ZED: exploring how to manipulate light through a tangible interaction

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ABSTRACT

This pictorial documents the design process of ZED, a multimodal light and sound instrument developed in an interactive materiality course at TU Eindhoven. Using iterative prototyping , ZED combines light, sound, and tactile elements for an immersive experience. This material-driven approach centered on light as the primary element, with multisensory feedback enhancing user engagement. Weekly feedback sessions shaped design choices, highlighting how expressive interactions can create skill development and immersive user experiences.

INTRODUCTION

This pictorial explores the design process of ZED, a multimodal light and sound instrument, developed as part of an 8-week interactive materiality course at TU Eindhoven. The pictorial provides insights in our design journey driven by iterative prototyping and theoretical reflection, drawing on frameworks that explore the relationship between materials, user experience, and sensory engagement. During the process, weekly sessions with two professors and other students in the course were held to reflect on the experience, gain new perspectives and map theory to the presented prototypes.

Material as an Agency

Research on expressive materiality and aesthetic interactions in Human-Computer Interaction (HCI) enables designers to be guided by the materials, discovering the interactions they can naturally offer. The process originating from a workshop in which a transition from transparent to opaque was analyzed using different materials. This workshop was based on Ingold's (2009) concept of textility of making, where the material has agency in the design process, meaning that designers must listen to the material and let it lead. Today, the materials for our designs are still chosen based on functionality, low cost, and ease of production. It is about monopoly agreements and price-fixing that result in the materials that are chosen to use for our designs today (Papanek, V., 1985). As a result, many products lose their authentic craftsmanship, and the potential of materials is reduced to a purely functional role to fit mass production purposes.

Expressive Interaction

In Human-Product interaction, the term "pleasant interaction" is often used. The rich interaction framework aims to capture methods for designing pleasant, useful interactions that create a more meaningful connection to the outcome (Frens, 2006). The Interaction Frogger framework (Wensveen et al., 2004) and iterations on expressivity all give insights in creating more engaging user experiences. Also, Winters et al. (2022) propose a framework to do this by using dynamic changes to capture attention and provoke emotional responses. Bruns et al. (2021) suggest that skill development, where experience over time is crucial, can be closely tied to a pleasant interaction with an object, like the way skills develop with musical instruments or tools.

Multisensory Interaction

Designing user experiences using multiple sensory channels adds expressiveness to the experience (Bruns et al., 2021). For an immersive experience by engaging multiple senses, such as touch, sound, and visuals simultaneously, users can more quickly reach the intended state desired by the designer. Additionally, the interaction feels richer because users can explore different layers, each offering something new to focus on and discover. Challenges arise when materials used are untouchable such as light. In this case, multimodality is essential to stimulate expressiveness through other senses. This process will provide insights into how light, as a material, shaped the design process and how multiple senses were used to create an immersive experience with light central to the interaction.

METHOD DESCRIPTION

This project focused on a Material-Oriented Design approach, starting with a workshop material exploration using a transition allowing the materials to “speak” without forcing preconceived ideas onto them (ingold,2009), using the material as an active participant in the creation process. In this workshop, a transition between opaque and transparent states was chosen. A broad range of materials were selected, including coffee grounds, latex, candle wax, baking paper, and other materials found at home, such as tomato paste, torn cotton balls, and balloons. By observing and interacting with how these materials naturally responded to different manipulations, a selection and identification of key material qualities were made, using a video for this analysis.

https://www.youtube.com/watch?v=kRTDoenwEe8

The project combined hands-on exploration with emerging design tools to understand and communicate material qualities through physical interaction and multimodal feedback. Experience prototyping was used, allowing the designers to engage directly with materials to iteratively refine the design vision of ZED (Buchenau & Suri, 2000).
Weekly feedback sessions were held with both professors and peers, where the designers presented different iterations of the prototypes, focusing especially on the ‘look and feel’ (Houde & Hill, 1997). The team mapped existing prototypes to theories such as Interaction Frogger framework (Wensveen et al., 2004), expressivity in interactions (Bruns et al., 2021) and the three form-elements in the practice of interaction design (Vallgårda, 2013).
After each session the team reflected and iterated accordingly. After 9 weeks the team presented their final fully working interaction during demoday on which they received their last points of feedback which were all considered during the creation of this pictorial.

Figure 1: left and right hand interaction with final design

MATERIAL MAPPING AND ANALYSIS

Light as a material is not tangible, so how can light be made tangible? Through several material explorations, the team discovered how to manipulate intangible light (and its effects) through tangible materials.

During the introduction workshop, an array of materials was explored regarding the theme of transparency and opaqueness together with sunlight. Here you find the materials which were explored and what aspects were promising for our next step.

The materials were graded 0 to 5 and were mapped based on:

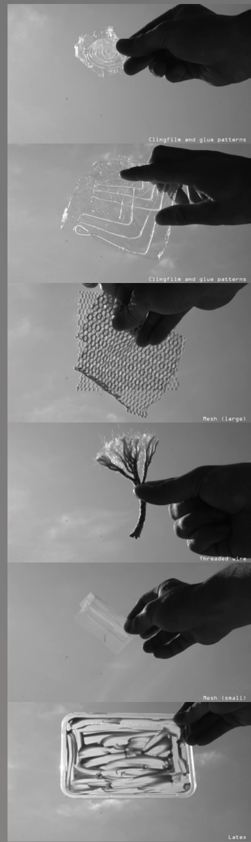
1. Capability to change in opacity, how well does light (not) get through? (O)
2. Stability, how controllable is this change in opacity? (S)
3. Approachability, how inviting is the material to interact with? (A)
4. Processability, does the material allow for manipulation or collaboration with other materials? (P)

It was found important to pick a material which was capable of showing controlled subtle differences in opacity, so these could be combined with subtle interactions later on in the process. Furthermore, the tangibility of the material was important as the feel of the material would also have influence on the interaction. And lastly, to create a visually pleasant ensemble, it was important that the material was able to fit next to other materials.

The material with the most potential was the baking paper. The transparency of the material could be easily adjusted and allowed for detailed adjustments by the designers through folding or cutting, but it was also interesting to see how the material itself created shapes when unfolding after it was being cropped. Furthermore, due to the familiarity of the material, it was quite approachable and inviting to touch. Processability of the material was also high as baking paper is easy to fold, cut or tear, but also allows it to be attached through, for example, glue, tape and nails.

The materials which did not work well, were materials which contained a certain "randomness" while handling. Take for example the latex, magic sand, and tomato paste. Though they had a good ability to change in opacity, it was difficult to create controlled subtle differences in transparency because of their liquid nature.

The other materials, the transparency was not as strong, or it was difficult to manipulate the material.



Material	O	S	A	P
Baking paper	5	5	4	5
Baking paper	5	5	4	5
Baking paper	5	5	4	5
3D glasses lenses	5	5	4	4
Candle wax	5	4	4	2
Torn cotton balls	4	2	4	2
Stretched balloon	4	2	3	2
Clingfilm and glue patterns	3	4	2	2
Clingfilm and glue patterns	3	4	2	2
Mesh (large)	3	2	4	3
Threaded wire	3	2	4	2
Mesh (small)	1	2	4	3
Latex	5	2	1	1
Magic sand and dish soap	5	2	1	1
Tomato paste	5	2	1	1
Feathers and wire	2	1	4	1
Sol-U-Film with sprinkled water drops	2	1	2	1
Wire, glue and garlic peel	0	1	1	1
Wire and candle wax	0	1	1	1

Figure 2: Material mapping broad exploration

VISUAL DESIGN PROCESS

Using light as a material

During the introduction workshop, the transition of Transparent vs Opaque was selected. Through a material driven process (Karana et al. 2015) and working together with different types of materials (Ingold, 2009), explorations were done to translate transparency and opaqueness in different materials.

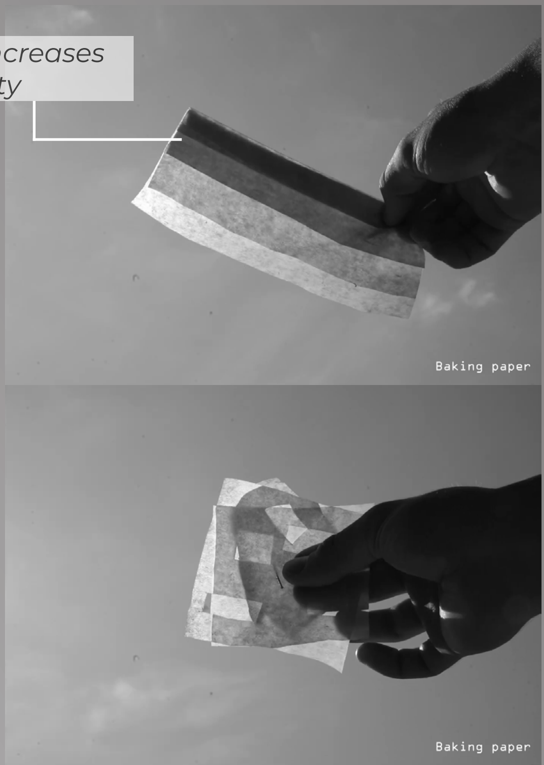


Figure 3 and 4: Baking paper material exploration

The team discovered that light played an important role in this transition and it was decided to pick light as our main material. With the help of the sun, some of the first explorations showed the transition really well. The full analysis can be found in Material Mapping and Analysis.

Concept development

As concluded from the material mapping and analysis, baking paper was the most versatile and useable material in the context of our transition. Thereafter it was time to experiment with colours, patterns and other materials to see how could transfer these material qualities of baking paper and how they could be influenced.

While exploring the materials in the Vertigo workshop, the team stumbled upon vinyl film together with transparent plastic sheets (Vivak and acrylic). Combining the two resulted in a rigid plate which became more opaque the more layers of film were applied. Explorations with colored film were also done, however it was concluded that color would distract too much from the focuspoint: the transparency.

After this exploration a first experience prototype was created. Through a slider, the viewer could rotate and alter the shadowplay on the ceiling. The slider was connect to the Feelix motor (Van Oosterhout et al., 2020) which was used to create custom force feedback. This made the slider easily move to certain positions, while adding more difficulty moving into others. Incorporating the Feelix motor, gave the opportunity to add more depth and room for subtleties in the interaction.

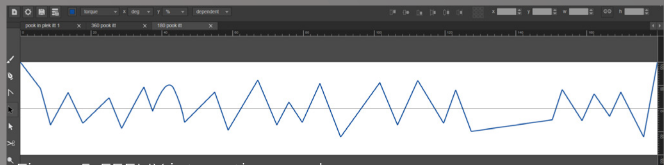


Figure 5: FEELIX interaction graph

During explorations into these subtleties the Feelix motor unfortunately broke down. Therefore it was decided to use an elastic band as an alternative to provide forced feedback, this unfortunately left less room for subtleties.

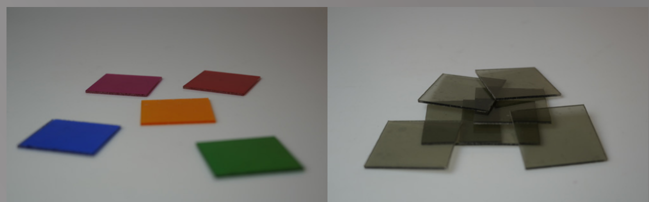


Figure 6: exploration with plastic sheets layered with vinyl

Figure 7: first prototype

Figure 8: shadowplay in first prototype

Exploring interactions

The slider from the first iteration did not give a rich and interesting interaction. Through experience prototyping (Buchenau & Suri, 2000) several interactions were designed. The interactions ranged from subtle finger movements, to whole hand interactions. The team tried to create interactions that were connected to the transition of transparency.

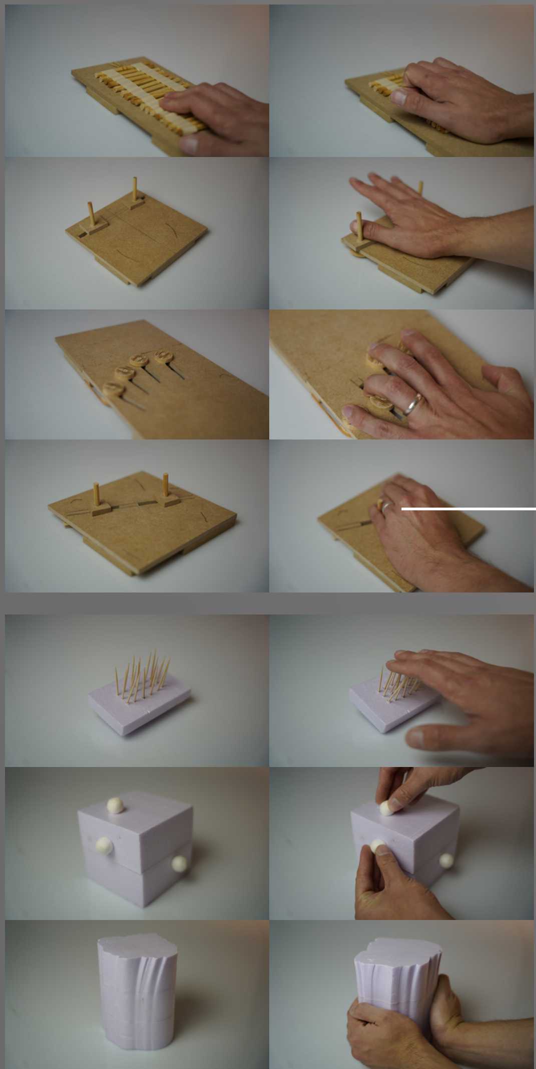


Figure 9: experience prototyping

Transparent interactions through opening and closing fingers

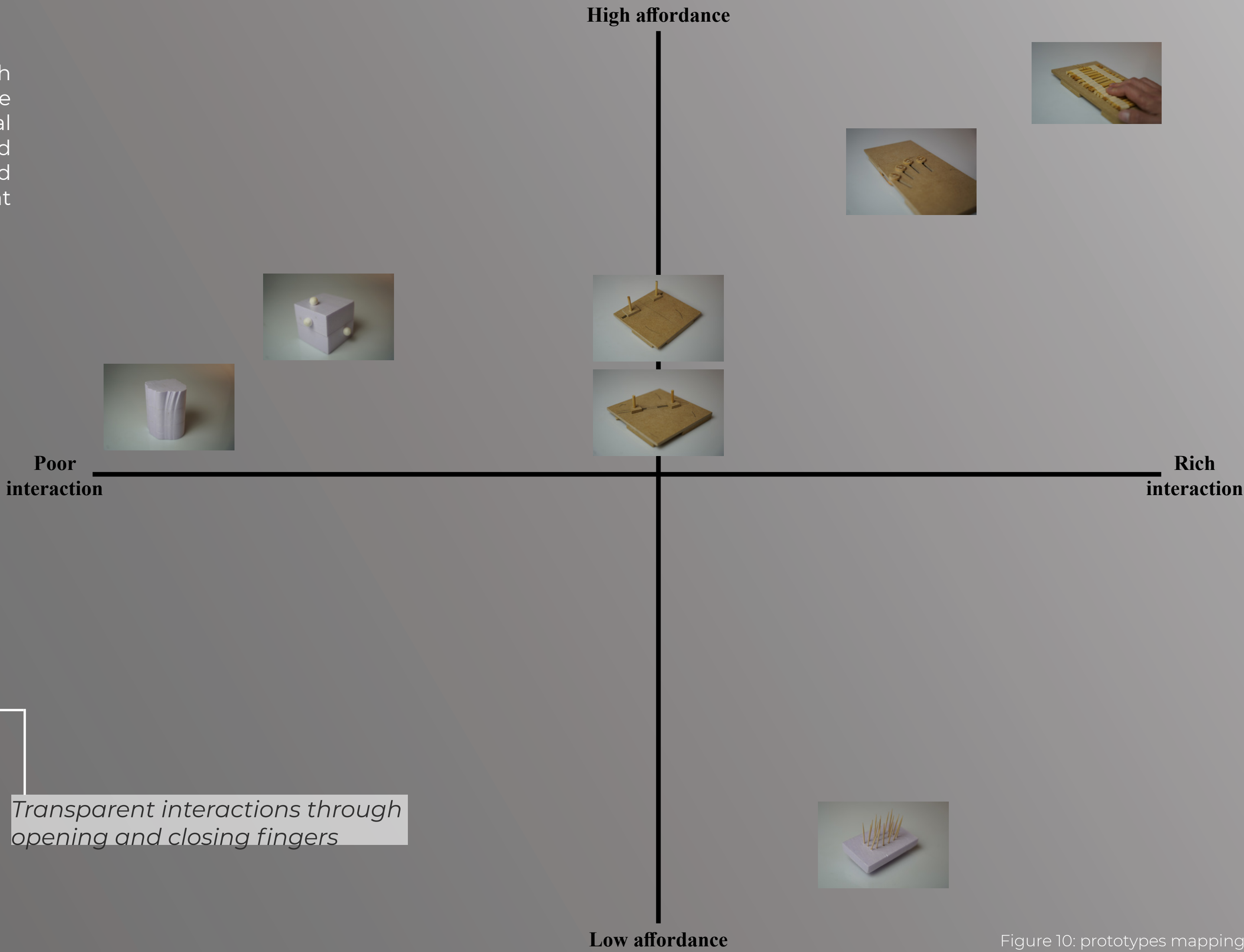


Figure 10: prototypes mapping

The interaction with the wooden sticks came out on top. Due to the use of wood it was inviting to touch and there were several interaction possibilities as you could use your whole hand or individual fingers to control it. Furthermore there was a subtle force feedback (Wensveen et al. 2004) when pulling back the sticks.

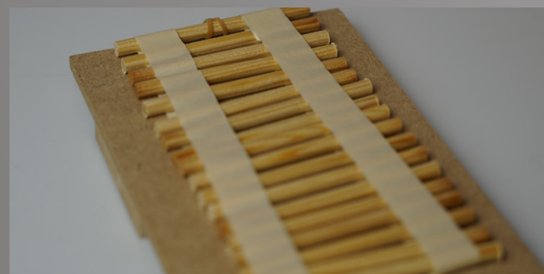


Figure 11: final wooden stick interaction

Final design
After receiving feedback during a feedback session it was concluded that our physical wooden design had similarities to a lamp in a zen garden. Reasons for this being the uses of wood and the overall shape.

It was decided to further explore this. Therefore inspiration from Japanese tattoos and mandalas were used in the creation of the final shadow play disks.

To further create coherence in the interaction aesthetics. A sound design was created which took inspiration from a Japanese harp and a soothing and calming base layer to further constitute the zen garden aesthetic.

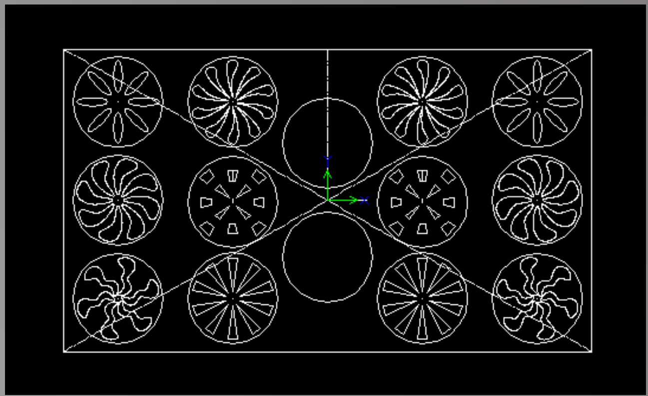


Figure 12: shadowplay patterns for lasercutting

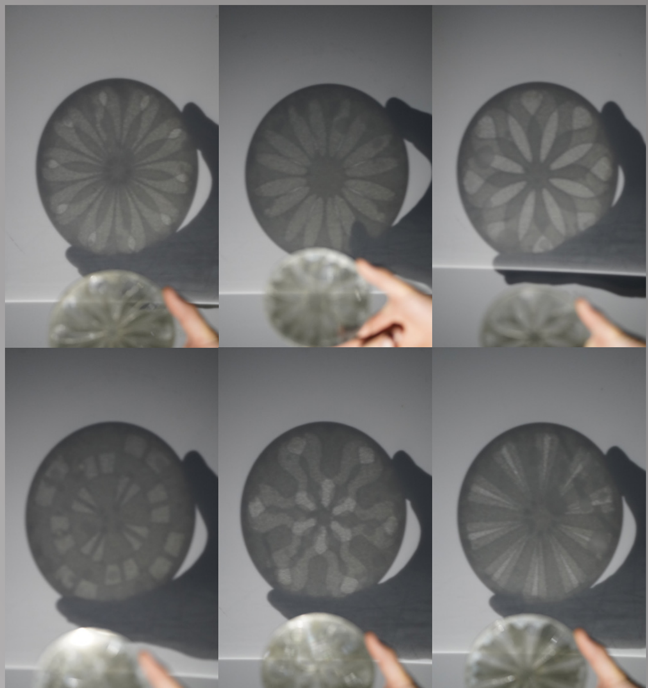


Figure 13: shadowplay exploration

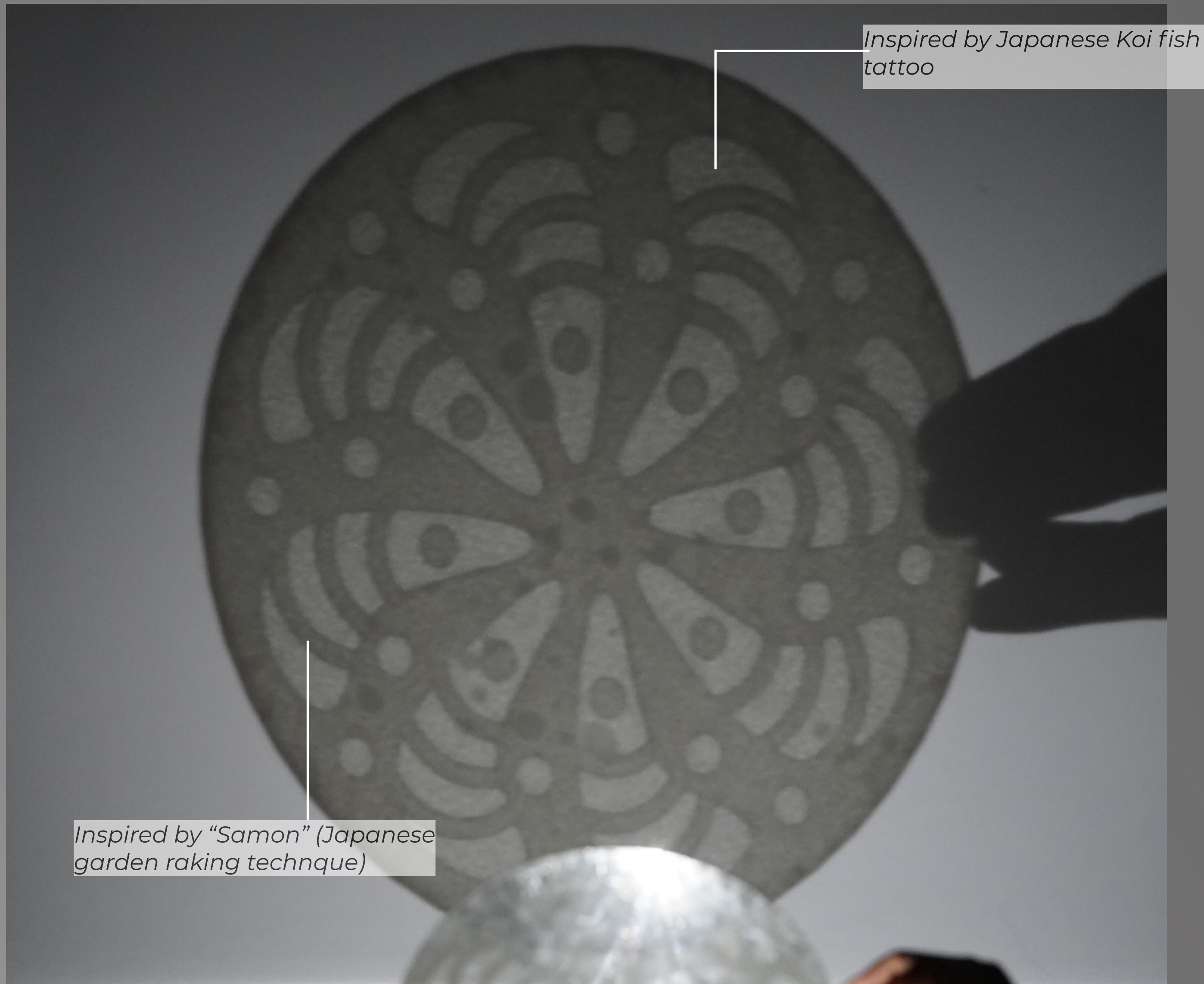


Figure 14: final shadowplay

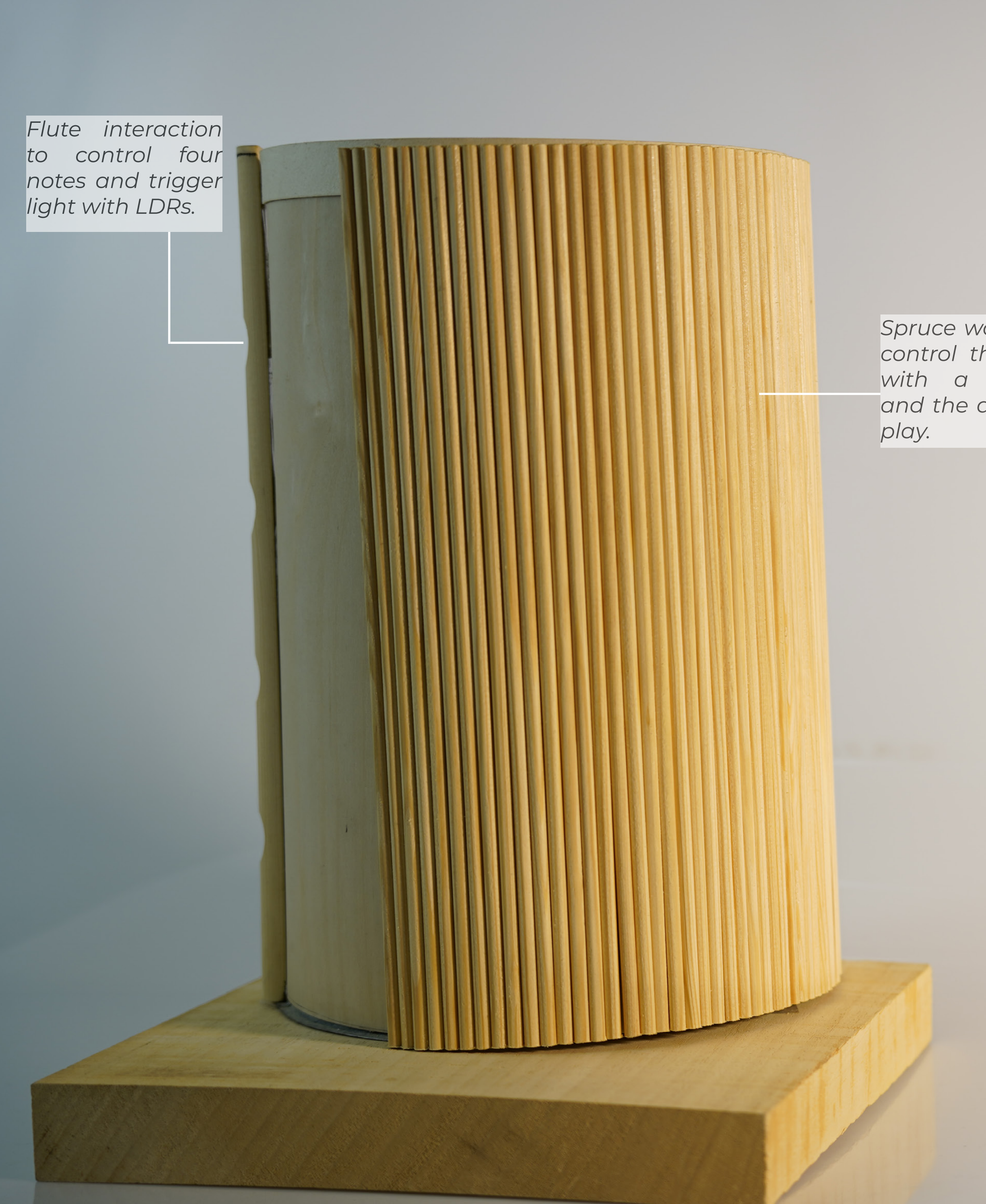


Figure 15: final design

Although there was light and touch in our design, it felt like something was missing. Something was needed to emerge the user in the design and create a whole experience. Mesmerising sounds were added to enhance the experience and elevate the interaction.

At the end, a beautiful multimodal (Bruns et al., 2021) experience was created in which the right hand slider controls a soothing base tone, the left hand enables an elegant harp, all while a beautiful pattern is displayed on the ceiling (see detailing for an in-depth elaboration).

Figure 16:: close up of disc pattern on final design

SYNTHESIS

The physical aspect involved refining the structure to ensure stability while encouraging user interaction. This included adjusting the placement and height to afford interaction and adding elements to encourage exploration of the light and sound features. Various materials and forms were tested for optimal light diffusion, with an emphasis on transparency to align with the theme of dynamic shadow play. Because the wooden panel could only turn at an angle of 45 degrees, a gear system was used to allow the rotatable disk for the shadow play to turn 360 degrees. To make the sound correspond to the rotation of the wooden panel, a potentiometer was placed on one of the gears. Based on feedback from one of the sessions.

The interactive behaviour was focused on mapping out multimodal feedback, combining sound and shadow play in response to user input. This included calibrating the touch-sensitive flute section with LDR's and the wooden panel movements to produce corresponding sounds. The cylinder suggests an action similar to placing hands around it or rotating it. This cylindrical design act as feedforward by inviting users to grasp or turn it intuitively, hinting at rotational interaction. The design incorporated the basic principles of a flute to afford users an intuitive way allowing them to move their hands over it to produce sound. Additionally, The choice was made to only show the light, and therefore the shadow play, when interacting with the LDRs. This creates a clear link with the use of both hands, and, just like with an instrument such as a guitar, it functions better when both hands are used together. The system's response was programmed to return to a neutral state corresponding with a low base sound, in line with the Japanese Zen-inspired concept, allowing users to reinitiate interactions and explore potential skill development through repeated engagement.

To ensure users would not look into zed but rather look up at the ceiling, it was decided to have people kneel so that they would naturally look up, where the shadow play takes place. The music box was also placed on the ceiling to direct the attention. Lastly to make the LDRs functional in a dark space, a light is placed to the left of the flute. At the same time this helped guide the interaction.

user	none	move wooden panel	touch flute holes
sound	neutral base	pitch the base	trigger a sustained note
light	light off	light off	light on
shadow-play	none	altering pattern	visible shadowplay

Figure 17: interactive material experience mapping

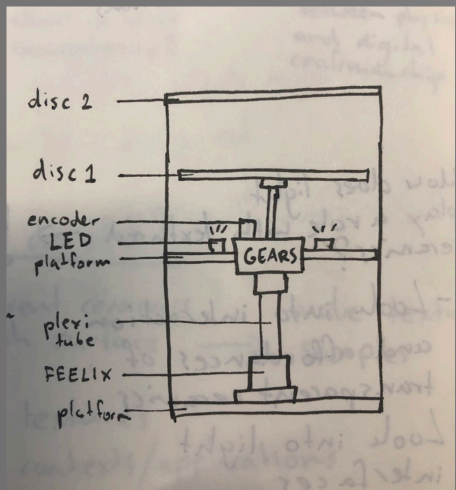


Figure 18: internals schematic

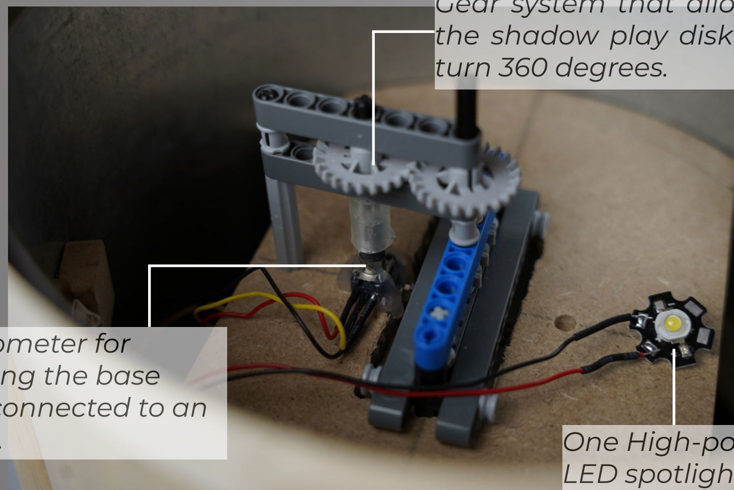


Figure 19: lego gear system and potential meter

DETAILING

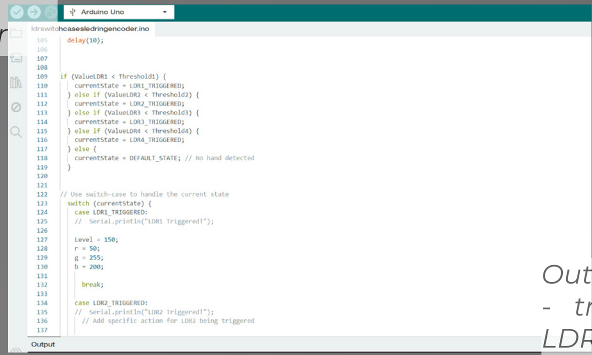
In its resting state, Zed produces a low droning sound creating a calm atmosphere, simultaneously arousing curiosity within the user inviting them to interact. Furthermore this drone functions as a base layer on which further layers can be added for more complexity during the interaction.

The left hand interaction is based on the appearance of a flute. This is done to afford the user to cover the holes on it. When one of the four holes is covered this will simultaneously trigger a sustained note and the light to shine making the shadow play visible. As soon as the holes are uncovered the sound and light will fluidly decay in sync.

Subtleties can be found in the way users cover the holes. This can be done using their fingers, but also using their arm or both hands at the same time. Thereby this allows for more expressivity in interaction through freedom of interaction (Wensveen et al., 2004), enabling more ways of creating different sounds.

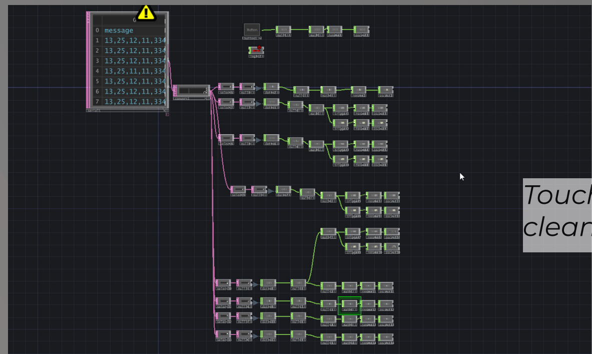
For the right hand the panel interaction is created, For this, inspiration is taken from an accordion. This panel affords to place your full hand on it and turn it with the curve of the cylinder. When the panel is pushed away from its starting point the timbre and morph values of the drone sound are increased see left figures for an overview of technological programs. This causes the tension of the sound to build. A parallel is created in the audible and the haptic tension by adding resistance to the sliding movement, making it gradually more difficult to slide it further. The tension is automatically resolved when the user either moves the panel back to its starting point or removes their hand, making the panel automatically slide back to this position. This effect of haptic tension was achieved with a elastic band which would stretch when the panel was pushed away, and inherently this also made the panel snap back to its starting position when release, resulting in a audible cue when the panel hit the edge of the slot in which it moved.

Reads sensor input:
- LDR's
- potential meter



Output:
- triggers light on LDR threshold

Figure 20: Arduino code



Touchdesigner used to clean and process data

Figure 21: Touchdesigner code

VCVrack produces base sound and changes sound based on incoming data

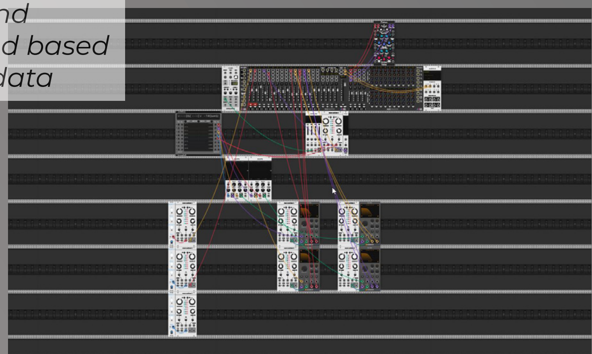


Figure 23: vcvrack interface

Figure 24: vcvrack interface close-up for base sound

DISCUSSION

Tension and release:

Because the light instrument was in a separate dark space during the demo, where visitors had to kneel and a constant bass sound drew them into the interaction and environment, a certain tension was built up in the interaction. However, this did not reach a climax or outcome in the way the design could express itself. Instead, a tension arc was used, inspired by Japanese culture, which involves not having a climax , with ZED always returning to a neutral or "0" position when there is no user input. This approach could be expanded by experimenting with different tension arcs and storylines within the interaction to build toward a climax, for instance, through a sequence of sounds. This could also encourage potential skill, as users may want to discover how to reach the climax point.

Affordance

There was extensive experimentation with the placement and height at which the design was presented; however, further iterations could explore different shapes to ensure that feedforward, a form of hinting users about possible interactions (Wensveen et al., 2004), is clear, without requiring the product to be positioned in a specific way. It could even adopt qualities of string instruments that users pick up and hold in a particular position. Although the cylindrical shape, according to participants in the session, suggests it should be held with both hands, it is unclear whether it is meant to be moved due to the fragile appearance of the wooden panel. Various interactions were explored using light as a material. To improve the feedforward of the wooden panel, a different interaction could be introduced, such as an accordion effect that, when pulled apart by the force of interaction, would let light escape. This creates a link to the transparent interaction with which the designers began the project.

Shadow play

In the final execution, it was not possible to achieve the intended shadow play effect as seen in the earlier iterations. As a result, the desired effect ultimately became more abstract and was perceived by participants as not fully coherent with the sound and overall appearance of the design. Additionally, participants mentioned that the sound was on the foreground, which shifted focus away from the shadow play. This suggests that although light was intended to be central in the design, the focus during the design process may have shifted unconsciously due to the presence of multiple physical elements. Other physical elements, for example the light, space and the prototype itself can only be fully experienced when you specifically focus on them. Sound, however, is constantly present, which allowed it to take the foreground.

CONCLUSION

ZED represents a application of material-driven design principles in creating a multimodal interaction instrument. By embracing materials as active participants in the design process, ZED demonstrates how light, sound, and touch can harmonize to provide an engaging user experience. The interaction builds a rhythm that allows users to explore and develop skills over time. Feedback from demonstrations revealed opportunities to further refine feedforward elements, enhance shadow play coherence, and experiment with additional tension arcs to enrich the narrative of the interaction. This project shows the potential of material-centered, multisensory design to create expressive interactions. This way, offering a foundation for future explorations into skill-based, immersive user experiences.

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PEER REVIEW TEAMWORK

To start, I want to say that I am very happy with this team. I observed clear roles that were necessary throughout the project, from technical to aesthetic. I speak for all of us when I say that, despite our experience in the Bachelor of Industrial Design, we found it challenging to give clear direction to our project. This made it difficult to make decisions collectively, and it took the first few weeks to get on track. After that, we began working with the same mindset. I enjoyed having discussions, connecting theories to our prototypes, and learning these concepts in a new way. We spent hours together in the workshop discussing the best choices to make.

I saw my role as overarching, I worked on the internals of the final design in combination with aesthetics and considered where sensors should be placed within the prototype. I was also able to contribute to assembling the electronics for the final design since I had knowledge of tools like TouchDesigner.

However, this process had a small twist at the end. Since I was going on a business trip, we had divided the tasks carefully on time. Due to unforeseen circumstances, the choice was made to postpone the video, which led to Dion feeling frustrated because a lot of pressure was placed on Jelmer and Dion's shoulders. I think our expectations within the group were different. After reflection, it became clear that Dion is more of a perfectionist, while I am more about the bigger picture. I really appreciate how hard Dion and Jelmer worked during the last week, and I acknowledge that they contributed more effort to the group part of the pictorial. I am ultimately happy that this peer review led to discussions, allowing us both to reflect on how we have been working together. In the end, We had an open and honest conversation, which taught us a bit more about ourselves. All in all, I am proud of how we worked as a team during the project and the final result of the design.