a room for the next meeting with my supervisors, giving me some energy after a tiring meeting just before. And I would like to thank Carlita Kooman for helping me realise my final setup, and helping out finding materials.

Preface

After finishing another project on the behalf of the library of the TU Delft, I was talking to Arjen, who had helped me with the creative side of that project. He asked me what I was going to do next with my life. I told him I still had to graduate to finish my masters, and was looking for opportunities to do so. He told me it might be something he'd like to try, becoming a client to such a project, so we stayed in touch. After pitching his idea, I became enthusiastic too, and thought it had potential to become something, and also give me some more experience in the world of art.

I knew there would be plenty of technical challenges along the road, something I enjoy solving thoroughly. At heart I am still an engineer and a maker who likes to work with his hands, and has the curiosity to want to understand everything. Over the years this has built up to an acceptable library of knowledge, which can come in handy on projects like these. It involved a lot of experimenting, trying new setups and materials, slowly growing into the final result it has eventually become.

Where I struggled a little more was the storytelling. Something I would consider important in any artwork, as you are trying to speak to your audience. Having only limited experience here I made it one of my learning goals for this project. After a couple frustrating weeks I think I eventually managed to get the message across, and it has given me some holds for future projects so that it should be easier next time.

All in all I can say that I am satisfied with the result. There are a hundred things I would still like to improve, but I saw this as a last opportunity to learn something from the goldmine of knowledge a university is, not to deliver a perfect project. Enjoy the read.

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Introduction

People and nature (in western society) are growing more and more disconnected from each other. We forget we are a part of nature, and instead live in a world we have completely designed ourselves. Because of this, we miss out on a lot of experiences and benefits most of us do not even realise nature offers. We once were a part of nature, and still are, and probably will always be.

This project attempts to make this human-nature connection visible, through the medium of air. It is all around us, and while the biggest part of the "outdoors" stays there, air manages to creep through cracks and holes of our buildings, providing a bridge between in- and outside. Next to that, as air is invisible, people are not aware of this connection between in and out, functioning as a metaphore. The challenge is to make the invisible visible, and use the changes in environmental air pressure to power a kinetic art piece. It will be ever changing, moving with the flow of the weather, showing the transience of nature.

The artist/designer Arjen Witteveen (atelierAW) aims to bridge this gap and inspire people with an art piece to feel more connected to their environment and get a feel for the environmental air pressure as a natural phenomenon.

This report will attempt to provide an advice on how to best achieve such an artwork. The physical principles of air are analysed, after which gradually evolving experimental setups are constructed to eventually turn into a user tested prototype. All this to gain an insight into the many challenges there are on the way to such an artwork. The report will finish with a list of recommendations to the client (Arjen Witteveen), so that he can continue the development of this installation.

“Create a kinetic artwork that moves by changes of the environmental air pressure and makes the viewer aware of their connection to nature”

Background

In order to get a better grip on the rather broad assignment these first few chapters will cover the topics of air pressure, its behaviour, particularly in the Netherlands, but also our disconnect to nature, biophilia and the emotion of awe. Further imputs from the client are also discussed, and all is eventually summarised into a more consise formulation of the assignment, with a more narrow and achievable scope.

The gained insight in the theory will then be used to start constructing prototypes that are improved iteratively. The most important test results are shared and eventually implemented in a final prototype.

Picture by Jos Kruijthoff (2018)

1. Air pressure

Air is all around us, and like all matter, has certain properties. This chapter will elaborate on some of those properties, particularly pressure, how this is measured, how it relates to the weather, and what its behaviour is, especially in the Netherlands.

History

Already centuries ago, people proposed the concept of a vacuum, a place with no matter. For a long time they believed this was impossible, that there always had to be something. Around 1640, Gasparo Berti set up an experiment where he made a long tube, filled with water and closed at both ends. He would put the tube upright in a basin filled with water, and opened the bottom end. What he saw was that the water level lowered, but not all of it flowed out of the tube. There was a column of about 10.3 meters of water left. Since there was no air to fill in the space at the top, he theorised that he had created a vacuum. And that the vacuum had some suction properties that kept the water from flowing out.

A couple years later, Evangelista Torricelli came up with a new theory, suggesting air had weight. Up till then the convention was that air had no weight, it just floated around us. But Torricelli saw it as a balance. The water pushing on one side, air on the other. To make the setup more suited for inside, he theorised if he would use a denser liquid, the tube would have to be less high. So he did the experiment again with mercury. Being almost 14 times denser than water, the column would be 14 times lower, or 760 mm. This turned out to be true, and the barometer was born, see Figure 1.

This tool could be used to measure the air pressure. Fluctuations cause the level to drop or rise depending on the pressure. (The Editors of Encyclopaedia Britannica, 1998)

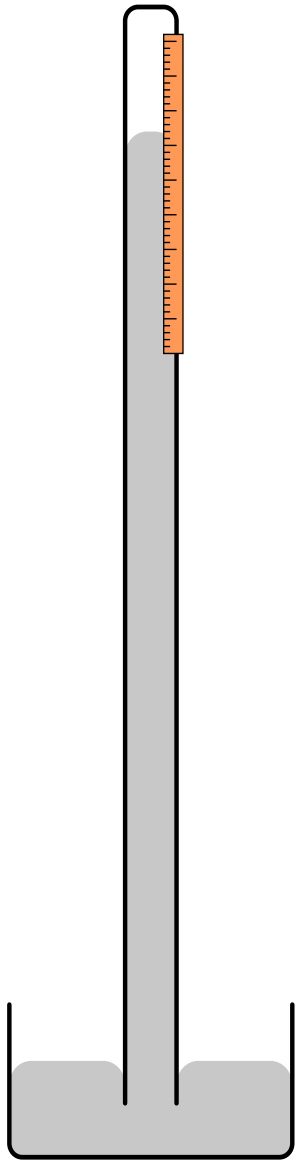


Figure 1: The setup of a mercury barometer (Danomagnum, 2009)

After a while, people noticed a relationship between air pressure and the weather. High pressure generally meant fair weather, low pressure meant poorer conditions. It was especially useful on the long journeys at sea to be able to predict the weather, and therefore potentially dangerous situations.

Aneroid barometer

But having a column of poisonous mercury aboard a rocking boat was not ideal. So exactly two centuries later, in 1844, the aneroid barometer was invented. It was less accurate, but far more convenient when travelling. It uses a small evacuated box called an aneroid cell that flexes depending on the air pressure. Through a system of springs and levers this motion gets translated to a pointer that shows the pressure on a scale. (Wikipedia contributors, 2025) A simplified diagram can be seen in Figure 2.

So air has weight, and the pressure it exerts changes gradually with the weather. Not enough so we can feel it (human ears can adjust quicker than the pressure changes), but enough so that it is measurable. This is where the idea for this artwork starts. To attempt to create visual motion from these changes in pressure.

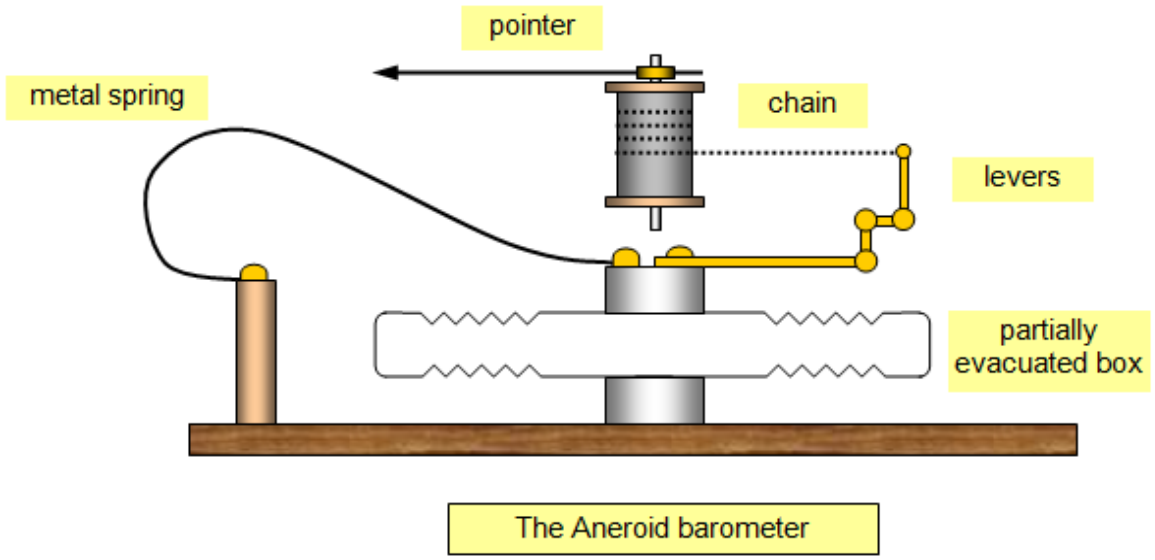


Figure 2: The basic inner workings of a typical aneroid barometer (Hodgkins, z.d.)

The dutch weather

To specify exactly what conditions we are dealing with, we can analise the circumstances we are given, and principles by which air pressure works.

Looking at data from the KNMI, we see that air pressure naturally fluctuates. The highest pressure ever recorded in The Bilt is 1050 hPa, while the lowest 956.4 hPa. However, these are extremes. More generally, the average pressure is 1015.5 hPa, and it roughly fluctuates between 980 and 1040 hPa. Seasonal changes make that the pressure is generally slightly lower in the autumn compared to spring. (WOW-NL: Jouw Weer op de Kaart!, z.d.)

More pronounced are the short term changes in pressure, differing from day to day. Figure 3 shows the changes in air pressure over the past year. We can see it ranges from about 975 hPa to around 1045 hPa, which are roughly the values between which the weather generally fluctuates. Also apparent from the graph is the fact that the weather over the winter is far more chaotic than during summer. The graph becomes coarser from September till April, which is also the period where both extremes are found. In order to make use of these pressure changes, they need to be turned into a force. Pressure and force relate to each other according to Equation 1, where F is force, P is pressure and A is the area on which the pressure acts.

Equation 1: $F = P*A$

If we had an area of 1 m^2, it would experience a force of $1.016*10^5$ N, or about $1*10^4$ kg's at average atmospheric pressure (1015.5 hPa). However, the laws of physics state that a pressure at a certain point in a fluid (liquid or gas) must always act in all directions. Let's take a table as an example. If there is a pressure of 1015.5 hPa, this means there is about $1*10^4$ kg's of weight pushing on the table. Most tables would not hold this. However, there is also $1*10^4$ kg's of weight pushing up on the bottom of the table. Therefore, they cancel each other. So what we are really after is pressure differences. And this is what the weather creates.

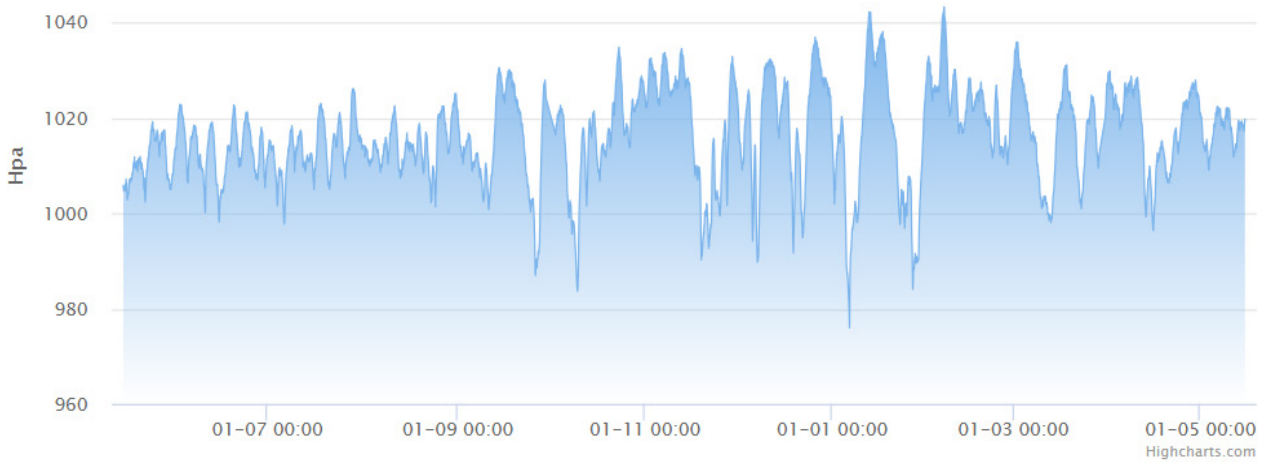


Figure 3: The environmental air pressure in Epe, measured from May 2024 to 2025 (Luchtdruk Laatste Jaar, 2025)

But in order to make use of these in changes in pressure, it would be good to quantify them, and see with how high forces we are dealing. With fluctuations of maximum 35 hPa (1015.5 - 980 hPa), we get pressure differences of about 3500 N/m^2. For reference, most air pressure tools work on around 6.3 bar, or 6300 hPa of pressure differences, significantly more. Nonetheless, if a large enough area is chosen, still significant forces can be generated (see Equation 1). However, we are not there yet. Because if the force is only sufficient to create some form of motion at maximum pressure, whatever you are trying to move will remain still. When the force reaches its maximum, it is about to create motion, but then the pressure drops, and so nothing has moved.

Energy

To put it in a little more perspective, if the system were to experience its maximum pressure difference away from the mean (about 35 hPa), a cubic meter of air would be able to harness approximately 63J of energy, roughly equal to the energy in 0.004 grams of sugar. With pressure changes of 1 hPa, required for semi-continues motion, this goes down to 0.05J.

In order to create almost continuous motion, the pressure difference at which movement occurs should be made as small as possible. But that has a downside that the force decreases accordingly. So either the motion is non-continuous, but can be achieved by significant force, or the motion is (almost) continuous, but must be achieved with a smaller force. There is a trade-off there.

To summarise, the weather, and with it the environmental air pressure, is constantly changing. Significant drops or rises happen over the course of a couple days, with calmer weather in summer and more chaotic in winter. Devices that can measure the changes have been around for a over three centuries. They need to be sensitive, because these changes are small, with pressure ranging from 975 to 1040 hPa in the Netherlands, with an average of 1015.5 hPa. So for this project too, a high sensetivity setup is required to generate a visible effect.

Figure 4: A classic aneoroid barometer (Olorvida, 2021)

Now the technical part of the problem has been explored, we can take a look at the societal part. The next chapters will elaborate on the growing disconnect between humans and nature, and look for possible ways how this art work can come across as natural, and make its viewers feel more connected to nature.

2. Disconnect to nature

In today's Western societies, people are increasingly disconnected from nature. While this divide has historical roots, its current form is shaped mainly by modern lifestyles, digital technology, and urban environments. This disconnection shows up in everyday behaviours, fewer people spend time outdoors, and nature-related language has declined in mass media since the 1950s. Children, in particular, are more likely to stay inside, drawn to screens rather than outdoor play.
Research from the UK Mental Health Foundation (2021) shows that young adults often do not engage with nature due to lack of time, safety concerns, or having no one to go with. Some even report not enjoying nature at all. This suggests a broader cultural shift where nature feels distant, unfamiliar, or inaccessible.

Theories like Nature Deficit Disorder (NDD)(Louv (2008)) and biophilia (Wilson, 1984) help explain these trends. NDD suggests that a lack of exposure to nature, especially in childhood, can impact mental and physical well-being. Biophilia, on the other hand, argues that humans have an genetic connection to nature, and we suffer when that link is broken. Both point to real psychological benefits of nature and the costs of ignoring it. However, only limited evidence can be found for these theories.

Other research (Beery et al., 2023) highlights eight areas where this disconnect is visible, from our food systems to education and urban planning. Even how we talk about nature, calling it a disconnect between "humans" and "nature" would suggest that we humans are not part of nature, but rather outside it, separated.

While the causes are complex, it is clear that modern life makes it harder to feel connected to nature. It is not realistic to solve this large, multifaceted problem by a single piece of art, especially since its causes are so diverse and interlinked. But it would be nice, if every once in a while, we are reminded that we are part of nature, that we should enjoy its beauty, and should be grateful for it what it brings us, treating it with care. More information on the disconnect to nature can be found in Appendix B.

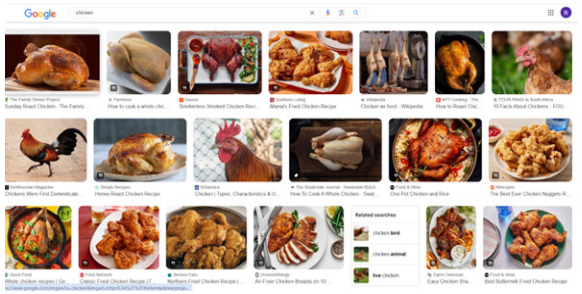


Figure 5: A quick google search on the word "chicken" shows way more results of the food rather than the animal, an example of society disconnecting from nature. (Chicken - Google Search, n.d.)

3. Biophilia

As we have established, people and nature have become more and more disconnected in recent years. But this does not need to be a problem per se. However, research has pointed out that being connected to nature and spending time in natural environments can have a number of health benefits.

Based on the health benefits nature can provide, a branch of design called biophilic design has emerged. The term 'biophilia' was first coined by social psychologist Eric Fromm (1964) and later popularised by biologist Edward Wilson (1984)(Browning, 2014). It means as much as that ingrained in human DNA is a desire to spend time in natural surroundings. We are programmed to prefer nature over artificial environments. And Richard Louv (2008) consequently states that in case this desire is not met during childhood, it can cause mental health problems later in life. However, the biophilia theory has so far not been proven in the sense that it is ingrained in our DNA. Nonetheless, we can use parts of it like Attention Restoration Theory and Stress Reduction Theory. These are sub-theories with a more profound scientific basis. They are further elaborated on on page 15. They can be used as a reason to incorporate natural elements in design to diffuse the line between natural and artificial, and potentially bridge the gap between human and nature at the same time.

Biophilic design

Designing with biophilia in mind is called biophilic design. It aims to introduce natural elements in artificial surroundings to create a more natural environment, inducing the health benefits mentioned above and more. It is often confused with biomimetic design, and while there is definite overlap between the two there is an important difference. Biomimetic design looks at nature and draws inspiration for it, mostly looking for innovation or technical improvements. Biophilic design uses human preference for natural environments to introduce organic elements in artificial surroundings to induce the health benefits biophilic design has. Mostly used in architecture and interior design, it is used as a framework that helps integrate these natural elements in a space. This framework can also be useful in this case, as it can be used to transform (part of) a space into a more natural environment, that in turn can make people aware of their connection to nature.

To see how exactly a biophilic design can be made, we can look at its design patterns. Over the years, several attempts have been made at categorising the elements of biophilic design. Stephen Kellert identified six elements, divided into three categories: Nature in space, Nature analogues and Nature of space. Later, William Browning came up with 14 design patterns, subdivided in the same three categories. (Browning, 2014). More recently, another pattern was added for a total of 15. It should be noted that these design patterns seem rather arbitrary, with the paper giving no explanation why exactly these 15 categories are chosen. Nonetheless, they are all supported by scientific research, some more strongly than others. So they provide some structure in coming up with a biophilic product.

Figure 6: Tulum Sfer in Brazil is a cultural centre in the jungle, constructed along biophilic design rules. (Metropolis & Forrest homes, n.d.)

Design patterns
Biophilic design patterns that will turn out to be of particular interest are: Presence of water, connection with natural systems, biomorphic forms and patterns, refuge and mystery. All fifteen design patterns can be found categorised and examplified in Appendix C.

Presence of water
Water has a number of effects, from reduced stress to lower heart rate. According to Browning et al. repeated experiences do not lower the interest, so even if people see the artwork multiple times, it will remain captivating. Important when applying this pattern is that the water must be flowing and clear, appearing clean.

Figure 7: Presence of water in architecture (PYE interiors, n.d.)

Connection with natural systems
This is quite directly related to this project, as the changes in weather form the driving force. Its objective lies in making people aware of natural processes, and potentially showing pro-evironmental behaviour as a result.

Figure 8: Natural process can help in biophilic design (Tips for Buying and Planting a Fruit Tree, n.d.)

Biomorphic forms and patterns
Shapes and forms that mimic those found in nature can enhance the natural feel of a space. However, it is unclear to what abstraction level this can be done. Presumably, the more closely something resembles nature, the stronger its effect.

Figure 9: A biomorphic house design (Pavie Architects, n.d.)

Refuge
This refers to the human need to feel safe and protected. To create refuge, a space should "feel separate or unique from its surrounding environment." "The principal spacial condiation is protection overhead and to one's back, preferably on three sides." It too reduces stress and lowers the heart rate.

Figure 10: Refuge built into a home, giving shelter (Giftthaler, 2022)

Mystery
According to Kaplan and Kaplan (1989), "people have two basic needs in environments: to understand and to explore. " Hence the mystery pattern can be used to draw attention, and make people want to keep watching.

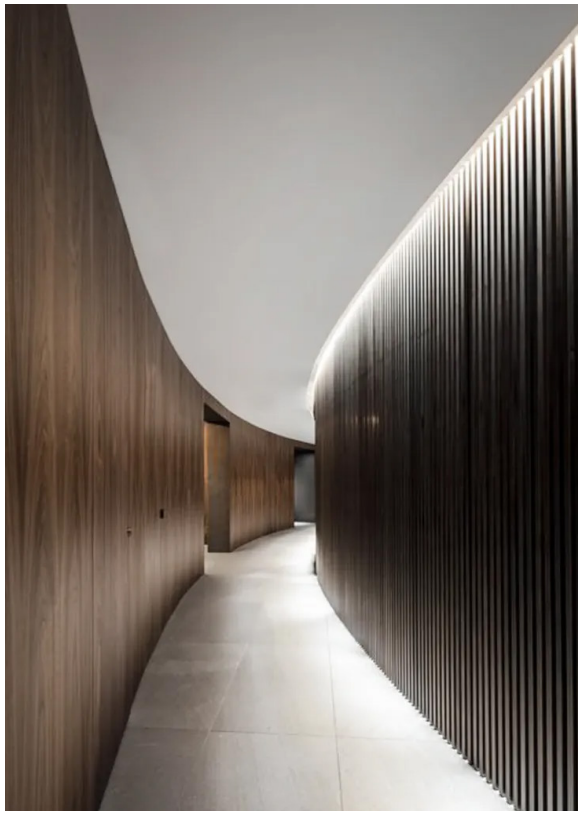


Figure 11: Mystery in an interior (Studio mk27, 2020)

Awe
This pattern was discovered later, but was also found seperately in this research. It sparked particular interest, hence it has its own dedicated chapter (Chapter 4).

It will become clear once the full design is revealed in Chapter 9 why these patterns in particular are relevant for this project.

Figure 12: Tall tree can evoke awe (Mackenzie & Mackenzie, 2018)

Attention Restoration Theory (ART) & Stress Reduction Theory (SRT)

Attention Restoration Theory

Attention restoration theory (ART) is a theory developed by Rachel and Stephen Kaplan that proposes that spending time in nature helps improve the ability to focus and stay concentrated. They split attention up into two categories, direct or voluntary attention, and indirect, involuntary attention. Direct attention is focussing on something intentionally, like reading a paper, executing mathematical arithmetics or watching an instructional video. It is characterised by a focus on the task at hand, and filtering out irrelevant information from someone's surroundings. Indirect attention on the other hand, can be seen when people are naturally drawn to something, and cannot help but focus on it. Like the moving clouds overhead, the smell of flowers or listening to birdsong.

Kaplan and Kaplan theorise that longer periods of direct attention result in fatigue, making it more difficult to filter out irrelevant stimuli from the environment and losing focus as a result. As a solution, the direct attention should recharge. This can be achieved by spending time in a state of involuntary attention. Involuntary attention is gentle, drifts from one subject to another and is unforced (Kaplan & Kaplan, 1989).

Stress Reduction Theory

Related to ART, there is Stress Reduction Theory (SRT). Proposed by Ulrich et al. (1991), it states that looking at a scene with natural elements can induce calm after a stressful situation. He based his theory on tests in hospitals, but in the meantime empirical evidence has shown up in other settings such as prisons, residential communities, offices and even schools (Moore, 1981) (Thompson et al., 2012) (Shin, 2007), (Ulrich, 1979).
These effects can be highly desirable in a world with increasing stress-related diseases and mental health problems. Already, rehabilitation gardens are built, in for example Alnarp (Sweden), that help people recover using occupational therapy, or in Hogeweyk (Netherlands), where they have built a dementia village.

ART and SRT prove that spending time in natural environments can have certain health benefits. Hence they can be used as a base for the design of this work.

Figure 13: A dimentia village designed according to biophilic design rules (Vivium Group & Rinaldi, 2023)

Figure 14: Singapore has applied a lot of biophilic design througout the city, as seen here in there airport (Singapore Airport, n.d.)

4. Awe

However, the ART and SRT do not trigger a feeling of connectedness. But a different emotion can be activated to do so. The emotion of awe has been linked to both (vast) natural landscapes, as well as positive influence on mood, feeling more selfless, more social and more connected to the world around you. Because of this, could be it an interesting emotion to explore since it might hold potential in bringing connection to nature.

Defining awe

In the Oxford English Dictionary, awe used to be defined as: a feeling of fear or dread, mixed with profound reverence, typically as inspired by God or the divine. Later, this turned into: a feeling of reverential respect, mixed with wonder or fear, typically as inspired by a person of great authority, accomplishments, etc., or (from the 18th century) by the power or beauty of the natural world. So as awe is inherently linked to nature, and has potential to create connection, it could have a potential purpose in this artwork.

According to Keltner and Haidt (2003), the emotion of awe consists of two essential parts. First, there is perceived vastness. This can be physical vastness, but extends also towards perceptual or conceptual vastness. They say "Vastness refers to anything that is experienced as being much larger than the self, or the self's ordinary level of experience,". Examples are powerful inspiring people like Mahatma Gandhi, but can also be an act of kindness between people or a complex, intricate structure for example. However, Piff et al. (2015), found that looking at a grove of tall trees can elicit awe, while looking at a tall building does not. So they suggest that size alone is not enough to generate awe. Second, there is a need for accommodation. This means, according to Keltner and Haidt who in turn refer to psychologist Jean Piaget, "a process of adjusting mental structures that cannot assimilate a new experience." The thing that induces the awe does

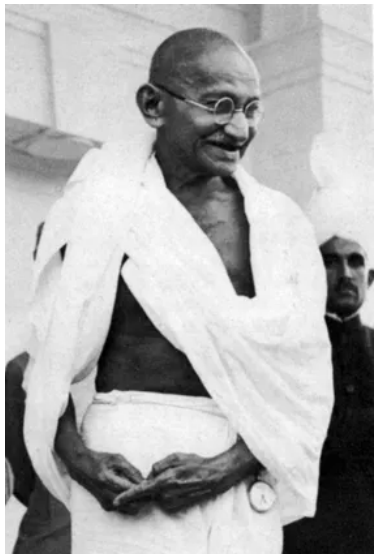


Figure 15: Awe can be evoked vastness in size, but also personality or complexity (Nanda & B.R., 2025), (Wikipedia-bijdragers, 2025)

not yet have a place in one's view of the world, hence it is looking for accommodation.

Since awe can come from different sources, Keltner and Haidt have identified five different types of origins for awe. These flavours as they call them are: threat, beauty, ability, virtue and supernatural causality. The most interesting ones in light of this report are beauty and ability-based awe. Beauty, in the sense of aesthetic pleasure can be induced by for example a person, a natural scene (note how ingrained separation between human and nature is), or work of art. Ability based awe is thought to come with admiration of a person, specifically their skill or talent to be able to achieve an extraordinary feat, in the case of this project the artist.

As a result of feeling in awe, people can have several common experiences. Multiple studies have shown that in awe-inspiring moments, people also experience a "diminished sense of self" and feel as if they are in the presence of something greater than themselves. Also, they feel more connected to others (Allen, 2018).

Origin of awe

Some emotions are closely related to awe, namely elevation, inspiration and admiration. However they are different in the sense that they do not show a relation to vastness Keltner & Haidt (2003). Reasons for why humans have developed awe seem only hypothetical so far. One proposal by Keltner and Haidt is to keep certain social hierarchies in order. Another theory, proposed by Chirico and Yaden (2018) is more nature related. They state that feeling awe for mountain ranges/ high places could be because they are safe, offering shelter and providing overview over the surrounding landscape, making it easier to spot oncoming threats. It relates to the biophilic design patterns of Prospect and Refuge (Browning, 2014). This second theory seems more well supported, although it does not explain the need for cognitive accommodation that awe has. A third theory focuses more on this latter point, stating that since awe brings a need for accommodation, it might have caused our ancestors to be more open to new information, instead of relying on the mental structures in place. This in turn results in better processing of new, potentially dangerous, situations.

In the end, it comes down to social behaviour. The self-transcending function of awe, reducing one's self-focus and feeling more connected to others would have caused our ancestors to tackle vast situations together instead of alone. It is better to tackle a difficult, complex situation together rather than alone, is the theory. (Stellar et al., 2017)

There is limited data on the connection between awe and social class, religion, character traits or culture and personality, so for this project, user testing will have to show if awe is triggered in the target audience. (Allen, 2018).

To summarise, awe can make people feel more connected, to each other, but also to their surroundings, which could be nature. Next to that, people experience a diminished sense of self, making themselves less important, and caring more about their surroundings. These two factors could both help in restoring the connection between human and nature. Therefore awe can be of use in this project.

Figure 16: Mountains are known for evoking awe, due to their vastness (own picture)

5. Expression

In the past chapters, relevant topics that resulted from research have been elaborated on. In this chapter, we will take a further look at imputs from the client that followed during meetings along the project.

Elaboration on the assignment
When talking to the client about his vision for the final product, he mentioned a few key elements that he thought would add to the design. They form input for when creating ideas and later developing the concept, and can comply with some of the biophilic design patterns mentioned earlier. These three elements are: Honesty/openness, natural variation and transiency. Below I will explain what is meant with these terms. Note that we are talking about kinetic art here, so motion will play a key role in all of these works.

Honesty/openness
By honesty/openness is meant that it is clear how the artwork pieces together, how the motion is created, what the workings behind the movement are. Machine with Wishbone by Arthur Ganson as depicted in Figure 17 is a good example. The structure is not hidden away, but made part of the art. The wishbone clearly draws attention, positioned away from the rest of the object, making a human-like walking motion. But the mechanism on the left draws as much if not more attention. Even though it might look complex at first, the viewer can deduce how the wishbone is made to move the way it is. And also when you do not take the time to figure the whole mechanism out, you immediately get the feeling there is nothing hidden in this piece. The slender wires simply do not give a place where something can be hidden. There are no large surfaces to hide behind.

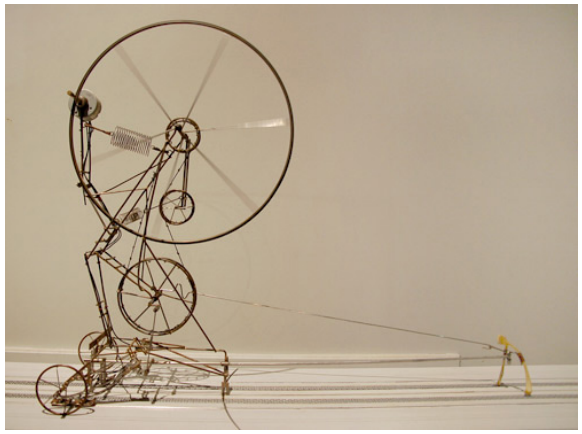


Figure 17: Machine with Wishbone from Arthur Ganson is an example of an "honest" artwork. (Arthur Ganson, 2009)

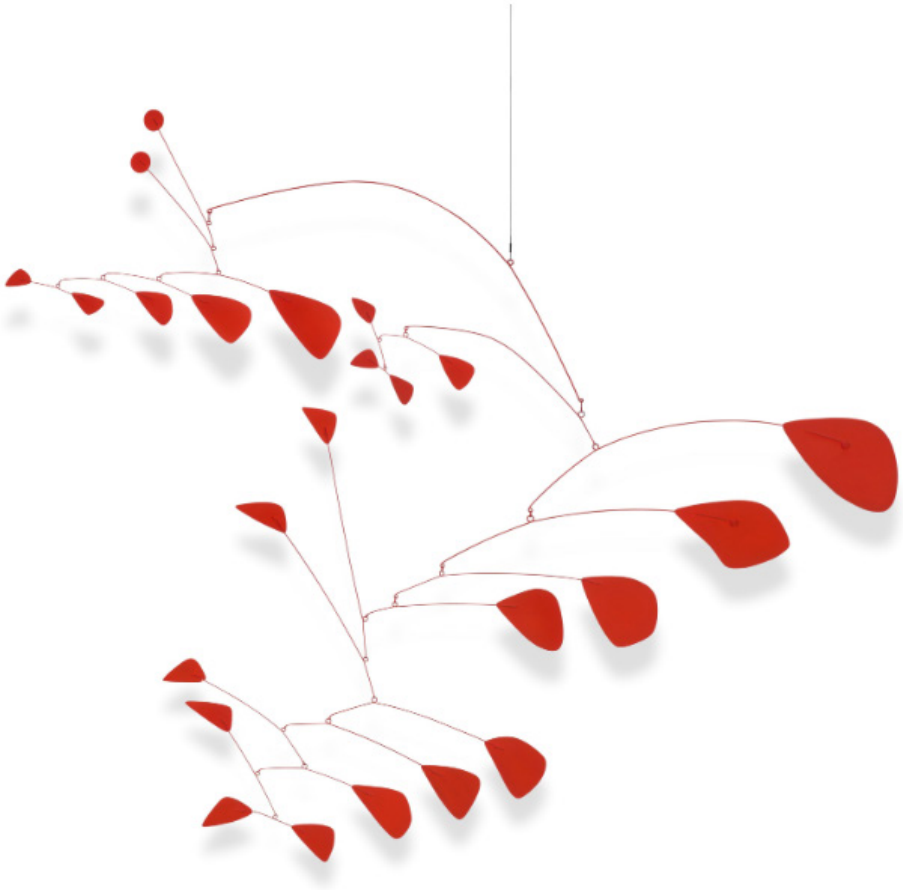


Figure 18: The works of Alexander Calder often have an element of natural variation (10 Things to Know About Alexander Calder, 2024)

Natural variation

With natural variation is meant that in nature, no two exact copies of something exist. Certain parts of an organism might look very similar, but are never completely the same. This notion can be used when making something appear natural. A flower can have many petals, and while you can clearly recognise them as petals, they are similar in shape, position, colour etc., there will never be an exact match. Alexander Calder's mobiles provide an example of natural variation, see Figure 18. No two of the leaves are the same, yet they do form a coherent whole, and are clearly related to each other. Even when a design drawing is made by hand, this occurs. As Wim aan de Stegge (2018) put it in his report, on a computer you can make three lines that are perfectly straight, and exact copies of each other. If you try to do the same by hand, you will get three almost straight lines, but none perfect, nor exact copies of each other.

Randomness/Transiency/Fragility
Nothing in nature is permanent. Everything is constantly changing under the influence of weather, the tides, chemical processes etc. And there is a certain random feel to these processes. It is hard to predict what the weather will look like in a week, let alone how the world has changed (under the influence of it). Will it rain, or will there be sun? Which flower will blossom first? And which will die first? Because that is also part of nature. Things come, and they go.

In Dutch this lets itself capture best in the word Vergankelijkheid. It translates roughly to transience, something that will only last a while, but is not permanent. And that has a certain fragility to it.

The link to the weather is particularly relevant in this project, because the whole idea that its end product changes by the environmental air pressure. So this direct link can be used to introduce this effect of randomness in the installation.

This video shows a work of William Darrell (stills can be seen in Figure 19) of a balloon in a 3D-printed structure of a strawberry. By blowing up the balloon little bubbles pop through the holes. But you never know which one is going to go first. This randomness in combination with the motion is fascinating, drawing involuntary attention. This of course relates to ART, as discussed in Chapter 3, providing a moment to restore one's focus, and is one of the goals of this project.

These three factors (Openness, Natural Variation and Transiency) will be used as a framework when designing the appearance of the art piece. They form part of the assignment, to give guidance in the development of its visual form, and to test the final model to.

They go together well with the goal of connecting humans to nature. Especially natural variation but also transiency are inherent parts of nature, so these aspects of the design can be used to reinforce the message.

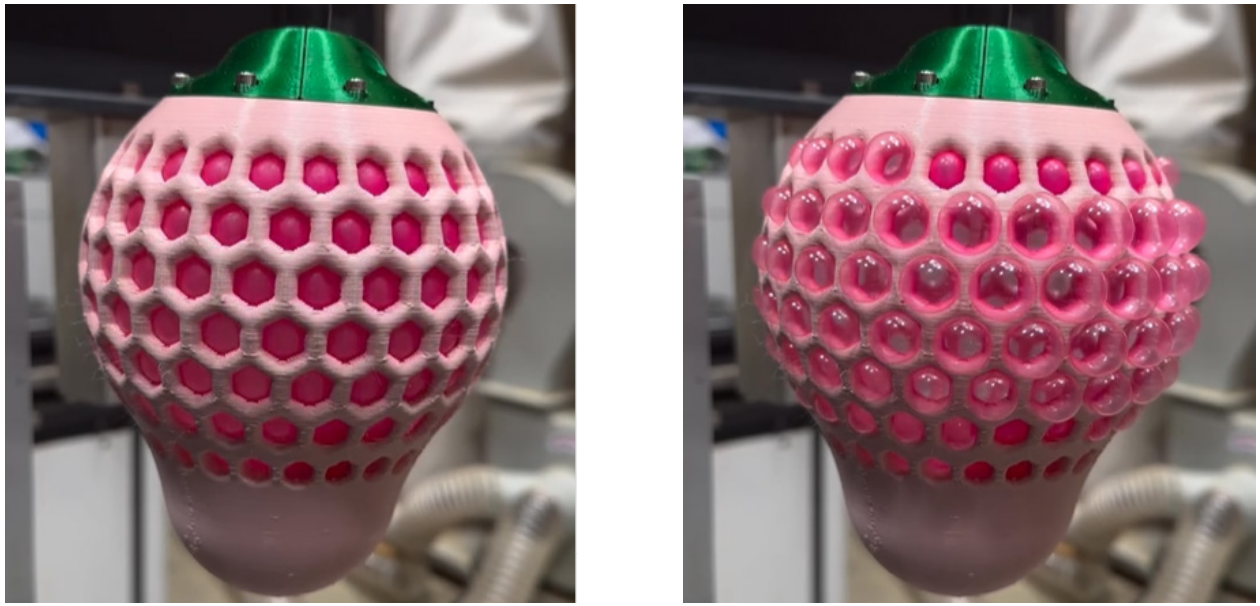


Figure 19: This work from William Darrell shows tranciensy and of randomness of nature. (Darrell, 2024)

“Create a kinetic artwork that moves by changes of the environmental air pressure and makes the viewer aware of their connection to nature through awe, while showing openness and the transience of nature”

6. The Assignment

We have already established a few factors that will play an important role in this project, both for a technical basis, as well as on the expression of the piece. Here, they will be summarised, so that concrete steps towards a clear goal can be taken. The previous chapters provide the framework necessary to continue development within a scope that fits the timeframe of this project.

The goal

The goal is to show the connection between in- and outside, between humans and nature. Viewers should see the beauty of nature, experience its stress reducing properties, and feel they are able to focus better viewing the piece. A possible way to achieve this is by trying to evoke the emotion of awe, which creates a lower sense of self, and feeling part of a larger system. And by using biophilic design patterns, with the knowledge of ART and SRT, the work can bring calm and focus.

The message

The means by which this is done, is by using air as a medium to bring this message across. Environmental air pressure changes all the time as part of the weather system. Where most of nature can be kept out the door, air creeps in, unseen, through small gaps and holes, connecting in- and outside. And these changes are so small, we cannot feel them, see them, hear them or detect them ourselves. So the aim is to make these changes visible in the form of a kinetic sculpture. By using the changes in pressure as a driving force, enlarge its effect, and make people see that nature is all around us, constantly changing. Initially, the research will focus on developing a principle way of creating motion by these changes in air pressure. After that, the focus will shift towards clearly translating this message to the viewer.

In fact, it will be an extravagant barometer. It should be clear that unlike in an actual barometer it is more a qualitative change in pressure that is brought across to the viewer than a quantitative one. It does not matter exactly how much the pressure has changed, just the fact that it is constantly changing.

Much like air, light plays an important role in nature, and it too manages to bridge the gap between in- and outside. It will be used to reinforce the message, creating a stronger metaphor and elevating the artwork.

The appearance
With the message in mind, the work can still take many shapes, and the assignment is remains broad. However, as discussed, the artwork should express three key elements. Openness, natural variation and the transiency/fragility of nature should all be present in the piece, and will be used as building stones in shaping its appearance.

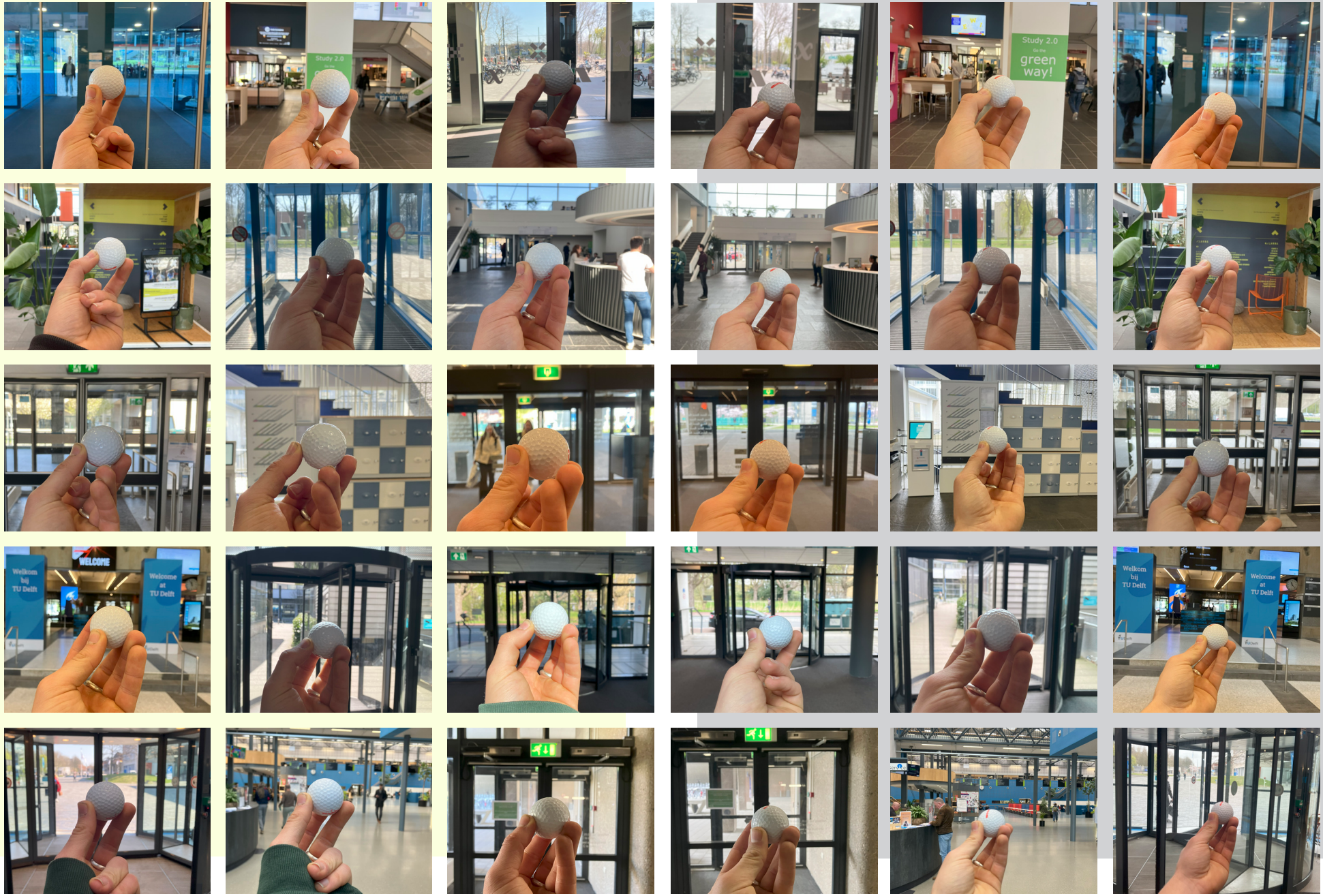
Audience and location
As for a target audience, we can look at the research above and see what group would benefit most form such an artwork. Because ART and SRT reduce stress and restore focus, people that experience a lot of stress, and need to focus a lot of the time are a sensible target group. They are often found in offices. Next to that it is necessary that viewers pass the object regularly, so they notice the changes from one moment to another. So the aim is to place the work in an office building lobby, to give workers a moment of involuntary attention and stress relief.

What is particularly important is the lighting on location. In order to create a captivating experience, it is key to understand the lighting situation. It has a large effect on the atmosphere of a place. And vice versa, of course the place effects how an art work is designed.

Lighting
To make sure the art work fits the location, a deeper look was taken at the lighting in lobbies on the campus of TU Delft. Here I took measurements of the illuminance using a lux meter, facing the window, facing the building, facing up, and to either side, all at eye level, and also facing up at ground level. Tests were done both on an overcast and a sunny day. The results can be found in Appendix D. The main outcome was that lighting is highly diverse, and very dependent on the location and weather. Values ranged from 13.1 lux facing away from a window in a dark hallway, to 2606 lux on a sunny day facing perpendicular to a window in a bright entree. It mainly suggests that an adaptive setup is required, so the effect of artificial lighting is strong enough to not be overpowered by the natural lighting from outside.

Next to that I took photos of a light probe, a golfball, on all locations, both facing towards and away from the window, see next page. The results of this can be seen on the next page. Even though the software of the smartphone corrects for the conditions, it is still visible that conditions differ significantly between locations. Some are far brighter than others, and when comparing the left pictures of a sunny day, to the right ones taken on an overcast day, the light is flatter in the ones on the right.

This is the assignment, with a goal, message and desired appearance, target audience and a location where to reach them. They all provide boundaries to the design, and give a framework from which to start designing.


Study 2.0
Study 2.0
Go the
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way!
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Welcome
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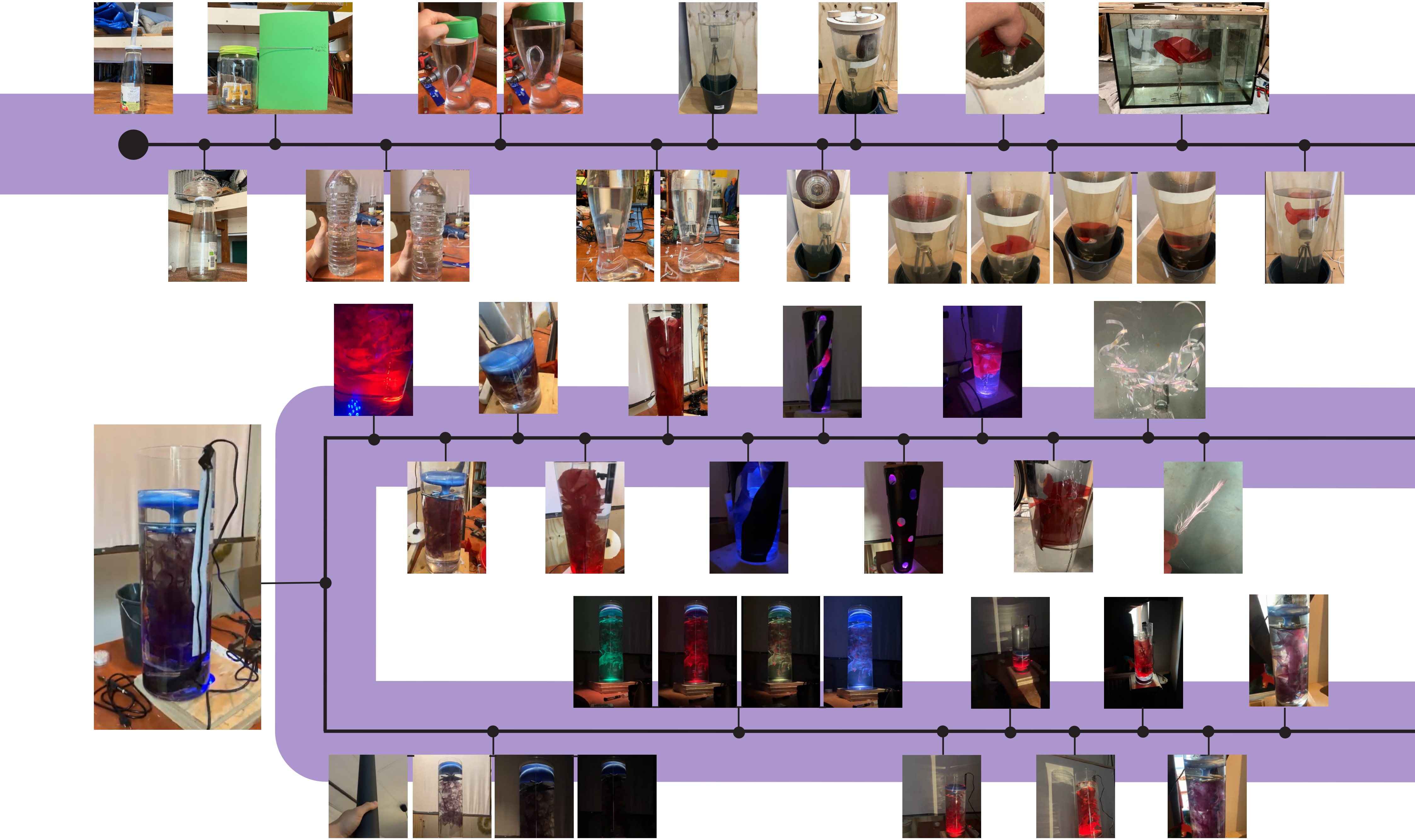
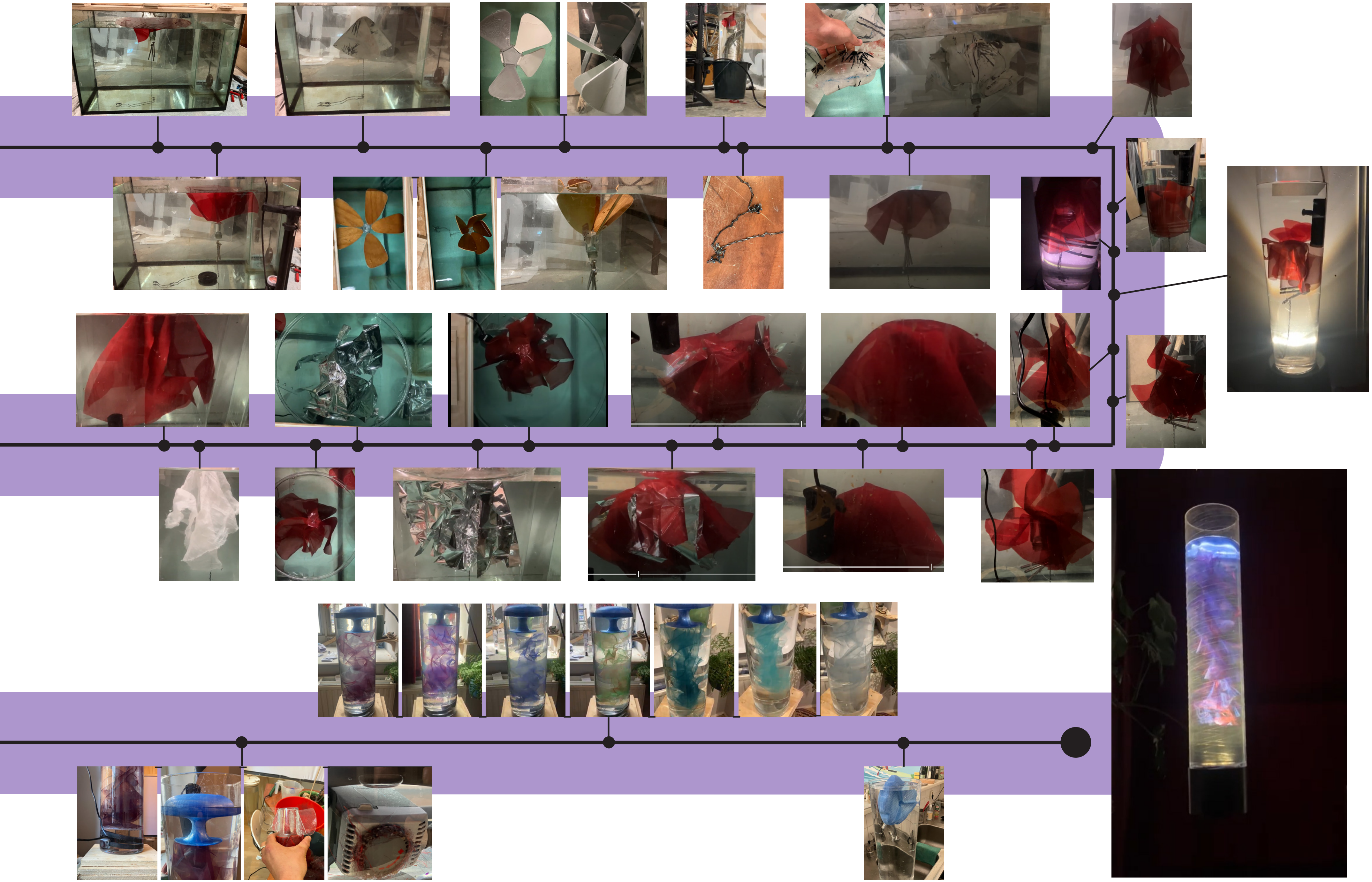
7. Experiments - Creating motion

Now the scope of the project has been more closely defined, we can focus on building the actual art piece. The process started with looking for a working principle that can create significant visible motion powered by the changes in air pressure. Once this technical challenge had been solved, priorities shifted to incorporating all the desired properties described in the previous chapters. It would not make for a pleasant read to discuss all prototypes in this report, hence an overview has been made that can be seen on the page below. These prototypes will be further illustrated in Appendix E. Figure 20 already gives a hint towards the final design.

Figure 20: A close-up of the final prototype





As established before, we are dealing with a system that has limited energy involved with it. To give another example, a pressure difference of 1 hPa on a cubic meter of air is enough to lift a mass of 5 grams one meter, friction neglected. After trying several ways to achieve significant motion, the Cartesian diver proved to be the first that had motion large enough to be immediately visible.

The Cartesian Diver

Drawing inspiration from science videos for kids to explain the physical world, the Cartesian diver showed potential. It is a demonstration of buoyancy, the ability of an object to float.

It works by placing a small container is in a larger one, with the small container having a pocket of air inside it, and the larger one being filled with a liquid, usually water. The small container is made such that it has an opening facing down, so the air cannot escape, like in Figure 21. For the bigger container you can take a large bottle, so that it can be closed by screwing on the cap. Initially, the smaller container (the diver) floats because of the air bubble that is inside it. When you apply pressure to the bottle, the diver sinks. As you can see in Figure 21, the pressure results in the air being compressed. So the bubble becomes smaller, and water flows into the diver. At some point, the volume of air is so small that it can no longer support the diver.

Now we have found significant motion by a difference in pressure, which was one of the goals of this project.

However, there are still a number of challenges. It took quite some force to squeeze the bottle hard enough to get the diver to sink. We do not know how sensitive the diver is, if the setup is scalable and if the diver can also float in the middle, or only be at the top or bottom.

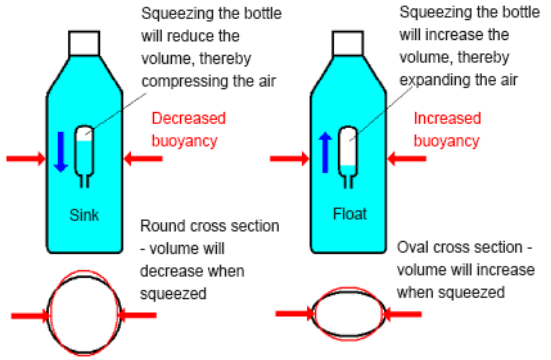


Figure 21: Drawing of the working principle of a Cartesian diver (JSME FED:Activity:Enjoy Fluid Experiments Lab.:Cartesian Diver That Floats When Squeezed, n.d.)

Figure 22: Cartesian divers are usually sold as toys (Jellyfish Diver Cartesian Experiment, n.d.)

Figure 23: A pressure chamber was constructed to do more controlled tests

Technical feasibility

To answer these question and test on a larger scale and create a controlled environment, a glass vase (80 x 18 cm) was fitted with a lid that could be closed air tight, Figure 23. A bicycle valve was added to increase air pressure. Using a barometer, the pressure could be measured. The diver was scaled up, which made a substantial difference to the sensitivity. It moves easily with a 4 hPa increase in pressure, and even when left overnight (in the open vase), the diver was in a different position the next morning. The most important test results can be seen in the box below. The tests showed proof of concept, meaning the setup had potential to become technically feasible. The motion is large enough to be visible by regular passers by. Next to that it is sensitive enough to create this motion with a difference of 4 hPa, where the available range is about 60 hPa. Hence a chain was added with the dual purpose of increasing the range (it would take a bigger change in pressure to also lift the chain), and to compensate for the increase in pressure as the diver sinks deeper under water. This proof of concept can be developed further, adapting its appearance to convert the intended message.

Test insights

- *The centre of gravity needs to be below the centre of "lift" in order to create a stable diver*
- *Testing with a larger volume of an air bubble made the diver much more sensitive, to the extend that only a small increase in pressure would send it in motion*
- *Measuring the pressure with the system air tight, the diver was at the top at a pressure of 1022 hPa and down at 1026 hPa. This gave a range of about 4 hPa over which the diver travels a distance of about 35 cm. This range can be extended by selecting a heavier chain.*
- *A chain was added to the setup, running from the diver to the bottom of the vase, to get the diver to float in any position. Now the diver can float at intermediate positions instead of only at the top or bottom.*

8. Experiments - Taking shape

Now that motion by changes in air pressure is achieved, the focus can shift towards shaping the diver. Since the medium in which the diver is floating is water, the natural world of the sea for inspiration was used to draw inspiration.

On youtube there are countless videos of aquaria, underwater habitats and oceanscapes with titles like: Underwater Ambience, Deep Relaxing Music, Sleeping Music, Meditation Music that have millions of views. It is known that blue spaces like rivers and seasides are causing a sense of calm in people. (Geary et al., 2023)

In these videos, movements are always slow, fish swimming around corals gently, seaweed going back and forth with the flow of water, a sea turtle passing by. The music is calm and generally light. Scenes are open and well lit, with no possibility for danger to hide in large dark spots. See Figure 24 for a still of such a video.

What makes these videos so appealing is the slow motions of everything. Because water is more viscous than air, all life moves slower. And because mostly life has neutral buoyancy, it is floating around, with always some of motion there, drawing te eye. Nothing is exactly still, like you see on land. Potentially, these are the reasons why these videos generate high view counts, why they are so relaxing. And why people have aquaria in their home. There is always some motion, and it is always slow, making it come across as gentle.

Figure 24: A still of a youtube video with 4.1 million views, depicting an underwater "ocean-scape" of corals moving in the flow of the water.
(Music for Body and Spirit - Meditation Music, 2019)

Figure 25: First experiments with lighting the diver

Giving form

Hence testing started by looking for materials that move well in the flow of water, like in these videos, with the main criterium of being having a density that is close to water. That way it can flow both up and down. After several experiments, flexible materials like foil and fabrics gave better results over rigid materials like wood or PLA.

Because motion was still limited, a pump was introduced as well, to introduce a secundary form of actuation, in order to keep eyes tied on a shorter time scale as well. Eventually, this resulted in the diver dressed up as shown in Figure 25. The main material is polyester fabric, which has a density slightly higher than that of water, so it drupes. On the top there is a plastic foil which floats. Also, some steps have been taken in lighting the setup, with coloured lights from directly below showing the most potential. The ligthing is further elobarated on later in this chapter.

The main issue with this setup is that is still does not create enough motion to keep the eyes drawn.

Test insights

- *Thin, plastic materials work best, since their density approaches that of water. Especially fabrics with thin yarns and a low dernier count.*
- *Rigid materials do not work for the "petals", they do not move in an interesting enough way, not drawing ones eye.*
- *Adding more volume to the petals helps draw attention, giving the viewer more to look at, e.g. y stacking multiple layers of fabric.*
- *The fabrics need incisions to be able to move more freely, and again create more motion.*
- *The pure up and down motion is still rather limited, not giving the sufficient material to look at. By spinning the water by adding a pump to the setup, motion on a shorter time scale is induced, giving the viewer something to look at in the moment, as well as keeping them drawn in on a larger time scale.*

Inspiration

After numerous tests, the results are mixed. Some setups prove to create some "interesting effect", generating fascination, drawing attention, but not to a satisfying degree. So more inspiration was draw form nature. Partially at a subconscious level, and partially being aware of it, the diver has come to look like a jellyfish.

Main inspiration was drawn from a video of a giant phantom jellyfish. It can be seen in Figure 26. The creature has four long tentacles that reminded of sheets of fabric, a material already used. Since more random movement is desired, more fabric was intruced in the water in the form of long tentacles, hanging from the diver, replacing the chain. Initially earlier tests showed thread or fabric would prevent the diver from moving freely to the bottom, and was therefore not suitable as a material. However, there can be ways around that, and replacing the chain with fabric would mean a lot of material being introduced to the water. Material that could make interesting movements.

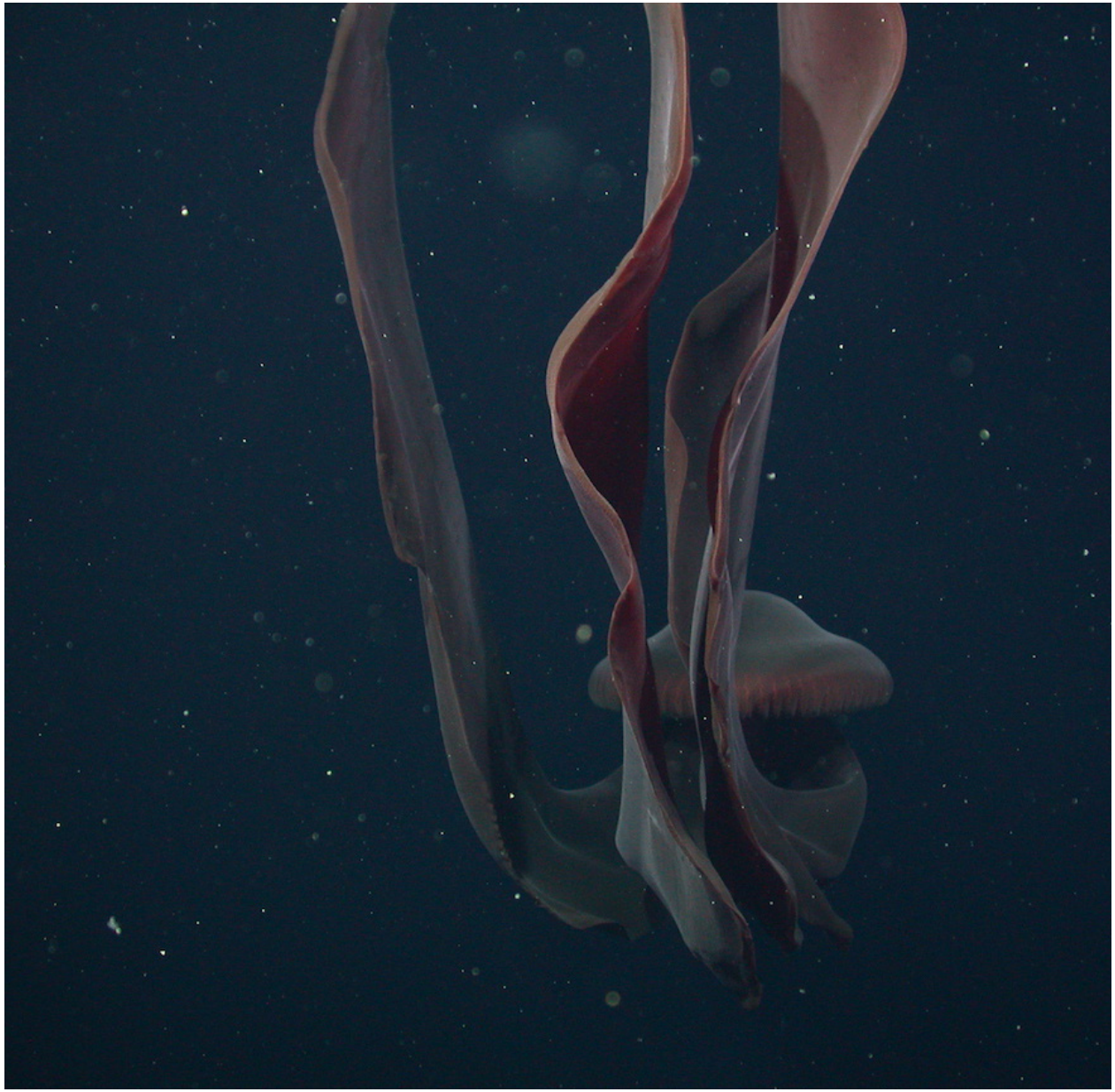


Figure 26: A picture of a phantom jellyfish, sparking inspiration to add tails to the diver (Monterey Bay Aquarium Research Institute, 2023)

Volumes

Based on the jellyfish, larger ribbons of fabric were hung below the diver instead of on top. This creates far more interesting movements. There is just more to look at, drawing attention, in a calming way. Exactly what SRT (Chapter 3) describes. The setup draws involuntary attention, which gives time for the focused attention to recharge. Different shapes and sizes were tested, to find an optimum amount of fabric in the vase. This fabric has evolved to be two-tone Organza, with the weave in one colour of yarn, and de warp in another. This changes the colour depending on the angle one views the fabric, and since the fabric is in constant motion, rotating by the pump, colour changes all the time, adding to the attention drawn. The diver has changed as well, inspired by the jellyfish.

Test insights

- *Hanging the fabric gives a more exciting effect than just fabric around the diver. There is more possibility of movement. However, there is an optimum. Too much fabric and it gets in the way and appears crowded, restless and claustrofobic, too little and it is not exciting enough*
- *Adding incisions to the fabric gives it a look of seaweed, and provides even more opportunity for motion. All the seperate flaps can move individually, drawing the eye from one spot to another.*
- *The diver cannot sink that far. Exactly why a chain seemed better, as the fabric still has some compressive strength. The diver is going to rest on the fabric once at the bottom, as the fabric rolls up and is pushed against the walls. This decreases the rotational speed of the diver, creating a stronger tie to the weather. In fair weather, the diver sinks, which induces more friction, slowing the diver down. Calmer weather means a calmer diver.*
    - *Further reinforcement of the message is added when the diver is backlit through a window. It brings a connection between in- and outside, and when the diver is lower, the weather is calmer, more light enters the room through the vase and vise versa.*

Figure 27: A vase full of fabric gives a lot more material to look at

Lighting

Elaborating on the lighting, a look was taken at how to light the diver as well. This page gives some background on the terminology, aiding further reading. Because many elements can play a role, from the features of the lamp (brightness, colour, focus, etc.) and how it is placed (position, angles etc.) in case of artificial lighting, to the time, size of windows, placing of windows etc. in case of natural lighting. And the room plays a role too. Size, colours, texture, other objects etc. Therefore most of the lighting setup will be evaluated on location, also because natural lighting will play a key role. However, it is good to have some knowledge on the subject, and have some vocabulary to understand what is going on. There are three general categories in which lighting can be divided. (Fagerhult, n.d.)

Ambient light

This is light that creates a uniform background of light, making everything in a room well visible. It is soft light that does not draw attention to any particular point in a space. It avoids creating shadows and makes the room calm. Think of it as the background light in a room. The light is usually diffuse, or has reflected many times, meaning it does not have any particular direction/is roughly equal in all directions.

Figure 28: Example of ambient light (Crystal Clarke, n.d.)

Focal glow

As the name suggests, focal glow places the focus on certain elements of a space. It creates shadows and contrast, so that some elements come to the forefront while others drop back. It gives the eyes more direction on where to look. The light itself often has a direction, instead of illuminating a whole space evenly like ambient light. A spotlight in a theater would be an example.

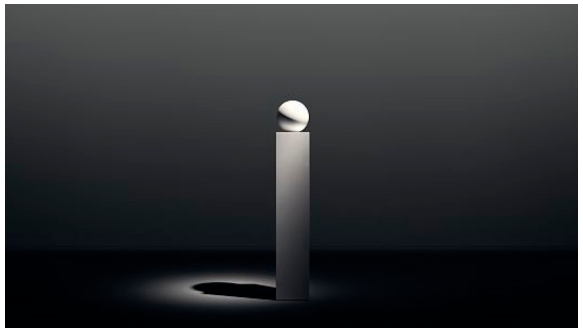


Figure 29: Example of focal glow (Erco GmbH, 2024)

Play of brilliance

This creates the real highlights of a space. They use the highly reflective properties of some materials in combination with placement of lights to create some sparkle or glitter to the room. It creates energy and fascination.

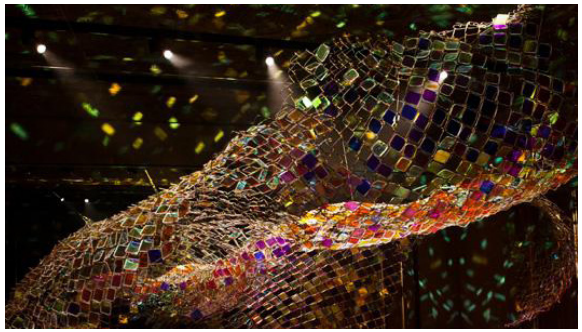


Figure 30: Example of play of brilliance (Donny, n.d.)

Experimenting with light
Looking at the light conditions on location, we can make a number of comments. From Chapter 6 we conclude that ambient light is unpredictable and changes per location. So the setup needs to deal with its visual influence.

Next to that, from earlier experiments, play of brilliance needs to be avoided as it is restless and comes across stressful when in motion.

Focal glow is desirable, to draw attention to the diver, and direct the eye of the viewer. By creating a spotlight from below, the diver is well lit, standing out. Adding colour further creates an interesting interaction with the fabric.

Ambient light can be partially blocked out by hanging large curtains around the piece. However, it is important that they are still partially transparent such that the whole setup does not become closed off from its surroundings. This would increase the mental threshold to view the piece, potentially keeping people away. After all the tests, the results can be used to construct a final setup that fulfils the design goal of this project.

Test insights
- *Lighting from below works best, elevating the piece and adding to the floating effect, see Figure 31.*
- *A spotlight from above does not add much, as the diver blocks most of the light before it gets to the fabric. This will be different with a transparent diver, so further testing is necessary.*
- *Backlighting the diver creates a bridge between in- and outside, adding to the message. Only through the diver can a viewer look outside.*
- *Coloured lightning, with the colour matching that of the fabric gives the best results. If you do not match the colour, the material will mostly absorb the light instead of reflecting it to the viewer, appearing dark.*
- *The light from below will have to be bright enough to overcome the abbient light, current lights (reading 4 lux on a lux meter) are only visible in a darkened room, see Figure 31.*

Figure 31: Lighting the diver from below gives a nice visual effect.

9. Complete setup

During testing, partial results have been found on what works well for the design, and what does not. This chapter will go over the different elements, and see how they add to the overall goal. Figure 34 shows a first proposal for the setup, to which further changes can be found in the Chapter 11.

The diver

The diver should appear light and floaty. It is aimed to resemble a cloud, fitting with the theme of air. Hence it is also made from a transparent material, and also to ensure an open/honest piece. For the test setup this is 3D-printed PETG, later glass is recommended. Its irregular surface makes it appear more natural. See Figure 32 for the latest version of the diver. Protrusions at the bottom both function to attach the fabric to, and allow the current to take the diver along and make it spin. It moves up and down by changes in the environmental air pressure. To regulate its height more accurately, weights can be added to the fabric that hangs underneath it.

Figure 32: Latest render of the diver, given a glass appearance

The fabric

The fabric is a two-tone, red and blue organza, a shear material that makes it look fragile, expressing the transiency of nature. The material is chosen such that its density is similar to that of water, making it flow easily in the current. Incisions in the fabric are made such that they make it move around in the flow of the water, inspired by seaweed. This causes the two colours to show well, and draws involuntary attention, in line with ART. The motion is meant to be fascinating and awe inspiring. Next to that, it plays to human nature, as research has found that clean, flowing water has a calming effect on us. The diver-fabric is rotating around in its container by a pump at the bottom. When the diver is at the top, it rotates at its maximum speed, at a speed just before it becomes looking restless. By moving the diver down, the fabric gets compressed at the bottom, slowing the rotation of the diver and calming it down consequently. This corresponds to the weather, where higher pressures (diver sinking) generally come with fair weather, and lower pressures mean poorer conditions. This also means the fabric is obstructing less of the light coming from outside, meaning more of it can reach the viewer. Again, higher pressure corresponds with more (sun)light or better weather and vice versa.

The vase

The vase is a clear acrylic cylinder that is hung in the air to make it appear light and afloat, fitting with the theme of air. Minimal material is used for this to ensure an open appearance, and an unobstructed view into the vase. It is suspended just above eye level, to make people look up slightly, and have it appear larger than it is, to induce a sense of awe.

The veils

The veils are the large black sheets shown in Figure 34. They are made from semi-transparent dark fabric and serve a number of purposes. Firstly, they block out part of the ambient light, making the spots stand out more. Especially on overcast days, where ambient light can make things look very flat, this is useful to keep the diver-fabric looking interesting. Secondly, they channel the outside light towards the vase, emphasising the connection between in- and outdoors.

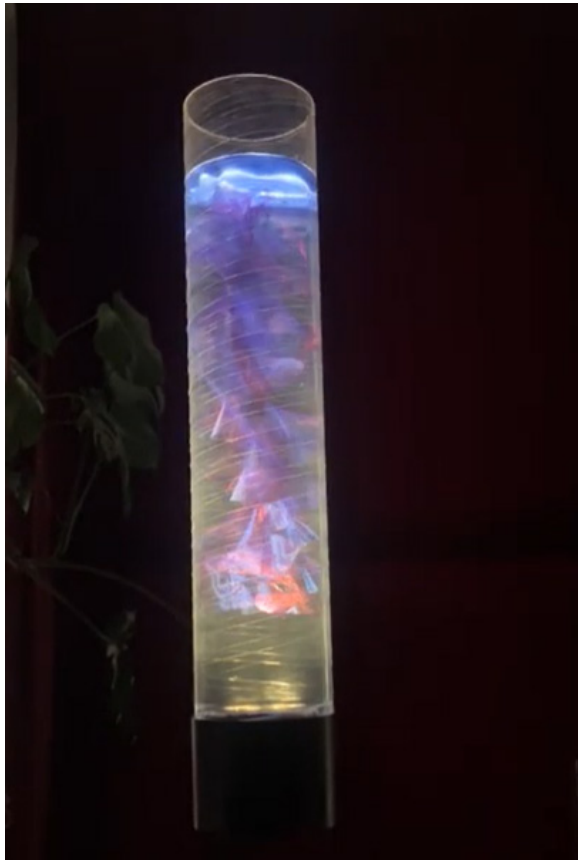


Figure 33: Full prototype of the vase

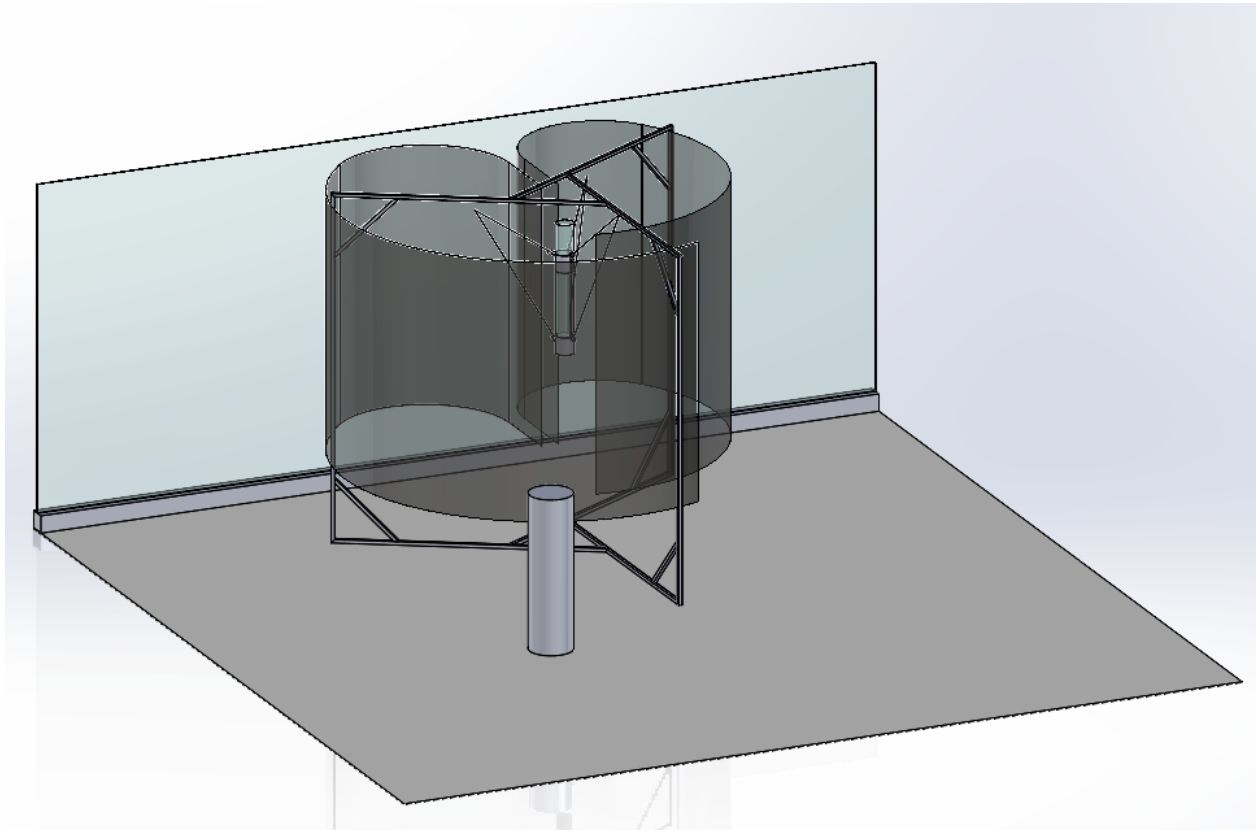


Figure 34: Idea for a first full setup of the entire prototype

Thirdly, they create a sense of mystery, a biophilic design pattern that speaks to our need to "understand and explore" (Browning, 2014), creating curiosity in the viewer. Fourthly, they provide a sense of refuge, another biophilic design pattern, meaning people can retreat to the space, but not feel separated from society. This is part of the reason why the veils are semi-transparent. Another part of the reason is that if the veils were completely opaque, it would be impossible to see inside. People that pass by every day might not enter every day, and it is desirable that they can still observe the changes. Making the veils opaque would create a larger threshold for people to enter. Lastly, the veils provide a background for the reflections from the light from outside to project onto, so they can actually be seen by the viewer. Tests showed that the light tunneled by the veils through the vase create interesting reflections on the wall behind the diver. Especially because the fabric in the vase is constantly turning, the reflections are doing so too, giving more motion for the eyes to look at.

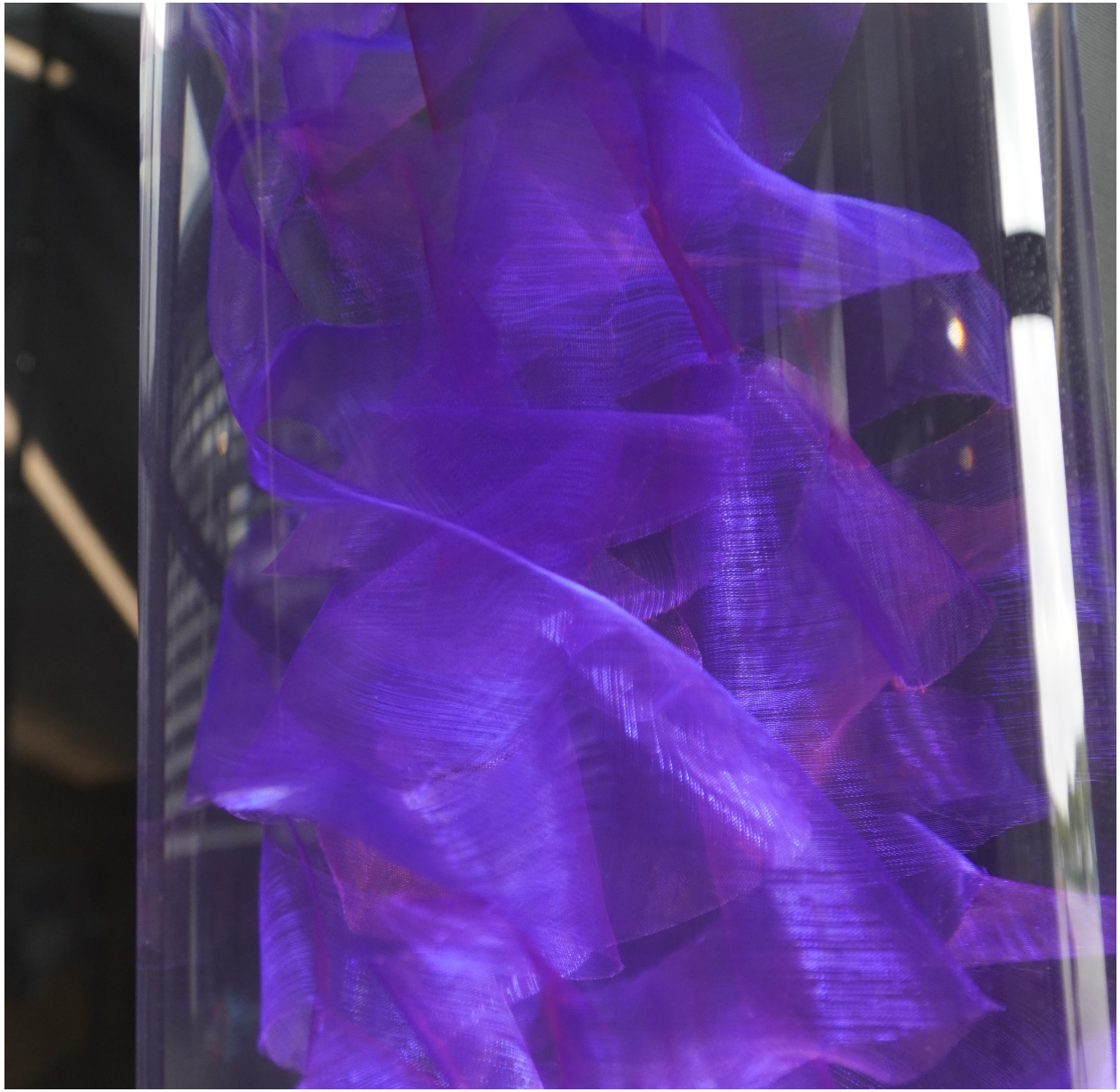


Figure 35: The fabrics of the diver are a two-tone organza, red and blue here

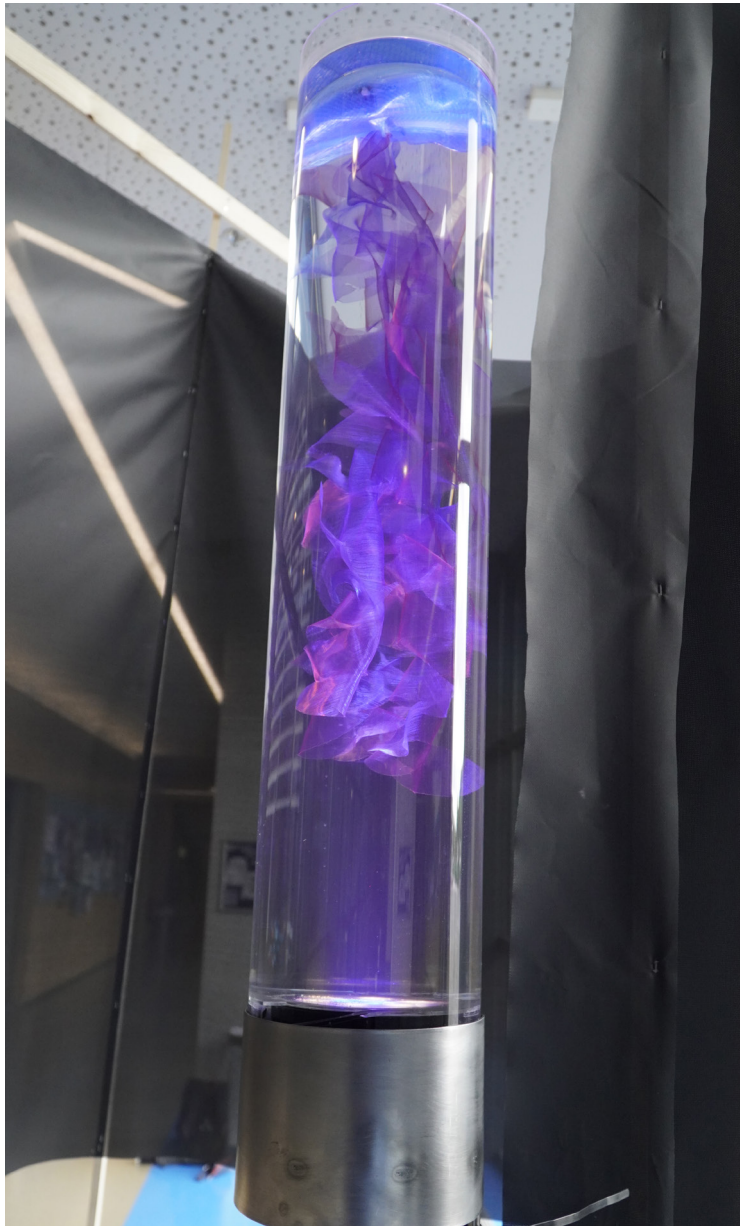


Figure 36: For the test setup the vase was put on a pedestal rather than being suspended

Figure 37: The full test setup, with the veils and the vase and diver inside

10. Final prototype

For practical and financial reasons, this full setup was not constructed. Nonetheless, a simplified version was built for user testing, to see if the experience by viewers is approaching the one that is intended. Furthermore, the lighting situation had to be validated and improved, so it was important that from a lighting perspective the situation matched as close to the final version as possible. This because so many factors play a role in lighting, that the test would not be suitable to translate into any meaningful advice otherwise. Figure 37 shows the setup in the hall of the faculty of Industrial Design Engineering at the TU Delft.

The main adjustments made for the test setup are the size of the vase and replacing the frame by a pedestal to hold the vase and some uprights to support the veils. The vase was scaled down mainly for financial reasons. An acrylic tube of two meters was outside the budget. Next to that, because the frame was replaced by a pedestal, the vase was no longer hanging but standing on the floor. This does take away some of the awe the piece meant to evoke. To make sure to keep viewers feeling awe-inspired, the pedestal was designed as slender and light looking as possible, to maintain the illusion of a floating vase/diver. To hide the pump and lamp in the bottom of the vase, a steel collar was placed at the top of the pedestal. This looks bulky, but because of the long slender rods supporting it, the floating appearance is still approached.

The veils are attached to some uprights, made from a steel foot and wooden slat. This is a quick and cheap solution that works well for its simplicity. The veils hang in straight faces rather than an arc, taking away some of the natural feel. However, they still support the enclosed feeling, creating refuge and directing the light at the vase.

Figure 38: The veils are placed such that they form a tunnel for the light

User testing

In order to see if the artwork has the desired effect on its viewers, fifteen participants were asked to fill in a questionnaire while looking at the artpiece, placed in a test setup. This setup can be seen in Figure 39. Most questions were closed ones, asking participants to rate how strongly they agreed or disagreed with statements about the piece on a Likert scale. Only the last questions were open, to see what viewers associated with the artpiece. The testing was set up like this to get some initial qualitative data on the object. Mostly closed questions were chosen to ease the processing of the data due to time restrictions of the project. The full questionnaire can be found in Appendix F. The complete test procedure can be seen in Appendix G. All participants signed consent forms, an example of which can be found in Appendix H.

Figure 39: Participants were asked to enter the veils one by one

The results

As the goal of this project was to make the viewers connected to nature by creating awe, openness and draw involuntary attention, these were the factors tested for in the questionnaire. The result can be seen in Figures 40, 41, 42 and 43. The raw data is found in Appendix I. Kaufman and Yaden (2018) have developed a list of questions to measure awe. This list was taken as a starting point, but pruned to make testing shorter and hence more accessible for participants.

In all diagrams below, the error bars indicate the standard error. It seems that overall people did not experience awe. Most results turned out negative, with only the temporal ones showing a somewhat significant positive outcome. By far the most negative result is "feeling connected to humanity", with also "oneness with all things" and "feeling connected to everything" scoring low. However, people did rate the experience positively on the other factors. This was partially in line with the expectations. The questions related to awe were on a deeper level than the other questions.

Participants were also asked to indicate their stress level before looking at the artwork, and then once more after they walked away from the piece. The results can be seen in Figure 40. After performing a one-tailed t-test, we can conclude stress has dropped with 95% certainty. The data used to plot these graphs can be found in Appendix J.

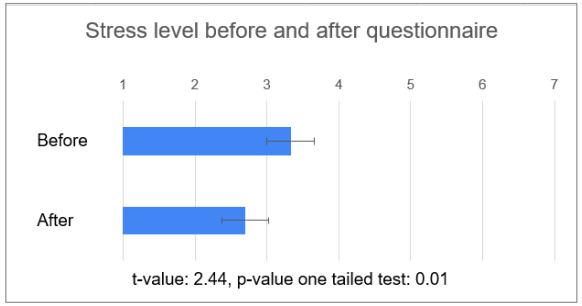


Figure 40: Stress level has reduced between before and after seeing the diver

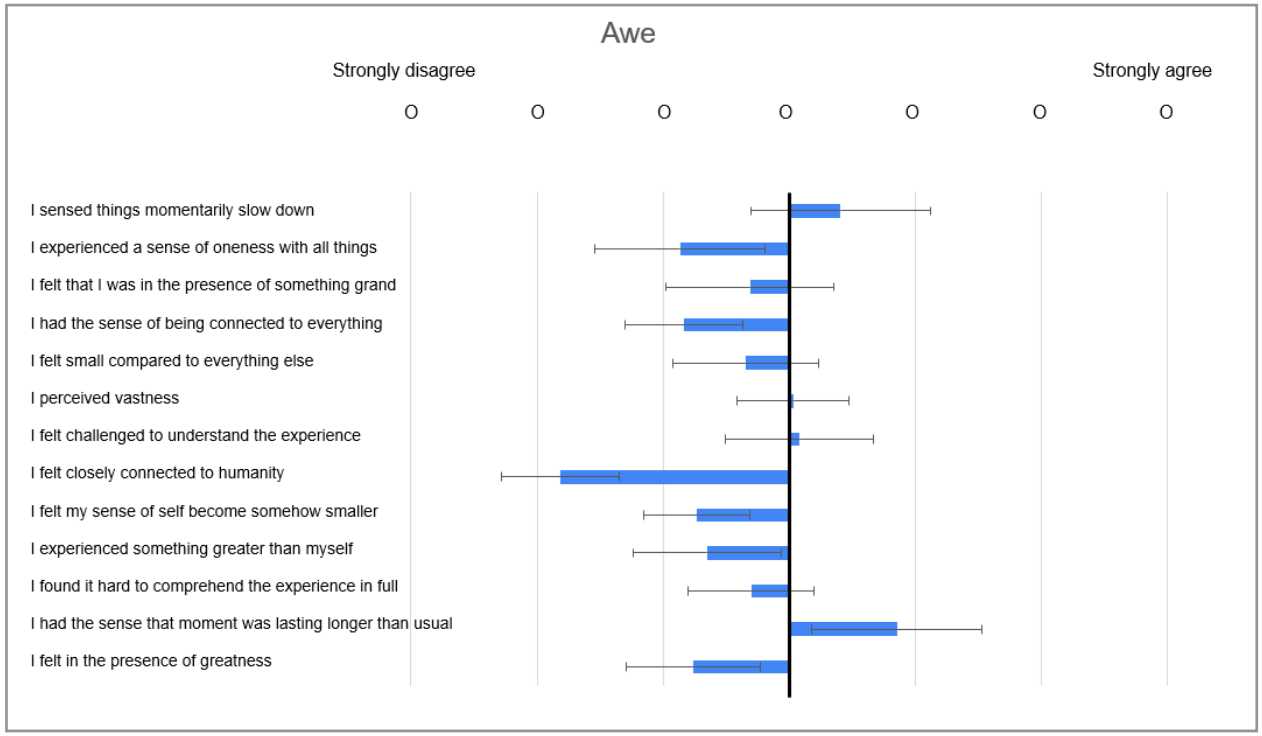


Figure 41: Results of the questions about awe asked during user testing

However, more questions were asked about the envisioned experience of the art work. People did indicate experiencing the art piece as open, and found it calming. They were fascinated by it, and their eyes were drawn to it, indicating that involuntary attention might have been triggered, Figure 42. Also, in the questions about awe, the most positive result came on the questions about experiencing a shift in time perception. People did feel time slow down, indicating the work could have a calming effect. This is further supported by the open questions, where participants were asked to write down three words they associated with the setup and why. A word cloud of the results can be seen in Figure 43. Terms mentioned most were words like "calm", "calmness" and "rustgevend".

Other terms that occurred multiple times were water related ones, like "jellyfish", "ocean", and "sea life". This makes sense as this functioned as inspiration for the work. More surprisingly, multiple people indicated association with space, mentioning "universe" and "cosmic".

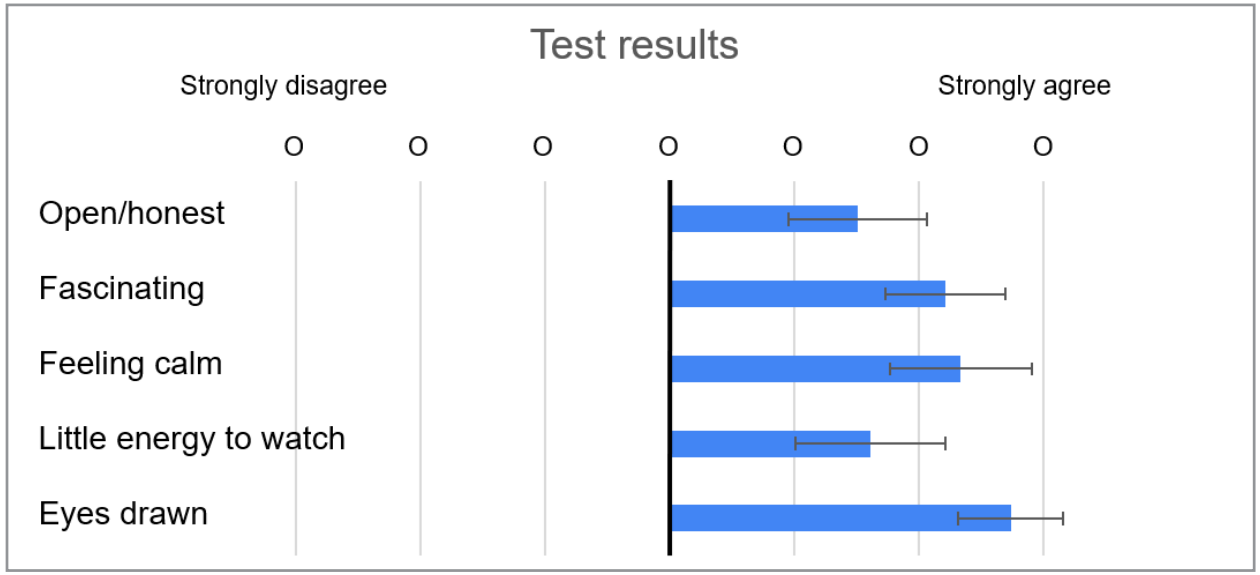


Figure 42: The artwork was perceived as open, fascinating and calming

Figure 43: A wordcloud of term given to describe the setup. Terms in categories that came by more often are printed larger

Finally, one interesting result from observation was that almost everyone stood to the side, making sure there is a dark background behind the diver, instead of looking through the vase to the outside. This can also be seen in Figure 39. Presumably this is because it creates better contrast, making the colours and shapes of the fabric in the vase more visible, looking at the dark background of the veils rather than the backlight from the "tunnel". Next to that, most people pick a single spot from where they watch the piece, while some are more curious/explorative and walk around it to view different angles.

Recommendations

After interpreting these results, we can come to a couple of recommendations. The most important ones have been listed here. Further recommendations, commenting on the scientific validity of this test can be found in Appendix K.

- Regarding the fact that awe was not achieved in all its elements, there are a few suggestions. Firstly, people did experience time slow down, a positive result. It seems most logical that this is related to the fascination people have for the object, temporarily forgetting what they were doing, or what was on their mind. The slow movement of the fabric helps here, so that should be kept as is. Or, as three people indicated afterwards (without being asked) they felt that the spinning was still rather fast.

- Secondly, the lowest scores were on connectedness. The absolute lowest score was on people feeling connected to humanity, which on its own was not a goal of this project. However, it was one of the goals to make people feel more connected to nature. But these are secondary effects of creating awe. So in order to evoke awe, it would be an option to look at the direct causes for awe, vastness and need for accommodation Keltner and Haidt (2003). On those questions, people answered moderately negative to neutral. Thus, if those scores could be increased, awe itself and connectedness should increase consequently. Next to that, in this case people were specifically asked to enter the veils alone, to create independent tests. This could have decreased scores on connectedness.

- When aiming for vastness, physical size plays a role. So increasing the size of the vase, and elevating it further, increasing the general scale could improve the experience. Of course, the surroundings in which it is going to be placed have to be taken into account. And if the size (diameter) of the vase increased, also more complicated patterns could be added in the fabric, potentially creating a vastness in complexity. Furthermore, multiple vases could be arranged in an array, if the space allows it.

- Creating a need for accommodation could be more difficult to achieve. It goes together with vastness, but is less easy to pinpoint how to create it. In the testing it was not visible how the diver moves up and down very slowly. This is harder to intuitively understand, so perhaps the time element could cause it. Further testing is required to confirm this.

- Looking more generally at the terms given by viewers to describe the piece, it comes across as calming, fascinating, colourful and nature-related. This is the atmosphere that was intended, although more nature-related words were expected. In order to benefit more from ART and SRT more, it might be better to improve the natural appearance of the art piece, although further research is suggested as to what elements are and are not perceived as natural.

Conclusion

All in all, the artwork was experienced as open and drew (involuntary) attention. People found it fascinating and described the experience as calming. However, the setup did not evoke awe. People felt time slow down a little, but other factors that are related to awe like vastness and connectedness were not triggered. Further testing is still needed for more conclusive results, but this test did give an indication the general experience is in the right direction towards the final goal.

11. Recommendations

After development and testing, this chapter will give advice on how to continue this project in order to develop a fully functional prototype, that can eventually be turned into a research supported art piece. There are a number of things that could not be tested completely, or have been tested but are important to emphasise so a next generation of tests can be executed. For a full list of the test results, see Appendix E. These results have also been turned into a List of Requirements, for that see Appendix L. This chapter will highlight the most important insights from the tests, and give recommendations on how to continue.

General

Firstly, because user testing showed awe was not achieved, it is recommended to increase vastness by increasing the size and/or number of the vase(s) and diver(s). Vastness is directly related to the physical size of objects. During user testing already a scaled down version of the vase was used, of a meter tall. So it would be better to build a one to one scale prototype. However, scaling up can become costly. So alternatively the number of vases can be increased, placed in an array to create vastness. This does take up more space so depending on the location, an optimum needs to be found. And in this scenario too, costs will increase, but less quickly than in case of scaling up the entire vase.

The diver

General

- Make the diver operate between 970 and 1050 hPa. That way the diver will almost never reach its extreme positions. So it is always floating in the middle, aiding to the feeling it is always free floating.

- Create neutral buoyancy. The diver should be designed such that it has neutral buoyancy. Only that way can it float up and down with the changes in air pressure of its surroundings. In order to do so make sure the diver can at least hold enough air to keep itself afloat. Preferably, there is room for a little extra air, so there is room for some tweaking on location. The script in Appendix M can be used to calculate the

Figure 44: Filling the diver with air to make it just float

Figure 45: Fins on the diver help it catch the flow and keep spinning

minimum required volume of air, depending on parameters like size and material of the diver.

The easiest way to achieve neutral buoyancy is to let some water in the diver, make sure it sinks, then with something like a thin hose blow back in some air, such that you can add a small bubble at a time. Eventually the diver will just be able to float. Then add a little extra water, so that the diver is just below the surface. Make sure you do this on a day with low atmospheric pressure. It can be done on days with higher pressures, but this is more cumbersome, as you will have to let the diver sink to a certain depth each time, instead of keeping it at the top.

- Give the diver fins, Figure 45, or something for the flow to catch onto. If the shape is too smooth, the current from the pump will not be able to make the diver rotate. Do not place these fins at the widest diameter, see previous bullet. Minimum size of the fins should still be tested, and is dependent on the size of the vase and capacity of the pump.

- Make the air pocket in the diver at least 100 mL. This gives sufficient accuracy to play with the amount of air to create neutral buoyancy. Any smaller and it becomes difficult to tune the diver accurately.

- Keep the centre of gravity low and in the middle. This way the diver is always in a stable position. Otherwise it can tip over. Make sure most of the mass of the diver is at the bottom. Also take into account that if the air pocket is too flat, and a little water needs to enter to balance the diver, the water will move to one side and put the diver at an angle. The solution is to make the entrance tunnel to the air pocket sufficiently long.

- Give the diver an approximately circular shape. Make sure the diver is close to circular at its widest diameter. This way, it can rotate smoothly inside the vase. If the shape is too irregular, it can cause the diver to get stuck, halting the rotational movement.

- Make sure the inside of the diver is made such that water always flows out completely once the diver is in the upright position. This makes tweaking less time consuming, and gives certainty that the diver will remain in an upright position, instead of tipping over. So make the insides slope downwards.

- Do not put any flat or concave surfaces at the top of the diver. They hold water and stick to the surface of the water by surface tension, throwing off the accuracy of the diver since it will not immediately sink when the pressure increases.

Material

- Currently, the prototype is constructed from 3D printed plastic PETG. With a density just above water, and an infill percentage of 25%, the diver is too light to be neutrally buoyant on its own. Therefore it is necessary to add weights to it to make it sink. This shows, and will most likely be less appealing than a diver made of a single material.

- Glass is recommended because it is about 2.5 times denser than water, giving it the possibility to achieve neutral buoyancy. And because it can be made transparent, it fits with the appearance of the translucent fabrics, giving a light, floaty feel to the whole setup. Make sure to test how accurately the air/glass ratio can be created, to check that it is within range to achieve neutral buoyancy.

Appearance

- Given the light and flowy appearance of the fabric, make sure it continues in the diver itself. Hence a transparent material is recommended, combined with an organic shape. See Figure 46 and 47.

- Give the diver a (cumulus) cloudlike shape, to continue the theme of air, and reinforce the connection to it. Make sure natural variation is present, avoid symmetry.
  - Material and shape together can play together with the light as well. If glass is chosen, make sure to test it again before making a final version.

Figure 46: Render of a more cloudlike diver from above

Figure 47: Render of a more cloudlike diver from the side, showing the fins at the bottom

It will behave differently than PETG, and has not been tested so far. See what its limits are in shaping, properties in relation to light etc.

Chain

- The chain does not quite fit with the appearance of a light, cloudy diver, yet it is necessary in order to make the diver float halfway along the depth of the diver. The large amount of fabric will serve part of its duty, but will most likely not be enough.

Hence a single chain can be hung from the middle of the diver as the most simple solution, although it does obstruct the clear, open view through the fabric, somewhat breaking the illusion. On a more practical note, the fabrics and chain could get entangled, and in that case are unlikely to untangle themselves without human interference. A more elegant solution would be to hide small weights in the centre of the fabrics. These parts do not move as much, so they would be affected less by the weights. The distribution of the weights would follow one according to the script in Appendix M. Best would be to have a continuous row of weights hanging all the way to the bottom, but you could also hang them at certain distances from each other, so the diver goes up and down in steps rather. Of course, these steps will not be visible to the viewer due to the slow nature of the pressure changes, unless marked on the vase or background for example. If it desired to bring across a more concrete message of pressure change, this could be a way to do it.

- Currently, only tests have been done with a chain of homogeneous weight distribution. Due to the properties of air, as shown in Appendix M, the ideal distribution would be non-homogeneous, although it could be approximated that way. The best way to do so would be to choose a chain with homogeneous weight distribution at the maximum value of the graph. Figure 48 show how a chain would normally hang in the middle.
- Tests showed that even with a chain, the setup can be quite sensitive. If it is too sensitive, it is advised to increase the weight of the chain. That way, the range of motion can be tweaked such that it match the range of pressures that can occur in the air on location. So the weights/ chain should be adapted such that the diver has a range of motion of about 60 hPa, with an average of 1015.5 hPa.

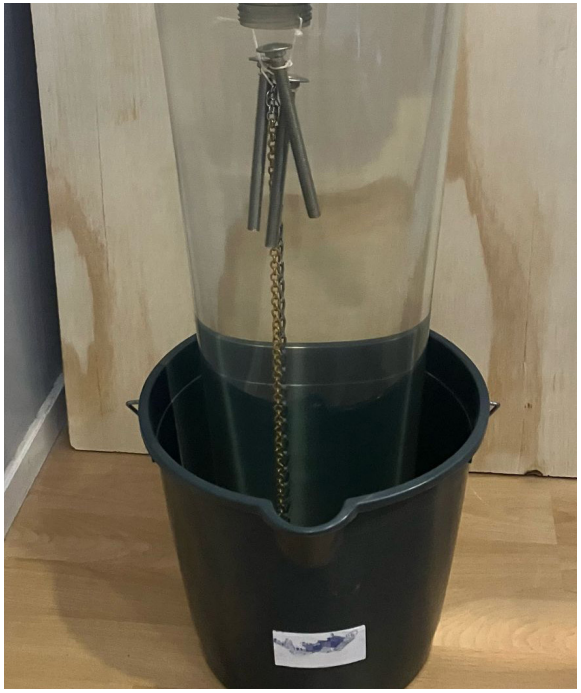


Figure 48: A chain helps compensate forces for higher pressure at depth

The fabrics

Material

- Organza is a material that works well, and with which most tests have been done. It is a fabric with a low thread count, giving it some see through abilities. It also enables the fabric to move relatively easily with the flow of the water, compared to thicker fabrics. They come both in polyester and nylon form. Nylon is recommended for its durability and UV resistance, which are both superior to those of polyester. When it comes to looks, both should still be compared in further testing, after which an informed choice between the two can be made.
    - Organza comes in a form where warp and weft are chosen to be different colours. As a result, depending on at which angle it is viewed, it appears to have a different colour. With the fabric moving around slowly in the water, it of course keeps changing angle to the viewer, hence keeps playing with colour. Another way to draw the eye.

Measurements

- So far several measurements for the fabrics have been tried, but not on a wide spectrum. For the width of the fabric mostly values of around two thirds of the diameter of the vase were taken. Some tests used a wider fabric (about three quarters diameter) which resulted in the fabric getting tangled. Thinner strips have not been tried, with the hypothesis that smaller strips mean less material to look at for the viewer, therefore are less interesting. Keep the strips of continuous width for most of the length, as to fill the entire diameter of the vase with fabric. The tail ends can be tapered to create a more natural ending instead of an abrupt one.

- As for the length of the fabric, it would be advisable not to make them the entire length of the vase, but around two thirds. This would be easily tested once a vase of final dimensions is acquired. Test a few lengths of fabric to see what works well visually. Here too, make sure

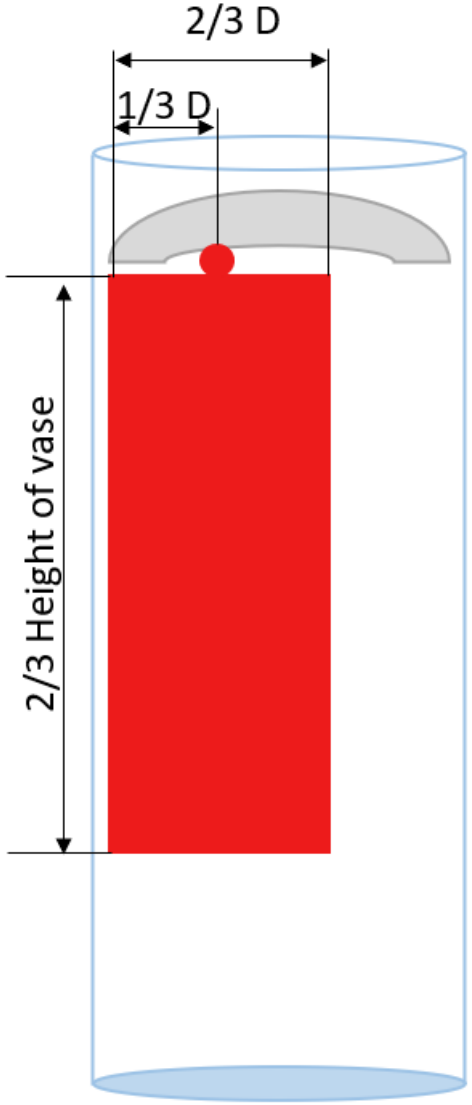


Figure 49: Several relevant measurements. These can be used as rules of thumb

Figure 50: Cutting pattern for the flaps in the fabric

the lengths are not all exactly the same (natural variation) to avoid a very abrupt ending of the fabric.

- The reason they cannot be too long is that they will get tangled up for higher pressures once the diver is at the bottom. And in the same situation they obstruct the flow and great large amounts of friction, bringing the spinning of the diver to a halt. Once that happens, the chances of it moving back up once the pressure drops are slim.

- Only hang three strips of fabric on the diver. Odd numbers are generally considered more aesthetic in circular geometry, and five strips turned out to be more chaotic/restless, as well as limiting the free flowing movement of the fabric. Three was the optimum. Hence also the relatively wide strips, to still add sufficient fabric to the vase to visually fill it.

Attachment

- Attaching the fabrics to the (glass) diver is easiest with a clear glue. Make sure to take a UV resistant one, that adheres both to glass and to fabric, and shows minimal colour change over time.

- The fabric is hung such that they are perpendicular to the flow. Only perpendicular and tangent to the flow were tried, where perpendicular came out on top due to the movement created, getting less in the way of each other. Other angles could still be tested, especially in combination with different breadths of fabric.

- Positioning of the attachments is best such that the fabric hangs half of its breadth away from the wall of the vase. So in case of a breadth of two thirds the diameter, the fabric should hang one third of the diameter away from the wall. See Figure 49 for clarification.

Incisions/pattern

The most suitable pattern found so far is the one shown in Figure 50. The incisions curve upwards, to mimic leaves of kelp (seaweed). Because the flaps become thinner at the top, they move more at the outsides at these tips, which looks

better than simple straight cuts. Furthermore, it enhances the double colour structure of the organza.

- Cuts can almost go to the middle of the fabric, but should avoid going past it. If that happens the fabric begins to twist, altering its appearance negatively.

- Cuts should be about five or six centimeters apart. Some natural variation here is fine, and should actually be taken into account when designing the pattern on a computer. It would be better to sketch it by hand.

- Eventually it is recommended cutting the fabric with a laser. Since it is quite thin material, you can get a lot of loose fibres that get torn away from the fabric, creating holes, and clogging up the pump eventually. A laser cutter would singe the fibres, creating one outline that is melted together. It should be tested if the material holds its flexibility this way.

Colours

Blue and red turn out to work the best. They create a mysterious look, give a high contrast compared to other colour combinations and the blue creates a further connection with the air, see Figure 51 for the colours. If possible, the red could also combine well with the sky in the mornings or evenings, but this is very location and weather dependent, only occurring once every so often. It might be wise to not regard it too much in choosing a location. However, the red still contrasts well with the blue, drawing in the involuntary attention. When asked what colour viewers found most fascinating, red-blue and green scored almost equally high, indication green is also an option. However, opting for green would mean losing the two-tone effect, which arguably helps draw attention. Hence I would recommend further, more elaborate testing with those two colours.

Figure 51: The fabric is made of different collors of yarn

The vase

Dimensions

- Length: in order to achieve vastness, physical size could be aiding to this. During user testing, a vase of one meter tall was used, of which the bottom part was covered in order to hide the pump and lighting system. For the full scale setup, a vase of at least 2 meters tall is recommended such that vastness is achieved.

- Diameter: Standard diameters for acrylic tubing go to about 500 mm, but with cost quickly rising. A tube of dimensions 2000x500x5 mm is €1335 (incl. VAT). In testing, a diameter of 200 mm was used. Important to keep the vase looking tall, otherwise it can start appearing plump. So smaller diameters might even be better, depending on the length of the vase. Best would be to go to a wholesaler and get a feel for the sizes.

- Make sure the vase is a cylinder, not a cone. The parallel walls make sure the diver stays in the middle, and tapered walls would in- or decrease the friction with the fabric unnecessarily depending on the height of the diver.

- The inner walls of the vase should be a smooth continuous circle, for the same reason the diver should not be too lumpy. If the inside is bumpy or has corners in it, it could obstruct the diver in its rotational or vertical movement.

- The cylinder and bottoms are bought separately. The bottoms are glued in, one that separates the electronics from the rest of the vase and one at the bottom to keep the water in. The upper one is mainly to keep the electronics from interfering with the fabric, and halting the rotational motion. Its shape also helps in keeping the water spinning.
  - Might be best to look for a way to make the lower bottom removable, in case of maintenance, or for further testing. Glueing it in makes the pump and light inaccessible.

Material

I would recommend keeping the vase made out of acrylic. Glass was opted, but after contacting a glass blower, it turns out to be difficult if not impossible to make such high vases. At least not by blowing, for which the maximum height (at their facility) was about 40 cm (glasmuseum Leerdam). In case it would be possible, it would still be very expensive (€160 per hour in labour cost alone). Next to that, glass is far less practical. It would be harder to install the pump and lights, make adjustments, take measurements etc. And the inside surface would be less smooth, which is important for the rotation of the diver as described before.

Pump

Try different sizes of pumps. Currently the EHEIM compactON 600 is used, which displaces 600 L/h. This is enough to keep the diver rotating in the top position, but not at the bottom. Hence, a stronger pump is necessary. For cost reasons no larger pumps were tested. Another option would simply to install more than one pump, as it is not the speed of water that matters, but the momentum.

Adjustable flow exit speed: it would be best if the pump had an adjustable flow rate. When the diver-fabric sinks, the fabric accumulates at the bottom, bunching up and pressing against the walls of the vase. This causes extra friction, slowing the rotation of the diver down, eventually bringing it to a halt.

- A solution would be a stronger pump, but then care must be taken that it does not spin the water too fast when the diver is in its upper position. Otherwise it will look restless instead of calming.

- Solutions could be either passive or active. I would advise to try a passive solution with a few attempts as it is more elegant, but otherwise switch to an active one.
  - Passive: tunable nozzle, that puts out the optimum water speed such that the diver still spins at the bottom, but not too fast at the top. By varying the nozzle diameter this can be achieved. However, this only has an effect to a certain level, and is harder to get exactly right. An active solution would give a higher degree of guaranteed success.

  - Active: controlled pump. If the flow rate of the pump is controlled by a microcomputer (like an Arduino) it can adjust the pump to give the desired rotational speed for the diver in a feedback loop. This is a less elegant and more complicated solution, but most likely requires less testing/adjusting, so would probably save time.

- Another reason for the flow rate to be adjustable would be to reinforce the connection to the weather. The water should spin slower, make the diver-fabric appear calmer in fair weather, and spin faster if a storm is coming. This automatically happens when the diver sinks (as it does with fair weather/ higher air pressures). However, it is unlikely to do so at the right amount. So it could be compensated by an actively adjusted pump.

Figure 52: The pump will be hidden in the bottom of the vase

Figure 53: After a couple months the water becomes cloudy

Appearance

Keep the vase simple. Do not let it distract from the fabric too much. It could give an interesting, more natural look if a simple pattern was placed on the vase, by a clear material, so that would be open for testing. There is definitely still potential for further research in this area, especially with biophilic design patterns in mind. Right now, the vase looks far from natural.

- Blocking parts of the vase with black opaque foil only left the viewer guessing, and rather turned attention away (in my opinion) than create curiosity to keep watching.

The water

Tap water is not pure water. It contains minerals and organisms that could potentially damage the system. Over time, organisms can start to grow larger quantities in the water, and calcium could harden and break the pump. In order to prevent this, a number of measures can be taken.

- Demi water: Instead of using tap water, fill the tank with demi water. It is pure water, with very low contamination values. Since the system is a closed loop, there will not enter any more contamination, and the system will need less maintenance.

Preservation of the water quality

- Bleach: this will kill most organisms, preventing them from multiplying. However, it will also discolour the fabrics.
- Alcohol: Is only effective at high percentages >60%
- Anti-algae agents: these can be helpful, but rather aggressive chemicals, not very fitting with the message to connect to nature
- The most natural but labour intensive way would be to refresh the water every so often. Most aquarium websites recommend replacing 25% of the water every month. This would be easier than to empty the entire vase, since the system can keep running in the meantime. As a downside, it would add some monthly cost to maintain the artwork, especially with demi water. However, since this is no aquarium, it should not be necessary to refresh the water so often. With no organic material in the water, so it would take longer for contaminations to reach concerning levels.

So there is no perfect solution. The best two options are anti-algae agents or replacing the water.

- Since the water would otherwise slowly evaporate, it is recommended to close the top of the vase with something that does prevent the water from escaping, but at the same time does let the outside air pressure influence the setup. Some plastic film would work well here, but even a solid lid that is laid on top won't close the system air tight.
  - This also helps stop microorganisms entering and spoiling the water.
  - If it is chosen to replace the water regularly, it is not necessary to add a lid. However, since the lid also prevents microorganisms from entering, it is still recommended.

The surroundings/dressing

The frame

- The idea is that the vase and veils hang, which could be from the ceiling, but to create independence from the situation it would be better to have a standalone frame to support the artwork. If done well, it could work well with biophilic design, which is traditionally more aimed at developing spaces. The setup shown in Chapter 9 is a very practical one, where the focus lay on getting it done quickly in time for user testing. I would recommend giving some more attention to the formgiving of this part, fitting it with the artwork.
  - Important is that the frame is placed outside the veils, such that it is not in the way of the viewer.

  - The frames should completely support the veils from the top. It is recommended to hang the veils like a curtain, from a rail/bar at the top of the frame. At the bottom it can be hanging freely, however this has not been tested.

Suspending the vase

- Structure: The idea is to hang the vase in a steel frame (Chapter 9) by some steel cables. I would still recommend trying to make the vase hang, rather than standing on a pedestal, to emphasise

Figure 54: After a couple months the water becomes cloudy

Figure 55: After a couple months the water becomes cloudy

the airy, light appearance. Depending on the look of the vase, the structure around it can be designed accordingly. If the clear, straight acrylic tube is kept as it is, a more straight, geometric frame around it would fit better. But if a more organic pattern is used on the vase, a more organic shape should be chosen for the surroundings as well.

- The advantage of steel is its strength. That way it requires less material than if for example wood is used. Less material means a more open structure is possible, allowing the viewer to see the fabric instead of the structure around it. As mentioned, and shown in Appendix , obstructing the view to the diver-fabric is not beneficial.

The veils/lighting

- It is already difficult to see through the veils from outside them. Thus they should not be made any darker, or the mental threshold for entering the enclosed space becomes too large.
- It feels quite cramped inside the veils, especially with multiple people. A wider setup would be better. The situation would already improve with a rounded shape of the veils, instead of the straight faces in the test setup. An optimum needs to be found between small enough for one person to be comfortable in, but large enough to accommodate a group of people that are having a break, typically four or five.
- Make the veils of material that is hard to wrinkle to ease the initial installation and longevity of the setup.
- Test with different colours of veils. This could change the atmoshpere completely. This has not been tested yet.
- Natural light: From building the prototype setup, it could be observed that the natural light from outside is bright, particularly on sunny days. It easily overpowered the artificial lighting in the setup (700 lm), which was still visible, but appeared rather weak.

- Ambient light entering from above and below the veils was bright enough to diminish the reflections that were meant to be cast by the vase. Hence I would recommend blocking this light. This can be done by extending the veils further up, or to be more location independent, cover the entire top of the setup with fabric as well. Also in the current setup the veils came high off the ground, about a meter, which allowed for a lot of the restlessness from the hall to enter the space around the artwork. So I would recommend hanging them lower. Tests on location will have to determine the optimum height.

- The tunnel to the outside formed by the veils was only visible from directly in front of the artwork. However, as the user testing showed, viewers prefer the higher contrast provided by the veils, so they stand to one side. As a result the message created by the tunnel does not come across. To emphasise it more, I recommend making the tunnel have a larger angle, with the two veils meeting at a straight angle instead of being paralel close to the vase. This way there are more positions for a viewer to see through the vase to outside.

- Artificial light: Currently, the diver is only lit from below with an artificial light source. I would recommend keeping it that way. Testing with a bright flashlight from Advanced Lighting Equipment, lighting the diver from different angles, did not improve the setup, and was already so bright it could blind viewers when looking directly into the diver.
- Considering the colour of the light, choose a colour that is a mix of the colours of the fabric, in case of two-tone organza. So purple in the case of a red-blue fabric. That way the fabric can reflect (part of) the light. Otherwise it gets absorbed and the fabric will appear darker.

Figure 56: The fabric are lit from below with a coloured light

The location

- Having the window facing in different directions has different advantages. Having the window either east or west has the light come in at a low angle through the vase either early or late in the day, providing sunlight directly through the vase. Facing south has the benefit that the diver will get backlit more throughout the day, and the reflections are more likely to be visible on the veils. Facing north will create a dimmer experience, providing more contrast from the lighting from below, drawing more attention to the diver itself. There is not per se a better or worse choice. To emphasise the message of connecting to nature, having a south facing window will be best.

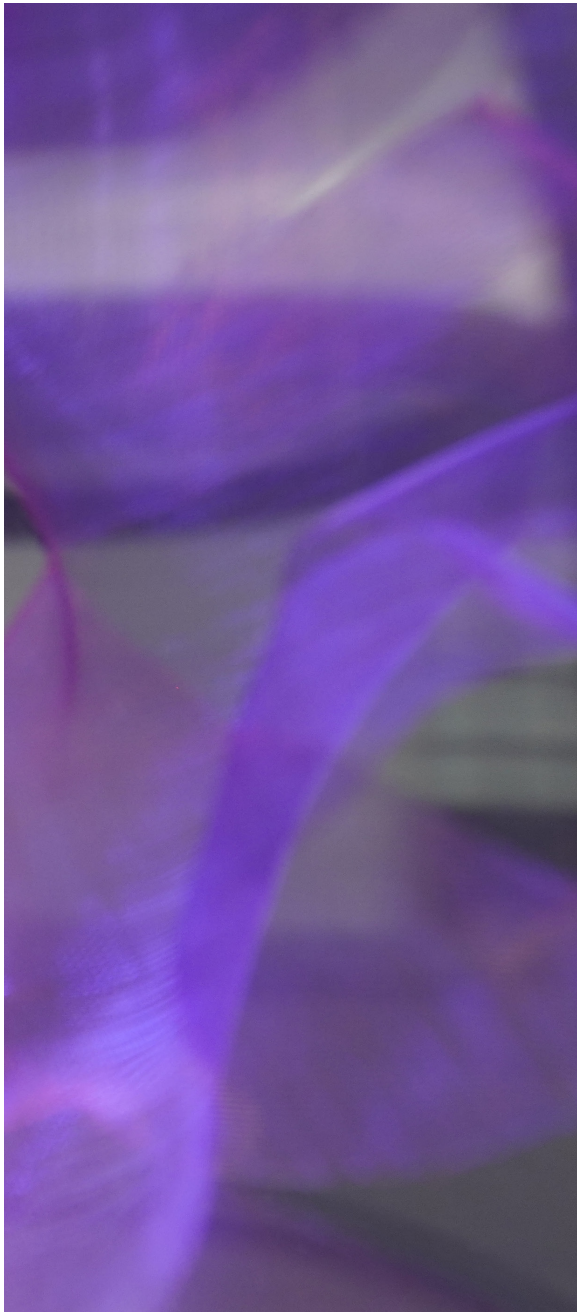
- Choose a location that is visited regularly by the same people. User testing revealed that nine out of fifteen people pass by the entrance more than seven times a week. This comes down to over once a day on average, which should be sufficient to notice a difference in the height of the diver over time.

Summary

These recommendations, along with the test results they are derived from (Appendix E) form the main deliverable for this project. Along with all the visual materials they provide insight in the problem of making an artwork that moves by air pressure, and aims to makes its viewers feel connected to nature.

Due to the broadness of the assignment and limited time there are a lot of things still undiscovered. Further testing in the appearance of the setup is necessary before creating a fully functional artwork towards an interested party. Especially when it comes to evoking awe, there are still large gains posible. Focussing on the appearance of the diver, making a glass version and full scale setup with a larger vase would be my recommendations as next steps to take.

I do believe there is potential in this artwork, and would recommend to keep developing it. Especially seeing the reactions of people during user testing, they were fascinated and intrigued by the design. This is my final advice.



12. Conclusion

Starting with a broad assignment, there were a lot of areas to dive into and explore, test and iterate. It is therefore not surprising there are many recommendations that can be applied to improve the current design. However, the core of the assignment was: *Create a kinetic artwork that moves by changes of the environmental air pressure and makes the viewer aware of their connection to nature through awe, while showing openness and the transience of nature.* And this has been (partially) achieved.

The piece moves up and down by small changes in air pressure, using a diver that encases an air bubble just large enough to keep it afloat at low pressures. Increasing air pressure compresses the bubble, making it smaller, letting the diver sink. It translates the invisible changes in ambient pressure into visible motion. This can be observed by passers by that view the piece regularly, which can be expected in a lobby of an office building.

Its appearance is inspired by jellyfish and seaweed, making it look natural, with the fabric moving gently in the flow of the water, bringing across the transience of nature. The diver itself will be made of glass in an irregular shape, giving it an airy, cloudlike appearance, fitting with the floating, calming motion. Biophilic design patterns like "presence of water", "refuge" and "mystery" have been implemented to trigger ART and SRT. The setup draws involuntary attention, giving the mind time to restore its voluntary focus, and makes people feel less stressed.

The emotion of awe was not achieved, so changes will have to be made to do so. The main improvement would be to test on a one to one scale, increasing the size of the vase and diver. If that is insufficient, the scale can be further increased, or multiple vases can be placed in an array in order to create the necessary vastness.

Testing showed that the art piece does express openness, and people's eyes are drawn to the piece. Time slowed down among viewers, and they were fascinated by the piece. The veils create an enclosed space, improving the lighting of the diver as well as enforcing the message of connection between humans and nature.

In the end the goal was to give an advice to the client, such that they can continue this idea and have a scientific foundation from which to start further development. This report has provided such an advice, giving knowledge and insight in at least one way to create such a setup. The project has potential but will need more time and testing to become viable.

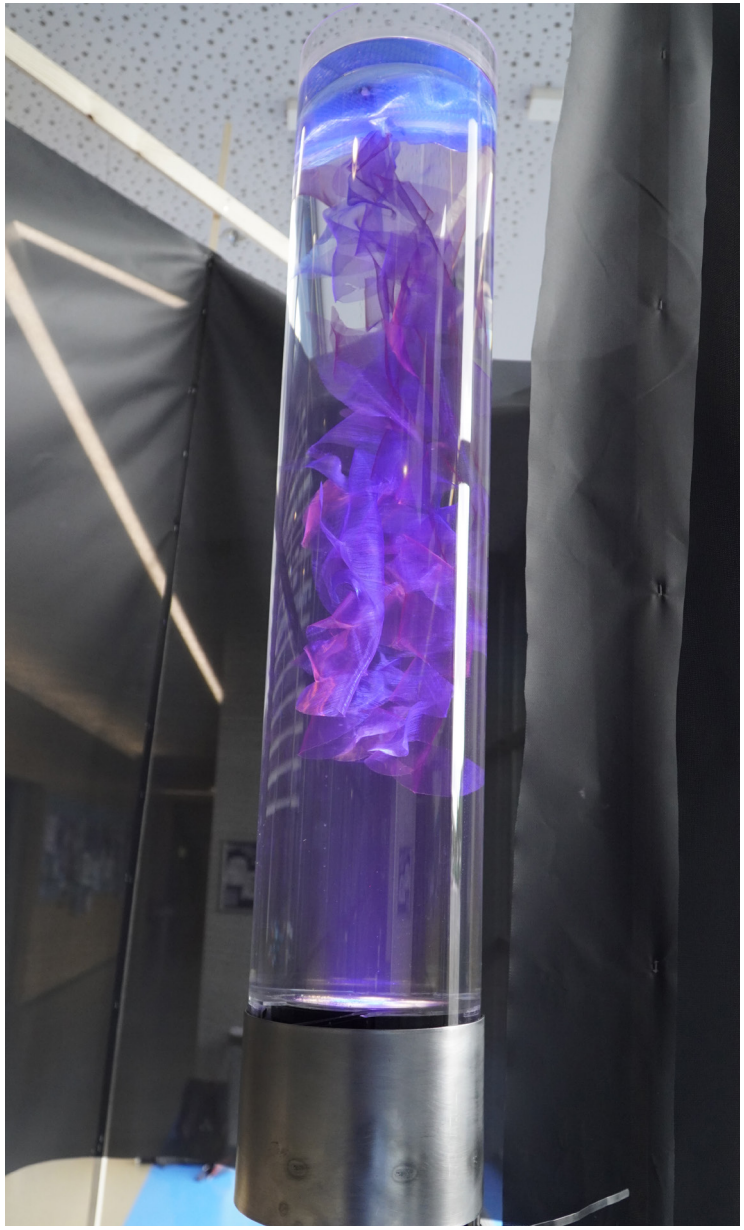


Figure 57: The current setup with a floaty appearance. It triggers ART and SRT, but does not evoke awe. Refining the appearance of the diver and building a bigger, full size prototype will be the next steps in developing it further.

Summary

This summary will cover the project in short, from its goal till conclusion. The project was initially broadly defined: develop a kinetic artwork that moves by changes in the environmental air pressure, to make its viewers aware of the connection between humans and nature, and present this as an advice to the client. To narrow this down, research was done into why this connection is so important. It turns out that natural environments can bring a number of health benefits. Biophilia hypothesises humans need nature around them to thrive. Part of it, stress reduction theory (SRT) states that natural environments provide a calming effect on humans, while attention restoration theory (ART) theorises that natural environments restore focussed attention in people.

Next to this, research into the behaviour of air pressure returned that we are working with small amounts of energy, below one Joule, and that changes occur over the timespan of a couple of days. Hence changes are slow, and only noticeable if the artwork is viewed regularly.

With this in mind, office workers were found as the target group. They often experience stress, have to focus and enter/leave their building multiple times per week. So if the artwork was placed in an office lobby it had most potential of achieving its goal. Awe was discovered as an emotion that evokes connectedness among people, hence could bring humans and nature closer. It requires vastness and a need for accommodation to be experienced to be felt. This gives to clear design direction, alongside the client's wishes for the piece to express openness, include natural variation and show the transiency of nature.

The result is a diver system that floats up and down in water in a vase, powered by the changes in environmental air pressure. Its appearance is flowy and light, resembling some sea creature that is floating in water. It is designed to capture the viewers eye and trigger SRT, ART and awe. The setup can be seen in Figure 57.

User testing showed that people did experience a reduction in stress, found it easy to look at the diver, restoring their focus and reviewed it as open. Awe was not triggered, and further improvements need to be made to do so. Since awe is evoked by vastness, which is dependent on size, it is difficult to test for it with scale models, so a full size model needs to be created to verify the emotion of awe.

The final advice is that the art piece has potential to be successful, but more testing and further development is needed. It has many facets, that could all only be tested marginally in the time scope of this project. Improving the appearance of the diver-fabric and vase, and building a full scale setup would be the next logical iteration.

Thank you for reading this report, I hope you enjoyed.

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Appendices - Table of contents

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Veldhuis
Initials	R.B.
Given name	Romeo
Student number	5653061

IDE master(s) IPD ✔ DfI ☐ SPD ☐

2nd non-IDE master	
Individual programme *(date of approval)*	
Medisign	☐
HPM	☐

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Sylvia Pont	dept./section	HCD/HICD
mentor	Susie Brand-de Groot	dept./section	HCD/HICD
2nd mentor			
client:	Atelier Arjen Witteveen		
city:	The Hague	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

Sylvia Pont - IO

Digitally signed by Sylvia Pont - IO
Date: 2025.03.11 12:45:47 +01'00'

Name Sylvia Pont Date Signature

CHECK ON STUDY PROGRESS

To be filled in **by SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total _____ EC

Of which, taking conditional requirements into account, can be part of the exam programme _____ EC

★	**YES**	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

L. Boot Digitaal ondertekend door L. Boot Datum: 2025.03.18 08:38:03 +01'00'

Name Lisette Boot Date 18 mrt 2025 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	★	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is …

★	**ALLOWED** to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen Digitally signed by Monique von Morgen Date: 2025.03.18 10:32:33 +01'00'

Name Monique von Morgn Date 18 Mar 2025 Signature

Personal Project Brief – IDE Master Graduation Project

Name student Romeo Veldhuis **Student number** 5,653,061

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Designing an indoor kinetic light sculpture based on differences in environmental air pressure. Werktitel: Lichtdruk

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)

People and nature (in western society) are growing more and more disconnected from each other. This can be found in countless scientific papers, and can also be seen when walking around in the streets. People live in cubic shapes, are constantly on their phone (in a different, digital world) and can completely regulate their surroundings, from what colour they paint their walls to the temperature the house should be when they get home from work.

Yet we do have an inherent connection to nature, and next to that a curiosity to find out how the world around us works. Sometimes it can sink deep beneath someones surface, and it takes an external source to make it bubble up again. That is exactly the aim of this project. To trigger the "inner child"and make a wonderous audience, even if it is just for a split second, and make us feel a little more connected to nature again.

An interesting way to bring this to attention could be environmental air pressure. It is all around us, and while the biggest part of the "outdoors" stays there, air manages to creep through all sorts of cracks and holes, providing a bridge between in- and outside. Next to that, air is invisible, and the differences in environmental air pressure are (almost) undetectable for us humans. So people are not aware of this connection between in and out. Next to that I could also be an enhancement to add an element of light to the sculpture. It too surpasses that barrier between in- and outside, and like air is an inherent, grand part of nature, hiding invisibly all around us, only to be seen directly from the source or as a reflection, but never floating around mid-space.

The artist/designer Arjen Witteveen (atelierAW) aims to bridge this gap and inspire people with an art piece to feel more connected to their environment and get a feel for the environmental air pressure as a natural phenomenon.

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introduction (continued): space for images

image / figure 1

image / figure 2

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)

The biophilia hypothesis states that there is an inherent, possibly even genetic connection between humans and nature. Patients have proven to heal faster in environments with elements of nature in them, overall wellbeing is higher in humans with a stronger connection to nature and levels of pro environmental behaviour are higher in people with a stronger connection to nature as well. Yet the connection between humans and nature is growing further and further apart, causing a loss of these benefits nature in a human environment provides.

So it would be beneficial to emphasise the importance of this connection between humans and nature, creating awareness and reinstate a connection to nature. We see this particularly in locations where people spend a lot of time inside, in human-made environment, like offices or educational institutions.

Additionally, it will be an option to use the product to teach children about air pressure (or their bond with nature). Because the product is intended to trigger some emotion, spark the "inner child", it could ease and aid understanding abstract subjects like air or a connection, very different topics but both invisible, therefore potentially difficult to understand.

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:

Develop a prototype barometer kinetic light sculpture that makes its audience aware of the inherent connection between humans and their natural surroundings, sparking the "inner child", and do so in a semi-public environment.

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)

The assignment is developing a dynamic light object that functions as a barometer, with the aim of adding a natural dimension to a space. It changes gradually over time based on fluctuation in air pressure, creating visual changes in its shape. This causes the shape of the artwork to subtly react to weather and environmental conditions, creating a surprising visual effect for the beholder, bringing the natural elements inside and the space to life. The aim is not only to create an aesthetically pleasing object, but also to enrich the user experience by making the environment respond dynamically to nature. This dynamic offers a contrast to the fixed, unchanging objects in a room, making the light object not only functional but also a poetic reflection of nature in everyday life. Air pressure and light are seen as suitable messengers as they invisibly surpass the barriers humans have created to seperate in- and outside
This challenge will be tackled using an iterative and hands-on approach. To facilitate this, an agile, iterative approach is chosen. Taking the double diamond as a base, potential useful design techniques could be: Interviews, WWWWWH, Design Drawing to Discover, Mindmapping, Braindrawing, C-Box, SCAMPER, How-to's and Experience Prototyping.

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	17 Feb 2025
Mid-term evaluation	14 Apr 2025
Green light meeting	11 Jun 2025
Graduation ceremony	10 Jul 2025

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)

First of all, I find it interesting to inspire people, to make them feel something, make them ask questions. Be that first push, to kick-start something that people already have inside themselves, but often forget to use. And in this particular case to link the outdoors to the inside, link a physics phenomenon to everyday life and make people understand the world around them a little better. That is my personal drive behind this project. Next to that I have following learning objectives for myself: 1. I would still like to learn how to properly convey information to the viewer. How to create interaction with a human on one side and an inanimate object on the other. 2. Moreover, I want to learn how to judge a good narrative, what is a strong story behind a work of art and what is not. 3. I want to broaden my knowledge on different materials. Not that I want to limit myself now and choose a specific material for the design, but I would like to be able to do more with (bio)plastic, to make something beautiful out of it, despite its often cheap appearance. Or work with metal, and get more experience there. At least include a material in the design that I have limited experience working with 4. Learning to take time to create overview in individual projects. I notice that in group projects I often take on that task, and that goes well because it's a specific task. But in an individual project, I forget to take that step back more easily, because you always want to keep going, there is always something to be done in the short term, and then I forget to keep an eye on the long term. 5. Important for me that it does trigger something in people, so I do want to do some research into how something like that works, what do people find interesting. Ultimately I want to make an artwork, not a (mass produced) product.

Appendix B - Disconnect from nature

For some time now, there has been an expanding disconnect between humans and nature in the western world. The length of this time can be argued upon, from the rise of visual entertainment, to all the way back to Aristotle. Just in the wording of “disconnect between humans and nature” we separate the two, as if humans are outside of nature, above, next to, excluded from it. So first, I want to give a little background on how this disconnect has emerged, and mention some factors that have played a role in reinforcing it.

We can go back a long time. It can be argued that the first settlers already created a disconnect, by saying they “owned” a piece of land, a piece of nature, resulting in a hierarchy. But the first documented case of hierarchy is from Aristotle. He is quoted to have said: “plants are for the sake of animals, and that the other animals are for the sake of human beings, domestic ones both for using and eating, and most but not all wild ones for food and other kinds of support, so that clothes and the other tools may be got from them.” (Calarco, 2015)

By saying this he not only creates a separation between humans and nature, but even categorises humans, animals and plants.

Later, the catholic church would reinforce this idea. The bible states that “The garden of Eden was created for Adam and Eve to live off of”. Of course this is a translation, and can be interpreted ambiguously. But the general explanation is that Christianity and other monotheistic religions have promoted the “uniqueness of humans in the face of an external nature” (Loreau, 2023). Later again, Descartes would lay the foundation for modernity, and create a boundary between nature and thinking. The politics of reason: Towards a feminist logic by Val Plumwood (1993) also states that in western culture there has been a divide between culture and nature, reason and nature and human and nature(non-human), civilised and primitive (nature) among other dualisms. Especially since post-enlightenment times, dualisms are characteristic for western culture. This might have reinforced the view of a separation, instead of creating a spectrum from natural and artificial things, the western world likes to view things in black and white, human and nature.

In more recent times, there can be found some evidence for a separation by virtual entertainment (Greater Good Magazine et al., 2017). They have looked at the number of times nature related terms have been mentioned in pop culture (e.g. song titles, books and movies). From there they try to explain the disconnect to nature. As they show, since the 1950’s there has been a significant decline in the mentioning of these terms, suggesting that people have indeed been associating themselves less with nature. They link this with the rise of virtual entertainment, starting with television in the 1950s, video games in the 1970s and the Internet in the 1990s. A look at the playgrounds in your neighbourhood confirms this. They are far more quiet than 20 years ago, which can be related to the rise of smartphones and tablets. As Richard Louv (2008) quoted in his book by a seven year old when asked why he likes playing indoors better than outdoors: “‘cause that’s where all the electrical outlets are”

Current situation

Now that we have an idea on the history of the disconnection, we can look at the current situation.

When we look at research from 2021 in the UK, we see the following: Research from the British mental health foundation found that some of the reasons for not connecting with nature are insufficient leisure time (especially among young adults), safety concerns and lack of shared activities.

43% of 18-24 year olds found a barrier in time spent working or studying. In the same age group, 18% said they did not have other people to join them in their nature related activity. 18% of UK residents felt unsafe to physical harm. And 8% of young adults did not even want to spend time or did not enjoy being in nature (compared to the 3% average in the UK). (Mental health foundation, 2021)

These reasons can all (partly) be related to a disconnect with nature. Fear or disinterest in nature can be explained by the concept of biophobia, which can occur when someone has particular negative emotions with nature. Lack of time can be a valid argument, but is also a matter of priority in cases. It could also mean that the distance between urban and natural environments is too large, costing too much time to bridge. Next to that it can go in circles. Students feel stressed, by study, but also by lack of nature experiences, hence they feel like they should study more, spending less time in nature. Breaking this circle and going out in nature can have a stress and anxiety reducing effect according to stress reduction theory (SRT).

The fact that younger generations are less connected to nature could be related to the concept of nature deficit disorder (NDD). This is a postulate by Richard Louv (2008) that builds on the concept of biophilia. Biophilia is the idea that humans have an ““innate tendency to focus on life and lifelike processes”. (Wilson, 1984) It implies that humans have evolved to benefit from being around nature, explaining more why there are so many benefits to being in nature. NDD consequently proposes that the increased disconnect to nature of the past decades, especially at an early age, can be associated with health deficits later in life. However, this theory also disagrees with biophilia on a level. Biophilia states that the connection to nature is purely genetic, nested in our genes. NDD argues that this deficit arises in early life, relating it to nurture. Both theories seem to hold some truth at their core, both trying to explain why humans tend to prefer natural scenes over artificial ones. However, it has yet to be proven that such a single theory lies at the centre of our (dis)connection with nature. Nonetheless, for parts of these theories there has been collected empirical evidence, that can be used as a foundation for this research.

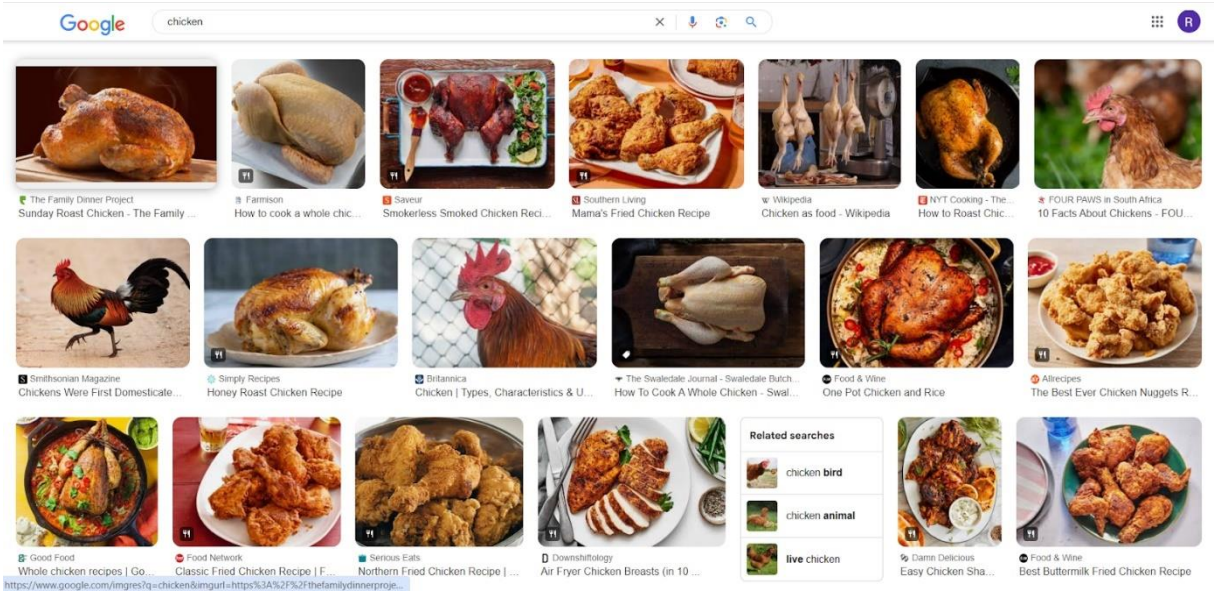


Figure above: Searching chicken in Google does not show the animal, but rather the food. We are programmed to look a certain way at nature. In the “related searches” box you can see you need to add a term to get a picture of a live chicken. *(Chicken - Google Search, n.d.)*

Beery et al. (2023) have even identified eight different fields in which humans have experienced disconnect to nature. They are: material, experiential, cognitive, philosophical, sociocultural,

institutional and political. They have found evidence for a disconnection with nature in literature in all of these fields. Examples range from changes in the way we process and view food, including food deserts, a decrease in the consumption of natural food, to lack of knowledge about nature and an increase in VR(Virtual reality) nature experiences. This shows already how complex the rise of this disconnection is, how many factors play a role. There is no single source, which makes it unlikely there is a single solution. In any case, that will not be the aim of this report.

To indicate how common this disconnect is to us humans, we can just look at the term “disconnect between humans and nature”. As Robert Fletcher says: by stating that there is a “disconnect” with nature, we imply that humans are not part of this nature. Since if we were, we would not have to connect with it (Fletcher, 2016). Therefore it is important that one is aware of this oxymoron when trying to counter NDD. We have said this for so long now that it has become the accepted truth. For the sake of convenience we will keep using the term “disconnect between humans and nature” in the rest of this report. An example could be taken from the approach many indigenous people take when educating themselves about nature. They do not make the distinction between human and nature. Instead, they take a far more holistic approach, where humans are part of nature, in a system that depends on each other. (Beery et al., 2023). Traditional societies even relate their scale of madness and sanity to their relationship with their natural surroundings (Chavaly & Naachimuthu, 2020). European colonialism has caused this idea of a separation between humans and the world to spread and infuse in other cultures (Beery et al., 2023).

To summarise, the exact origin of the disconnect between human and nature is unknown, and most likely not a single source but rather an array of contributing factors, ranging from philosophy to the food industry to the rise of virtual entertainment. Some factors stimulated the separation early on, while others adapted to it, making it difficult to see where the problem started, what its core is. And it might in our case not matter where the problem came from. We have now identified a number of factors that play a role, and so we can look at where a kinetic artwork can provide some help in reconnecting to nature in any of these fields.

Appendix C – Biophilic Design Patterns

2014: Terrapin Bright Green

14/15 Patterns of Biophilic Design

Nature in space	Nature Analogues	Nature of Space
1. Visual connection with Nature 2. Non-Visual Connection with Nature 3. Non-Rhythmic Sensory Stimuli 4. Thermal and Air Flow Variability 5. Presence of Water 6. Dynamic and Diffuse Light 7. Connection with Natural Systems	8. Biomorphic Forms and Patterns 9. Material Connection to Nature 10. Complexity and Order* *NOTE: Terrapin Pattern 10: Complexity and Order is found under Kellert's "Evolved Human-Nature Relationships" and "Experience of Space & Place", corresponding to Terrapin's Nature of Space (rather than Nature Analogues).*	11. Prospect 12. Refuge 13. Mystery 14. Risk/Peril 15. Awe *NOTE: Pattern 15 Awe was added in 2020.*

2008: Kellert, Heerwagan, and Mador

Biophilic Design Elements & Attributes

Environmental Features	Light + Space	Place-Based Relationships	Natural Shapes & Forms	Natural Patterns and Processes	Evolved Human-Nature Relationships
Color Water Air Natural ventilation Plants Animals Natural materials* Views and vistas Façade greening Geology & landscape Habitats & ecosystems Fire	Natural light Filtered & diffused light Light & shadow Reflected light Light pools Warm light Light as shape and form* Spaciousness Spatial variability Space as shape and form Spatial harmony Inside-outside spaces	Geographic connection to place Historic connection to place Ecological connection to place Cultural connection to place Indigenous materials* Landscape orientation Landscape features that define building form Landscape ecology Integration of culture and ecology Spirit of place Avoid placelessness	Botanical motifs Tree and columnar supports Animal motifs Shell and spirals Egg, oval and tubular forms Arches, vaults, domes Shapes resisting straight lines and right angles Simulation of natural features Biomorphy Geomorphology Biomimicry	Sensory variability Information richness Age, change and patina of time Growth and efflorescence Central focal point Patterned wholes Bounded spaces Transitional spaces Linked series and chains Integration of parts and wholes Complementary contrast Dynamic balance and tension Fractals Hierarchically organized ratios and scales	Prospect and refuge Order and complexity Curiosity and enticement Change and metamorphosis Security and protection Mastery and control Affection and attachment Attraction and beauty Exploration and discovery Information and cognition Fear and awe Reverence and spirituality
* apply to Kellert et al.'s Natural Shapes & Forms; Patterns & Processes * apply to Terrapin's Naturae Analogues			* apply to Kellert's Evolved Human-Nature Relationships * apply to Terrapin's Nature of Space		* apply to Terrapin's Nature Analogues

2015: Kellert and Calabrese

Biophilic Design Experiences & Attributes

Direct Experiences of Nature	Indirect Experiences of Nature	Experiences of Space and Place
Light Air Water Plants Animals Weather Natural landscapes & ecosystems Fire	Images of nature Natural materials Natural colors Simulating natural light and air Naturalistic shapes and forms Evoking nature Information richness Age, change, and the patina of time Natural geometries Biomimicry	Prospect and refuge Organized complexity Integration of parts to wholes Transitional spaces Mobility and wayfinding Cultural and ecological attachment to place

Table 1: Comparison of Terrapin's 15 Patterns as the Primary Framework with Kellert et al.'s corresponding categories and attributes. Source: (Terrapin Bright Green, 2014; Kellert, Heerwagen, and Mador, 2008; Kellert and Calabrese, 2015)

This tables shows the fifteen different biophilic design patterns, categorised and exemplified.

(University of Minnesota, n.d.)

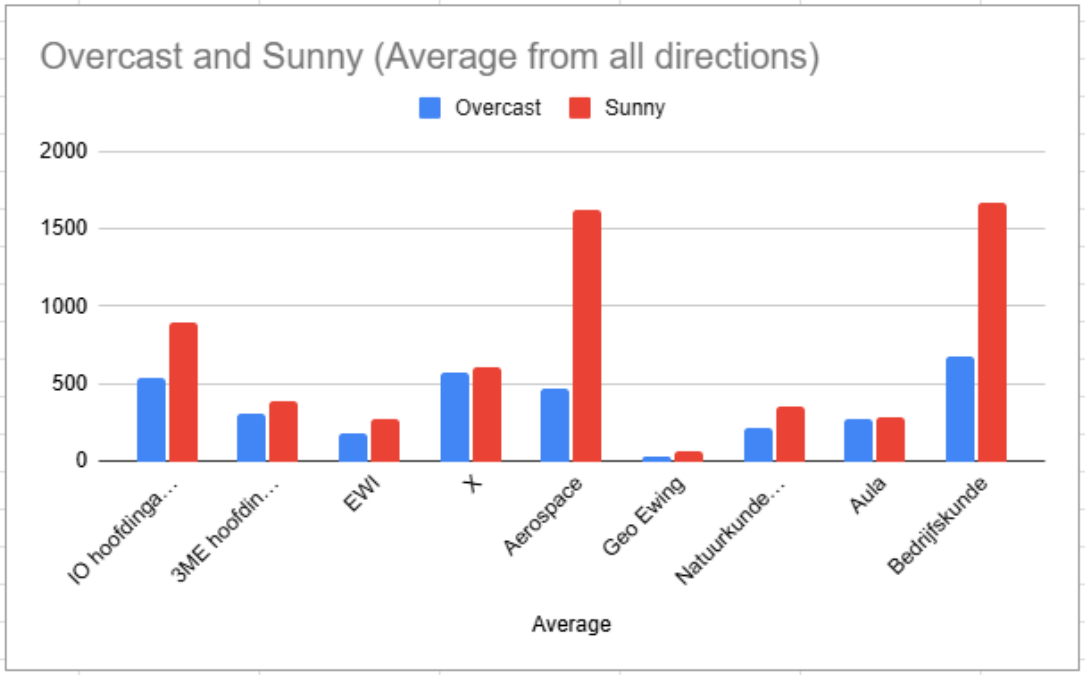
Appendix D – Light measurements around campus

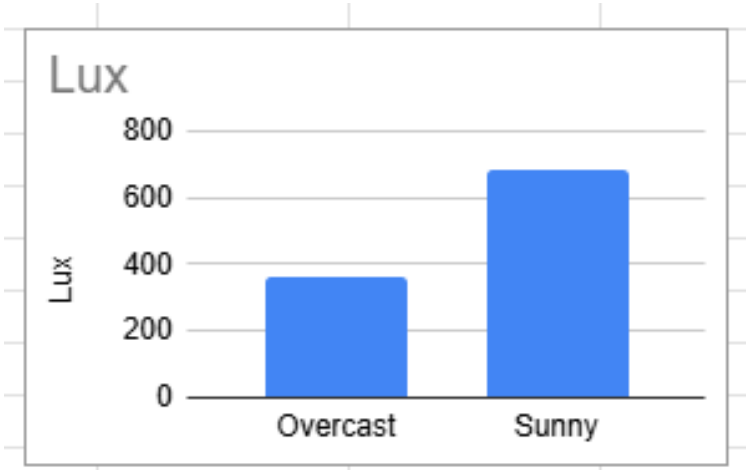
	A	B	C	D	E	F	G	H	I	J	K	L
1		IO hoofdingang	3ME hoofdingan	EWI	X	Aerospace	Geo Ewing	Natuurkunde ho	Aula	Bedrijfskunde	Bewolkte dag	
2	Hor	908	458	277	1019	544	34	337	451	730		
3	Vloer	772	381	267	728	613	44	296	378	887		
4	VertT	492	291	160	441	471	32	175	248	1261		
5	VertA	253	171	90	481	330	13	200	116	234		
6	VertP	242	215	105	196	391	48	86	198	290		
7	Average	533.4	303.2	179.8	573	469.8	34.2	218.8	278.2	680.4	363.4222222	
8											Zonnige dag	
9	Hor	1652	505	328	874	1466	37	352	449	1941		
10	Vloer	1307	450	311	781	1833	54	466	387	1000		
11	VertT	684	438	236	711	2089	58	311	300	2115		
12	VertA	458	203	146	393	935	19	498	120	689		
13	VertP	368	366	333	305	1809	140	142	188	2606		
14	Average	893.8	392.4	270.8	612.8	1626.4	61.6	353.8	288.8	1670.2	685.6222222	
15												
16												
17												
18												
19												
20	Hor: Horizontally measured at eye level											
21	Vloer: Horizontally measured at ground level											
22	VertT: Vertically measured with the sensor pointing towards the entrance											
23	VertA: Vertically measured with the sensor pointing away from the entrance											
24	VertP: Vertically measured with the sensor pointing perpendicular to the entrance											
25	All measurements were taken inside, in the middle of the doors, 2 meters away from them. In case of revolving doors, the measurement was taken at 2m away from the most inside point of the circle.											

Raw data from light measurements in hallways around the campus of the TU Delft. Values are in Lux, measured with an Infurider YF-881D digital lux meter. The top section are measurement from an overcast day, the bottom section from a sunny day. All measurements were taken in April, around noon.

Average	IO hoofdingang	3ME hoofdingan	EWI	X	Aerospace	Geo Ewing	Natuurkunde ho	Aula	Bedrijfskunde
Overcast	533.4	303.2	179.8	573	469.8	34.2	218.8	278.2	680.4
Sunny	893.8	392.4	270.8	612.8	1626.4	61.6	353.8	288.8	1670.2

Average data, average taken per location, of all the direction measured in.





	Lux
Overcast	363.422
Sunny	685.622

Average data, average taken per location, of all the direction measured in. You can clearly see the difference per location, some locations experience 250x more lux than others. We can also clearly see that on sunny days, measurements are almost twice as high. And the entrances pointing south (Aerospace and Bedrijfskunde) experience more sunlight than other locations at this time of day.

Appendix E - All the prototypes

This appendix will go into detail on all the prototypes and tests made during this project. It starts with simple tests to acquire motion from changes in air pressure, to developing the shape of the diver system.

As a start, it is nice to build very simple prototypes to get a feel for the matter. Where the problem in this early stage is still mostly physics based, and could therefore be worked out on paper alone, it will eventually turn towards appearance, so it seems good to get a feel for the matter early on and make more tangible models. The initial goal was to get some controlled motion out of air, driven by a change in (environmental) air pressure.

Test #1

Perhaps the most intuitive way to let air move something, at least for me, was a piston and cylinder system. So I made one. To try to get a bigger effect, the volume was increased by attaching the piston, in this case a syringe, to a glass bottle. Important was that the container would not change shape (otherwise the motion would go into reshaping the container instead of moving the piston). We can see the setup. Doing a quick back-of-the-envelope calculation we can come to the conclusion that with a change of FIXME hPa in pressure, the volume would change FIXME mL, which would be readable on the syringe. This change in pressure would create a force of about FIXME N, which would not be enough. On the scale the syringe read about 270g (CHECK) to be pushed in while moving, and 630g(CHECK) to overcome the initial static friction. In other words, 2.7N and 6.3N respectively. But better to check.

Turns out it is true, the syringe did not move, with changes of environmental pressure greater than 10 hPa, according to the weather app on iPhone. Research on the internet showed that most pneumatic tools work with pressure differences of around 6.3 bar, or 6300 hPa, quite a different scale compared to 10hPa.

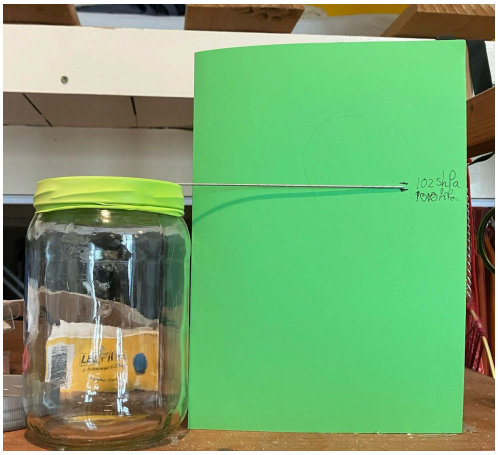
Test #2

But syringes are made of solid materials that create quite some friction, which they need to stay airtight. How about liquids, would they work better? So I tried replacing the syringe with a long tube, in which I placed some coloured water. The idea was the same, pressure from outside would change, disrupting the balance between pressure inside the bottle and outside. As a result, if the outside pressure increased it would compress the air in the bottle, moving the liquid in order to do so, or vice versa, if the pressure outside decreased, the pressure in the bottle would push harder and move the water the other way.

This worked a little better. The water moved slightly in the next hour, but when I checked the next morning, the drops had collapsed. The adhesive forces were not strong enough to hold the shape of the drops, and once they collapsed they did not create a seal anymore, allowing the air to pass freely from outside to inside and the other way. Next to that, the drops would slowly shrink by evaporation over the next few days. Eventually they would disappear completely. But at least there was motion. I already created a number of ideas around this concept, pictures of them can be seen in Appendix FIXME.

Test #3

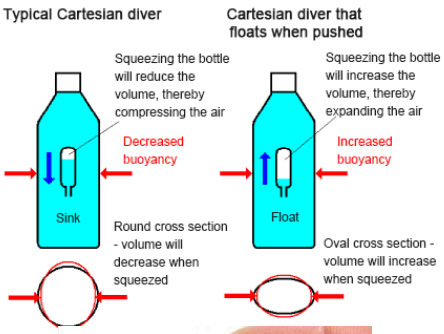
Going back to barometers, it is possible to make a simplified version at home. Taking a bowl or large jar, stretching a membrane over the top, in this case a balloon, and attaching a pointer set in front of a piece of paper, we have a pressure measuring device. However, for some reason I never got mine to work properly. It moved only minimally and was quite inaccurate, potentially due to changes in temperature also messing with volume of the air inside the jar. The idea is nice, the execution less so. What we are after is a larger, easily visible movement, so that it does not require significant effort or attention from the viewer to notice. So that is what became the main topic of research. In the meantime, I looked for inspiration in other art installations that would use air as a medium to create motion.



What I realised mainly was that what made these art pieces so attractive to look at was their calm, slow movements that created a sense of calm (relate to SRT). They usually make the connection with our own breath, following the cadence of a person slowly breathing in and out.

The Cartesian Diver

Since it is a physical phenomenon I am working with, I also looked at a number of science videos for kids to explain the physical world. In these videos they come up with all sorts of ways to visualise the effects talked about. Which is exactly what I am looking for. Visualising a physics phenomenon. At some point, I came across the Cartesian diver. It is a demonstration of buoyancy, the ability of an object to float.



How it works is that a small container is placed in a larger one, with the small container usually having a pocket of air inside it, and the larger one being filled with a liquid, usually water. The small container is made such that it has an opening, but the air cannot escape, like in Figure FIXME. For the bigger container you can take a large bottle, so that it can be closed by screwing on the cap. Initially, the smaller container (the diver) floats because of the

air bubble that is inside it. But now you apply pressure to the bottle. As you can see in Figure FIXME, the pressure results in the air being compressed. So the bubble becomes smaller, and water flows into the diver. At some point, the volume of air is so small that it can no longer support the diver, and it sinks. Now we have found significant motion by a difference in pressure, exactly what we were looking for.
https://www.jsme-fed.org/experiment-e/2012_8/001.html
https://professorplums.com.au/products/jellyfish-diver

Test #4: The diver
After constructing a diver, it was time for testing it. Figures FIXME show a folded piece of tube in the bottle. I learned several things from this test:

- It is a large motion, going completely up or down above or below a certain pressure
    - This also means it is a binary system. There is no stable position for the diver to be in in the middle.
    - The large motion gives this principle more potential than the previous tests.
- You need quite a lot of force to get the diver to move
    - Also with different lengths of tube, to try to get the diver to just float when no pressure is applied, it is still difficult to achieve neutral buoyancy
    - This could be due to the relatively small volume of air, so it is difficult to make small changes to it
    - Surface tension of the water might play a role too here. It is uncertain what exactly causes the high required pressure, but it would need to be solved in order to get the motion effect by the relatively small changes of environmental air pressure.

The system is binary because once the diver starts sinking, it drops deeper and deeper below the surface of the water. And moving down in water increases the pressure. So the bubble in the diver gets even more compressed, making it even less buoyant, causing the diver to sink even further. This positive feedback loop only stops once the diver hits the bottom of its container.

Test #5 and 6: Improving the diver

So there are several issues with the concept of the diver, but there is potential. For practical reasons the bottle was swapped for a vase in the following tests. In order to simulate the environment a bit more accurately, it was chosen to use a balloon across the top of the vase that could be pressed in to produce changes in air pressure, see Figure FIXME. Finer tuning of the diver made it a

little easier to get it to sink, a little more sensitive. But it was still a relatively small volume of air, causing a relatively high inaccuracy. So to overcome this, we can take a larger volume of air, as seen in Figure FIXME. The syringe was used again, with a volume of 10mL CHECK. The top of the syringe was glued closed so no air could leak out. The amount of air in the syringe could be accurately applied using a second syringe to add small bubbles of air until neutral buoyancy was achieved. A small weight (standard stainless steel M10 nut) was hung underneath the diver to counter the upwards force.

Additionally a solution for the binary was tried. Ideally, the diver is stable in every position, so the air pressure can roughly be read when looking at it. It would make for a more interesting piece if the diver could float at any height, instead of only being at the bottom. Next to that, if we were to scale up this setup to a meter high, likely later on to create an effect of awe, the setup would pose another problem. Underwater, pressure drops by about one bar per ten meters. So in a setup of a meter tall, this would mean an increase of pressure of 0.1 bar at the bottom compared to the top. 0.1bar is 100hPa. And since the air pressure in the Netherlands generally is between 980 and 1040hPa, a difference of 60hPa, once at the bottom, the diver would never get back up again. In other words, the water column could be a maximum of 60cm high. And even then, the diver would only come up to the top on the day with the highest pressure of the year, and lay on the bottom the rest of the time.

So now the solution. If we hang a string below the diver that would touch the bottom of the container it provides extra weight that pulls the diver down. We make sure that with the string attached, the diver is neutrally buoyant at the top at around 980hPa. Now when the pressure increases, the air in the diver gets compressed, and the diver sinks, increasing the pressure from the water with the extra depth. But as a result, it also has to pull up less of the string. The added downwards force caused by the increased pressure at depth is countered by the less weight the diver has to pull.

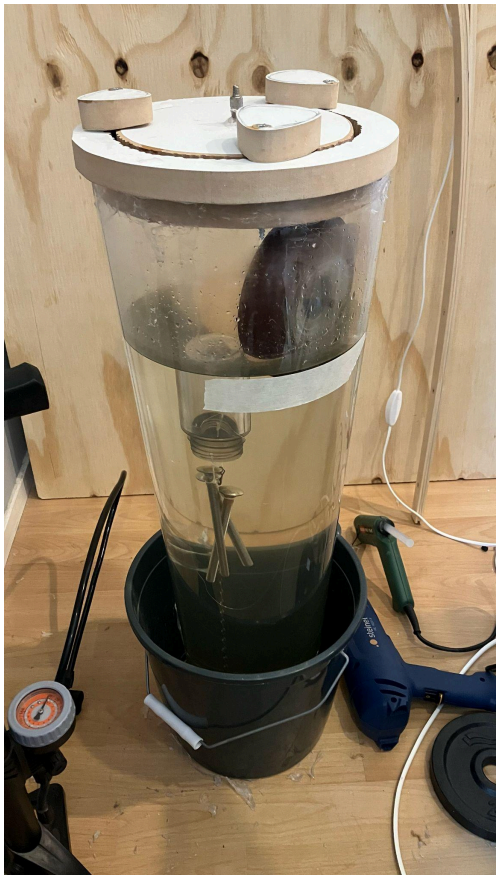
Working with the new setup with string, a couple new insights were gathered.

- The strings work a bit, but they are still too stiff, causing the diver to get stuck halfway to the bottom. A chain might be a better option since it can hold no compressive forces whatsoever.
- Already takes a lot less effort to push in the membrane to get the diver down

After testing with the membrane, it was removed to see if the setup would be sensitive enough to react to changes in environmental air pressure.

- The two photos from Figure FIXME were taken about 12 hours apart. You can clearly see that movement has taken place. So the system is sensitive enough to changes in ambient pressure (according to the Apple weather app, there was a difference of 5hPa between the two photos).
    - One drawback though, when pressure was back to its first level (Figure FIXME), no change in position could be seen. So accuracy is still lacking.
- The extra volume of air already makes the system so much more accurate
    - By using a second syringe you already get a balanced enough system to get weather-induced movement. This is an (estimated) accuracy of 0.05mL on a total volume of air of about 4mL, so that works out to 1.25%.

Getting accurate



Now we have a proof of principle, it is time to get more specific. So far we either pushed on a membrane, with no indication what that did to the pressure, or waited for the weather to change. But sometimes the pressure does not change for a week, especially in spring/summer when the weather is calmer. So I made a more controlled environment, shown in Figure FIXME. The setup is bigger again, with the vase being about 80cm tall. On the top a double edge is constructed such that the centre circle at the top is lying on a ledge with a silicone seal. The three clamps have a slight angle at the bottom, tightening the lid once they are twisted inwards. A bicycle valve in the lid provides a way for air to enter using a bicycle pump.

Test #7

A barometer is hanging in the cylinder to accurately read off the pressure. The diver itself now is a 125mL plastic bottle turned upside down with weights hanging down below it. The total weight is 183g, with a chain of 17g/m.

From this test, several relevant results emerged:

- The chain seems to work well. If the pressure is held at constant value, the diver floats in the middle of the water column.
- The diver is (still) sensitive to changes in the weather. Once the lid is left off overnight, the diver still changes height, as expected.
- Diver is much better to adjust with a larger volume of air. Now we are at ~100mL of air with still an accuracy of about 0.05mL. So this now amounts to 0.05% accuracy, a significant improvement compared to the previous 1.25%
- There needs to be a point on the diver to reduce the influence of surface tension. In previous tests this was not a problem, but in this one the flat bottom of the bottle causes

the diver to stick to the surface of the water, so to speak, and then suddenly sink to the bottom.
    - In later tests this was solved by glueing a hollow plastic cone to the top (bottom) of the bottle to break the surface tension.
- Measuring the pressure with the system air tight, we can look at the numbers. The diver was up at a pressure of 1022hPa and down at 1026hPa. This thus gave a range of about 4hPa over which the diver travels a distance of about 35cm. It is a rather small range, but it can be extended by selecting a heavier chain.

Thus we have proof of a working setup that makes sufficiently large movements for application in an artwork, such that passersby can see its change with the naked eye, without needing to pay close attention.

Test #8: Diver with tip, and adding a barometer and airtight seal

Idea: tip at the top of the diver breaks the surface tension so that the diver no longer "sticks" to the surface. By adding it, the air pressure in the system can be measured, and a number of sensitivity measurements can be made.

What learned:

- This works immediately, and ensures minimal sticking
- Having some extra air in the tip made it even more accurate
- Adding a barometer and gluing the system shut allowed accurate pressure to be built up.
    - This established the sensitivity of the system. The diver was up at a pressure of 1022hPa and down at 1026hPa. This thus gave a range of about 4hPa over which the diver travels a distance of about 35cm.

Test #9: Diver in lukewarm water

Idea: Testing the influence of temperature on setup. Even though it doesn't matter much to Arjen how much influence temperature has on the setup, it's still worth testing. As Arjen also pointed out, the location where this work will be located will probably be air-conditioned, and thus have a fairly stable temperature profile. The test was conducted with water at a temperature of 24 degrees Celsius, with an ambient temperature of 15 degrees Celsius at the beginning of the test, 16 at the end.

What was learned:

- The diver only dives down at higher pressure. This is because the air is expanded and thus occupies a larger volume. With

that, the diver's buoyancy increases, and so a higher ambient pressure will be needed to make the diver sink. The diver went down at a pressure of 1035hPa

- The diver is much more sensitive. With a pressure difference of only 1hPa, the diver goes from the very bottom to the very top of the tank. I have not yet wound an explanation for this.

So the main way of converting differences in air pressure into motion has been covered. There is a messenger to bring the message across. But what message? And what should it look like?

Taking shape

So now that we have established what we are aiming for, it is time to get crafting to achieve this. Since the medium in which the centre of attention is floating is water, we can look at the natural world of the sea for inspiration.

On youtube there are countless videos of aquaria, underwater habitats and oceanscapes with titles like: Underwater Ambience, Deep Relaxing Music, Sleeping Music, Meditation Music that have millions of views. It is known that blue spaces like rivers and seasides are causing a sense of calm or relaxation in people.

In these videos, movements are always slow, fish swimming around corals gently, seaweed going back and forth with the flow of water, a sea turtle passing by. The music is calm and generally positive. There are rarely fish on the hunt, making rapid movements. No scary beasts lurking in a hole.

I think what makes these videos so appealing is the slow motions of everything. Because water is just so much more viscous than air, all life moves slower. And because mostly life has neutral buoyancy, it's floating around, with always a little bit of motion there. Nothing is exactly still, like you see on land. I think these are the reasons why people watch these videos so much, why they are so relaxing. And why people have aquaria in their home. There is always some motion, and it is always slow, making it come across as gentle.

With this in mind, the experiments continue. It started with buoyancy. In order to have a material follow the gentle motions of flowing water, it must be about the same density as in this case water. Otherwise the material will have a strong up- or downwards force giving it a clear direction of motion. And we want to make it move in the direction of the flow of water, which can change over time. So by choosing a material that is similar (in density) to water, it will act similarly as well.

Next to that it should not be too stiff, but bend easily. Looking at plastic foils they have densities just a little lower than water and are quite thin and flexible, making them suitable materials for some first testing.

The figure shows a first test, glueing one big circle to the top of the diver. This already gave surprisingly nice movements. As the diver sinks, the plastic trails behind it, waving in the relative flow. This is important to achieve in future tests as well. The waving motion of the foil catches the eye, intriguing the viewer. Yet it still has some issues like limited developed motion, and a rather stiff appearance.

Test #10: Diver with foil

Idea: by adding foil try to create natural movements and build a bit more of a story.

What learned:

- Natural effect is partly created. Movement does not yet seem very smooth and elegant, seems to be mainly due to the stiffness of the foil, and the fact that it is now just a circle without further shaping.
- Circle folds double under the influence of momentum downwards, but recovers its shape once the diver has come to a stop at the bottom. Also means that the film has almost neutral buoyancy.
- The translucent foil already creates interest and makes it look underwater-like, reminding a bit of a jellyfish, who are most often not opaque either.
- Current in the water could perhaps add some movement.

Suggestion: it would be cool if the flow rate is also tuned to air pressure. This will be tested later. First let's keep playing with the material. Making some incisions in the foil gives it more freedom to move, looking like fins or petals of a flower. Interesting to see here is that the petals move, even if the water is undisturbed and the diver is not moving. These gentle, random wavy motions look calm and relaxing and could be used in future designs.

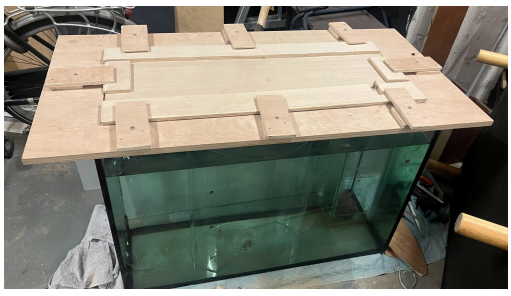
Test #11: Diver with foil with incisions

Idea: cutting the foil gives it a bit more freedom of movement and makes the stiffness of the material matter less.

What learned:

- Movement already seems more natural. Even in virtually still water, the foil moves slightly up and down, which feels very calm and soothing.
- Even described by some as poetic
- The foil does tend to stick together more
- When the foil is on the surface, it looks a bit messy as the flaps double up or lie over each other

Eventually the goal is to cause awe. This emotion is related to a sense of vastness. Vastness is related to size, of which in this case physical size seems the most obvious to test. So it was decided to scale up, and increase the size of the tests. Similar to the vase in the previous tests, an aquarium of 100x44x66cm was given a double edge at the top, with a removable lid. Again, the container could close sufficiently air tight that pressure could be built up to levels above 1040hPa.

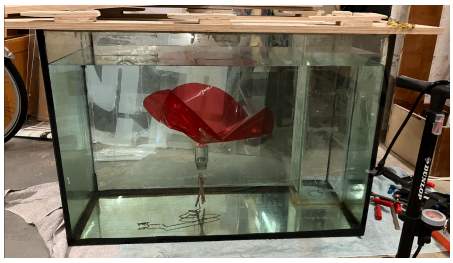


This way the size of the foil addition could be increased to see if it behaves similarly at larger scales.

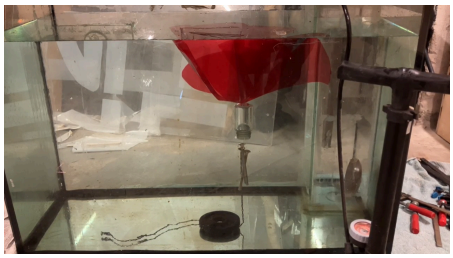
Test #12: Diver with foil (whole and cut), larger diameter (40cm)

Idea: By scaling up look at what scale problems this gives

What learned:



- With the larger size, the stiffness of the foil plays a weaker role, and buoyancy becomes more apparent.
- This has the effect that the foil wants to float upwards at depth and does not stay in roughly the same plane as in the smaller models
    - This effect is even stronger when the foil is notched, since it has more freedom to move
- The diameter of the foil was a little too big at first. This caused it to hit the sidewalls slightly, and this friction was already causing problems in rising and falling. So all friction should be avoided.
- Surface tension now also plays a bigger effect again. If the foil floats at the surface, as shown in the second photo, it takes quite a bit of force to get the diver down. So much so that with a pressure difference of 30hPa, it still clearly fails. When I feel with my hand to push it down, I also notice that it takes a surprising amount of effort. Once below the surface, it's very easy again, so it clearly seems to be down to surface tension.
    - This was confirmed by the test seen in Figure FIXME. Here I made sure the diver could not rise to the surface, by weighing down the chain to the bottom. Since the foil did not stick to the surface, the diver did sink when the air pressure was increased.



Next to that, weighing down the diver pointed out another effect. It showed that making sure the model cannot reach the surface all the way makes it less exciting, because it is precisely the interaction with the surface that creates more movement.

This is an important point, because that would mean that changing the height of the setup more while keeping the diameter of the film the same makes little sense for the appearance of the "flower". Because if the flower only moves when it is interacting with the top surface, then as soon as it is completely below the surface (which happens at a depth of roughly the radius of the flower) it no longer interacts with the surface. So the radius of the flower should be slightly smaller than the difference in height the diver travels, at least in case of a positively buoyant material for the flower.

A sensible test to do now would be to try negatively buoyant materials, in other words, ones that sink. Again, they should not have too high of a density, but just a little higher than water so that they slightly drupe. I tried using a piece of cotton fabric, which with a density of between 1.14 and 1.54g/cm^3 depending on the source, is slightly denser than water.
This is rather boring. In fact, it was very boring. The figure shows the position the fabric was in at a certain time, but during the whole up and down movement that shape hardly changed. It was as if a solid object was moving up and down in the water.

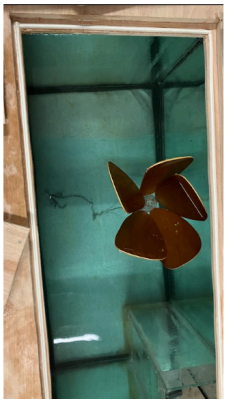
13th test: Diver with cotton (higher density than water)

Idea: Because the buoyancy of the foil gave problems, see if a material that is just higher density than water (and therefore sinks) gives better results.

What learned:

- Very boring
- Happened pretty little. Perhaps the difference in density is too great, or because there is now no interaction with the surface at all, but the substance only goes up and down a bit and keeps pretty much the same shape. Not nearly as lively as the foil
- Could be because the fabric is a lot thicker than the foil, and thus has more mass and thus takes more energy to build momentum.
- Thinner fabric still worth trying

Continuing the search for neutrally buoyant materials, several more materials were tried, like wooden pains and even 3D printed petals. PLA, a material often used in 3D printing has a density of around 1.15 g/cm^3 and by adjusting the infill percentage of the print can be adjusted to be made exactly neutrally buoyant. It turns out this is around 76% infill, so I made petals with that infill, but as can be seen in Figure FIXME (topview), in that case some petals sink while others float. Even petals that were printed on the same printer behaved differently. This, in combination with the fact that the stiff, solid petals did not give a very interesting visual effect, and caused some new complications, made me abandon the idea of these petals and decide to continue with flexible materials.



14th test: Diver with wooden blades

Idea: To see what effect rigid leaves have compared to the flexible sheets of fabric and foil

What learned:

- This doesn't work very well. Because the leaves straighten up as soon as the diver drops, the dynamics change completely. Some of the leaves come out of the water
- The diver is much less sensitive, it takes much more effort to get the leaves submerged
- What is cool, though, is that if the leaves all fold inwards equally, they give the diver a slight twist in its movement downwards.
- Perhaps a material with a density more around that of water will give better results. (PLA would be an option, density of 1.0-1.05 g/cm3 (so does just sink (at 100% infill))).

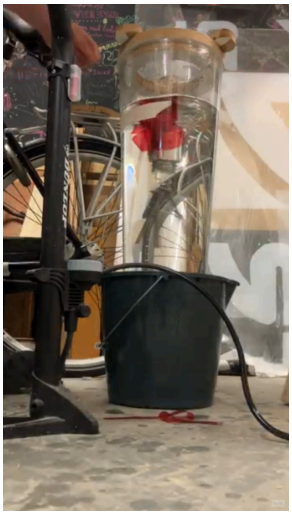
14A test: Diver with PLA sheets, 3D printed, 2 layers wall thickness, 76% infill

Idea: PLA has a density very close to water, and by playing with the infill percentage you can (in theory) perfectly give an object a neutral buoyancy.

What learned:

- No success, some leaves float, others don't,
  so the printer is too inaccurate for it to succeed. You could print all the leaves on the same printer in the same orientation, maybe that would have a chance of success
- Rigid leaves are much harder to make them move organically, so this idea was rejected pretty quickly. PLA could possibly still be an option with some kind of chain mail or something, giving a somewhat more flexible structure. But since fabric seems an easier option for this effect, I think it would be better to go down that route and do more experiments with it.

What is needed is more movement. Like said before, what makes underwater landscapes so interesting to look at are the slow, gentle motions that almost never seize. A simple test was to stir the water in the vase, and then close the lid quickly and apply pressure. It was chosen to go back to the vase because its circular shape would obstruct the water less, and its lid was easier to close, taking less time, allowing less momentum of the water to be lost. The first test was still executed with the red foil rather than the fabric. The results of the test were:



15th test: Diver with foil in spinning water

Idea: See what effect movement in the water has on the diver's movement

- At high speed, the petals especially get tangled, stick together etc.

- The diver is thrown outwards instead of staying nicely in the middle, due to the centripetal forces.
- I would expect that especially the weights at the bottom want to move outwards (higher density, so stronger centrifugal forces) and that the bottle with air wants to stay in the middle. This does not appear to be the case (at least in this test). This is caused by the inverted vortex paradox, as explained by Steve Mould in https://www.youtube.com/watch?v=gHZB112xPcI
- At lower speeds, it does give a more interesting result to look at, as there is just a bit more movement. But soon it is too much movement and feels chaotic. There is a balance there.
- The petals are strongly sucked up into the vortex at the beginning, so there is little "random" movement. The primary motion of the rotation dominates. Only at lower rotation speeds are the primary (rotational) movement and the secondary (turbulent) movement of the leaves scaled to each other and it looks calm, soothing.
- Observation: the chain gets tangled by the rotating water, and therefore cannot fulfil its function. A clump of links arises that has to be lifted from the bottom all at once, instead of a distribution of force depending on height.

In short, moving water seems the way to go. Without it, the object would be stuck in the same position to the naked eye. Because the pressure changes are so gradual, up and down motion would not be detectable in the couple seconds or minutes people usually watch an artwork. So in order to draw and keep attention and generate fascination it is desirable there is movement on a shorter time scale. For more continuous motion, a pump was placed in the vase. This also ensured more repetitive results in the tests. Testing with the fabric proved to give a big improvement to the setup. It caused far more interesting random motion, drawing the eye. However, there were still some hiccups to overcome.

The next experiment was with a piece of fabric I still had laying around. It is most likely made of polyester, which with a density of 1.04 to 1.46 g/cm^3 is slightly denser than water. This actually resulted in quite a desirable effect. The petals flowed around nicely, giving small movements when going up and down. There is still a lot that could improve, but it seems like a way forward.

17th test: Diver with thin polyester

Idea: Nylon has a density reasonably close to water, and the fabric used is a lot thinner than cotton, and therefore less stiff.

What learned from the polyester test:

- Already gives a more interesting effect, fabric moves much more with the movement of the water.
- Also more visually interesting because the fabric is slightly translucent.

- Would perhaps be even nicer if the fabric was slightly lighter than water, that it just floats. But this comes pretty close. Finding exactly the same density is impossible.

Test #18: Diver with thin polyester, with incisions

After trying with a circle of fabric, I added some incisions to create more freedom for the material to move like before. This resulted indeed in more motion.

- Looks much more flowy, fabric has much more ability to move freely.
- Still testing how many incisions are optimal for quiet movement. Currently there are seven petals, but less or more might work better.

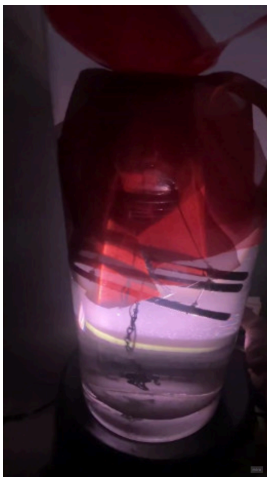
Test #19

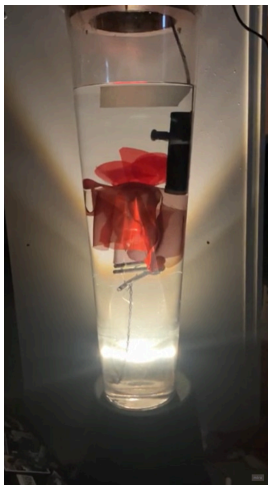
What learned:

- Indeed more movement that attracts attention
- If there is too much chain on the bottom, it creates too much resistance that counteracts the object's rotation. Depending on the flowrate of the pump and depth of the diver it is able to stop it from spinning with the water.
- Rotation has a small to no effect on the diver's vertical motion
- The chain still gets entangled in itself
- The speed at which the water now moves is on the edge of nice and too fast (pump is 50L/hour, rotational speed about 2.5rpm)
- The diver now stays in the centre of the vase (in the horizontal plane) but this could be due to friction with the vase. The question is whether it is the same when the friction is not there.
- In my setup, the vase is too narrow at the bottom to properly position the pump such that it causes rotation. But it would still be worth testing whether the height of the pump has an effect (and, for example, since the fabric sinks in water, it might be pushed up a bit by having the pump pointed slightly upwards.

Tests will now be scaled up to the aquarium, and different materials tested. Not all of them turned out successful, but did give more insights in the matter. A number of different materials were tried, some of which are shown below.

20th test: Diver with thin nylon, cut in spinning water, with light added





Idea: To see what effect (different colours of) light has on the appearance of the setup

What learned:

- Light (and background) matters a lot for the look. With the spotlight from below, you immediately get a more mysterious effect. Combined with red, purple works best for the desired look. Other colours I have yet to document. Have already tried them, but haven't made footage of them.

Test 21#: Diver with thin nylon, cut in rotating water, larger tank

Idea: By giving the diver more room, see if it then stays in the middle as well

What learned:

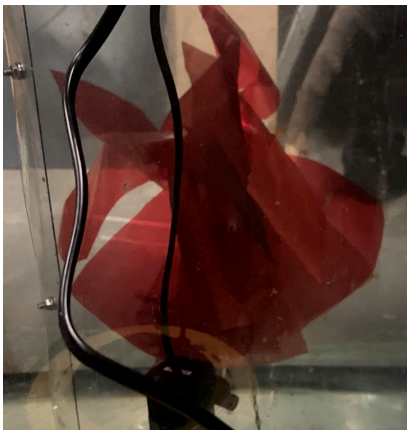
- Yes, the diver stays reasonably in the middle. Occasionally it goes slightly off centre, but barely against the edge. If you let the diver rotate for several hours (and you can therefore assume that the initial conditions no longer have any influence), the diver still stays in the middle. So at least it is not an unstable equilibrium in the middle.
- The pump might have an influence though because the leaves sometimes hit it, pushing the diver towards the centre.

Test #22: Diver with thin nylon, cut in and under it cut in plastic, for double effect, in spinning water, larger tank

Idea: To see if the double layer, combination of plastic and fabric, makes it more exciting. And it whether the plastic (which floats) causes the fabric (which sinks) to float a little more, thus making it move more.

What learned:

- Yes it makes it slightly more exciting, but not a whole lot. Plastic and fabric get a bit mixed up because of the indentations, which actually stops it flowing.
- The floating ability of the film is not enough to carry the fabric.



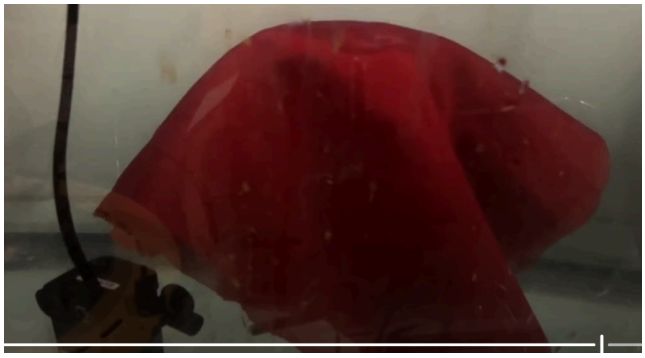
Test #23: Diver with thin nylon, cut in and plastic on top, for double effect, in spinning water, larger tank

Idea: To see if the double layer, combination of plastic and fabric, makes it more exciting. Now that the plastic is on top see if the two layers get less tangled, generating more movement

What learned:

- Yes, this is again a bit more exciting than the previous test. It does remain tricky that really big movements are lacking. That's why I think it's scaling up. That it all gets a bit more awesome.
- Also perform it more neatly. Now there are quite a lot of frayed edges, which gives a somewhat sloppy and unkempt look.

Test #24: Diver with three layers of nylon, with the middle one cut in



Idea: Check what effect multiple layers have

What learned:

- Multiple layers give a somewhat fuller effect, but because they are not yet cut in, the movements remain quite modest. Besides, it's not like three layers gives three times as much movement.

Test #25: Diver with three layers of nylon, clipped in

Idea: Check what effect multiple layers have, now with notches

What learned:

- More notches is better. I have now always done about seven notches per

layer, which seems to be a good balance so far (although I have no reference).
- Gives a nice effect when the flaps briefly come into the flow of the pump. Then they accelerate for a moment, which attracts attention.
- The effect of multiple layers is not as dramatic as I had hoped. There is a bit more movement, but the layers also get in each other's way.
- The higher density of fabric does make it look more like something substantial. It is a bit more massive. Because the outer layers are still floating around fairly freely, the fragility is not yet gone either.

Idea: give some layers a larger diameter, so they move smoothly, while the other layers give a bit of body to the whole

Idea: do not attach leaves on top of the diver, but as a skirt

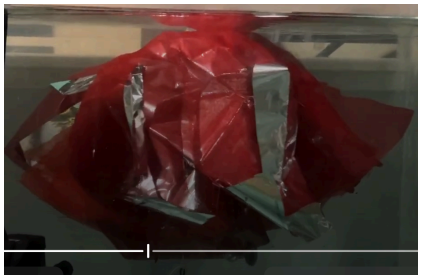
Test #26: Diver with three layers of nylon, cut in and a layer of rescue blanket

Idea: The reflection of the rescue blanket could cause an interesting interaction with light

What learned:

- Because the rescue blanket is a bit stiffer it does give a nice effect on the fabric, pushing it out of position a bit more. This adds a bit more movement to the fabric
- The foil gives a nice effect with the light, still testing how that goes with spotlight. The light is a bit chaotic though, which doesn't help the intended calming look of the artwork. In that respect, the stiffness, with strong folds/creases is not ideal, and would prefer a flowing shape

Test #27: Diver with three layers of nylon, notched and a layer of rescue blanket, with about 14 notches per layer

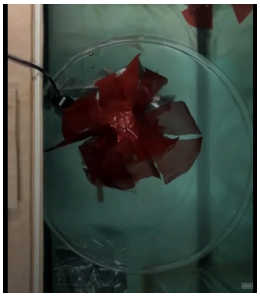


Idea: To see if more movement is created by doing multiple notches

What learned:

- Yes, the whole thing becomes more exciting by adding notches. But also more chaotic, which does not necessarily benefit the calming qualities of the object. So yes it attracts more attention, but in a restless way.

RPM: Testing how fast the diver is spinning now. After two minutes, the diver had made about 4.33 laps, so it is about 2,167 RPM. This (on this scale) still just gives a calming effect. But it shouldn't go much faster.



Test #28: Diver with a larger diameter rescue blanket.

Idea: To see if the larger shape causes the diver to stay more in the centre. With smaller shapes, it spins along the edge in circles. The slight friction is enough, though, to keep the diver itself (the central unit) from colliding with the edge.

What learned:

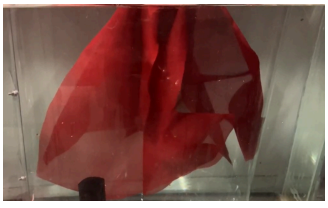
- This already works a little better, but the extra mass also makes the leaves droop more. So it's not the case that twice as big leaves also keep twice as big a distance from the wall
- The bigger leaves start drooping earlier and thus also hit the ground faster. Be careful that this does not disturb the effect of the diver (going up and down due to air pressure).
- The silver foil is far too crowded. Because of all the folds that are already in it due to the packaging method, and because the material creases very easily, the foil gives a rather restless effect.
- The foil does move interestingly as soon as it enters the flow of the pump. There really could be something to be done with this.

Test #29: Diver with larger diameter loose leaf fabric.

Idea: See if fabric does the same as the rescue blanket, with larger diameter

What learned:

- Does about the same as the rescue blanket. Fabric has a bit more mass and is less prone to wrinkles. making the movements seem a bit smoother.
- Fabric still hangs a lot though, would be nicer if it floats a bit better. Certainly seen from the side, it would be nicer if it were more in one plane
- The pump does give a nice effect

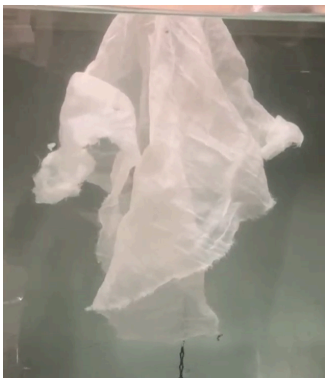


Idea: place several pumps around it, possibly at different heights to provide more movement

29A: aiming the mouth of the pump upwards creates a stronger jet of water spraying against the fabric. This creates more movement, which gives a more exciting effect. .

Test #30: Diver with cotton cheesecloth

Idea: To see if this form of cotton (a lot thinner) moves a bit more in the water



What learned:

- Works okay, is still stiffer than the red synthetic fabric, but a lot less than the blouse tested earlier. The fabric does still move very little in the flow of the water.
- There are already creases/crumples in the fabric, presumably from previous use/storage. These give a somewhat disturbing/rusty appearance, which makes for less relaxation

Test #31: See if feathers still do something cool under water

Idea: Maybe feathers are also very flowy under water. Density is at least 1.01 g/cm3, which is the closest to water of all tests so far.

What learned:

- Nope
- The "hairs" of the feathers stick together even if you squeeze the feather from air under water, and shake the feather back and forth/attempt to loosen the hairs. It does not become an elegant shape and looks mostly like wet dog.

Test #32: Effect of balloon ribbon on the diver

Idea: Very different shape, which might give interesting movements.

What learned:

- Is okay, no wow factor yet, but nice buoyancy, and in this case another effect with the light due to the iridescent property of the ribbon.
- Because the sprites are so thin and do have some stiffness, they don't immediately move upwards, but do float with the movement of the water.
- Now there is still a slight curl in it due to the way it was packaged. Let's see if we can get it out, or if it actually adds something.

After testing several materials and types, the results are mixed. Some setups prove to create a certain amount of “interesting effect”, generating fascination, drawing attention, but not to a

satisfying level. So I took a step back, and went to look for more inspiration in nature. Partially at a subconscious level, and partially being aware of it, the diver has come to look like a jellyfish. This fits with the underwater world, that I used as an argument to start this journey looking for a calming artwork.

33rd test: Test with air pressure and running water

Idea: Testing whether the up and down movement works even when the pump is on.

What learned:

- Yes this works fine. The diver is no more or less sensitive than without the water turning (sounds logical, but still good to check
- The diver only starts turning as soon as it rises a bit from the bottom. Only the weights already touch the bottom, so we are already talking about a very small area, with practically neutral buoyancy, so this friction is very minimal. But even with these relatively small forces, the diver thus stagnates. Rotating surface could be a solution.

34th test: Light from below

Idea: Getting an image of light from directly below.

What learned:

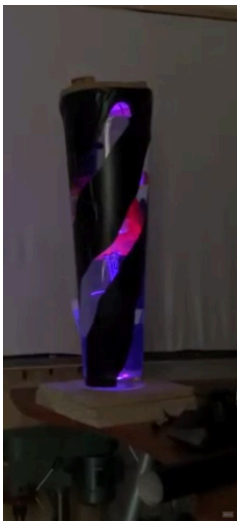
- Looks okay, especially in the purple colour, but only in an almost dark room.
- I personally liked the version from earlier (test 20), where light shines on the wall behind the object, because that still gives a drawing on the wall, and in this test (34) only the water lights up a bit
- Because the top is sealed (with a white piece of wood) it still reflects some light, which normally wouldn't happen (if the top were open). Take this into account.

35th test: Darkening of the vase

Idea: See if that still does something for the story, creates mystery, attracts attention and makes it clearer that change has taken place in the vase

What learned:

- Works a little, but mostly annoying that you can't see that much
- Contradicts the effect of "openness/honesty"
- At least this way, visual is too dark/bad for what happens in the vase

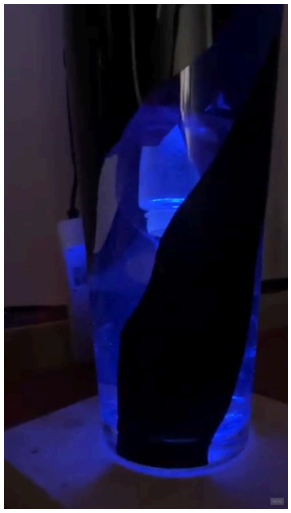


36th test: Darkening of the vase, but less

Idea: See if that still does something for the story, creates mystery, attracts attention, and that it does give enough view of the diver (improvement from test 35)

What learned:

- Makes it a bit better in terms of visibility, but the openness is nicer, so don't darken the vase



37th test: Different colours of light

Idea: To see if it matters which colour of light is used from below

What learned:

- Red and blue light are best, So that's top for implementing circadian rhythm. Red is actually nicest, blue is a bit dark. So taking a look at whether it is desirable to have blue light all day during the day. Create the most mystery/awaken (for me personally of course) the most curiosity at
- Yellow and green work a bit weird, doesn't look as pretty. Get a bit flaky/are just too bright. So if yellow is used to switch from blue to red, the brightness of the light has to be adjusted.
- Bought several samples of fabric, focusing on red and blue because those were the most interesting colours.

Realising that there still wasn’t enough motion to be interesting, I drew inspiration from the giant phantom jelly and decided that instead of placing material on top of the diver, I should hang it underneath it. So further testing will be done with that in mind.

Test #38: Lots of fabric in the water

- This gives a much more exciting effect than just fabric around the diver. There is much more possibility of movement
- There is an optimum though. Too much fabric and it gets in the way, too little and it's not exciting enough

- But more fabric than was used in the "jellyfish concept" gives a more natural effect
- The diver can't sink that far. Exactly why a chain seemed better in the first place. The diver is going to rest a bit on the fabric, and as the fabric rolls up and is pushed against the walls, the diver also finds it harder to come back up. This is in still water. Testing in moving water will have to be done
- Solution may be not to fill the column completely with fabric, but to make a longer tail. Or accept that the diver is somewhat hindered in its movements.

*Current pump is not strong enough to run the amount of fabric. So can't test effect of movement yet

This creates far more interesting movements. There is just more to look at, drawing attention, in a calming way. Exactly what SRT (Chapter FIXME) describes. The setup draws involuntary attention, which gives time for the focused attention to recharge. However, there are still some things to improve. Right now there is too much fabric in the water, so it gets in the way of each other, obstructing potential movement. Next to that, the theory was that large, continuous pieces of fabric would move slower and therefore induce more calm, while smaller pieces would move more frantically. After seeing the results here, the conclusion might be that here too there is an optimum. Too big of pieces and they are too heavy, too small and they become too light. Drawing inspiration from seaweed, the next test will be done with incisions in the fabric, to mimic smaller leaves.

Test #39

This works well. The pump is too weak to keep the entire construction moving, but with a little help to create the effect, the visual effect that is desired could be achieved. The incisions work well, although it might be better to make the flaps a little bigger again (so less incisions). In further tests an optimum is determined. Also, for now the cuts were straight ones, leaving sharp edges and corners. To create a more natural feel, it would be better to make curved cuts and round the corners. But the general effect is good, with more motion catching the eye.

- The motion draws attention, is intriguing.
- Even if the pump is too weak to spin the whole diver-fabric system, as soon as a few flaps pass in front of the pump outlet, they get sped up and draw attention. This means that the eye drifts from one leaf to the next. You naturally follow one, but then once the next passes in front of the pump, your eye jumps to that one.
- The fabric is still quite monotone, different colours/types should be tested.
- The vase feels rather full at the moment. This is with five strands of fabric, that all span about two thirds of the diameter of the vase (at the top). Next tests will be with less strands, as well as smaller ones. Also, the orientation matters. Tests with

both the fabrics radiating out (like rays of a sun) or forming a circle/pentagon were done. The ones radiating out gave better results. Clumping together less, and avoiding getting tangled, creating a more open feeling to the setup.

40th test: Lots of fabric in the water, with movement on the bottom

Idea: To see what happens if you let the water move (by stirring), while the diver is stuck on the bottom due to the friction caused by the fabric

What learned:

- The stirring causes some movement in the water, which pry the diver loose from its position on the bottom, so to speak. In fact, the diver was slightly compressed there, so it was unlikely that the diver would ever get so stuck under the influence of its own weight.
- It is inaccurate to stir like this, as it is unlikely that the water will later be moved like this. So it is relevant to get a stronger pump to test this better

A new diver design was made to move more towards a final design, and improve repeatability of the tests. The platform at the bottom is used to mount weights for the time being, because the 3D-printed PETG is too light. PETG is chosen because it is watertight, unlike PLA. So the diver won't sink without the weights. The shape is still very smooth and not natural enough, but it will help in making further steps.

41st test: New fabric: two-tone organza

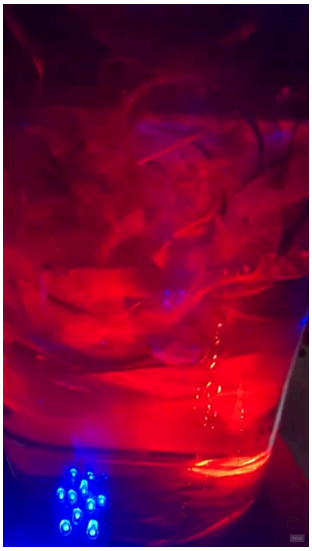
Idea: The material of this fabric is known, and controllable. Above, it is woven so that the threads are all made of one colour in one direction, and another colour in the other. As a result, you get a fabric that has one colour at one angle, and another colour at another angle. And sometimes a mixed colour of the two. In this case, it is dark blue and red.

What learned:

- This colour combination is interesting, but not very exciting yet. It is also not meant to be too much, but I have ordered

more samples in other colours, and a somewhat brighter red and blue
- The play of the two colours with the light is very interesting though, gives a lot more for the eye to look at
- In addition, the fabric is semi-transparent, as in previous tests, which maintains a nice effect with the multiple layers behind each other.

42nd test: Two-colour lighting next to vase



Idea: Perhaps two-colour lighting works well with two colours of fabric (where the lighting has the same colours as the stog)

What learned:

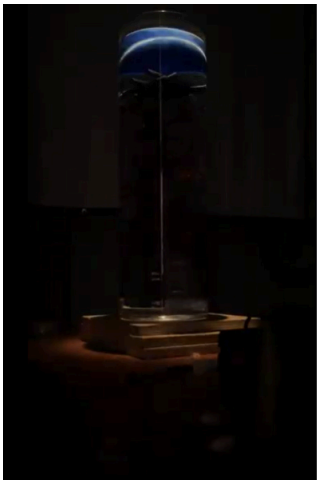
- This doesn't really add anything, and it is nicer if there is one light centrally under the vase instead of two around/next to the vase
- Moreover, this way one of the two colours always has the upper hand, making it unsettling.

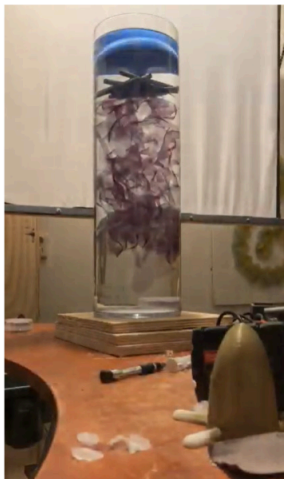
43rd test: Lighting from above (spotlight) with varying diameter

Idea: Trying different setups in terms of lighting, in this case to see if the spotlight from above adds anything.

What learned:

- The circle hardly changes in diameter for a very long time, only visibly getting larger or smaller at the last few centimetres the tube moves up.
- Moreover, the whole spotlight effect is gone as soon as the bottom of the tube is flush with the lamp
- Then, on the contrary, the whole room is illuminated, which takes the whole focus away from the diver/vase
- Doesn't seem very promising, and at this point in the project in terms of time planning not very useful to delve further into.





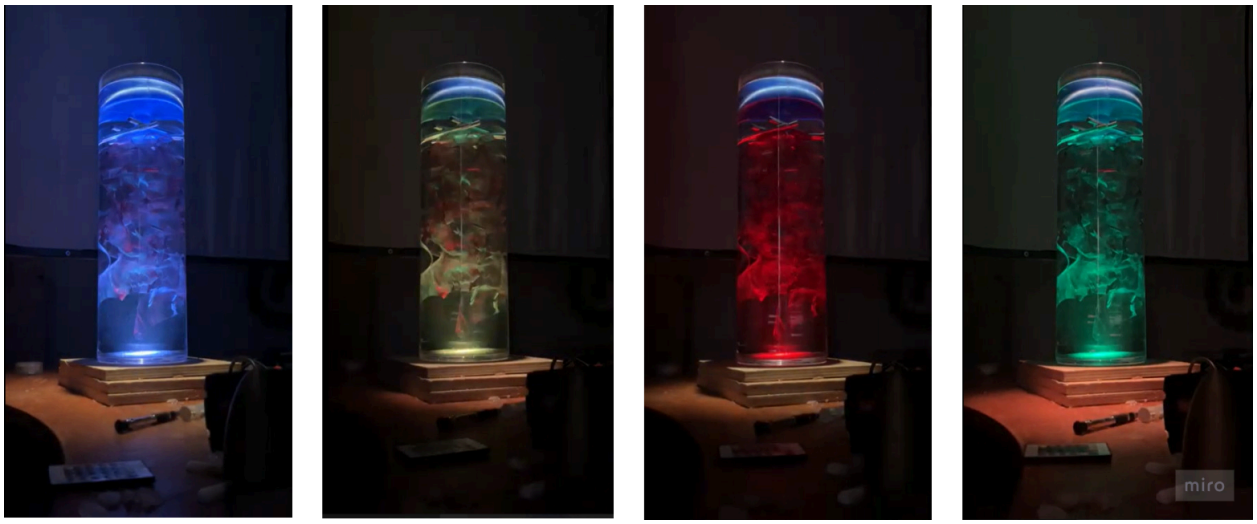

44th test: Lighting from above (spotlight) combined with different colours lit from the centre below the vase

Idea: testing which lighting works best. Whether adding a spotlight from above adds a bit more focus on the diver (by focal glow)

What learned:

- Emphasises the diver a bit more, also because of the partially iridescent material at the top, which reflects the light well.
- The question is how much that matters, if the diver is placed at altitude. Then the top is not visible
    - In addition, the diver (in this case) blocks almost all the light from above, so hardly any light enters the vase .
- Red seems the most interesting in this case (in combination with this colour of fabric (red-blue)), followed by blue light. This is probably mainly because those colours are also in the substance. Other colours of light reflect crazy from the red-blue fabric.

Worth testing in the final situation, though, as it puts a bit more focus on the vase than just light from below.



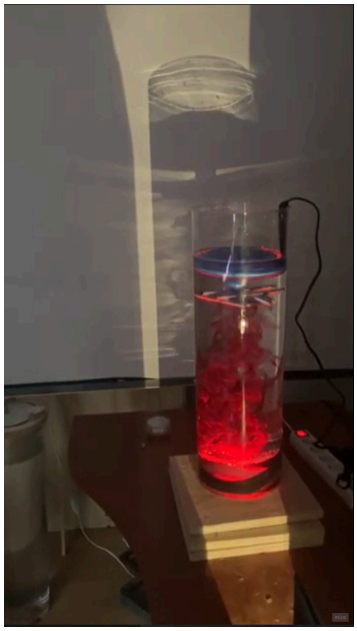
45th test: new more powerful pump

Idea: The previous pump was not strong enough to keep the larger amount of fabric moving. This pump has a flow volume 12 times larger (600L/hour).

What learned:

- This works better. The pump keeps the diver moving for an infinite time (more than an hour)
- Importantly, the diver has no possibility of snagging. Now the cord of the pump runs out through the top of the vase, which is where the (protruding) weights at the bottom of the diver occasionally get snagged. Then the diver stops almost immediately
- Furthermore, the flow rate seems on the edge in terms of quietness. It is just well, just not too fast for the eye. Suitable for unsettled weather, but will have to run slower in better weather conditions.

46th test: Lighting from one direction side



Idea: To reinforce the story between inside and outside, the idea is to create a kind of lighting bridge. By hanging cloths around the vase that only provide an opening like a tunnel to the window. Testing this in a home environment. The tunnel is made by books, with a spotlight between them simulating the outside light.

What learned:

- This gives a surprisingly interesting effect. The vase reflects light beyond the diameter of the vase, creating a wider pattern of reflections behind it. Where the fabric in the vase does not block the light, it passes through it and onto the wall where it constantly changes due to the changing shape of the fabric in the vase

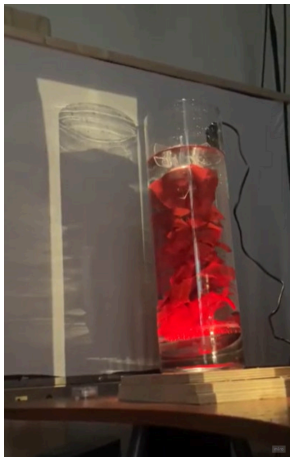
47th test: Lighting from one direction side, with diver below

Idea: To add to the story, the diver has a quieter look when it is down. So see if that is actually the case

What learned:

- Yes, no surprises, when the diver floats below there is less fabric in the way of the light, so it goes straight through the vase and there is no crazy movement.
- The pattern on the wall is still interesting though, it looks like there are streaks on the wall caused by (presumably) minimal differences in thickness of the glass

48th test: Testing perspective from below



Idea: More of a check than a real test, but since the diver is placed at altitude, a viewer will see it from below. So check if this perspective is as fascinating.

What learned:

- Yes this is still interesting. What matters most is that the light from below is now at eye level and mainly attracts attention. So people are more likely to look at the bottom of the diver than the top.
- This is also because this point catches the most light. Light is blocked from going further up.
- The surroundings fall away a little more. The attention is really mainly drawn to the diver itself.

49th test: Tunnelling lighting naturally through the vase.

Idea: More realistic setup of the light tunnel to be made later with cloth. Doing this by placing the vase in front of a window and folding the curtain so that only light can enter the room through the vase.

What learned:

- This works very nicely, although daylight is very strong, and it makes the lamp from below considerably less visible.
- The light from behind comes through the fabric nicely, which makes it even more interesting to the eye. Especially since the

light is so strong, it comes through the fabric and makes all the layers nicely visible
- The fabric itself is still unsettled, though, and could perhaps do better with fewer cuts. Too big flaps are not good because they have too big a moment and thus take too much energy to get moving, too small flaps are too restless

50th test: New shape clippings, cut more diagonally.

Idea: See what this does visually, inspired by seaweed, make it look a bit more like that.

What learned:

- Incisions are more angled down, instead of perpendicular to the edge of the fabric. Indeed, this way it already looks a bit more like seaweed.
- The movements of the flaps are already a bit more visually interesting, there is more movement in the flow, and it looks more natural, less straightforward.
- The vase is still too full, there is too much fabric in it, making it too difficult to follow everything properly.

51st test: new shape inknots, larger flaps, and a kind of quarter-circle as inknots.

Idea: by making the notches this way, the tips of the flaps are very thin, and so can move easily in the flow, while the flaps themselves can be larger and bring a little more calmness to the whole.

What learned:

- This works well. There is more peace in the vase, and the flaps again give better movement. Where previously there were 5 to 7 strips of fabric in the vase, three seems to be the optimum. This also allows a bit more light through, everything is not packed so tightly together.
- The flaps also move more, while maintaining calmness. The notches are now about every 5-6cm.

Practical notions

Idea: List a few practical considerations important to the design

What learned:

- The pump is tucked away at the bottom, under an acrylic plate with openings where currents can enter and exit the pump.
    - The openings are placed so that they get in the way of the currents as little as possible
    - The plate is needed so that fabric does not get caught behind parts of the pump and become stagnant
        - And so that fabric does not get sucked into the pump
- Once the weights (bolts) were removed from the diver, it was found that the diver could no longer continue to rotate in the currents
    - A full round diver is too slippery, the water cannot get a grip on it
        - So something like fins have to be made on it
        - This was tested in the rightmost photo, on a simpler model
            - This worked very well, except that the large fins could easily get caught behind the cord, but could also possibly get stuck against the wall of the vase. So ideal would be if the outer circumference is round, but can still have fins attached to it
- The fabric does sometimes let go of some fibres, which can clog up the pump
    - So had the model lasered, so that all the fibres are together, and washed well so that all the immediately loose fibres are out.

52nd test: all fabric colours

Idea: see which colour (combination) of fabric works best. The options are: blue-red, red-blue, yellow-blue, green-red, green, turquoise and light blue.

What learned:

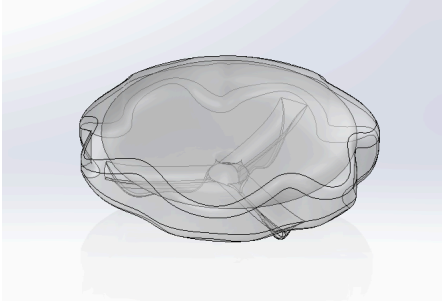
- Red-blue is the most fascinating, presumably because they are bright colours that contrast strongly with each other. This makes you see the difference in colours more.
- The lighter, green-blue colours were tested because they actually had more of a floating, lightweight appearance, as if they could be blown along with the wind in an instant. This was partly true, but it was also a lot less exciting, so it didn't hold your attention very well
- During testing, the shape of the notches was adjusted slightly more. The sharp points of the shape were rounded off, making the shape appear less prickly. This worked immediately, and was even noticed by one of my companions without mentioning it (she felt he came across as calmer)

53rd test: New diver design

Idea: The previous diver still looked very much like a jellyfish. Seeing if that could be made less so, and at the same time testing a new shape with fins (at the bottom). The new shape is a bit more cloudy, although very limited by my skills in 3D CAD, and the fact that Solidworks is not made for organic shapes.

What I learnt:

- The new shape is a lot better, but not yet top-notch. Certainly the top is still a big surface, although this matters less since that side of the diver is never seen by the viewer.
- The fins work well, the diver keeps turning, even for longer times.
- The diver doesn't snag on the vase either, the overall shape is round enough.
- In this version of the diver, I had glued weights so that it would actually have neutral buoyancy. However, this raised the centre of gravity so much



that the diver became unstable and started floating on its side. This is what you see in the picture.

- This should not happen when the diver is made of glass.
- On of the reasons why the diver tips, is that as soon it is at a bit of an angle, the water is not able to flow out anymore, hence it accumulated in the diver, tipping it further and further. So make sure the inside really slopes down towards the middle, and the centre of gravity is low, so water can keep flowing out.

Final setup

Idea: Here everything comes together, the diver is on a pedestal, with the pump and lighting concealed at the bottom. The vase is made of a one-metre acrylic tube, higher than the vase (60cm). The fabric is laser cut, which should melt the edges together, to prevent fraying. The diver has a cloud-like shape

What learned:

- This works pretty well now that it all comes together like this. The fabric moves nicely, and by placing the vase higher you're always looking up a bit, which adds a little to the awe.
- The diver still looks a lot like a jellyfish though, which is a bit of a shame. Due to a misunderstanding with the PMB, it is also blue instead of transparent, although I don't know how much difference that would make, as a jellyfish is also transparent most of the time
- Of course, for simulating a glass diver, this is less accurate.

User testing will have to show whether the whole thing is actually perceived as soothing, fascinating and natural.

-

After several more tests with different shapes of incisions, different materials, a new diver and a new pump that does have enough power to rotate the whole diver-fabric combination, we are coming close to the desired effects. The cuts are more rounded, and such that the flaps are thinner towards the end, so they can move around more freely, following a more natural curved shape. They are broader again, about seven to eight centimeters apart seems to work the best. Cutting them by hand gives the natural variation we are looking for. Testing with several divers showed that it is important that there are some fins on it to catch the current and keep it turning. Initially, the pump was too smooth, and will stop turning after a few minutes. Especially when the diver is at the bottom. The solution for stopping the diver from halting completely when it is at the bottom is to simply make the pump work harder when the diver sinks. This may seem counter intuitive, since with calmer weather (meaning the diver is at the bottom) you would want the diver to appear calmer. But the increased friction from the fabric when the diver sinks is larger than the pump can overcome, hence it would have to work harder.

Test insights

- The new incision shapes create more desired effects. The appear more natural, also the way they move in the flow
- The new fabric has two different colours, one for the warp, another for the weft. So depending on which way you look at the fabric it shows a different colour. Combined with the flow that twists the fabric in different angles, it gives an interesting visual effect, as can be seen in Figure FIXME. Both blue and red fibres are used in that fabric
- The diver will need fins to keep turning
- Depending on the breadth of the fabric it will tangled or not, this comes quite close

After all these tests, the full prototype setup was built on location, from which more insights were gained. They have been mentioned throughout the Recommendations section in the main report. These were all the tests done from start to finish, trying to document it as well as possible. Also videos are available from most tests, which will be handed over to the client together with this report. This is especially useful as this is a kinetic art work, so pictures alone are not always able to bring across the message.

Appendix F - Questionnaire

What is your current stress level?

Low O O O O O O O High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

- ☐ 0 - 7 times a week
- ☐ More than 7 times a week

I sensed things momentarily slow down

Strongly disagree O O O O O O O Strongly agree

I experienced a sense of oneness with all things

Strongly disagree O O O O O O O Strongly agree

I felt that I was in the presence of something grand

Strongly disagree O O O O O O O Strongly agree

I had the sense of being connected to everything

Strongly disagree O O O O O O O Strongly agree

I felt small compared to everything else

Strongly disagree O O O O O O O Strongly agree

I perceived vastness

Strongly disagree O O O O O O O Strongly agree

I felt challenged to understand the experience

Strongly disagree O O O O O O O Strongly agree

I felt closely connected to humanity

Strongly disagree O O O O O O O Strongly agree

I felt my sense of self become somehow smaller

Strongly disagree O O O O O O O Strongly agree

I experienced something greater than myself

Strongly disagree O O O O O O O Strongly agree

I found it hard to comprehend the experience in full

Strongly disagree O O O O O O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O O O O Strongly agree

I felt in the presence of greatness

Strongly disagree O O O O O O O Strongly agree

I felt like the art piece came across as honest/open

Strongly disagree O O O O O O O Strongly agree

I felt fascinated by this art piece

Strongly disagree O O O O O O O Strongly agree

I felt calm looking at the art piece

Strongly disagree O O O O O O O Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O O Strongly agree

What are three words that you would associate with the art piece

1……..…….. 2…….…….…..….. 3…..……..…..…….

Why did you think of these three words?

……
……
……
……

What draws your attention the most and why?

……
……
……

Those were all the questions. Thank you for participating. Have a nice day :)

Appendix G - Test protocol

“Welkom! Dankjewel dat je mee wil helpen aan het testen van mijn afstudeerproject. Ik zal eerst even kort uitleggen wat het project inhoudt, en daarna mag je een vragenlijst invullen over de ervaring die je hebt met het werk. Tenslotte laat ik je nog even alleen met het kunstwerk, zolang als je zelf wil, daarna heb ik nog een paar laatste vragen. Is dat duidelijk, of heb je nog vragen?”

Dan wil ik je eerst vragen om een toestemmingsformulier te tekenen. Hierin geeft je aan of je oké bent met het laten maken van beeldmateriaal tijdens dit onderzoek. De beelden zullen alleen gedeeld worden met de begeleiders S. Pont en S. Brand-de Groot, en de klant van dit project, AtelierAW van Arjen Witteveen.

- Dubbel laten tekenen consent form -

“Dankjewel, dan wil ik je nu kort iets vertellen over het kunstwerk. Het gaat om een kunstwerk dat beweegt op basis van omgevingsdruk. De drijver, die je bovenin ziet, heeft een luchtbubbel, die net groot genoeg is om de drijver te laten drijven. Als de luchtdruk toeneemt door weersveranderingen, krimpt de bubbel en zal de drijver wat naar beneden zakken. Het dus een beetje een soort barometer. Die veranderingen gaan zo langzaam dat je die beweging niet in het moment ziet, maar alleen van dag tot dag bijvoorbeeld. De draaiing die je ziet komt door een pomp die onderin zit, en die beweging wordt dus niet veroorzaakt door luchtdruk. Verder zal ik niet te veel vertellen over het werk, zodat je je eigen mening kan geven. Als je nu deze vragenlijst in zou willen vullen terwijl je rond het kunstwerk bent. Let op, het formulier heeft een voor- en achterkant”

- Vragenlijst geven, en naar binnen laten met het kunstwerk, zelf buiten blijven -

“Dankjewel! Dan mag je nog even naar het kunstwerk kijken zolang als je zelf wil, daarna heb ik nog een vraag voor je”

- Alleen laten met het kunstwerk, zelf op de bankjes bij de printer gaan zitten, op enige afstand, geen foto’s maken in deze fase -

Als ze naar buiten komen: "Dan de vraag of je nog een keer kan aangeven wat je stressniveau nu is.”

- Stressniveau laten aangeven -
- Deelnemer meenemen naar de verschillende kleuren -

“Als laatste wil ik je nog een vraag stellen over de kleuren van het stof. Zou je van de volgende stukken stof een top drie willen aangeven welke kleur je het meest fascinerend vindt.

- Top drie laten aangeven -

“Dat was het. Dankjewel dat je mee wilde helpen. Heb je nog vragen?”

- Checken dat ze een getekend toestemmingsformulier mee hebben. -

English

"Welcome! Thank you for wanting to help test my thesis project. I will first briefly explain what the project entails, and then you may fill out a questionnaire about your experience with the work. Finally, I'll leave you alone with the artwork for as long as you want, then I'll have a few final questions. Is that clear, or do you still have questions?"

Then first I would like to ask you to sign a consent form. In it you indicate whether you are okay with having footage taken during this study. The images will only be shared with supervisors S. Pont and S. Brand-de Groot, and the client of this project, AtelierAW by Arjen Witteveen.

- Having double signed consent form -

"Thank you, now I would like to tell you briefly about the artwork. This is a work of art that moves based on ambient pressure. The float, which you see at the top, has an air bubble just big enough to keep the float afloat. When the air pressure increases due to changes in weather, the bubble shrinks and the float will drop down a bit. So it's kind of like a barometer. Those changes are so slow that you don't see that movement in the moment, but only from day to day, for example. The rotation you see is due to a pump that is at the bottom, and so that movement is not caused by air pressure. Other than that, I won't tell too much about the work, so you can give your own opinion. Now if you would fill out this questionnaire while you are around the artwork. Please note that the form has a front and back"

- Giving questionnaire, and letting them in with the artwork, staying outside myself -

"Thank you! Then you may look at the artwork for as long as you like, then I have another question for you"

- Leaving alone with the artwork, sitting on the benches by the printer yourself, at some distance, not taking pictures at this stage -

When they come out, "Then could you state again what your stress level is now."

- Having Stress level indicated -
- Take them to the place where colours are shown -

"Finally, I would like to ask you a question about the colors of the fabric. Of the following pieces of fabric, would you indicate a top three which color you find most fascinating.

- Have top three indicated -

"That's it. Thank you for wanting to help. Do you have any questions?"

- Check that they have a signed consent form with them. -

The test setup where participants were asked to make a top three of the most fascinating colours

Participant ID:

Appendix H - User testing consent form

Lichtdruk graduation project

This research is conducted as part of the MSc study Industrial Design Engineering at TU Delft.

Student: Romeo Veldhuis

Informed consent participant

I participate in this research voluntarily.

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

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

1. Questionnaire about the art work constructed for this project

I am aware that data will be collected during the research, such as notes, photos, video and/or audio recordings. I give permission for collecting this data and for making photos, audio and/or video recordings during the research. Data will be processed and analysed anonymously (without your name or other identifiable information). The data will only be accessible to the researcher and their TU Delft supervisors, and the client (AtelierAW)

The photos, video and/or audio recordings will be used to support analysis of the collected data. The video recordings and photos can also be used to illustrate research findings in publications and presentations about the project.

I give permission for using photos and/or video recordings of my participation:
(select what applies for you)

- ☐ in which I am recognisable in publications and presentations about the project.
- ☐ in which I am not recognisable in publications and presentations about the project.
- ☐ for data analysis only and not for publications and presentations about the project.

I give permission to store the data for a maximum of 5 years after completion of this research and using it for educational and research purposes.

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

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

I will receive a copy of this consent form.

_____	_____
Last name	First name
___ / ___ / 2025	_____
Date (dd/mm/yyyy)	Signature

Participant ID:

Lichtdruk master afstudeerproject

Dit onderzoek wordt uitgevoerd als onderdeel van de MSc opleiding Industrieel Ontwerpen aan de TU Delft.

Studenten: Romeo Veldhuis

Toestemmingsverklaring participant

Ik neem vrijwillig deel aan dit onderzoek.

Ik erken dat ik vooraf voldoende informatie en uitleg heb gekregen over dit onderzoek en al mijn vragen zijn naar voldoening beantwoord. Ik heb de tijd gekregen die ik nodig had om in te stemmen met de deelname. Op elk moment kan ik vragen stellen met betrekking tot het onderzoek.

Mij is bekend dat dit onderzoek bestaat uit:

1. Vragenlijst over het kunstwerk gemaakt voor dit project

Ik ben mij ervan bewust dat tijdens het onderzoek gegevens worden verzameld in de vorm van bijvoorbeeld aantekeningen, foto's, video's en/of geluidsopnames. Ik geef toestemming voor het verzamelen van deze gegevens en het maken van geluidsopnames, foto's en video opnames tijdens het onderzoek. Gegevens zullen geanonimiseerd worden verwerkt en geanalyseerd (zonder naam of andere identificeerbare informatie). Deze gegevens zijn alleen voor de onderzoeker en hun TU Delft begeleiders, en de klant (AtelierAW), beschikbaar.

De foto's, video's en/of geluidsopnames zullen worden gebruikt ter ondersteuning van het analyseren van verzamelde gegevens. Video opnames en foto's kunnen tevens worden gebruikt ter illustratie van onderzoeksbevindingen in publicaties en presentaties over het project.

Ik geef toestemming voor het gebruik van foto's en video opnames van mijn deelname:
(selecteer wat van toepassing is)

- ☐ waarin ik herkenbaar ben voor publicaties en presentaties over het project.
- ☐ waarin ik niet herkenbaar ben voor publicaties en presentaties over het project.
- ☐ enkel voor data analyse doeleinden en niet voor publicaties en presentaties over het project.

Ik geef toestemming om gegevens nog maximaal 5 jaar na afloop van dit onderzoek te bewaren en te gebruiken voor onderwijs- en onderzoeksdoeleinden.

Ik erken dat er geen financiële compensatie gegeven wordt voor deelname aan het onderzoek.

Met mijn handtekening bevestig ik dat ik de informatie over het onderzoek heb gelezen en dat ik de aard van mijn deelname heb begrepen. Ik begrijp dat ik mijn deelname aan het onderzoek op elk moment kan intrekken of kan stoppen. Ik begrijp dat ik niet verplicht ben om vragen te beantwoorden die ik niet wil beantwoorden en dat ik dit kan aangeven bij de onderzoeker.

Een kopie van deze toestemmingsverklaring zal aan mij worden gegeven.

_____	_____
Achternaam	Voornaam
___ / ___ / 2025	_____
Datum (dd/mm/jjjj)	Handtekening

Questionnaire

What is your current stress level?

Low O O O O O O High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

- ☐ 0 - 7 times a week
- ☒ More than 7 times a week

I sensed things momentarily slow down

Strongly disagree O O O O O O O Strongly agree

I experienced a sense of oneness with all things

Strongly disagree O O O O O O O Strongly agree

I felt that I was in the presence of something grand

Strongly disagree O O O O O O O Strongly agree

I had the sense of being connected to everything

Strongly disagree O O O O O O O Strongly agree

I felt small compared to everything else

Strongly disagree O O O O O O O Strongly agree

I perceived vastness

Strongly disagree O O O O O O O Strongly agree

I felt challenged to understand the experience

Strongly disagree O O O O O O O Strongly agree

I felt closely connected to humanity

Strongly disagree O O O O O O O Strongly agree

I felt my sense of self become somehow smaller

Strongly disagree O O O O O O O Strongly agree

I experienced something greater than myself

Strongly disagree O O O O O O O Strongly agree

I found it hard to comprehend the experience in full

Strongly disagree O O ⊘ O O O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O ⊘ O O O Strongly agree

I felt in the presence of greatness

Strongly disagree O O ⊘ O O O O Strongly agree

I felt like the art piece came across as honest/open

Strongly disagree O O O O O ⊘ O Strongly agree

I felt fascinated by this art piece

Strongly disagree O O O O ⊘ O O Strongly agree

I felt calm looking at the art piece

Strongly disagree O O O O O ⊘ O Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O ⊘ O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O ⊘ O Strongly agree

What are three words that you would associate with the art piece

1. ocean 2. fluid 3. calm

Why did you think of these three words?

Because I think the piece looks a bit like a jellyfish in the ocean that is calmly moving with the motion of water

What draws your attention the most and why?

The light and colors. Especially the combination of the light and fabric that make it seem that the color of the fabric changes dependent on the angle of light on it

Those were all the questions. Thank you for participating. Have a nice day :)

Rood-blauw, groen, geel-blauw

Questionnaire

What is your current stress level?

Low ○ ○ ● ○ ○ ○ ○ High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

- [x] 0 - 7 times a week
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Strongly disagree ○ ○ ○ ○ ● ○ ○ Strongly agree

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Strongly disagree ○ ○ ○ ○ ○ ● ○ Strongly agree

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Strongly disagree ○ ○ ○ ○ ○ ● ○ Strongly agree

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Strongly disagree ○ ○ ○ ○ ● ○ ○ Strongly agree

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Strongly disagree ○ ○ ● ○ ○ ○ ○ Strongly agree

I experienced something greater than myself

Strongly disagree ○ ● ○ ○ ○ ○ ○ Strongly agree

Rood- blauw, groen, lucht groen

I found it hard to comprehend the experience in full

Strongly disagree O ● O O O O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O O ● O Strongly agree

I felt in the presence of greatness

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I felt calm looking at the art piece

Strongly disagree O O O O O O ● Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O O ● Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O ● Strongly agree

What are three words that you would associate with the art piece

1. captivating 2. calmness 3. jellyfish

Why did you think of these three words?

The motion and lighting are very captivating. Once looking at it the fascinating view overpowers any small worries and hence makes you feel calmer.
It physically resembles a jellyfish.

What draws your attention the most and why?

The irisent (iriserende) lighting of the fabric tentacles

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low ○ ○ ● ○ ○ ○ ○ High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

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I experienced something greater than myself

Strongly disagree ○ ● ○ ○ ○ ○ ○ Strongly agree

Rood - blauw, groen, blauw - geel

I found it hard to comprehend the experience in full

Strongly disagree O O O O ● O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O ● O O Strongly agree

I felt in the presence of greatness

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Strongly disagree O O O O O ● O Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O ● O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O ● Strongly agree

What are three words that you would associate with the art piece

1. ENDLESS 2. FASCINATING 3. NICE COLOURS

Why did you think of these three words?

Because it keep spinning and never stops, constantly changing in colour.

What draws your attention the most and why?

Spinning and changing ~~movement~~ colour, you can keep looking at the movement.

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low O O O ⊗ O O O High

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Strongly disagree O O O ⊗ O O O Strongly agree

I experienced something greater than myself

Strongly disagree O O O ⊗ O O O Strongly agree

Groen, geel-blauw, rood-blauw

I found it hard to comprehend the experience in full

Strongly disagree O O O O ⊗ O O Strongly agree

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Strongly disagree O O O ⊗ O O O Strongly agree

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I felt calm looking at the art piece

Strongly disagree O O O O O O ⊗ Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O ⊗ O O O O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O ⊗ Strongly agree

What are three words that you would associate with the art piece

1. byzonder 2. kleurryk 3. rustgevend

Why did you think of these three words?

gevoelsmatig

What draws your attention the most and why?

de kleuren, ondanks felle kleur toch rustgevend

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low O O O O ● O O High

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Strongly disagree O ● O O O O O Strongly agree

Groen, blauw-geel, rood-blauw

I found it hard to comprehend the experience in full

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It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O ● O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O ● O Strongly agree

What are three words that you would associate with the art piece

1. Rust 2. Water 3. Klimaat

Why did you think of these three words?

het voelt als een ocean

What draws your attention the most and why?

kleuren

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low ○ ○ ✓ ○ ○ ○ ○ High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

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I felt fascinated by this art piece

Strongly disagree ○ ○ ○ ○ ○ ● ○ Strongly agree

I felt calm looking at the art piece

Strongly disagree ○ ○ ○ ○ ○ ✗ ● Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree ○ ○ ○ ○ ○ ○ ● Strongly agree

My eyes were drawn to the art piece

Strongly disagree ○ ○ ○ ○ ○ ○ ● Strongly agree

What are three words that you would associate with the art piece

1. Peaceful 2. Vibrant 3. Continuity

Why did you think of these three words?

Omdat het rustig door blijft bewegen. De kleuren en vorm bepaalde uit springen, maar tegelijkertijd dus de continuïteit van beweging, rust en dus die kleuren en vorm je aandacht pakken en vasthouden. het geeft een soort tijdloosheid.

What draws your attention the most and why?

De constante voortdurende beweging van een gelijke vorm, omdat het hetzelfde is, maar elke milliseconde er anders uitziet.

Those were all the questions. Thank you for participating. Have a nice day :)

Groen Rood-blauw groen-blauw

Questionnaire

What is your current stress level?

Low O O O O O O O High

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

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I sensed things momentarily slow down

Strongly disagree O O O O O O O Strongly agree

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Strongly disagree O O O O O O O Strongly agree

I experienced something greater than myself

Strongly disagree O O O O O O O Strongly agree

Rood - blauw, geel - blauw, groen

I found it hard to comprehend the experience in full

Strongly disagree O O O O ⊗ O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O ⊗ O O Strongly agree

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It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O O ⊗ Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O ⊗ Strongly agree

What are three words that you would associate with the art piece

1. Sea life 2. fire 3. Universe

Why did you think of these three words?

Sea life because it slowly move in water
fire because you can keep on looking at it like fire
Universe the colours reminds of the milky way
and randomness of the stars

What draws your attention the most and why?

the purple turning thing

Those were all the questions. Thank you for participating. Have a nice day :)

8

Questionnaire

What is your current stress level?

Low O O ● O O O O High

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I felt closely connected to humanity

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I felt my sense of self become somehow smaller

Strongly disagree O O O O ● O O Strongly agree

I experienced something greater than myself

Strongly disagree O O O O ● O O Strongly agree

Green, Rood-blauw, groen-blauw

I found it hard to comprehend the experience in full

Strongly disagree O O ● O O O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O O ● O Strongly agree

I felt in the presence of greatness

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Strongly disagree O O O O ● O O Strongly agree

I felt fascinated by this art piece

Strongly disagree O O O O O ● O Strongly agree

I felt calm looking at the art piece

Strongly disagree O O O O O ● O Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O ● O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O ● O Strongly agree

What are three words that you would associate with the art piece

1. Everlasting 2. quasi-static 3. Calming

Why did you think of these three words?

these are my initial impression, observation and effect on me.

What draws your attention the most and why?

the perfect rotation of the ribbon

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low O O ● O O O O High

2

How many times a week on average do you pass through the entrance hall of the building you work/study in the most?

- [x] 0 - 7 times a week
- [ ] More than 7 times a week

I sensed things momentarily slow down

Strongly disagree ● O O O O O O Strongly agree

I experienced a sense of oneness with all things

Strongly disagree ● O O O O O O Strongly agree

I felt that I was in the presence of something grand

Strongly disagree ● O O O O O O Strongly agree

I had the sense of being connected to everything

Strongly disagree ● O O O O O O Strongly agree

I felt small compared to everything else

Strongly disagree ● O O O O O O Strongly agree

I perceived vastness

Strongly disagree ● O O O O O O Strongly agree

I felt challenged to understand the experience

Strongly disagree O O O O ● O O Strongly agree

I felt closely connected to humanity

Strongly disagree ● O O O O O O Strongly agree

I felt my sense of self become somehow smaller

Strongly disagree ● O O O O O O Strongly agree

I experienced something greater than myself

Strongly disagree ● O O O O O O Strongly agree

Rood-blauw, groen, geel-blauw

I found it hard to comprehend the experience in full

Strongly disagree O O O ● O O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree ● O O O O O O Strongly agree

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Strongly disagree O O O O O ● O Strongly agree

It felt like it took little energy to keep looking at the art piece

Strongly disagree O O ● O O O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O ● O Strongly agree

What are three words that you would associate with the art piece

1. pearlecent 2. display 3. jelly fish

Why did you think of these three words?

1. pearlecent, because the purple-to-pink hue is common for pearlecent prints
2. display, because the work was so constantly and statically (meaning not moving w.r.t. itself) spinning, like a car in a car show
3. jelly fish, because it looks like it

What draws your attention the most and why?

The color changes and the view of layers mixing in different ways

Those were all the questions. Thank you for participating. Have a nice day :)

10

Questionnaire

What is your current stress level?

2

Low O O O O ◉ O O High

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I experienced something greater than myself

Strongly disagree O O O ⊘ O O O Strongly agree

Groen, rood-blauw, lichtblauw

I found it hard to comprehend the experience in full

Strongly disagree O O O O ⊗ O O Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree O O O O ⊗ O O Strongly agree

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It felt like it took little energy to keep looking at the art piece

Strongly disagree O ⊗ O O O O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O ⊗ O O Strongly agree

What are three words that you would associate with the art piece

1. Dizzy 2. Stress 3. Wows

Why did you think of these three words?

I think it reminded me how fast daily lives continues. Spinning so fast made me think the earth is also rotating very fast, while having too little time to concentrate on details

What draws your attention the most and why?

Maybe this form in my hand, next to the rotation of the piece of art

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low O O O O O ⊗ O High
⊗

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Groen, rood-blauw, groen-blauw TU is blauw

I found it hard to comprehend the experience in full

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I had the sense that moment was lasting longer than usual

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It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O O O ⊗ Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O ⊗ O Strongly agree

What are three words that you would associate with the art piece

1. hypnotysing 2. open 3. strange

Why did you think of these three words?

I'm continuesly drawn to the artwork/want to look at it.
It feels like ~~and~~ something from outer space/alien.
It takes me out of the moment.

What draws your attention the most and why?

Soft colors, movement, ~~intere~~ interested in how the artwork works/moves.

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

Low O O O O O O High

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Rood - blauw Licht blauw Groen

I found it hard to comprehend the experience in full

Strongly disagree ● ○ ○ ○ ○ ○ ○ Strongly agree

I had the sense that moment was lasting longer than usual

Strongly disagree ○ ○ ○ ○ ● ○ ○ Strongly agree

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It felt like it took little energy to keep looking at the art piece

Strongly disagree ○ ○ ○ ○ ○ ○ ● Strongly agree

My eyes were drawn to the art piece

Strongly disagree ○ ○ ○ ○ ○ ○ ● Strongly agree

What are three words that you would associate with the art piece

1. Cosmic 2. Pretty 3. cute

Why did you think of these three words?

Because of the colours, the shape, the motion and the vibe. It is like a little mini universe.

What draws your attention the most and why?

The slow morning

Those were all the questions. Thank you for participating. Have a nice day :)

Spins a "little" fast

Questionnaire

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Groen, Rood-blauw, geel-blauw

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Strongly disagree O O O O O Ø O Strongly agree

? — It felt like it took little energy to keep looking at the art piece

Strongly disagree O O O O Ø O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O O O O Ø Strongly agree

What are three words that you would associate with the art piece

1. Mesmerizing 2. Balance 3. Texture

Why did you think of these three words?

- The color, curves, aesthic, rotation, light reflection it brought out a peaceful feeling

What draws your attention the most and why?

- The Texture and light - ~~fantastica~~ (creation aspect.

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

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Rood - blauw Blauw - groen Blauw - rood

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My eyes were drawn to the art piece

Strongly disagree ○ ○ ○ ◉ ○ ○ ○ Strongly agree

What are three words that you would associate with the art piece

1. jellyfish 2. shimmering 3. movement

Why did you think of these three words?

Thats what I observed

What draws your attention the most and why?

the "tentacles" because of the ~~Red~~ / blau / purple changing hew

Those were all the questions. Thank you for participating. Have a nice day :)

Questionnaire

What is your current stress level?

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Groen Rood-blauw Geel-blauw

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Strongly disagree O O ⊗ O O O O Strongly agree

My eyes were drawn to the art piece

Strongly disagree O O O ⊗ O O O Strongly agree

What are three words that you would associate with the art piece

1. Bloem 2. water 3. draaien

Why did you think of these three words?

dit was het eerste wat in mij op kwam

What draws your attention the most and why?

de zwarte doeken, waarom zijn die?

Those were all the questions. Thank you for participating. Have a nice day :)

Appendix J – User testing results

1	Question	Part. 1	Part. 2	Part. 3	Part. 4	Part. 5	Part. 6	Part. 7	Part. 8	Part. 9	Part. 10	Part. 11	Part. 12	Part. 13	Part.14	Part. 15	Average	Deviation	Error
55	Slow down	0	1	-1	0	1	3	0	1	-3	-2	2	1	3	-3	1	0.2667	1.86956	0.519
56	Oneness	-2	1	-1	-1	0	1	0	-1	-3	-2	-2	-1	3	-3	-1	-0.8	1.61245	0.447
57	Something grand	-1	2	0	0	-2	1	1	0	-3	-1	-2	1	3	-3	-2	-0.4	1.80476	0.501
58	Connected	-2	0	0	1	0	0	-3	0	-3	-1	0	0	1	-3	-2	-0.8	1.42428	0.395
59	Felt small	0	2	-1	0	1	-1	-1	2	-3	1	-3	-3	0	-3	2	-0.467	1.88478	0.523
60	Vastness	1	1	2	0	-1	-1	1	0	-3	0	1	2	0	-3	0	0	1.51186	0.419
61	Challenged to understand	1	-3	2	2	0	-1	0	1	1	-1	3	-3	0	-3	1	0	1.88982	0.524
62	Connected to humanity	0	-1	-2	2	-2	-2	-3	-2	-3	-1	-3	-3	0	-3	-2	-1.667	1.44749	0.401
63	Smaller sense of self	-1	-1	0	0	-1	1	-2	1	-3	0	1	-3	0	-3	0	-0.733	1.43759	0.399
64	Greater than myself	-1	-2	-2	0	-2	0	-1	1	-3	0	2	1	2	-3	-3	-0.733	1.75119	0.486
65	Hard to comprehend	-1	-2	1	1	0	-1	1	-1	0	1	-1	-3	0	-3	3	-0.333	1.63299	0.453
66	Longer lasting	0	2	1	0	1	2	1	2	-3	1	2	1	3	-3	-3	0.4667	1.95911	0.543
67	Greatness	-1	0	-2	-1	0	0	-1	0	-3	-1	1	1	2	-3	-3	-0.733	1.53375	0.425
68																			
69	Honest/open	2	2	-2	2	1	2	-1	1	0	1	3	2	3	0	0	1.0667	1.43759	0.399
70	Fascinated	1	2	2	3	2	2	2	2	3	1	2	2	3	-1	-1	1.6667	1.23443	0.342
71	Calm	2	3	2	3	3	3	3	2	2	-2	3	2	2	0	2	2	1.36277	0.378
72	Little energy	2	3	1		2	3	3	2	-1	-2	3	3	1	3	-1	1.5714	1.74154	0.483
73	Eyes drawn	2	3	3	3	2	3	3	2	2	1	2	3	3	0	0	2.1333	1.0601	0.294
74	Min	-2	-3	-2	-1	-2	-2	-3	-2	-3	-2	-3	-3	0	-3	-3			0
75	Max	2	3	3	3	3	3	3	2	3	1	3	3	3	3	3			0
76	Correction factor	1.5	1	1.2	1.5	1.2	1.2	1	1.5	1	2	1	1	2	1	1			0

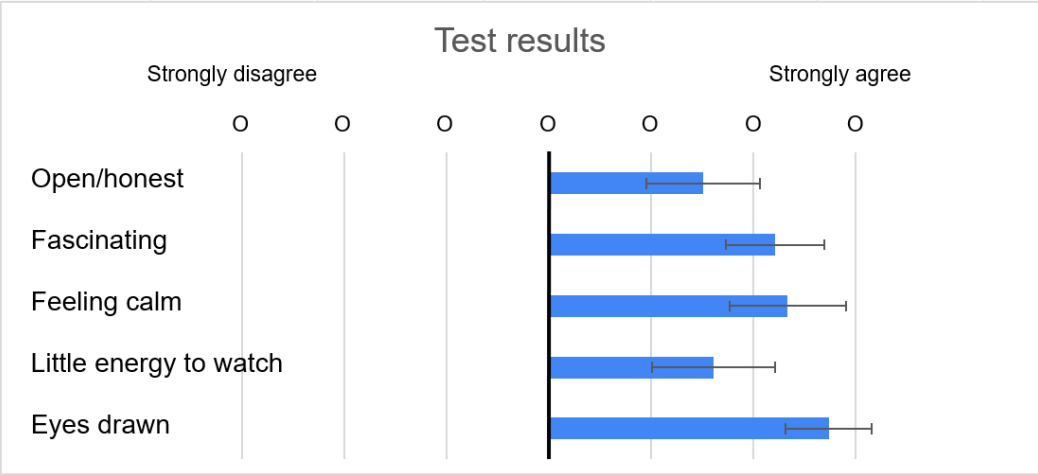
Data from the questionnaire, scored from -3 to 3.

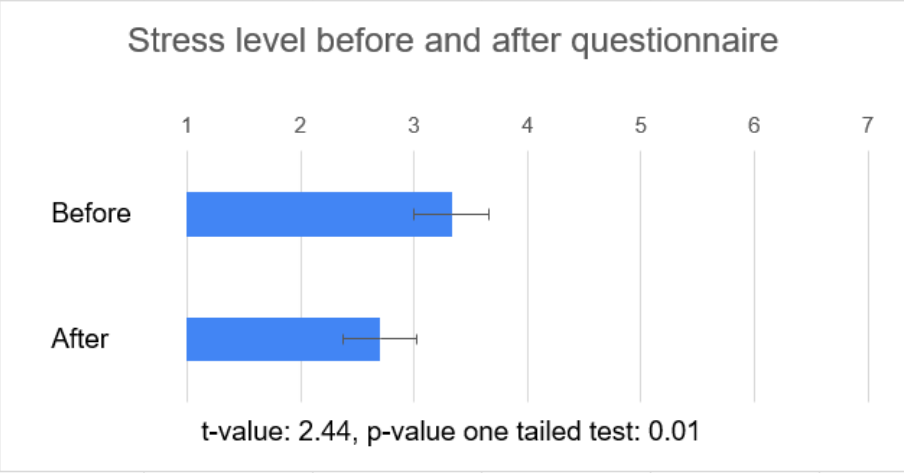
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Question	Part. 1	Part. 2	Part. 3	Part. 4	Part. 5	Part. 6	Part. 7	Part. 8	Part. 9	Part. 10	Part. 11	Part. 12	Part. 13	Part.14	Part. 15	Average	Deviation	Error
2	Stress before	2	3	3	4	4	3	4	3	3	5	6	3	3	3	1	3.3333	1.17514	0.326
3	Stress after	2	2	2	4	3	1.5	3	3	3	6	3	2	2	3	1	2.7	1.19224	0.331
4	Difference	0	1	1	0	1	1.5	1	0	0	-1	3	1	1	0	0	0.6333	0.93478	0.259
5																			
6	Slow down	0	1	-1.2	0	1.2	3.6	0	1.5	-3	-4	2	1	6	-3	1	0.4067	2.57195	0.713
7	Oneness	-3	1	-1.2	-1.5	0	1.2	0	-1.5	-3	-4	-2	-1	6	-3	-1	-0.867	2.42183	0.672
8	Something grand	-1.5	2	0	0	-2.4	1.2	1	0	-3	-2	-2	1	6	-3	-2	-0.313	2.39012	0.663
9	Connected	-3	0	0	1.5	0	0	-3	0	-3	-2	0	0	2	-3	-2	-0.833	1.68678	0.468
10	Felt small	0	2	-1.2	0	1.2	-1.2	-1	3	-3	2	-3	-3	0	-3	2	-0.347	2.0791	0.577
11	Vastness	1.5	1	2.4	0	-1.2	-1.2	1	0	-3	0	1	2	0	-3	0	0.0333	1.60074	0.444
12	Challenged to understand	1.5	-3	2.4	3	0	-1.2	0	1.5	1	-2	3	-3	0	-3	1	0.08	2.11464	0.586
13	Connected to humanity	0	-1	-2.4	3	-2.4	-2.4	-3	-3	-3	-2	-3	-3	0	-3	-2	-1.813	1.68941	0.469
14	Smaller sense of self	-1.5	-1	0	0	-1.2	1.2	-2	1.5	-3	0	1	-3	0	-3	0	-0.733	1.51924	0.421
15	Greater than myself	-1.5	-2	-2.4	0	-2.4	0	-1	1.5	-3	0	2	1	4	-3	-3	-0.653	2.11487	0.587
16	Hard to comprehend	-1.5	-2	1.2	1.5	0	-1.2	1	-1.5	0	2	-1	-3	0	-3	3	-0.3	1.79841	0.499
17	Longer lasting	0	2	1.2	0	1.2	2.4	1	3	-3	2	2	1	6	-3	-3	0.8533	2.44536	0.678
18	Greatness	-1.5	0	-2.4	-1.5	0	0	-1	0	-3	-2	1	1	4	-3	-3	-0.76	1.91975	0.532
19	Scaled Total Awe																-0.404	2.05556	0.57
20	Cummulative Awe	-10.5	0	-3.6	6	-6	2.4	-7	6	-32	-12	1	-9	34	-39	-9	-5.247	16.6499	4.618
21																			
22	Scaled Total Awe																-0.456	1.68423	0.467
23	Honest/open	3	2	-2.4	3	1.2	2.4	-1	1.5	0	2	3	2	6	0	0	1.5133	2.01525	0.559
24	Fascinated	1.5	2	2.4	4.5	2.4	2.4	2	3	3	2	2	2	6	-1	-1	2.2133	1.73817	0.482
25	Calm	3	3	2.4	4.5	3.6	3.6	3	3	2	-4	3	2	4	0	2	2.34	2.04932	0.568
26	Little energy	3	3	1.2	0	2.4	3.6	3	3	-1	-4	3	3	2	3	-1	1.6133	2.17317	0.603
27	Eyes drawn	3	3	3.6	4.5	2.4	3.6	3	3	2	2	2	3	6	0	0	2.74	1.5193	0.421
28																			
29	Times per week	7+	0-7	0-7	7+	7+	7+	7+	0-7	0-7	7+	0-7	0-7	7+	7+	7+			

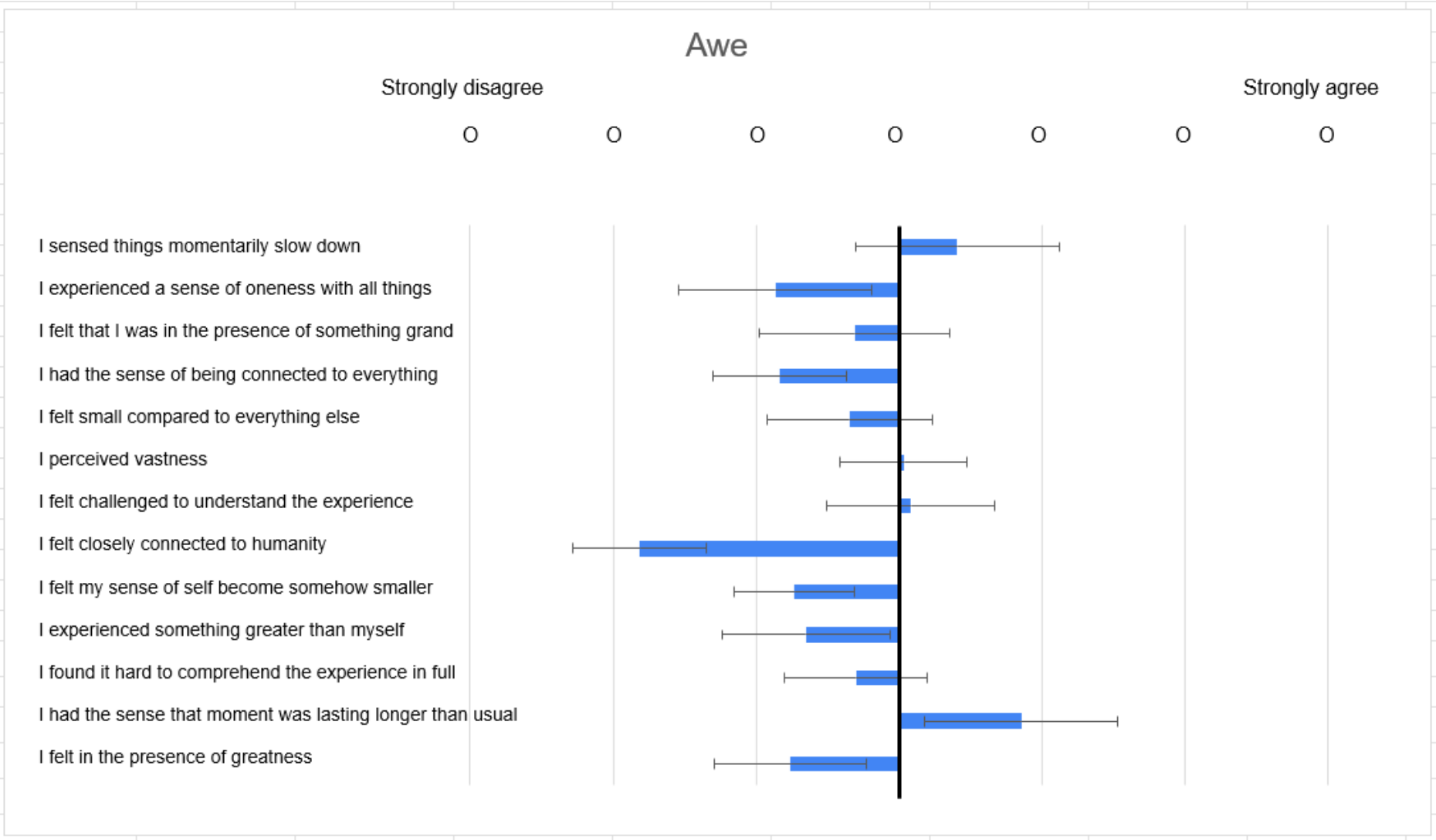
Data from the questionnaire, corrected by equalising scales for all participants. So if a participant only scored from -2 to +1, the scale is stretched such that it now covers -3 to +3, to account for more modest or outspoken participants.

Question	Part. 1	Part. 2	Part. 3	Part. 4	Part. 5	Part. 6	Part. 7	Part. 8	Part. 9	Part. 10	Part. 11	Part. 12	Part. 13	Part.14	Part. 15	Total
Groen-blauw		1				1		1			1			2		6
Geel-blauw	1		1	2	2		2		1				1		1	11
Groen	2	2	2	3	3	3	1	3	2	3	3	1	3		3	34
Blauw-rood														1		1
Rood-blauw	3	3	3	1	1	2	3	2	3	2	2	3	2	3	2	35
Lichtblauw										1		2				3

Colour ratings by the participants for most fascinating colours. Number 1 is given 3 points, number 2 is given 2 points and number 3 is given 1 point.






Awe
Strongly disagree
Strongly agree
I sensed things momentarily slow down
I experienced a sense of oneness with all things
I felt that I was in the presence of something grand
I had the sense of being connected to everything
I felt small compared to everything else
I perceived vastness
I felt challenged to understand the experience
I felt closely connected to humanity
I felt my sense of self become somehow smaller
I experienced something greater than myself
I found it hard to comprehend the experience in full
I had the sense that moment was lasting longer than usual
I felt in the presence of greatness

Results to the open questions

Why did you think of these three words?

1. **Ocean, fluid, calm**. Because I think the piece looks a bit like a jellyfish, in the ocean, that is calmly moving with the motion of the water
2. **Captivating, calmness, jellyfish.**The motion and lighting are very captivating. Once looking at it the fascinating view overpowers any small worries and hence makes you feel calmer. It physically resembles a jellyfish
3. **Endless, fascinating, nice colours.** Because it keep spinning and never stops, constantly changing in colour
4. **Bijzonder, kleurrijk, rustgevend.** Gevoelsmatig
5. **Rust, weer, klimaat.** Het voelt als een oceaan
6. **Peaceful, vibrant, continuity.** Omdat het rustig door blijft bewegen. De kleuren en vorm eruit springen, maar tegelijkertijd dus de continuïteit van beweging, rust en dus die kleuren en vorm je aandacht pakken en vasthouden. Het geeft een soort tijdloosheid
7. **Sea life, fire, universe.** Sea life because it slowly moves in water. Fire because you can keep on looking at it like fire. Universe, the colours remind of the milky way and randomness of the stars
8. **Everlasting, quasi-static, calming.** The are initial impression, observation and effect on me
9. **Pearlescent, display, jellyfish.** Pearlescent, because the purple-to-pink hue is common for pearlescent paints. Display, because the work was so constantly and statically (meaning not moving w.r.t. itself) spinning like a car in a car show. Jellyfish, because it looks like it
10. **Dizzy, stress, waas.** I think it reminded me how fast daily life continues. Spinning so fast made me think the earth is also rotating very fast, while having too little time to concentrate on details
11. **Hypnotising, open, strange.** I'm continuously drawn to the artwork/want to look at it. It feels like something from outer space/alien. It takes me out of the moment
12. **Cosmic, pretty, cute.** Because of the colours, the shape, the motion and the size. It is like a little universe
13. **Mesmerising, balance, textile.** The color, curves, aesthetic, rotation, light reflection it brought out a peaceful feeling
14. **Jellyfish, shimming, movement.** That is what I observed
15. **Bloem, water, draaien.** Dit was het eerste dat in me opkwam

What draws your attention the most?

1. The light and colors. Especially the combination of the light and fabric that make it seem that the color of the fabric changes dependent on the angle of the light on it.
2. The iridescent lighting of the fabric tangles.
3. Spinning and changing colour, you can keep looking at the movement
4. De kleuren, ondanks felle kleur toch rustgevend
5. Kleuren
6. De constante ronddraaiende beweging van een gekke vorm, omdat het hetzelfde is, maar elke milliseconde er anders uitziet
7. The purple turning thing
8. The perfect rotation of the ribbon
9. The color changes and the view of the layers mixing in different ways.
10. Maybe this form in my hand, next to the rotation of the piece of art.
11. Soft colors, movement, interested in how the artwork works/moves
12. The slow spinning
13. The texture and light, levitation aspect
14. The “tentacles” because o the red/blue/purple changing hue
15. De zwarte doeken, waarom zijn die?

Appendix K - Scientific discussion

This was a first rudimentary test to see if the general experience of the art piece is in the direction of the intended experience. However, there are still a number of subjects that could be tested in more depth, or have not even been touched upon at all yet. Next to that there are some improvements that could be made to the current test.

Improvements to current test

Regarding the result, there might have been some uncertainty among the participants. Some participants filled in the questionnaire mostly neutral, giving the middle score, indicating while others scored the lowest score quite consistently, indicating they strongly disagree. This might mean some participants have a different interpretation of the scoring system than others, skewing the results. This could be avoided by either explaining the scoring system clearly, or using a different scale, for example ranging from “neutral" to “strongly agree”. (And if necessary adding another one ranging from “neutral” to “strongly disagree”, although this could also confuse participants).

On the open questions, people often named terms as “calmness”, “rustgevend” and “fascinating”. But since the questions directly before were about fascination and openness, there might have been a bias in the results. So carefully take the order of questions into account in further testing.

There was one participant that indicated increased stress after the testing. When asked why he did as such, he explained that the whole procedure had caused him to feel more stressed, having to fill in (relatively difficult) questions, and that the moment of rest had given him time on how little time he left before his deadlines. This would vouch for more covert testing, although I already made sure to keep my distance and give participants their space, sitting over ten meters away.

Future testing

Testers could have had a clue to the desired results, and filled in the questionnaire biased accordingly. Some questions, like how fascinating or energy consuming the artwork was, could hint towards a desired outcome, creating a bias in the results.

The number of testers could be increased for more accurate results, especially since the standard deviations are quite high. Some people seem much more perceptible and open towards the experience than others. One participant scored “strongly disagree” on all awe related questions, while others scored “strongly agree” on some of the same questions. Since it is so highly personal (based on these results), it could be beneficial to take a larger test pool, or specify the target group more. But then you would also have to research how to do so.

In the actual artwork, viewers would not get a story about how the diver moves by air pressure. They would have to figure it out by themselves over time. On the questionnaire, nine out of fifteen people indicated passing by the entrance of their work more than seven times a week. So over time the idea is they notice differences in the height of the diver. However, since this was a onetime test, I gave the participants a short explanation about how the diver moves. This might have caused a bias, so in future testing this should either be avoided to simulate the final envisioned situation more accurately.

Ideally, testing is done covertly. It would be best to simulate the envisioned conditions most accurately, and to do so, you could build a setup similar to the one now, and leave it accessible to the public. The research could then observe how often people have a look at the work, and only after a

couple weeks ask questions regarding their experience. This way it could be seen if people voluntarily go to have a look, if they watch the work repeatedly over longer periods and if they notice the connection to the weather.

Appendix L – List of Requirements

Please note this is only a list of requirements I found during my research. I take no claim this list is complete, only that these requirement have followed from the research, which I can therefore state confidently.

Category	Requirement	Wish
1. Diver	Product should start working from 1hPa of pressure difference	
	Product should be calibrated to 1015.5hPa	
	Product should operate between 970 hPa and 1050 hPa.	
	Product should have an air volume of at least 100 mL	
	Is impossible for water (more than small drops due to adhesion) to remain in the diver when it is afloat	
	Centre of gravity is below centre of buoyancy	
	Diver's outside perimiter (top view) approximates a circle	Diver's perimeter (top view) is an organic shape
	Diver has pretrusions to remain spinning	
	Diver has no flat or concave surfaces at its top	Top of the diver is a sharp tip
	Diver is made of glass	
	Diver is made of a see through material	
		Diver has a cloudlike shape
2. Chain/weights	The chain is tuned such that it has the minimum density to compensate for pressure increase with increasing depth as the diver sinks	Chain has the exact density to make the range of motion optimal for pressures between 970 and 1050 hPa
		The chain is hidden away in the fabrics
3. Fabrics	The fabric is made of polyester or nylon	The fabric is made of nylon
		The fabrics are of a two-tone material
		Fabric is of red-blue colours
		The fabrics are cut with a lasercutter
	Fabric is around 2/3 of the width of the vase	
	Fabric is attached to the diver at 1/3 of the diameter of the diver, in the midpoint of the fabric	

Category	Requirement	Wish
	Length of the fabric is about 2/3 of the height of the diver	Length and shape of each of the pieces of fabric varies slightly from the others
	Three pieces of fabric are attached to the diver	
	Flaps of the fabric are about 5 to 6 cm tall (in a 20 cm diameter vase)	
	Fabric has no sharp tips	
	Incisions cannot cross the vertical centre line of the fabric	
	The pattern of the fabrics does not include any exact repetitions	
4. Vase	The vase is at least 2 meter tall	
	The vase is at least 20 cm in diameter	
	The vase is shaped as a cylindrical tube	
	The inner walls of the vase are smooth	
	The vase is made of a seethrough material	The vase is made of acrylic
	View of the vase is unobstructed	
	View into the vase is unobstructed	
	The vase has a space of 10 cm at the bottom to house a pump and light	
	The pump can move at least 600l/h	The pump has an adjustable flowrate
	The vase can be suspended in the air	
5. Frame	The frame can hold at least 1.5 times the weight of the vase filled with water	
	The frame does not hinder the viewer in any way, physically as well as visually	
	The frame can hold the veils up in a sort of circular shape around the vase.	

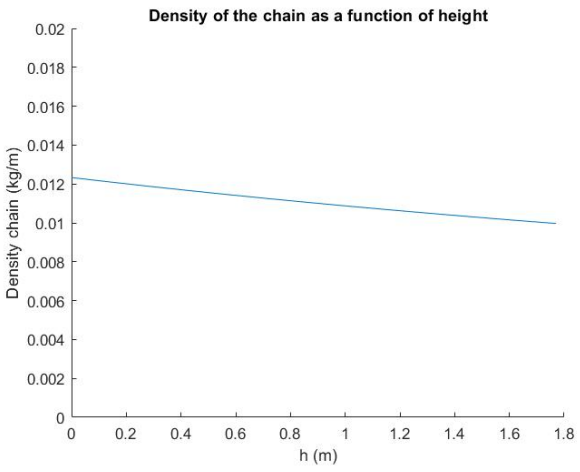
Category	Requirement	Wish
		The frame allows for some freedom of adjusting the shape, to fit is on location
6. Surroundings/veils/lighting	The lamp has at least an IP7 rating for water tightness	
	The lamp can produce at least 700 lumen	
	The lamp can light in multiple colours	
		Product uses mainly natural lighting
	The veils can accommodate at least five people	
	The veils hang a maximum of 50 cm of the floor.	
		The veils reach to the ceiling
	The veils are partly seethrough	
	The veils do not wrinkle	
	The veils meet at 90 degrees, with the distance of the vases diameter between their ends	
7. Location		
	Product should be placed indoors	
	Location should have a space of at least 5x5x3.5m	
	Location should have a window the full height of the setup	
		Window is facing south
8. General	Product should make the majority of its viewers (>50%) feel in awe	Product should induce a sense of vastness
		Product should create a need for mental accomodation
	Disassembled product should fit through a standard double door (160x200cm)	
	The setup can be assembled by two people	

Appendix M – Matlab code chain

Calculating the chain weight and mass and volume of the diver

```
%calculate chain density

clear, clc

%Variables to be changed by the designer

rho_liquid = 998.2; %density of the liquid (water in this case) in kg/m3

rho_cap = 1500; %density of materials of the diver (glass for now) in kg/m3 (should be higher than rho_liquid)

m_cap = 0.240; %mass of the diver in kg (only the central unit, without chains etc.)

rho_chain = 7800; %density of the chain, steel for now (kg/m3)

H_diver = 0.2; %Height of the diver in meters

H = 2; %Height of the tank in meters

H_red = H-H_diver; %height of the tank in meters minus the height of the diver, so it does not touch the bottom

rho_gas = 1.293; %density of the gas in the diver (air in this case) in kg/m3 (almost negligable)(technically dependent on air pressure as well, that is disregarded in this analysis)

P_air = 98000:100:104000; %range of air pressures in Pa with intervals of 1hPa


%DO NOT CHANGE. Variables dependent on the ones above.

h = 0:H_red/(length(P_air)-1):H_red; %range of heights, such that this vector and P_air are equal in length

g = 9.81; %gravitational constant

P_top = P_air(1); %lowest pressure at which something should happen (diver in top position)

P_bottom = P_air(end); %last element of the pressure vector, pressure at which diver should be in bottom most desired position

h_bottom = h(end); %last element of the height vector

R_cap_volume = - (rho_liquid-rho_gas).*(P_top./(P_bottom + (rho_liquid.*h_bottom.*g)))...

    ./((rho_liquid./rho_cap)-1) %Ratio of m_cap/V_top. Ratio of the mass of the diver over the volume of air it can contain.

% This is a design choice. The ratio is what matters, however, since a mass

% is often chosen, the volume of air follow from the following equation

%IMPORTANT this only works for a chain that sinks. You could also make the
```

```
%concept with one that floats, but in that case the situation flips

V_top = m_cap./R_cap_volume %Volume of air at the top, for which the diver is in equilibrium

%Make sure the diver can contain a little more air, so that it is not
%filled to the edge. Otherwise some bubbles could easily escape if the
%divers tips slightly. There is a murderer on the dancefloor
%V_top = V_bottom.*(P_bottom + (rho_liquid.*H_red.*g))./P_top
V_bottom = (V_top.*P_top)./(P_bottom + (rho_liquid.*H_red.*g))
V_air = (V_top.*P_top)./(P_air + (rho_liquid.*h.*g)); %Volume of air changing with depth

Fres = @(m_chain) ((((rho_liquid./rho_cap) - 1).*m_cap) + (((rho_liquid./rho_chain)-1)...
   .*(H_red-h).*m_chain) + (((rho_liquid - rho_gas).*V_air)).*g) == 0;

m_chain = -((((rho_liquid./rho_cap)-1).*m_cap) + (rho_liquid-rho_gas)...
   .*(V_air))./(((rho_liquid./rho_chain)-1).*(H_red-h));

figure (1), clf(1)
%plot(h, V_air)
hold on
plot (h,m_chain)
ylabel ('Density chain (kg/m)')
xlabel ('h (m)')
title('Density of the chain as a function of height')
axis ([0  H_red 0 0.02])
hold off
```



Plot show the local density of the chain necessary to compensate for the increase in pressure as depth is gained. We can see it is almost linear.