Through your eyes

Final Master Project by
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Image 1: Final design of “Through your eyes“. Photography by Sem Jordaan

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Motivation

Motivation & starting point

The starting point of this project was “Motion & Emotion” [22], a project developed under the coaching of Eva van der Born from Bureau Moeilijke Dingen and Stephan Wensveen from the department of Industrial Design of the from Eindhoven University of Technology. This project, “Through your Eyes”, explored a shape-changing interface that sensed users’ emotions through facial expressions and mirrored them via kinetic movement. The proposal for the final master project suggested a continuation of the technical and material elements while shifting its goal. The goal was to design a shape-changing, emotionally expressive interface that could infer users’ personality traits through physical interaction.

However, as the project developed, this focus shifted. Instead of inferring who someone is, this project explores how both humans and machines interpret social cues through subjective, non-objective lenses, revealing how meaning is constructed, misread, and projected in social interaction.

This direction was shaped by the designer’s broader design journey, which has focused on mental health and psychological experience. Across projects addressing domestic violence, panic disorder, OCD, depression, anger, and ASD (autism spectrum disorder), a recurring tension was encountered. While user needs were urgent, tangible technologies often introduced unintended psychological side effects, such as increased anxiety, dependency, or obsessive behavior. These contradictions begged the question of when technology meaningfully contributes to this domain. This reflection marked a shift away from designing technological coping tools toward designing interactions that make psychological and social processes visible.

Alongside this conceptual motivation, the project was driven by a professional ambition to develop as a creative technologist and interaction designer, bridging engineering and design through both conceptual thinking and technical making. With the aim of working at studios that build interactive installations or design social robots, these projects allowed the development of skills in computer vision, kinetic actuation, data analysis, and front-end development.

Combined with earlier projects “Merlett” [43] (Image 2) and “Motion & Emotion” [22] (Image 3), the project “Through Your Eyes” [23] (Image 4) completes a portfolio of robotic creatures exploring haptics, kinetics, and data visualization. Also contributing to a diverse array of social dynamics. Since “Merlett” was multi user with all user having the same role, “Motion & Emotion” being single user, and “Through your eyes” being multi user, each with distinct roles.

Image 2: The project “Merlett“ by Hanna Loschacoff, Isa Jansen and Stefan Hubbert [43]

Image 3: The project “Motion & Emotion“ by Hanna Loschacoff [22]

Image 4: The project “Through your eyes“ by Hanna Loschacoff [23]

Through your eyes

“Through your eyes“

“Through Your Eyes” is an interactive robot installation that explores how humans read social cues through their own interpretive “lens,” rather than objective truth. The robot observes visitors by tracking gaze and proxemics, responding to perceived behavior with kinetics. Alongside this interaction, a live visualization reveals how the robot interprets social cues, its own “lens”, making its reasoning visible in real time.

The interaction loop is as follows. When a visitor approaches, the robot categorizes their movement as either “angry” or “curious” based on speed. It then follows the direction of the visitor’s gaze, as if wondering what has captured their attention. When the visitor looks back at the robot, it reacts by shaking in surprise. After following the user’s gaze ten times, the robot suddenly rejects the visitor by turning its back, persisting longer for “angry” encounters than “curious” ones. As the visitor walks away, the robot’s base moves toward or away from them, leaving a trace of the interaction until the next person arrives.

Moreover, a live visualization reveals raw sensor data, camera and radar streams, and decision trees behind the robot’s behavior. The installation offers an embodied experience of being misunderstood, encouraging reflection on interpretive lenses, rejection, and the invisible ways we misread and judge others.

Image 11: Robot side of the prototype
Image 12: Full prototype, visualization side
Image 13: User 1 (left) sees User 2 through the eyes of the robot. User 2 interacts and is being read by the robot

Background

Background & Related works

Social cognition
Human social interaction relies on the ability to perceive, interpret, and respond to subtle social cues such as gaze, posture, proximity, and movement. In psychology, this ability is studied under social cognition, which examines how humans process social information and infer others' mental states [3, 5]. A key concept is "Theory of Mind", defined as the ability to attribute beliefs, intentions, emotions, and desires to others [25]. Humans infer internal states through verbal and nonverbal cues. Specifically, gaze is crucial as it both signals and perceives attention and intent [6, 27]. These interpretations are, however, subjective, shaped by experience, culture, and cognitive bias [44]. Although people are "chronic mind readers," research shows they consistently overestimate their accuracy in reading others [35].

Social anxiety amplifies these limitations due to the fear of negative evaluation by others [8]. Anxiety disorder is the most prevalent mental health disorder globally [34, 45]. Individuals with high social anxiety exhibit attentional, interpretation, memory, and attribution biases during social interaction [16]. Their heightened sensitivity to perceived threat leads to monitoring cues that confirm their feared outcomes [38]. This is driven by cognitive biases, which affect attention, memory, and interpretation [16]. Ambiguous social cues are therefore often attributed to negative conclusions, producing fast judgments [34].

A rejection loop can be created over time because the fear of rejection leads to avoidance, increasing perceived rejection [36]. This project makes such subjective lenses experiential by embodying elements of social anxiety in a robot, using its extreme positionality to reveal how ambiguous social cues are interpreted through bias rather than objective truth.

Social robotics
In recent years, social robots have increasingly been explored as tools by researchers to study social cognition. Instead of simulating human behavior, robots provide a controllable format through which perception, interpretation, and response can be isolated and examined [46]. Research highlights the importance of recognizing individual differences in social cognition as robots become more socially present, highlighting that social interaction can't be reduced to a single universal model [47]. Social robots are fitted to study social cognition between humans because of theories such as the "Media Equation Theory". It demonstrates that humans tend to apply the same social rules, expectations, and emotional responses to media and machines as if they were social beings [48]. Even simple systems can elicit empathy, attribution of intent, and personality projection, reinforcing the idea that interaction is constructed by both system behavior and human interpretation [9].

Art & robotics
This tendency to anthropomorphize has long been explored in art and robotics. The Heider-Simmel experiment [15] (Image 5) demonstrated that humans instinctively assign personality, motivation, and a story to abstract moving shapes. Early robotic artworks made this phenomenon experiential. Edward Ihnatowicz's "S.A.M. (Sound Activated Mobile)" (Image 6) consisted of microphones and motors orienting toward sound, yet its movement alone prompted viewers to perceive it as curious or attentive [49]. More recently, artists such as Madeline Gannon have explored how subtle body language and motion can give industrial robots an apparent emotion and intention.

In projects like "Mimus" (Image 8), industrial robots exhibit curiosity, hesitation, or distraction through timing, proximity, and orientation, producing playful yet unsettling encounters [50]. Similarly, Golan Levin's project, "Double-Taker (Snout)," (Image 7) used computer vision to create a worm-like robot that reacts with surprise to people passing by, simultaneously evoking feelings of surveillance and recognition [51]. These works demonstrate that abstraction and motion allow for a wide range of subjective interpretations, making ambiguity a powerful design material. The project presented in this report uses such insights to design with and takes inspiration from works using these phenomena. More specifically, the material and forms used in this project are

Background & Related works

abstract and use the modality of kinetics to create emotional expression, intent, and a projected personality.

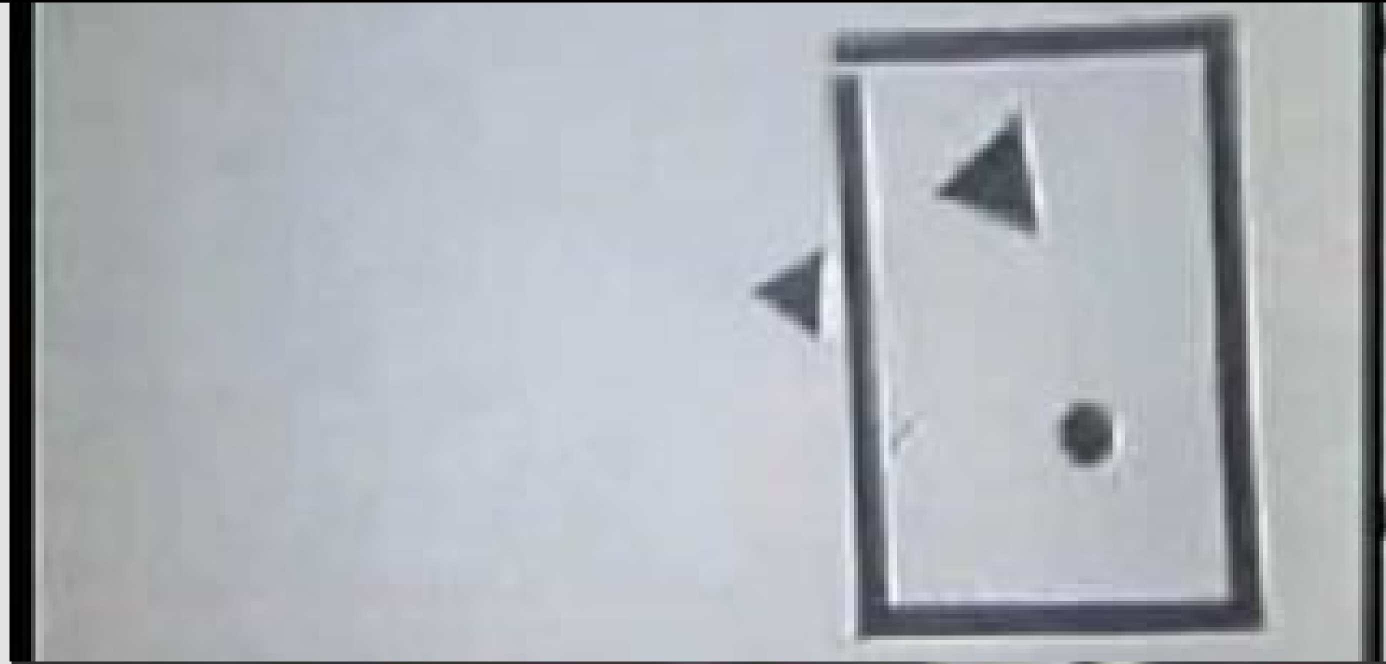
Sensing non-verbal cues

Parallel developments in academia and industry have focused on using non-verbal cues as interaction inputs. Google ATAP's (Advanced Technology and Projects group) [41] "Project Soli" introduced a miniature radar sensor capable of detecting micro-movements, hand gestures, and proxemic relationships [52]. Rather than relying on explicit commands, "Project Soli" proposes a new interaction paradigm in which devices infer user intent through attention, body orientation, and distance (Image 9). Demonstrations included ambient displays that expand weather information as a person approaches or reduce detail when a user glances while in motion [53]. These systems emphasize implicit interaction and bodily communication, reframing interfaces as socially aware rather than receiving direct commands.

In art and design research, computer vision and gaze tracking have similarly been used to explore intimacy and social feedback. Behnaz Farahi's "Caress of the Gaze" (Image 10) combines gaze tracking with a wearable, a responsive garment that changes shape when it is looked at. By using the body as an interface, the project explores themes of vulnerability, attention, and power in social looking [39]. Such works highlight how sensing nonverbal cues can externalize invisible social dynamics, making perception itself tangible.

Interaction design

Interaction design theory provides further grounding for these approaches. Specifically, embodied interaction highlights that our meaning of the world arises through bodily engagement with systems, which in turn are embedded in social and cultural contexts [33]. Interactive and immersive installations leverage this by positioning the audience as active participants whose actions shape the work in real time. In such installations, the distinction between artwork, performer, and audience becomes blurred [37].



Images 5: Screenshot of video of Heider-Simmel experiment [15]
Image 6: Screenshot of video of S.A.M. (Sound Activated Mobile) by Edward Ihnatowicz [49]
Image 7: "Double-Taker (Snout)" by Golan Levi [51]

Background & Related works

Design research on such interactive installations identified which elements can be used to maintain engagement: clarity, perceived control, adaptability, exploration, and surprise [7]. Additionally, discomfort and ambiguity can become productive when balanced carefully, transforming uncertainty into reflection rather than disengagement [10].

Social robotics: gaze tracking and proxemics

Within social robotics, advances in multimodal human-robot interaction (HRI) have enabled robots to perceive facial expressions, gaze, gestures, and affect using computer vision [32]. Gaze tracking, in particular, is studied as a clue into human intent, task difficulty, and attention [54]. Robots use gaze to establish joint attention, verify object references, and signal social presence [55]. Proxemics research similarly investigates how robots should approach humans while respecting social norms, interpersonal distance, and cultural expectations [28, 29].

Explainable robotics

Simultaneously, the complexity of robotic systems begs questions about transparency, trust, and explainability. When humans interact with social robots, they automatically create mental models to predict robot behavior, which may lead to under- or over trusting them [14]. Specifically, in the healthcare domain, research proposes AI and robotics' reasoning to be made visible [30, 31].

"Through your Eyes" is positioned at the intersection of psychology, social robotics, interaction design, and critical art. The project intentionally embodies bias; its live visualization exposes the robot's reasoning. By highlighting interpretive ambiguity, it encourages users to reflect on both how machines see them and how they see others.

Image 8: Screenshot of video of "Mimus" by Madeline Gannon [50]
Image 9: Screenshot of video of "Project Soli" by Google ATAP [52]
Image 10: "Caress of Gaze" by Behnaz Farahi [39]

Methodology

Methodology

This project follows a Research through Design approach [58], using the making of the installation and the installation itself as a means to generate knowledge. Knowledge emerged through iterative making, user studies, exhibitions, and continuous reflection during the design process. Public exhibitions (Makers Days, Dutch Design Week, Demo Day) functioned as informal research contexts, combining autoethnography [59] with observations of how visitors encountered, interpreted, and emotionally responded to the robot. These exhibitions enabled the project to step outside the industrial design department's academic "bubble," gathering more diverse perspectives and observing instinctive, automatic reactions. These participants were not related to the researcher, feeling less pressure to provide pleasing or positive responses. Autoethnography [59] was the most suitable methodology in these contexts due to the short interaction times and it being a public, non-anonymized setting, where other visitors could hear participants' answers.

Although the project "Through your eyes" was not presented at Dutch Design Week, the project "Merlett" was exhibited and used to generate interaction design guidelines (see "Iteration 2"). In addition to exhibitions, four user studies were conducted, collecting qualitative data [60]. These are outlined in Table 1.

Across the design process, methods included sketching, acting, and choreographing interaction loops; literature review; aesthetic benchmarking and 3D modeling; and hardware development, front-end development, and data visualization. Visual logs of the process and reflections were used to document the design process. These methods prioritize experiential, critical, and reflective design.

User study #	Goal and motivation	Demographic	Prototype
1	Identify improvements, perception, experience. Since the prototype had not yet been tested outside of the department of Industrial Design	3 strangers at the Built Environment department of the Eindhoven University of Technology	Improved "Motion & Emotion" prototype
2	Aplied participatory design research methods [33] to explore alternative data visualizations and their experiential qualities. This study addressed the designer's limited experience with front-end development and data visualization, as well as the bias of assuming the visualization was intuitive. A user generative method [33] was supported by providing a draft visualization to stimulate ideas and experiential feedback.	4 Master Industrial Design students at the Eindhoven University of Technology, all without prior knowledge of the project	Visualization
3	Expert interviews with professionals from the fields of: social robotics, art and technology, and critical design research. These provided conceptual, industry, and interaction design perspectives, evaluating the project's potential for psychoeducation and critical reflection.	The experts included: a CTO of a social robotics company (LuxAI) specialized in education of children with ASD (autism spectrum disorder); developer engineer of interactive art installations (Studio Drift) and a PhD candidate critical design researcher (IT University of Copenhagen)	Visualization + Robot
4	Experiencing the prototype to generate insights into overall perception, limitations, and triggered reflections.	5 participants recruited from the personal network of the student, without prior knowledge of the project	Visualization + Robot

Table 1: An overview of the four user studies conducted, their goal and motivation, demographic and the prototype it concerned

Iteration 1

Iteration 1

The Final Master Project began with the ambition to design a shape-changing interface capable of inferring user personality traits through physical interaction, building upon the project “Motion & Emotion” [23]. The initial research question asked: **How can a shape-changing interface interact with users to infer personality characteristics, grounded in psychological experiments and partially sensed through Emotional AI?**

Early research explored technological approaches to personality detection. A literature review identified data sources such as social media behavior, writing styles, eye-tracking data, image preferences, and profile pictures [6, 9, 19, 22] (see Image 14). While technical feasibility appeared promising in these domains, no approaches addressed personality inference through physical, non-verbal interaction.

Following a meeting with Associate Professor and Head of the TU/e Social Robotics Lab, Emilia Barakova, key conceptual challenges emerged. Personality was identified as dynamic, contextual, and situated, requiring the specification of a trait, user group, and context. Building further on the “Motion & Emotion” robot, introduced a problematic perceptual loop: the robot both measured personality and expressed its own behavior, influencing user behavior. This raised questions about whether a neutral camera could perform similar analyses. Additionally, few psychological experiments were adaptable to physical, non-verbal interaction, resulting in a conceptual dead end and a pivot toward making invisible interpersonal psychological processes visible (see Iteration 3).

In parallel with this conceptual shift, the “Motion & Emotion” prototype was refined and exhibited at Maker Days [62]. To make it ready for a two day exhibition, user studies were done to evaluate the interaction experience, limitations, and improvement priorities.

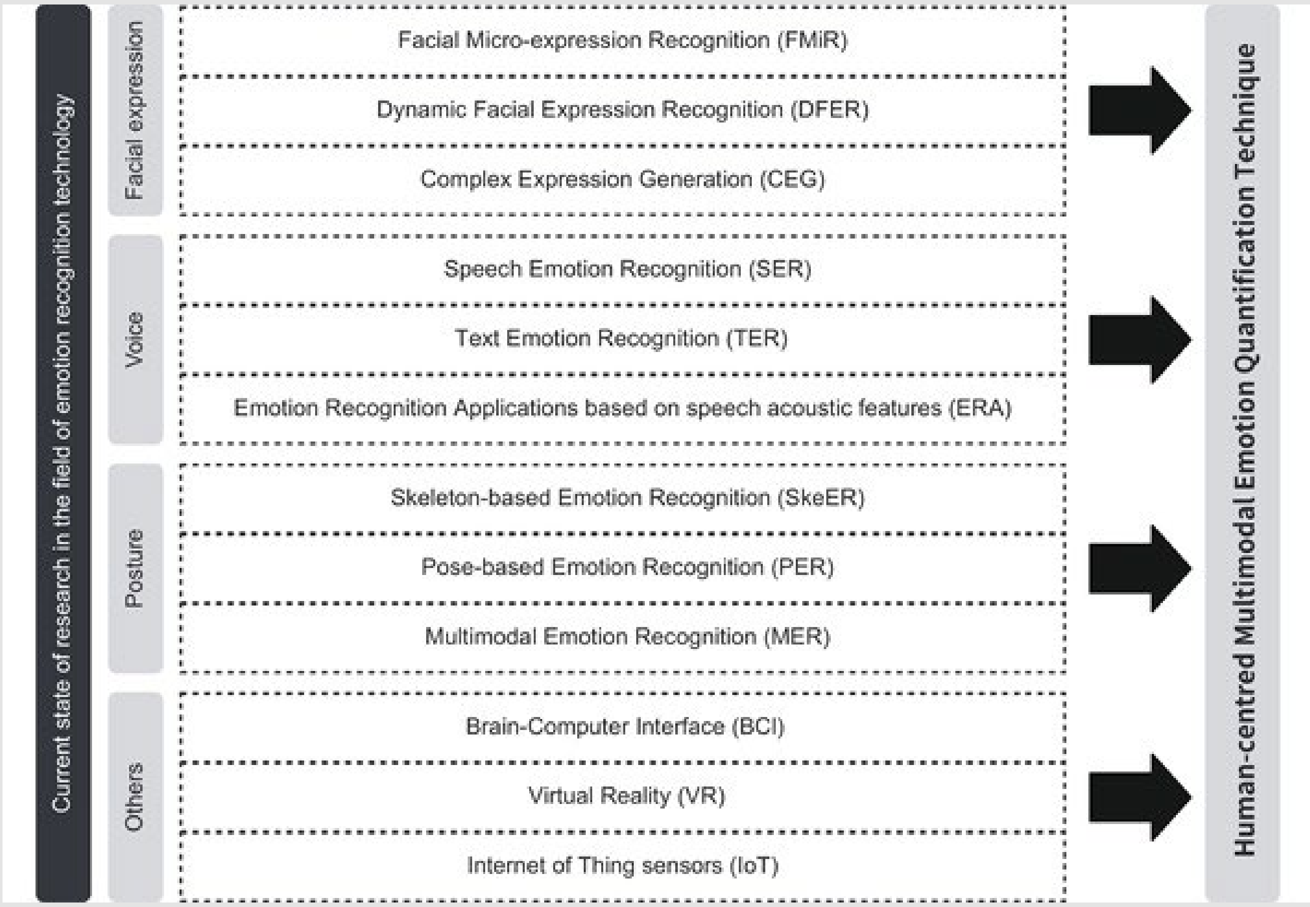


Image 14: Diverse techniques for emotion recognition technology [19]

User Study #1

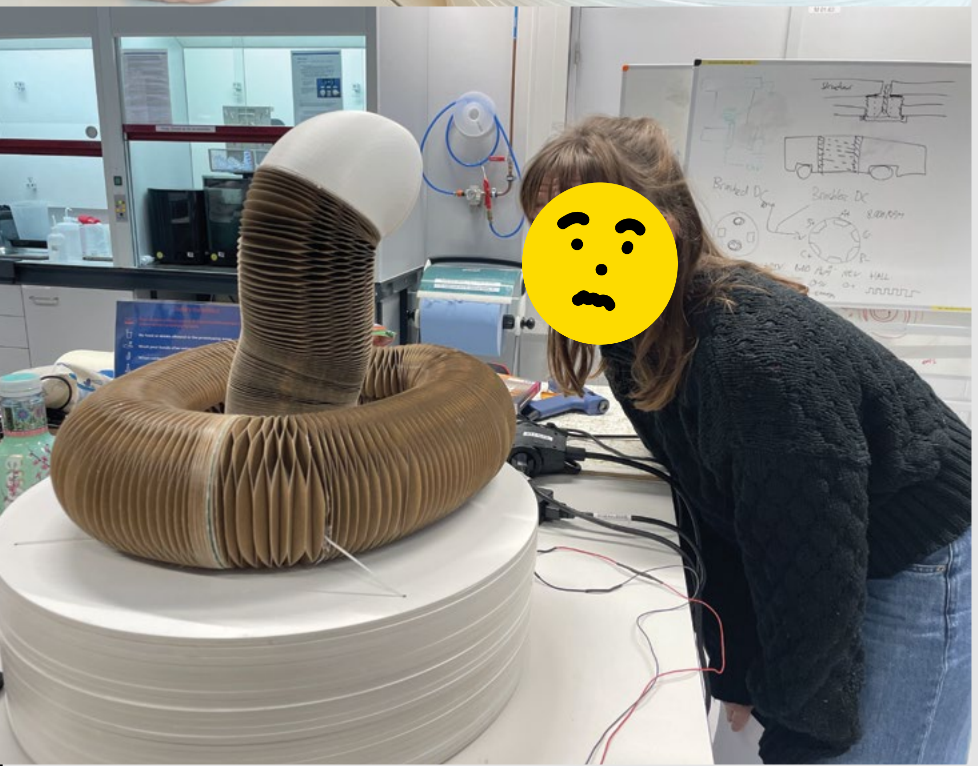


Image 15: User study #1, testing with strangers at Built Environment faculty of Eindhoven University of Technology
Image 16: User study #1, testing with a stranger

Demographics and recruitment
The participants were strangers at the Eindhoven University of Technology of the Built Environment Department. To recruit participants, the researcher wheeled the prototype to the respective building and asked students working if they were open to a user study. The procedure is described in Appendix A.

Findings
Using a thematic analysis, the core themes of the user study were defined as the following:
Theme #1: Emotional projection
The robot functioned as a “projective mirror,” revealing participants’ inner psychology rather than simply displaying emotions. P1’s experience of feeling dominant and self-blaming when the robot appeared angry demonstrates how the robot can act as a mirror of underlying patterns of guilt and anxiety. When emotions were misread or amplified, users questioned the gap between their internal states and external presentation, considering how others might perceive them.
Theme #2: Perception
Participants struggled to establish comfortable relationships with the robot, describing feelings of avoidance, confusion, and social hierarchy. The robot was described as “scared,” “awkward,” and “unapproachable”. For P1, this emotional distance generated guilt, and for P2 & P3, frustration.
Theme #3 Emotional surveillance
P2 & P3 pointed out that the emotional mirroring of the robot produced contradictory feelings: both surprise and engagement when recognized, but also feelings of being mocked by it. The exaggeration of the participants’ emotions felt simultaneously validating and threatening, empathizing anxieties about emotional surveillance and authenticity.
Theme #4: Embodied communication
Participants highlighted technical limitations that could be improved: a disconnect between head and body movements, insufficient feedback during processing delays, and base movements that were too subtle to read clearly. Participants desired coherent embodied expression and faster reactions between sensing and actuation.
Theme #5: Applications
P1 suggested applications around emotional support during conflict mediation and family therapy, by taking into account and making visible the emotions of all present. P2 & P3 suggested educational applications such as emotion identification for autism spectrum, and behavior reflection.

The following section describes the process of addressing the improvement points highlighted during User Study #1 and those noticed by the designer.

A primary prototype pain point was the slow Google Colab setup and high actuation latency. To bypass Colab's ephemeral library reinstalls, dependencies were stored on Google Drive, significantly cutting setup time. Latency was mitigated by lowering image quality to reduce processing load and checking the emotion predictions only when the servo motor stopped moving.

Key challenges included inconsistent face detection and handling mixed data types, which required careful preprocessing and validation before analysis. However due to time constraints these technical goals were not meet only being able to log the detected emotion, the confidence of the prediction and the date and time stamp.

```python
import pandas as pd

df = pd.DataFrame(emotion_log)
df.to_csv("emotion_log.csv", index=False)
```

```python
print("Saved log to emotion_log.csv")
print(df.head())
print(df.tail())
```

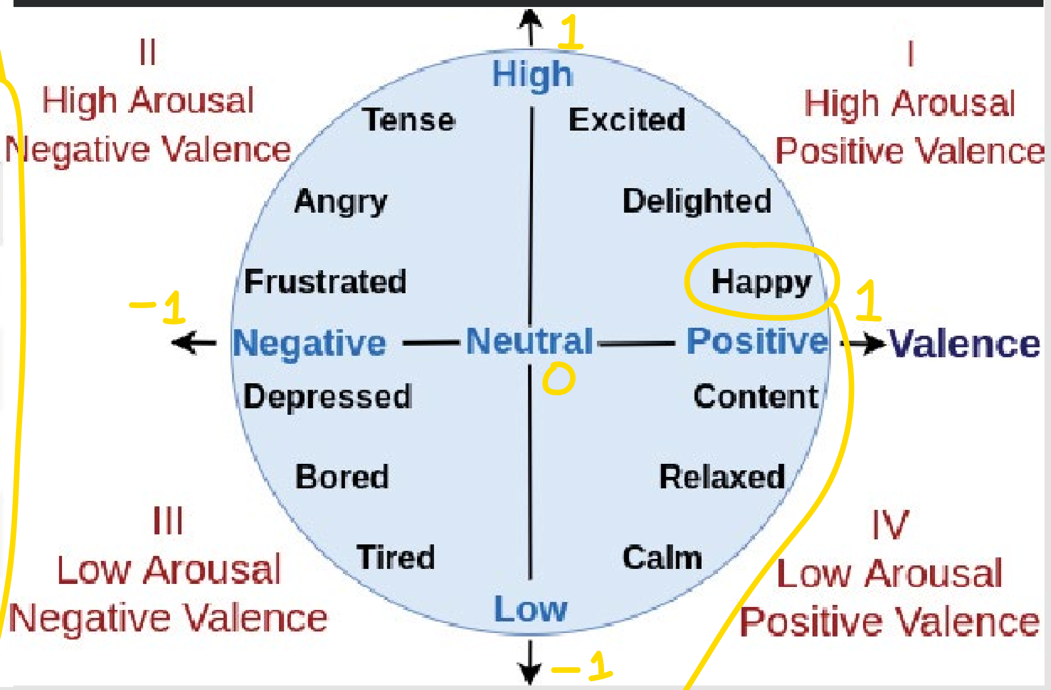
```
Saved log to emotion_log.csv
             timestamp emotion  confidence
0  2025-07-24 17:58:55    fear    0.262477
1  2025-07-24 17:59:00     sad    0.337727
2  2025-07-24 17:59:06    fear    0.269556
3  2025-07-24 17:59:11     sad    0.286773
4  2025-07-24 17:59:15    fear    0.297777
Loaded emotion log from emotion_log.csv:
```

	Timestamp	Emotion	Confidence
0	2025-09-23 13:15:15	sad	0.441464
1	2025-09-23 13:15:20	happy	0.870965
2	2025-09-23 13:15:28	fear	0.379508
3	2025-09-23 13:15:31	sad	0.387807
4	2025-09-23 13:15:34	sad	0.527587
5	2025-09-23 13:15:37	sad	0.360716

```python
df['prev_emotion'] = df['emotion'].shift(1)
df['next_emotion'] = df['emotion']


transition_counts = (
    df_transitions
    .groupby(['prev_emotion', 'next_emotion'])
    .size()
    .reset_index(name='count')
)

transition_probs = (
    transition_counts
    .groupby('prev_emotion', group_keys=False)
    .apply(lambda x: x.assign(probability=x['count'] / x['count'].sum()))
)
```



Furthermore, the pandas library enabled data analytics by saving emotion predictions, confidence levels, and timestamps into a tabular format. This allowed for possibility of insights into common emotion sequences and interaction durations.

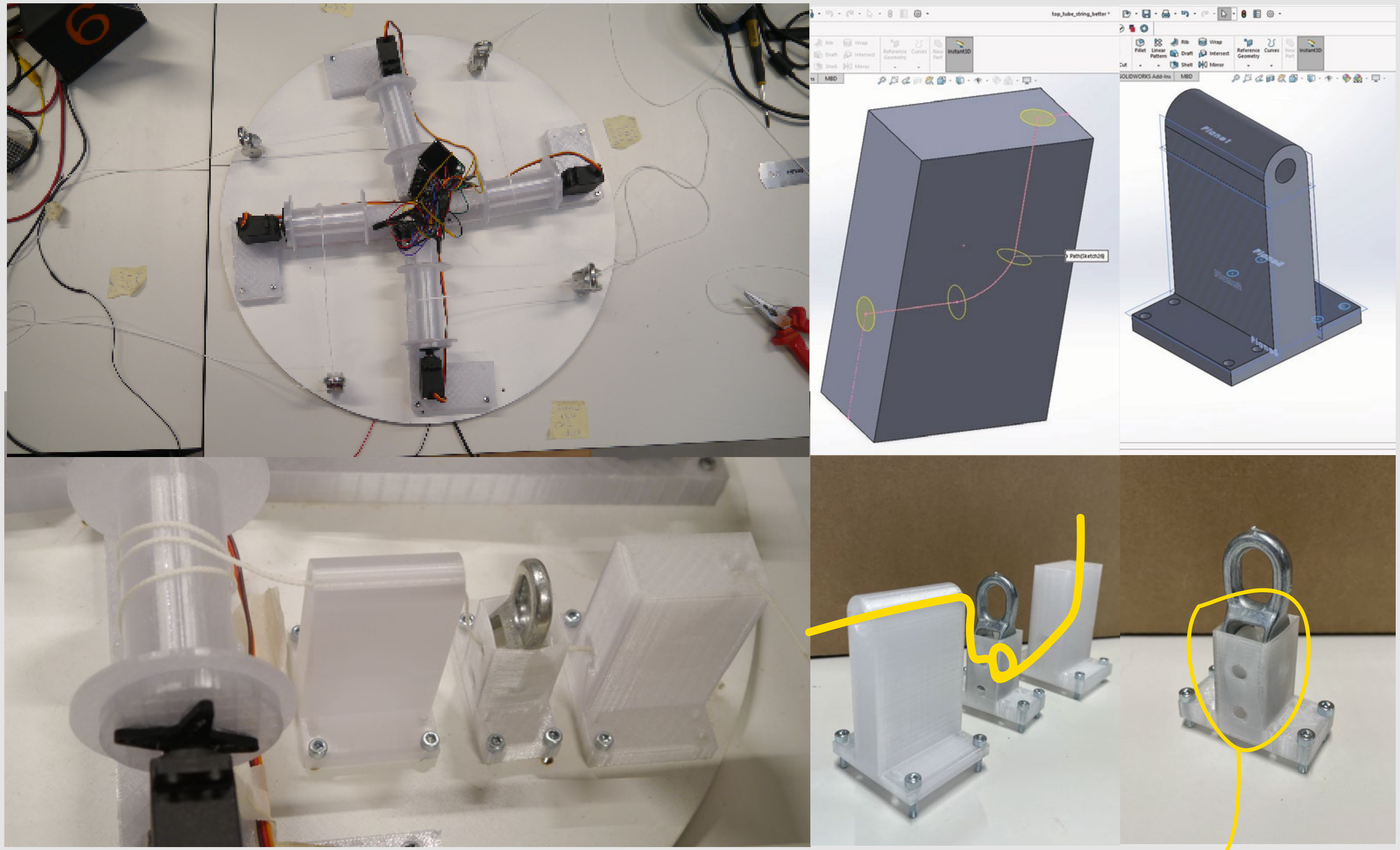
By logging sequential emotions, the goal was to explore which emotions were most likely to follow others and how confidence varied depending on emotional shifts. Emotions were mapped onto a valence-arousal model [4] for quantitative analysis, representing qualitative emotions as two-dimensional coordinates (ex: happy as (1,1)). This enabled quantitative analysis of emotional patterns, transitions, and confidence changes over time.

During the Demo Day of “Motion & Emotion,” a recurring issue was the instability of the robot’s neck attachment, causing the head to tilt backward and the camera to miss the user.

This was partly caused by cable interference pushing the neck upward. A redesigned base with cable slots and a threaded bolt improved stability.

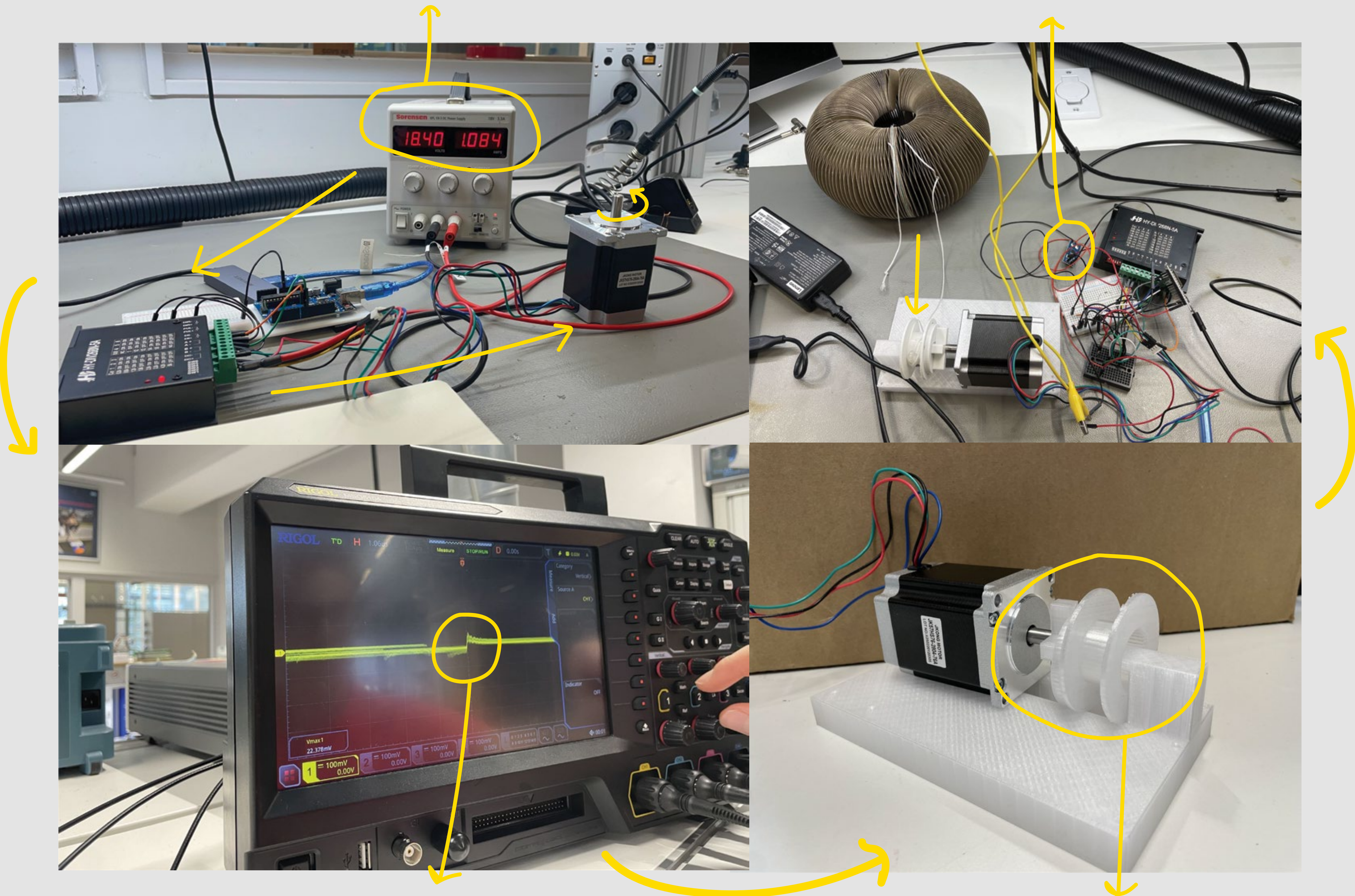
With support from mechanical engineer Edwin van den Einden (TU/e Innovation Space), a stainless-steel horizontal attachment was developed, improving weight distribution. Additionally, the actuation mechanism showed limitations: strings catching between pulleys, slipping off the bobbin, and pulley detachment under tension.

With the help of Assistant Professor Anke van Oosterhout, new components were ideated. Using SolidWorks, three new components were 3D modeled. These restrict the movement freedom of the string to ensure it stays in the bobbin area and the rotation area of the pulley. Additionally, a casing of the pulley ensured its sturdy attachment to the base.



To increase the sturdiness of the system, PET 3D printing filament and threaded bolts were used. Due to the thin walls of the pulley casing and small margins, the pulley can be clamped in place.

A NEMA23 stepper motor [61] with TB6600 driver [62] replaced the servos to increase force and expressivity, but required 18V/2.5A, incompatible with the 5V supply.



Current sensing (ACS724) [63] failed due to a 2.8A draw. Despite shunt and oscilator monitoring, motor size and sensing issues prevented integration, so the approach was abandoned.

Makers Days

The improved “Motion & Emotion” prototype was presented at Maker Days Eindhoven. Maker Days [64] is a festival showcasing innovation in the combination of creativity and technology. The showcase had the goal of gathering insights into the perception, interaction evaluation, and potential applications of the robot.

Findings

The Maker Days study identified possible usability and accessibility improvements. Visitors wanted clearer feedback for when sensing or processing was happening, proximity cues, and faster, smoother movements. Additionally, suggesting more reactive interactions with minimal delay between sensing and actuation. The robot’s personality was perceived as positive, conflict avoidant, and approachable, requiring a building of trust similar to human-animal dynamics. Users were very optimistic about the potential of emotional sensing technology.

Suggested applications focused on accessibility: supporting special needs populations, senior companionship, autism spectrum emotional education, and adaptive interfaces, such as automatically adjusting car controls based on detected anger or regulating procedures via pain sensing.

Researcher’s reflection

From the researcher’s observations, visitors tested the system using the following sequence of emotions: happy, sad, and then angry expressions. This suggests limited intuitiveness when expressing more complex emotions. In the future, indications of the camera’s field-of-view would be helpful, and base movements should be larger and smoother. The Maker Days audience, mainly technology enthusiasts, gave overwhelmingly positive feedback and strong trust in technology, often viewing it as a solution to all global challenges. This contrasted with User Study #1 at Eindhoven University of Technology, where students were more critical, identifying potential misuses such as commercial manipulation.

Image 17, 18 & 19: Exhibiting an improved prototype of “Motion & Emotion“ at Maker Days

Iteration 2

Dutch Design Week autoethnography

During Dutch Design Week 2025 [65], the project “Merlett“ was presented at the 4TU exhibition “Less Hope More Action“ [66]. This project was created during the course “Interactive Materiality“ at Eindhoven University of Technology together with Isa Jansen and Stefan Hubbert. The project is described as “Merlett transforms an industrial tube into an uncanny, shape-changing entity that evokes empathy through vulnerability. By responding to touch with sound and movement, this “struggling” creature challenges human-machine relationships, prompting visitors to reflect on their instinctive responses to care and unease.“ [43].

This project is included in this report because the autoethnography research conducted during this exhibition resulted in interaction design guidelines, which were used as a blueprint for the project “Through your eyes“.
The following pages describe the research methods used, the key findings, and interaction design guidelines derived from them.

Image 20: The designer in front of the stand of “Merlett“ at Dutch Design Week 2025

Research methods

Throughout the week, the researcher used the methods outlined below to collect experiential knowledge of visitors and make observations. Below are descriptions and reflections of these methods.

Directly prompting visitors yields specific insights on experiences and ideas, but may filter negative feedback to avoid offending the designer.

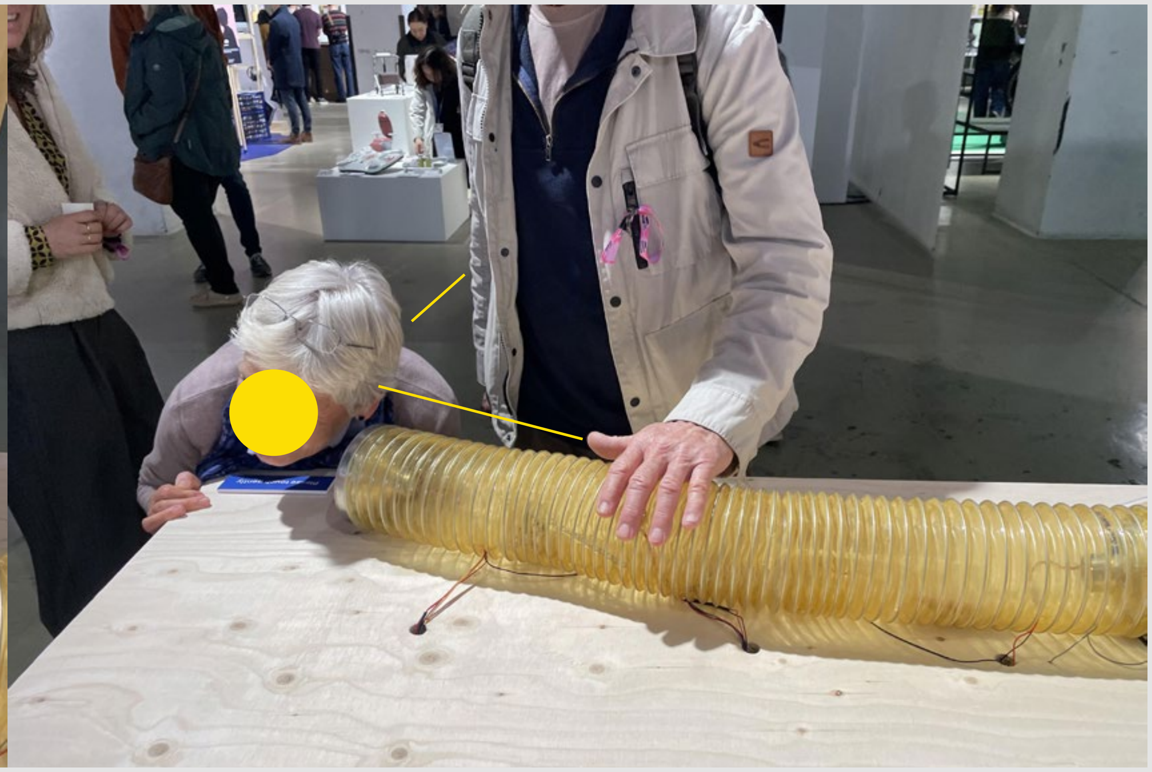
By observing visitors without direct prompting, the researcher captures natural interaction, social dynamics, and spontaneous comments. Advantage: broad, unbiased feedback. Disadvantage: the designer's presence may influence or inhibit unfiltered responses.

Observing anonymously from a distance captures unfiltered visitor reactions, but limits the researcher's ability to inquire further or clarify misunderstood comments.

Image 21: Research method of direct prompting visitors
Image 22: Research method of observing while visible as designer
Image 23: Research method of observing while anonymized

Interaction dynamics

Through out the exhibition, the researcher observed different interaction dynamics between visitors. Below are descriptions and reflections of these interaction dynamics.



In this dynamic, one person interacts with the prototype while others observe, then transition from hesitant observers to active participants, illustrating “social permission.” In public settings, visitors often first ask, “What will it do?”, seeking a demonstration to set expectations and avoid potential embarrassment when engaging with abstract objects.

Strangers or friends exploring the prototype negotiate shared space, often nonverbally, revealing its social stimulation potential. When the designer is absent, the ice-breaking question is usually about the prototype’s function.

Two familiar visitors explored the prototype, using sound and touch for cooperative play, inviting each other, enabling universal, simple participation.

Image 24: Interaction dynamic of one person interacting and the rest observing
Image 25: Interaction dynamic of multiple strangers interacting with prototype
Image 26: Interaction dynamic of two people cooperating during interaction

Interaction design guidelines

From the autoethnography research and designerly reflections made about exhibiting “Merlett“ at Dutch Design Week 2025, interaction design guidelines were defined.
These guidelines were used as a blueprint for the design of this installation.

#1 The artifact was perceived equally as cute and terrifying. This dual perception suggests that interaction design doesn’t need to be pleasant to engage audiences. The “distressing” movement and “struggling” sounds triggered deep empathy, with several visitors expressing a maternal instinct or a desire to “calm it down.” **Negative characteristics can be used for an emotional connection between the visitor and the artifact.**

#2 When a visitor was interacting with the prototype, the capacitive touch malfunctioned, causing “Merlett“ to move without being touched. This visitor believed they had special powers and relation with the creature even after the technical impossibility was explained. When the robot failed to respond consistently, visitors perceived it as having agency and free will. **Technical malfunction can add an element of unpredictability, which fosters a sense of agency of the prototype.**

#3 Several health care providers pointed out that “Merlett” flips the typical care robot dynamic. Usually, robots care for humans, but here the human cares for the robot. **Giving a sense of purpose and agency to the user can be essential for demographics that have little agency over their life.**

#4 Finding the right balance between predictability and complexity is a delicate challenge. During the initial moments of interaction with “Merlett,” if visitors perceive that their touch has no immediate effect, they quickly become disengaged. On the other hand, if the response is too consistent or lacks layered depth, the artifact becomes predictable, and visitors lose interest. **The interaction must be reactive while offering enough complexity and varied feedback to ensure users feel their input has a meaningful, evolving effect.**

#5 The artifact acted as a social ice breaker by bringing strangers together for a shared goal of comforting the creature. **Create an interaction that requires multiple people to function.**

Some of these interaction guidelines were later used to conceptualize the “Through your eyes“ installation and informed the aesthetic and experiential qualities defined. The following page describes the conceptualization process and framing of the project, which was heavily inspired by the experiences at Dutch Design Week.

Iteration 3

Conceptualization

Besides the interaction guidelines defined during Dutch Design Week, a mapping of the ideas and project directions ideated so far was made (See Appendix I). Additionally, the refinement of the designer's vision was done by selecting four current favorite projects and distilling the respective designer's vision, contribution, experiential qualities, and manifesto. From this, an analysis of what the designer resonated with and what they did not was conducted, leading to the definition of their vision and the experiential and aesthetic qualities desired for this project.
These qualities are illustrated below. A full size Image 27 can be found in Appendix E.
Experiential qualities: Playful, thought-provoking, interactive, analytical, embodied, visual, curiosity, discomfort, vulnerability, estrangement (making the familiar unfamiliar), consciously doing the unconscious.
Aesthetic qualities: Semi-transparent, minimalistic, control-room, abstract.
Ideation
The mapped ideas were grouped into the following categories: transparency of a machine, data visualization as a reflection tool, rejection by a robot, speculative social robots, and academic research (see Appendix X for an overview). Each category explored different ways of making invisible processes of perception and interpretation visible, creating opportunities for reflection on social dynamics.

While working with the radar sensor and attempting to attribute meaning to proxemics data, inspiration for the final concept emerged. For example, walking slowly toward someone can signal nervousness or curiosity, while walking quickly can indicate enthusiasm or anger. However, these interpretations depend entirely on the person observing the behavior. This interpretive lens is shaped by insecurities, culture, context, combinations of social cues, individual expression, and sensitivity to rejection. This realization highlighted how much of our social understanding is subjective rather than objective. This technical limitation, therefore, became a conceptual inspiration for the project.

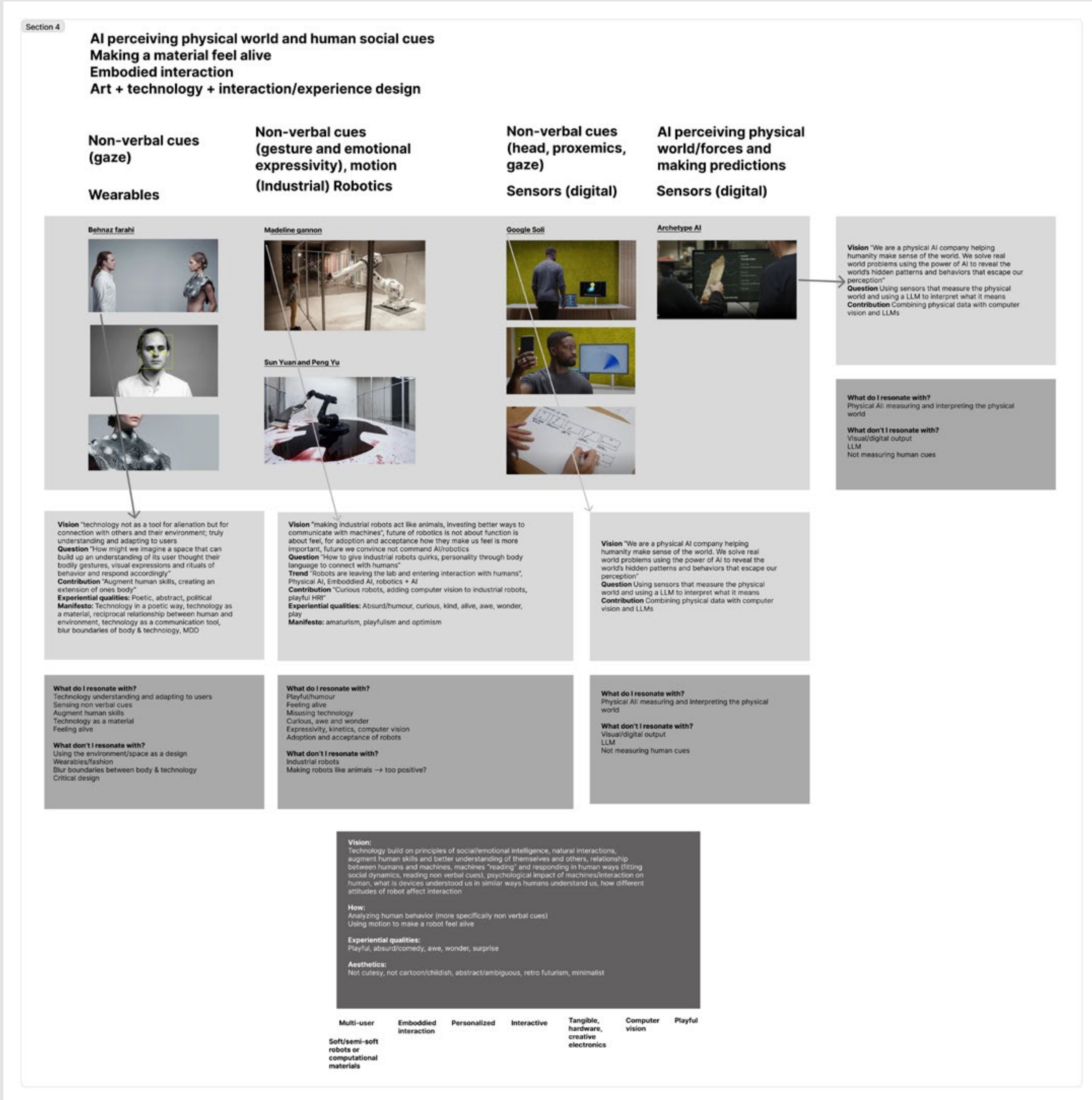


Image 27: Analysis of projects based on their vision, manifesto, questions explored and experiential qualities. Full size in Appendix E

Design process: Iteration 3

Concept

As introduced in the section "Through Your Eyes", this project showcases how everyone has their own "lens" through which they interpret the social cues of others. As introduced in the section "Background", this "lens" is used to make assumptions about others' intentions and inner states. These interpretations are influenced by cognitive biases. These biases can lead to misreading or overanalyzing social situations.

Consequently, this miscommunication can have significant effects on social interactions, creating misunderstandings and feelings of rejection which may not reflect reality [5, 38].

The installation has two sides: a robot and a live visualization side. The robot mirrors human misreadings of social cues, while the visualization showcases how the interpretations are made. Through this experiential, playful, and provocative installation, the project aims to trigger visitors to reflect on their own interpretive lens. The full interaction loop is visualized in the section "Interaction Loop."

The installation has multiple perspectives: a first person experience, a data perspective, and the perspective of observing others interacting. Rather than watching or analyzing, visitors feel misunderstood by the robot. This creates a double mirror, where visitors feel misread while recognizing their own patterns of misreading others. The emotional arc of the experience moves from curiosity to discomfort, rejection, and reflection.

Furthermore, the project uses estrangement by making familiar mechanisms unfamiliar. Design can function as an inkblot test, allowing users to project their inner states and worries onto the system [67]. This estrangement is especially integrated in how machines are often perceived as neutral and accurate, while this installation makes their subjectivity explicit, making it hard to trust. The robot's interpretive lens borrows traits from social anxiety, acting as an exaggerated model of social cognition. It does so through quick judgments, negative assumptions, and the rejection loop. The final concept, developed through the making process, with design decisions based on user study findings, is outlined in the following sections on "Sensing", "Interaction loop", "Visualization", and "Stand".

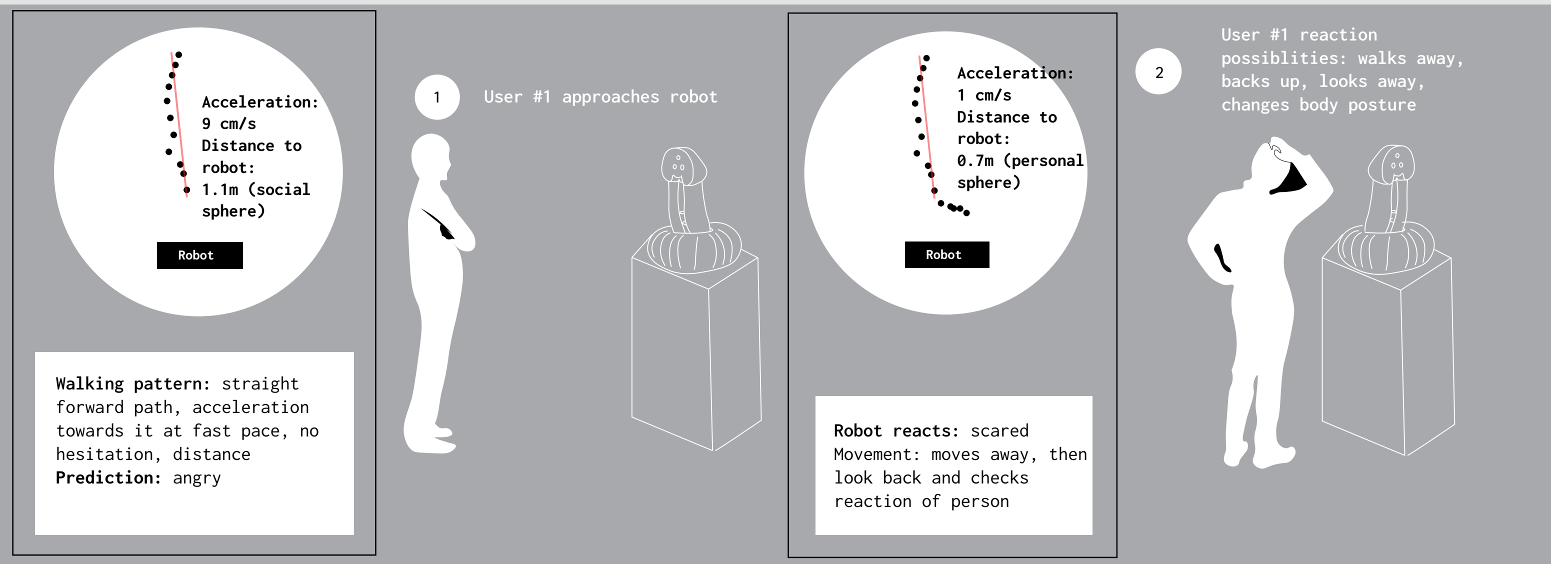


Image 28: A concept idea with the radar sensor. The robot is avoidant and easily scared and turns away when the person approaches. Possibly elicitting a feeling of rejection.

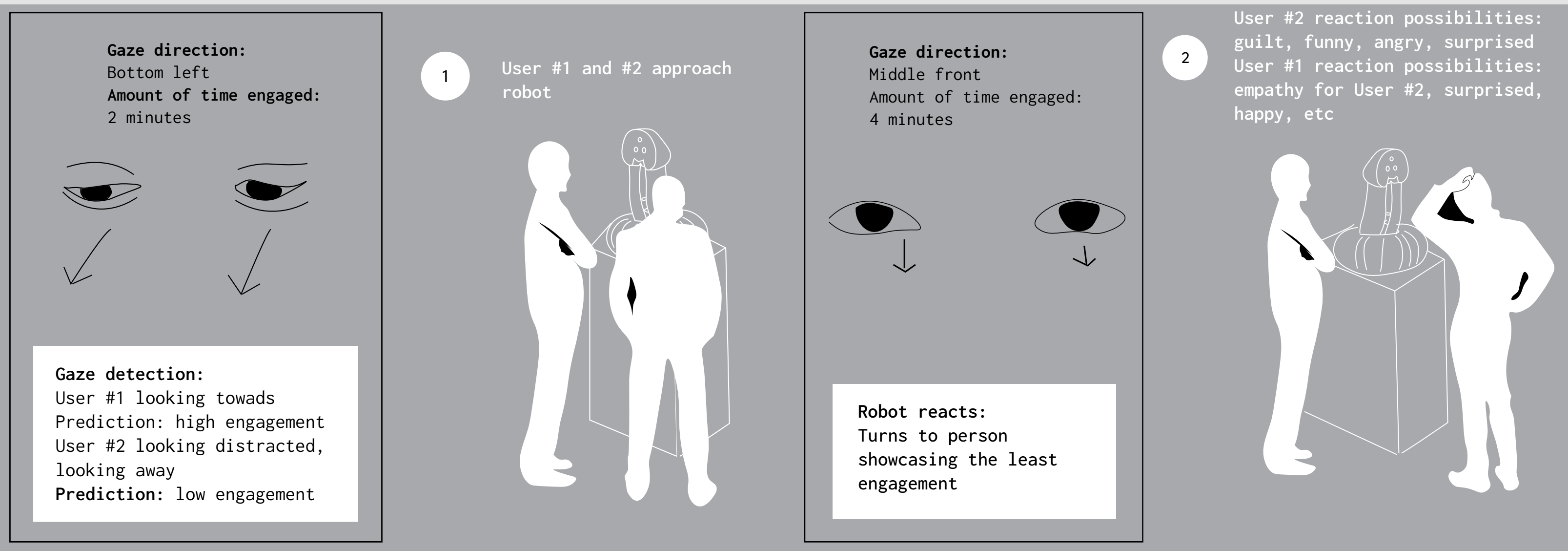


Image 29: A concept idea with the gaze sensor. The robot "looks" at the person giving it the least attention. Possibly eliciting a feeling of guilt.

Sensing: Radar

Sensing: Radar

Using the radar sensor “Ai-Thinker RD-03D 24 GHz” [70] , the non-verbal cue of proxemics was tracked. The sensor detects the x and y positions of up to three people simultaneously and functions through most materials except metal. This enabled the system to perceive distance, movement direction, and speed of approach or retreat, which are central to interpreting social intent.

Earlier prototypes, including “Motion & Emotion”, relied on an ultrasonic sensor (HC-SR04) to measure distance [68]. While sufficient for single-user interaction, this approach proved limited due to its narrow sensing angle, sensitivity to environmental conditions, and inability to detect movement dynamics. Radar sensing was therefore adopted for its wider field of view, robustness, multi-user tracking, and capacity to detect motion characteristics relevant to social interpretation.

Integrating the radar sensor introduced technical challenges related to data stability and synchronization. Initial measurements were inconsistent, with fluctuating values even when users were stationary. Through troubleshooting with a software engineer (Eden Chiang from the TU/e) and by adapting an existing implementation, data parsing was improved.

This was done using a state-machine approach that reliably identified valid data frames before interpretation, ensuring consistent positional tracking suitable for real-time interaction.

Rather than pursuing maximal sensing accuracy, the system prioritizes stability and responsiveness, aligning technical constraints with the project’s conceptual focus on subjective interpretation rather than objective measurement.

The following pages showcase the development and design decisions of the proxemics tracking.

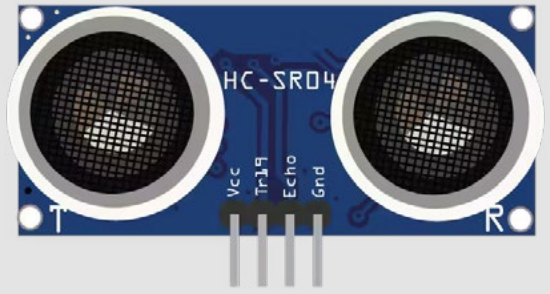


Image 30: The ultrasonic sensor used in the “Motion & Emotion“ prototype [68]

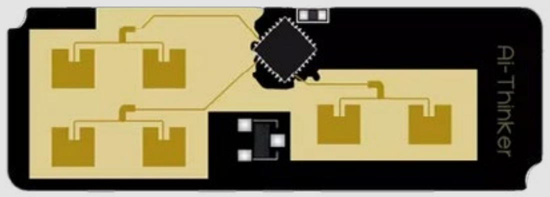
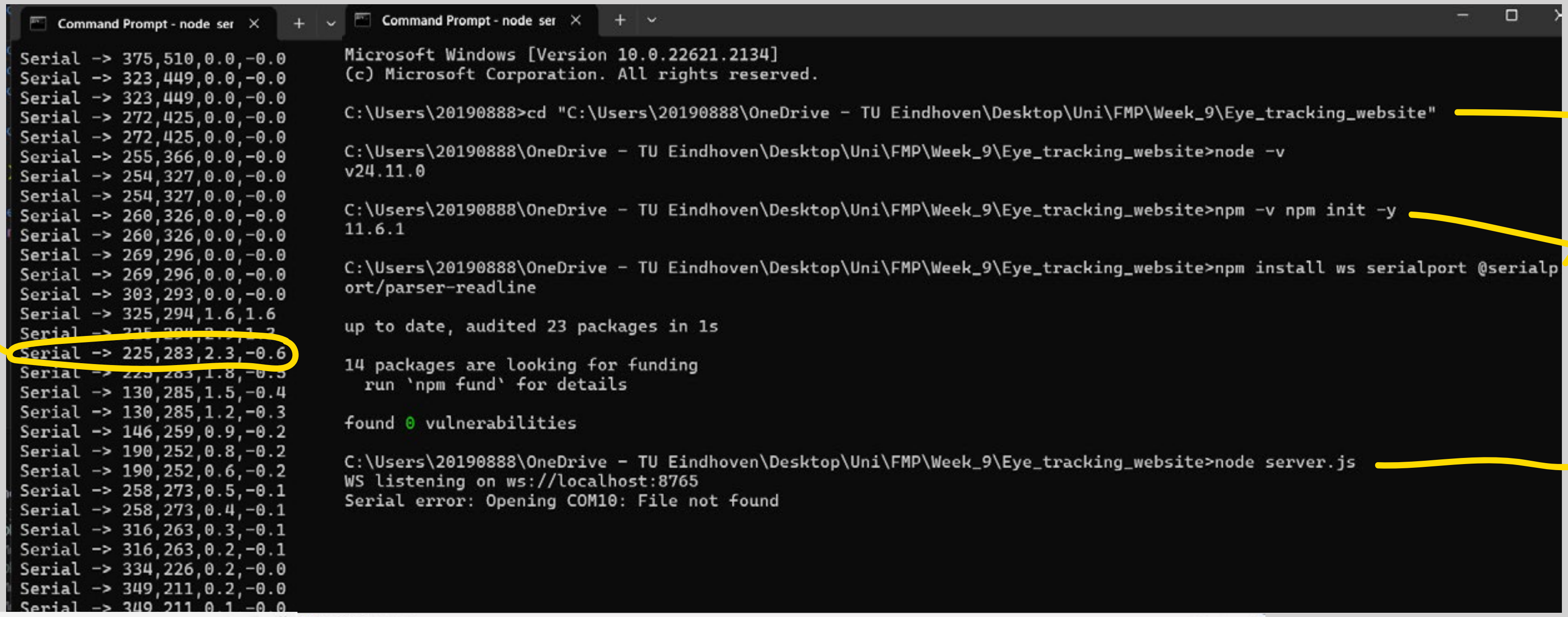


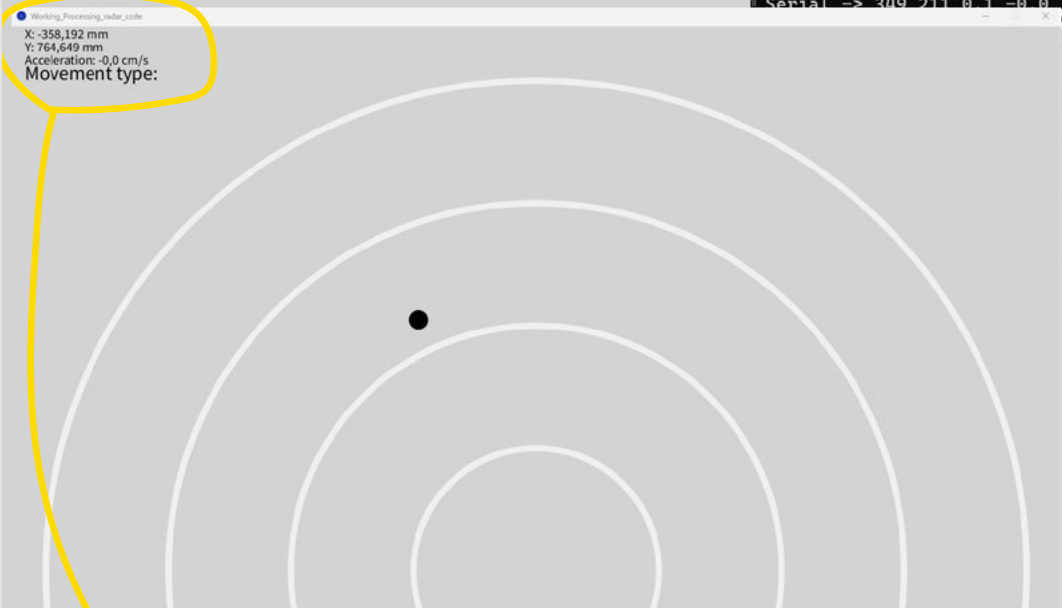
Image 31: The radar sensor used in the “Through your Eyes“ prototype [70]

Raw data from radar sensor: x, y, speed, acceleration. A negative number in acceleration means the person is moving away from the radar. The radar sensor is quite sensitive to electrical noise; filtering of values is needed, ignoring outliers, and adding thresholds. A balance between accuracy and responsiveness was iterated on.



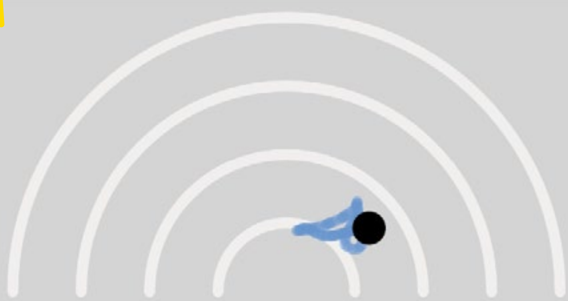
To set up the serial communication between the radar and the website, the following command prompts are executed:

1. Navigates to the project directory and verifies Node.js/npm installation
2. Initializes npm project and installs WebSocket and SerialPort libraries for radar-to-server communication
3. Launches a server connecting radar serial data to a webpage via WebSocket



Behavior Analysis
Straightness Score: 1.67
Direction Changes: -0.21
Speed Consistency: 6.01
Analysis Count: 3

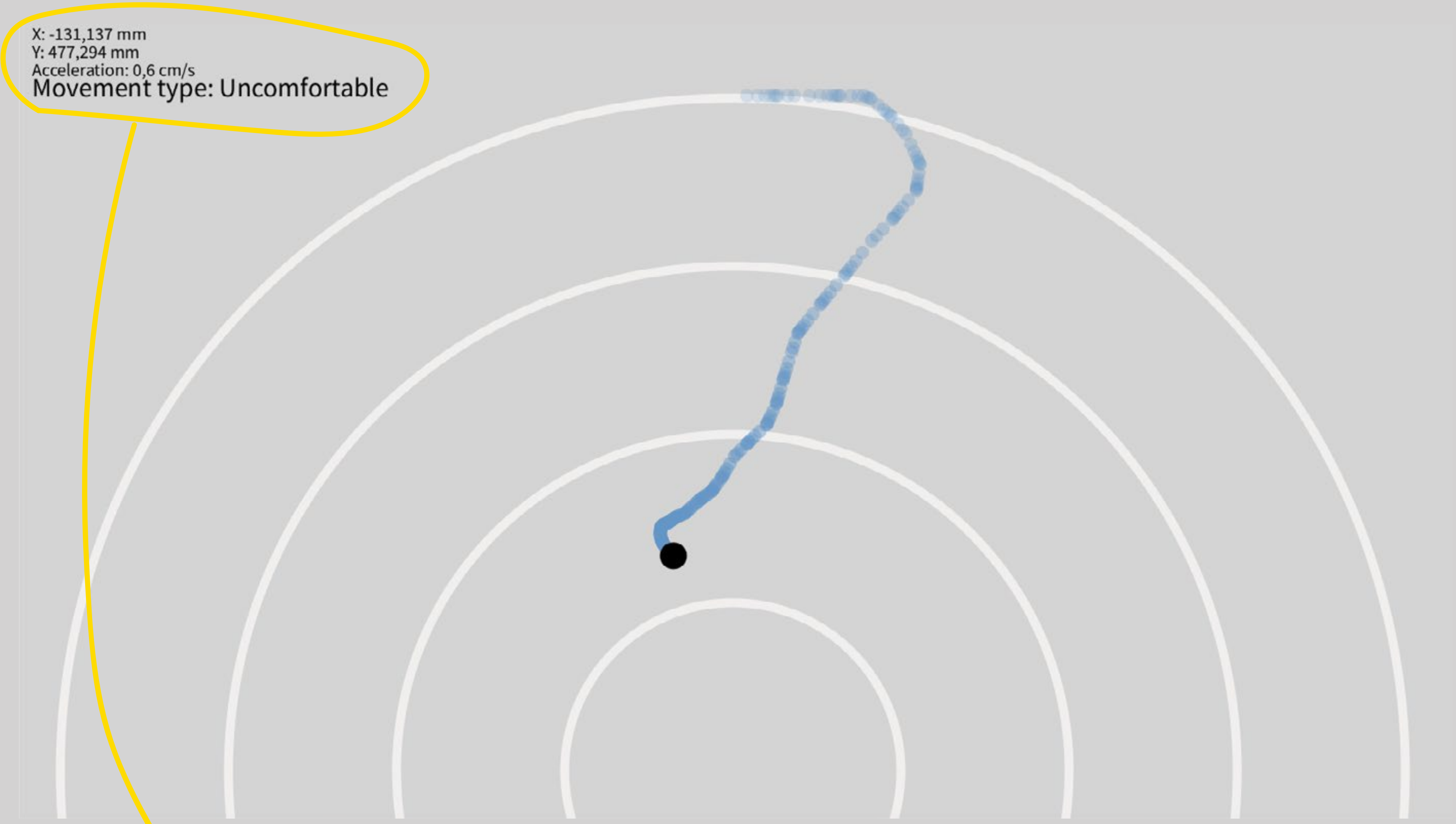
Behavior Type: Random



Reliable positioning of a person relative to the radar using x & y coordinates. Acceleration was not calculated due to a lack of data points collected to calculate differences in displacement. A simple radar visualization was used to test its reliable positioning.

To be transparent about the software processes, a trail of the data points collected to calculate acceleration was visualized. Adding a small fading animation to erase the trail after 30 points are collected.

Adding more nuance to the walking interpretation, metrics such as speed consistency and straightness score were measured. For example, if someone walks hesistantly they might have lower speed consistency or walk less linearly. System collects 300 points, calculating straightness, speed consistency, classifying behavior.



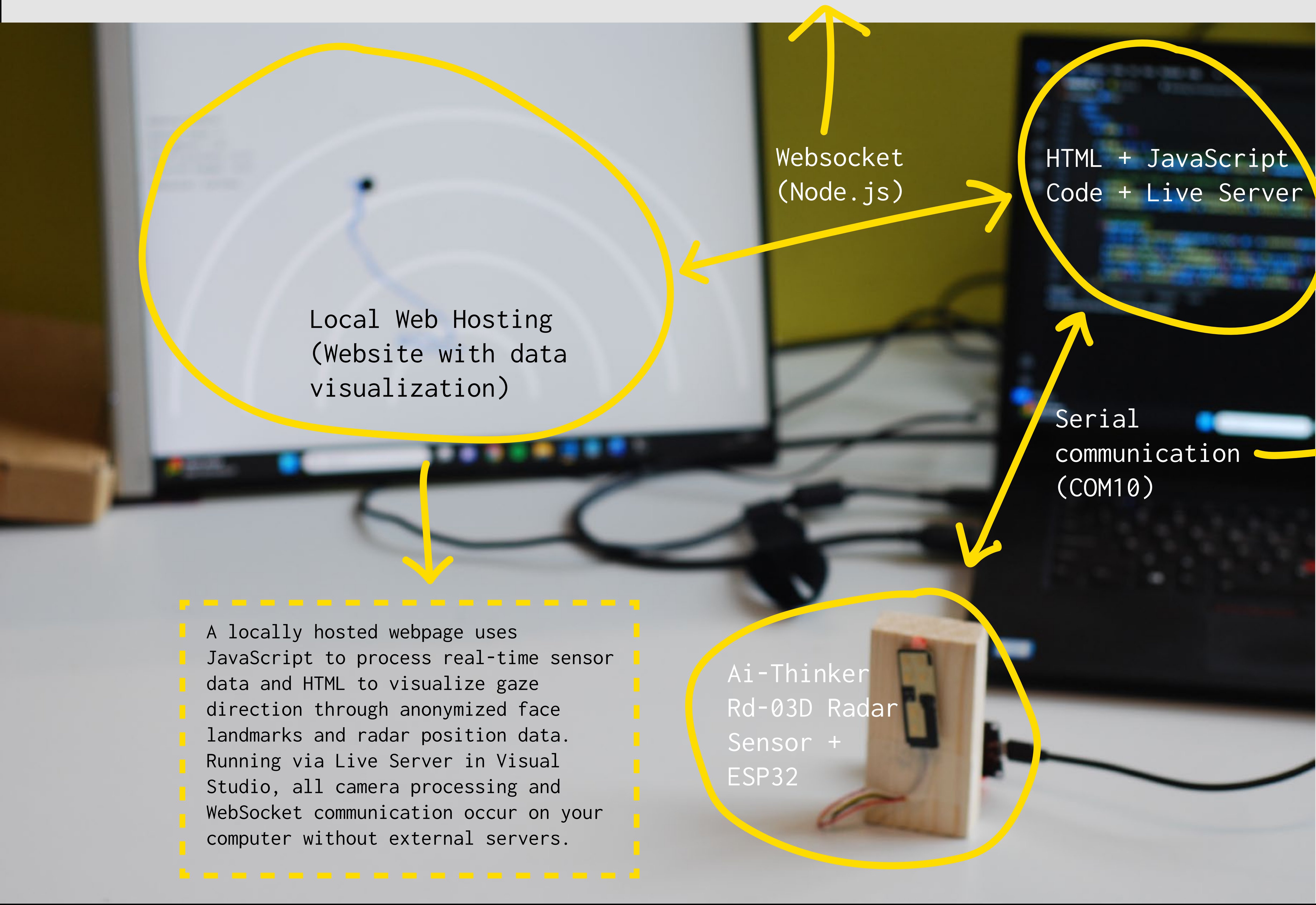
Movement direction

Speed	Towards	Neutral	Away
Fast	Angry	Same	Scared
Neutral	Same	Same	Same
Slow	Curious	Same	Uncomfortable

Emotional meanings were heuristically assigned to proxemics data using design intuition and informal testing. Inspired by Google Soli's proxemics framework [13] and Edward Hall's distance zones [26], movement direction and acceleration informed interpretation. Slow or fast approaches and retreats were mapped to four affective states (curious, angry, uncomfortable, scared). Thresholds were relative rather than fixed, prioritizing intuitive interaction and acknowledging that proxemic interpretation remains subjective and context-dependent.

Data pipeline

A Node.js WebSocket server runs locally on your computer, enabling real-time communication between the browser and ESP32 microcontroller. It receives radar sensor data via serial communication and transmits it to the webpage for visualization. All data remains in temporary memory and is automatically deleted when the server closes.



A locally hosted webpage uses JavaScript to process real-time sensor data and HTML to visualize gaze direction through anonymized face landmarks and radar position data. Running via Live Server in Visual Studio, all camera processing and WebSocket communication occur on your computer without external servers.

The ESP32 microcontroller connects to your computer via USB cable for serial communication. It receives radar sensor data (position, distance, angle) and gaze classifications. The ESP32 controls servo motors based on these inputs, creating physical shape-changing responses to detected user behavior.

Privacy considerations

Because the system interprets sensitive non-verbal cues such as gaze and proximity, privacy considerations were integral to the design of “Through Your Eyes”. The installation was developed to ensure that all data processing remained local, anonymized, and ephemeral, minimizing risks associated with surveillance and data persistence.

Gaze tracking is implemented using WebGazer, an open-source, browser-based library developed by Brown University [42]. All camera processing occurs locally within the user’s browser, where facial landmarks are used to estimate gaze direction in real time. No images or video frames are stored or transmitted; only abstract gaze coordinates are temporarily processed to classify broad behavioral states. All gaze data exists solely in temporary memory and is automatically deleted when the browser session ends.

Proxemics tracking is handled through a 24 GHz radar sensor connected to an ESP32 microcontroller. The sensor outputs anonymized positional data, such as distance and movement direction, without capturing any identifying features. This data is transmitted locally via USB and visualized in real time, with no external network connections involved.

Across the entire system, no data is written to the disk or shared beyond the local machine. By keeping all sensing, interpretation, and visualization processes ephemeral and offline, the project directly addresses ethical concerns surrounding gaze tracking and affective sensing, reinforcing transparency and participant trust.

Sensing: Gaze

Sensing: Gaze

The development of gaze tracking for this project involved significant technical challenges and multiple iterations before arriving at a functional solution.
More specifically, three iterations, each with its own library and setup, were developed.
Image 32 compares these in their architecture and technique for gaze tracking and the setup used. Then each page showcases the specific process and limitations of each iteration. (The full sized Image 32 can be found in Appendix D).

	M2.1 prototype			
Gaze tracking technique		**L2CS-Net** uses a two-branch CNN architecture with separate classification and regression losses to predict pitch and yaw of head to derive gaze angles from individual frames.	**LaserGaze** processes temporal video data across multiple frames using MediaPipe for facial recognition, dynamically refining gaze estimations for improved stability and accuracy in real-time video stream frames.	**WebGazer** self-calibrates by observing user webpage interactions, training a regression model that maps detected eye features to screen gaze positions.
Setup and libraries	Google Collab: running computer vision on virtual machine	Google Collab: PyTorch + OpenCV	Google Collab: OpenCV + MediaPipe	Local Web Host: API WebGaze + MediaPipe
Data processing		Take picture then make prediction	Live prediction	Live prediction

Comparison between L2CS-Net and LaserGaze:

Between L2CS-NEt and LaserGaze the difference is that the former takes a individual picture and makes classifications from it. The LaserGaze method uses temporal classification (using video live stream) allowing for the dynamic refining of the gaze estimation. The gaze direction is estimated depending on the head pose which is not a reliable predictor. Additionally, datasets of computer vision models are particularly sensitive to light settings, camera angle besides the inherent bias in demographics. These parameters can influence its accuracy if these don't match those found in the deployment data.

Comparison between LaserGaze and WebGazer:

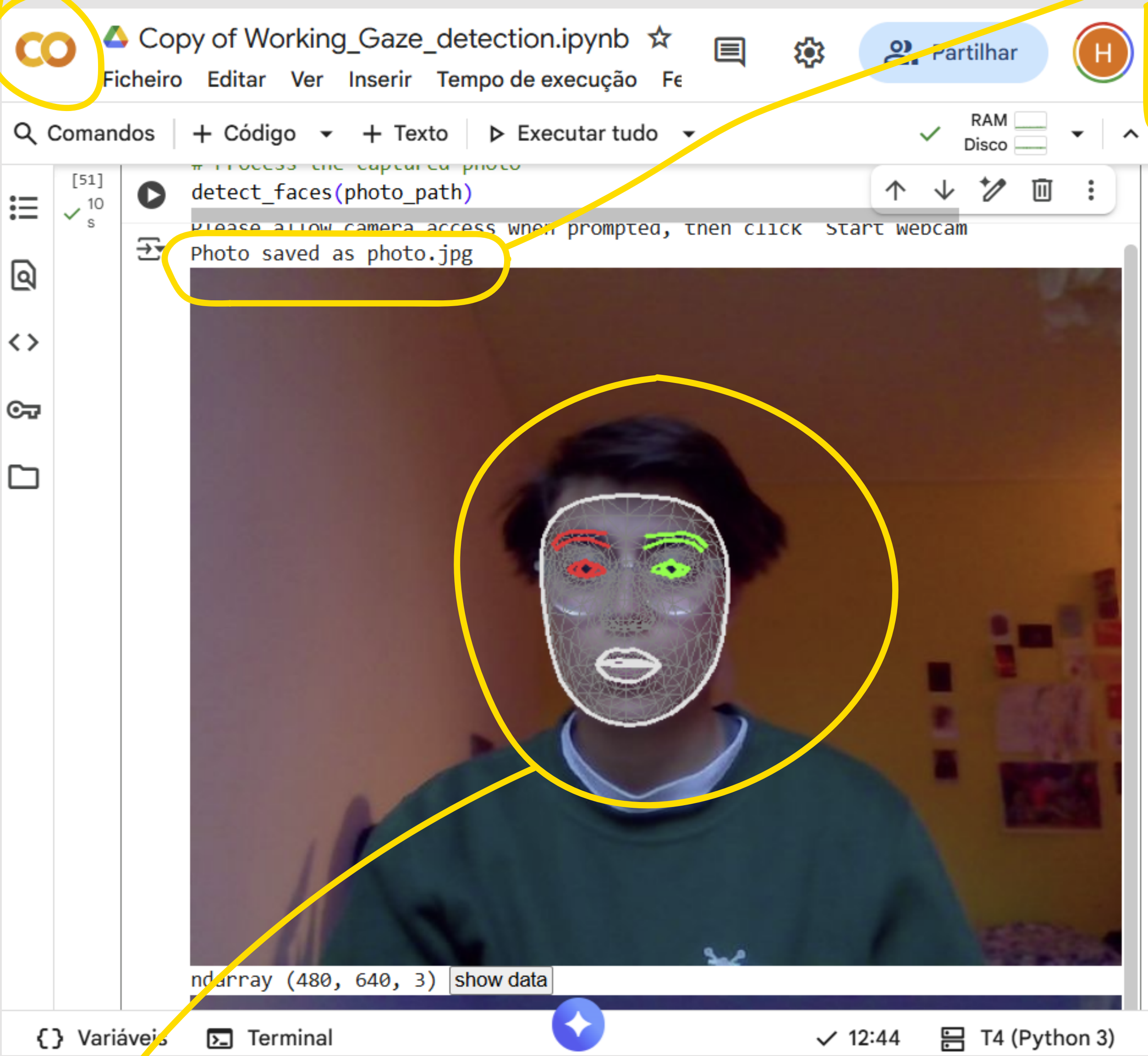
WebGazer was chosen over LaserGaze due to architectural compatibility. LaserGaze's 3D face model approach with affine transformations required Google Colab's virtual machines, achieving only 2-3 fps and frequently crashing. WebGazer uses browser based pupil detection with regression analysis, running locally via TensorFlow.js without requiring a powerful GPU. Its lightweight architecture enabled real-time processing, offline operation, ESP32 integration via WebSocket, and continous calibration, because the robot requiring immidate and accurate predictions.

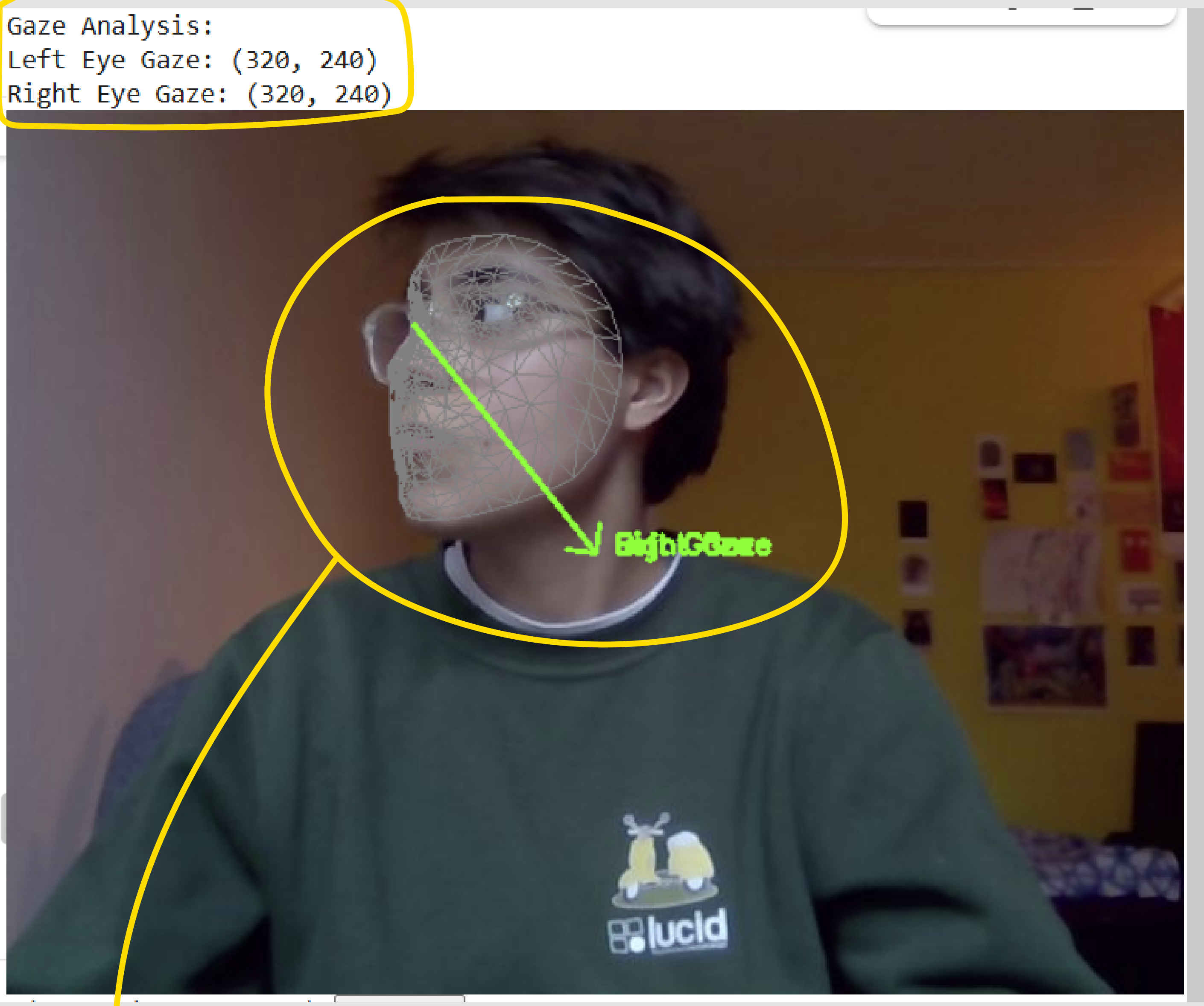
Image 32: A comparison between the three libraries used for gaze tracking, their technique and architecture

L2CS-Net

To run the computer vision AI models, Google Colab was used. This platform allows a virtual machine to be used to run the code on, which has a powerful GPU.

Individual frames are taken to process and derive gaze direction. However, it only achieved 2-3 frames per second and crashed easily, not being fitted for real-time interaction.





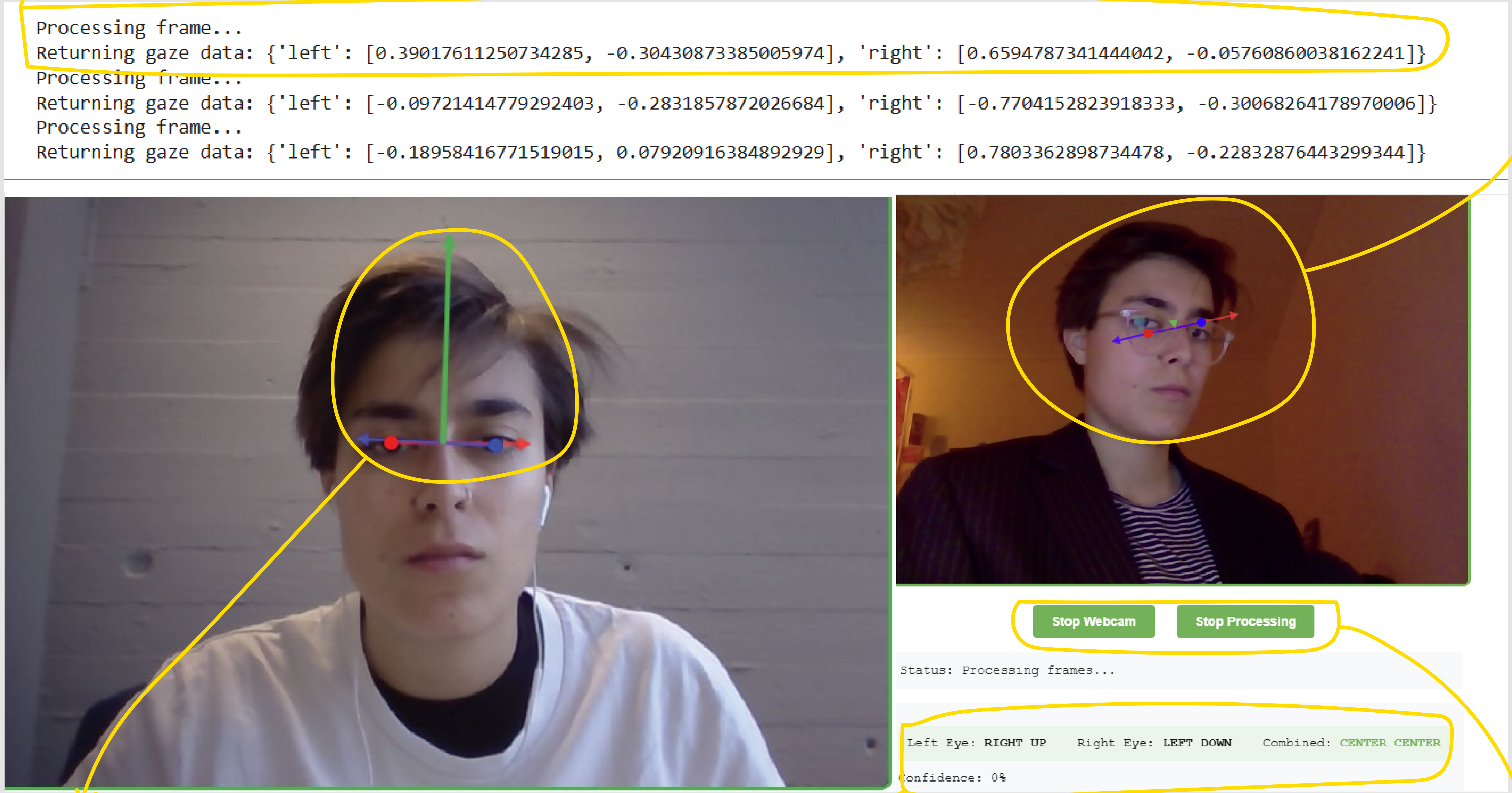
MediaPipe-based head pose estimation proved unreliable, as gaze direction was misinterpreted with head tilt. Additionally, reliance on Google Colab's ephemeral environment made real-time development inefficient and unstable.

As can be seen, the arrow of the gaze direction is not accurate both in both vertical and horizontal direction (it should be left up).

LaserGaze

Changing to a different gaze tracking library for more accurate results. The gaze prediction output is the x & y coordinates per eye.

This model derives gaze direction from head angle; however, these are not always related. Here is an example where the head is tilted upwards, but the gaze direction is downwards.

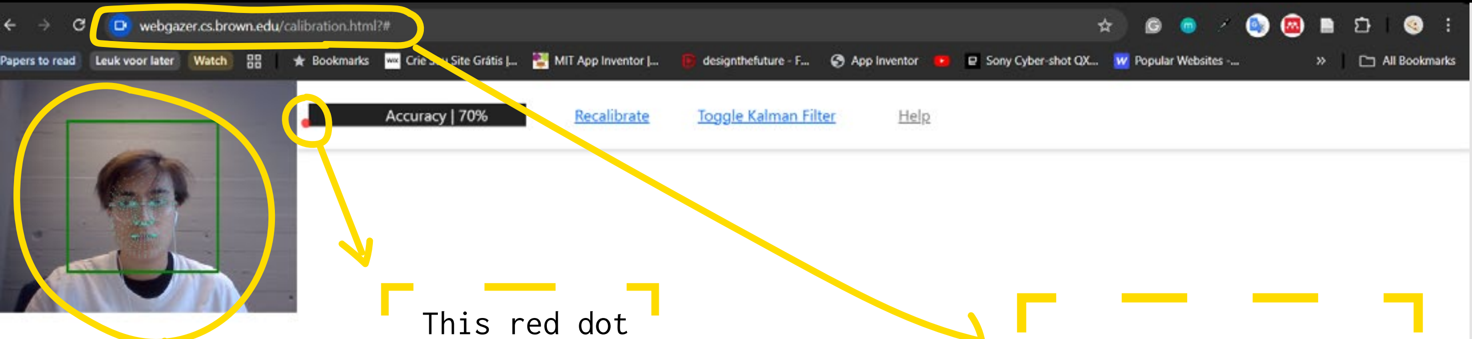


The model detects the pupils position using X & Y. However the gaze direction is not accurate because it uses yaw (vertical tilt) and pitch (horizontal tilt) of the head to derive it.

Moreover, this model didn’t provide a final prediction. It outputs the positions of the eyes vertically (up/center/down) and horizontally (left/center/right). However, “right up + left down” isn’t conclusive of gaze direction.

To ease troubleshooting, two buttons were added to control the webcam and the processing of the gaze predictions. It was difficult to confirm if the model was working correctly since I had to look at the center to do so.

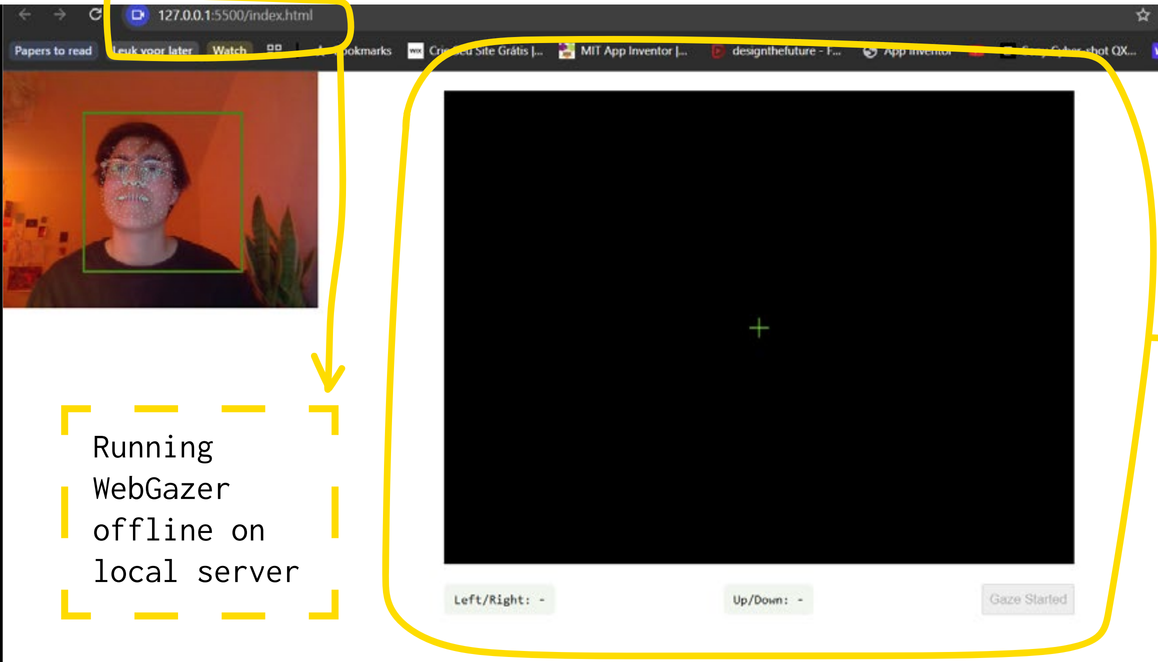
WebGazer



This red dot represents where the person is looking at

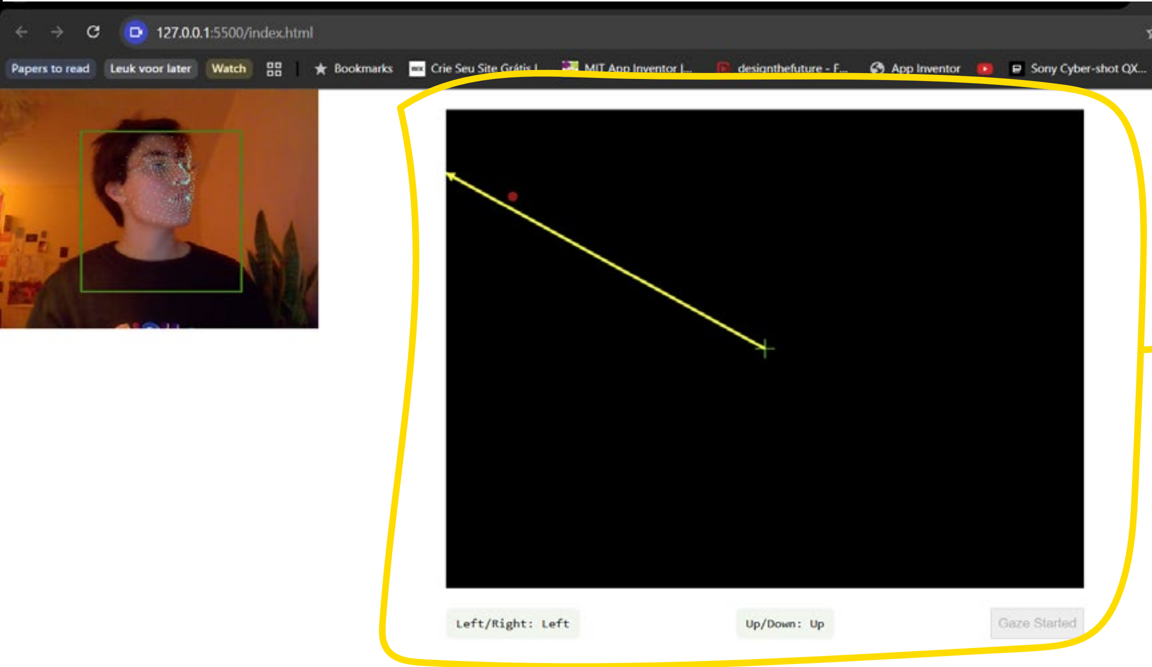
Testing the gaze tracking's accuracy on the WebGazer online website.

The green box indicates if someone is in frame



Running WebGazer offline on local server

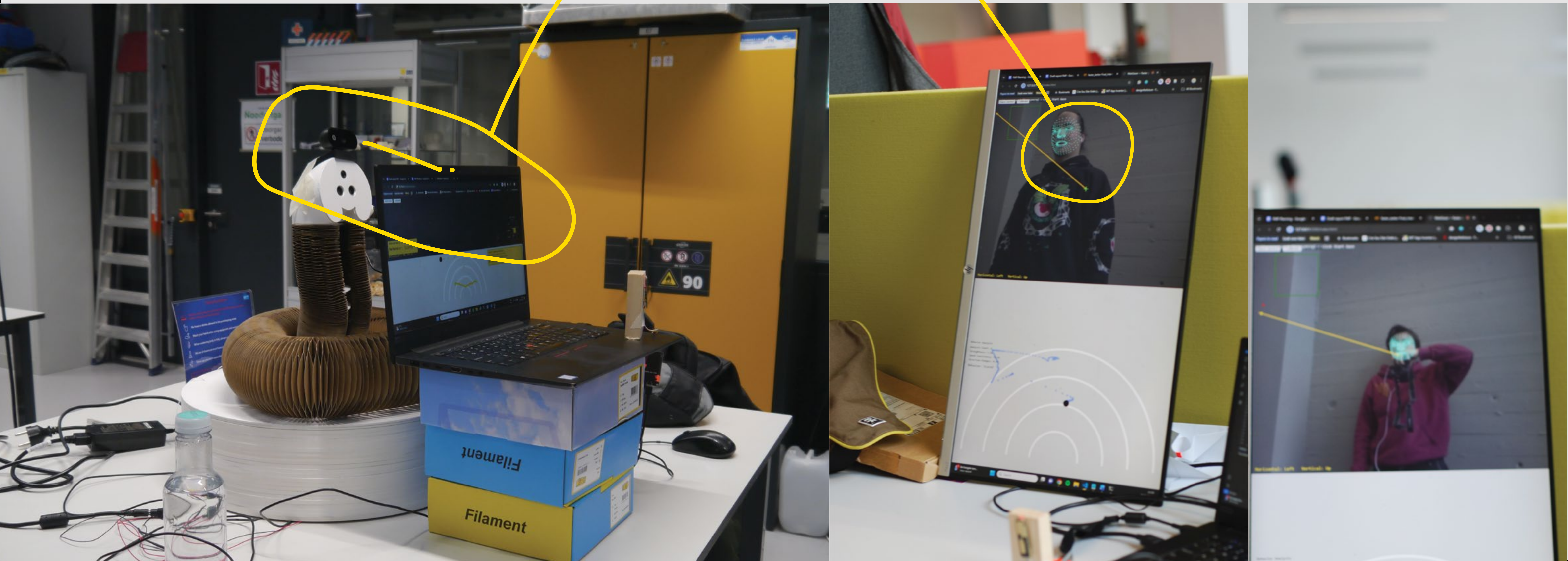
The vertical and horizontal gaze direction



Direction of gaze is visualized with an arrow, however its inverted

Recognizing these limitations, the project shifted to WebGazer, an open source, browser based gaze-tracking library developed by Brown University [71]. Commonly used in web accessibility and analytics, WebGazer prioritizes reliability and accessibility over laboratory precision. It estimates gaze using webcam-based pupil detection and regression analysis, processing data locally within the browser via TensorFlow.js. Gaze directions are classified into broad behavioral states without storing images or requiring specialized hardware.

Integrating WebGazer [42] into a physical robot posed challenges, as gaze calibration broke when the robot's head rotated. Gaze tracking, therefore, operated only while stationary, with calibration aligned behind the robot. The system classified gaze into nine broad directional zones, prioritizing robustness and interaction reliability over precise pixel accuracy.



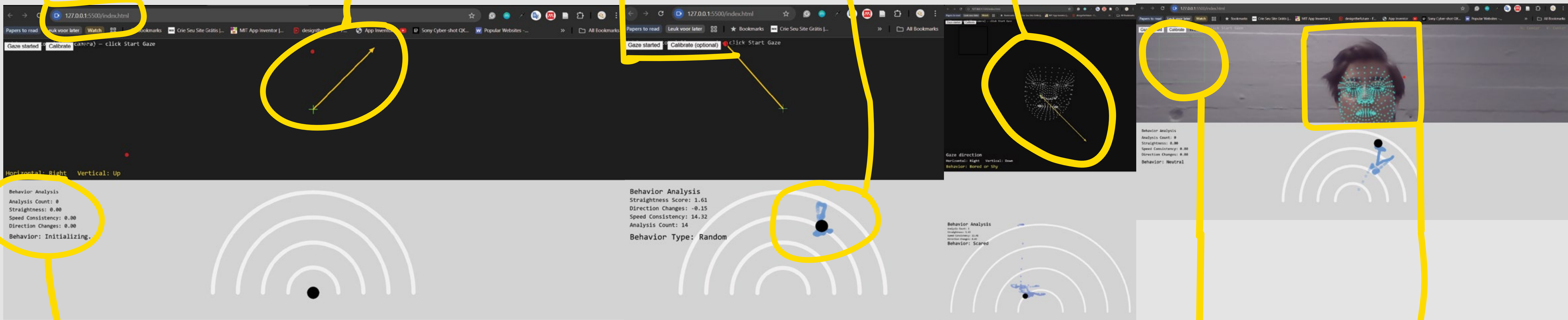
Visualization

For privacy reasons, the data visualization is run on a local server (run by Live Server Microsoft Visual Studio extension). The WebGazer library processes webcam gaze tracking locally in-browser using TensorFlow.

The WebGazer API outputs raw 2D screen coordinates (x, y) in pixels. From it, the arrow angle uses arctan2(Δy, Δx) where Δy and Δx are vertical and horizontal displacements from screen center to gaze coordinates, giving direction in radians.

20 data points were collected, and then an analysis of how straight the walk was and the acceleration was calculated. To communicate this data collection to the audience, a trail was displayed, which disappears every time a conclusion is made.

To track the gaze direction, the Web Gazer API uses Google Media Pipe to identify facial features and head angle. To communicate which person's face was being tracked, the mask overlay was used.



Radar data analysis breakdown:
-Analysis count: 20 data points are collected to filter out outliers and produce more accurate results. The following parameters are calculated, relative to the 20 data points, as a unit of time.
-Straightness: computed by tracking the ratio of lateral movement (x) to forward movement (y)
-Speed consistency: variation of speed over time
-Direction changes: inferred by tracking changes in the sign of speed (positive vs negative)

A feature of the Web Gazer API is the color of the square (red or green), indicating the presence of a person in the field of view.

The face mask of the previous iteration was not clear enough to indicate which person was being tracked. Therefore, the camera stream (with background) was added.

User study #2

Goal:
User Study #2 generated alternative visualization designs to test intuitiveness and experience. Design colleagues unfamiliar with the project contributed, mitigating the designer's bias. A draft visualization provided a starting point, facilitating idea generation, feedback, and clearer communication of the project concept, making the visualization more experiential and engaging.

Procedure:
The user study started by letting the participants experience the draft visualization, followed by an semi-structured interview, and then asked them to draw or collage their own design of the visualization. (More details in Appendix A).
Analysis:
The following are the three themes identified through reflexive thematic analysis of the interviews.

Theme #1: Self-Awareness and social perception
This theme captures participants' consciousness about how their behaviors and expressions are interpreted by others. P3 expressed awareness of how their social cues can be interpreted differently by others than intended. Additionally, noting that that reading social cues depends on relationship context, situational factors, and verbal communication. P2 identified the cause of this miscommunication, since people typically view the world from their own perspective without recognizing alternative interpretations exist.

Researcher's reflection: The visualizations appear to stimulate metacognitive awareness and social rejection, with users considering multiple perspectives beyond their own subjective viewpoint.

Image 34: The setup of user study #2, with the elements of the presented visualization and sketching tools

User study #2

Theme #2: Confirmation bias
This theme reflects how preexisting beliefs shape the interpretation of social interactions.
P3 was curious about how humans form conclusions about others. They noted that the absence of expectations met leads to rejection, with people seeking confirmation of insecurities.
Researcher's reflection: This suggests the visualization may illustrate how individuals selectively process social information to reinforce existing beliefs about themselves or others.

Theme #3: Surveillance
This theme addresses the uncomfortable experience of observing others through technological mediation. Participants described looking through the screen, felt voyeuristic, P1 comparing it to spying on someone. P4, express the experience felt like a distorted mirror. This was further echoed by P1, who felt the facial landmarks provided a mask-like effect. This made it harder to naturally read the facial expressions and caused them to redirect attention to face angle and body language to infer the emotions of the other.
In contrast, all participants did express trust in the data being shown, P2 describing a sense of competition with the robot in correctly sensing the emotions of the person.

Researchers's reflection: The technology creates an unsettling intermediary layer between observer and observed, disrupting natural social perception. Users engaged with the system both as a tool and as a comparative benchmark, negotiating between trusting the analysis and asserting their own interpretative abilities.

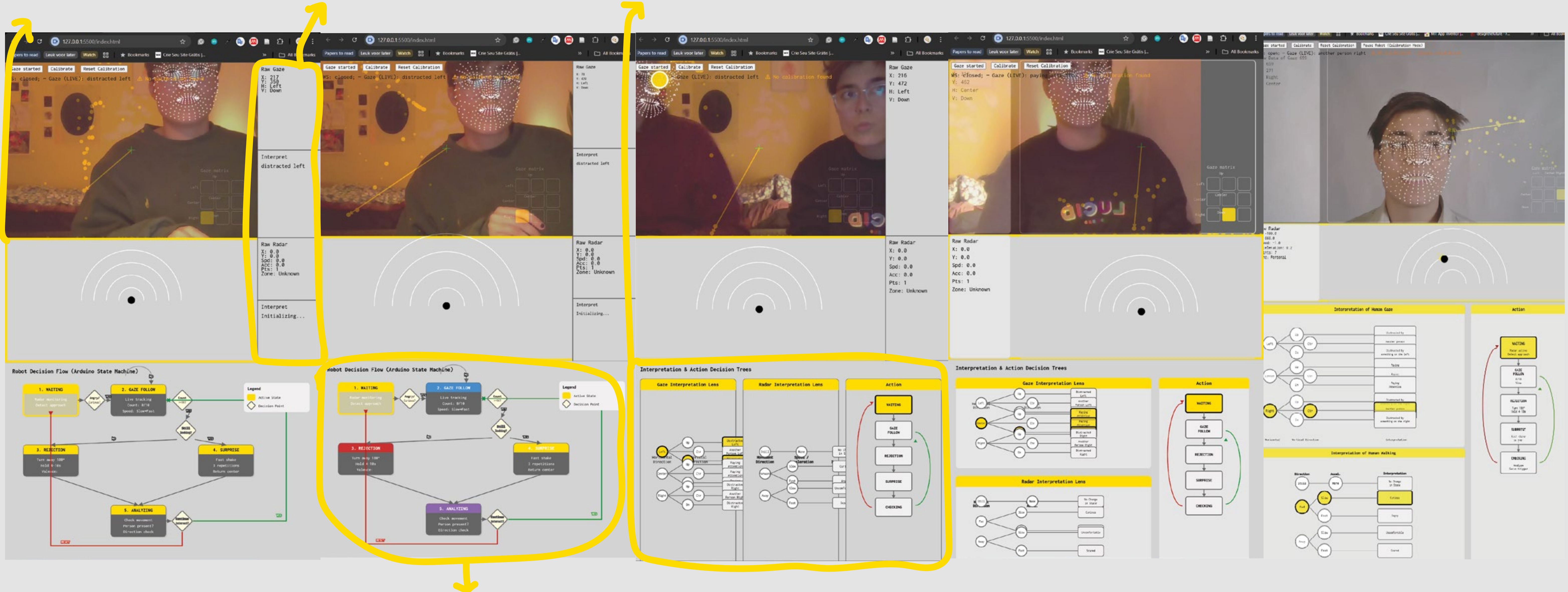
In the next page, the designer's reflections per sketch are shown, and the changes made to the visualization based on the suggestions made by each participant.

Image 35: User study #2, a participant sketching and collaging their alternative to the visualization

Highlighting the sensor that is being used to make a decision in the interaction loop.

To provide transparency and showcase the inner workings of the system, the sensor raw data is shown. Additionally, the interpretation label is shown per sensor.

Inspired by P4 from user study #2, three decision trees are used as visualizations. From left to right: the first one showcases the gaze interpretation lens options, showcasing which raw combinations of horizontal and vertical directions lead to which interpretation. The second one, the radar interpretation lens, shows which combinations of movement direction and speed lead to which interpretations. The third one is the interaction loop in a simplified manner (it's not actually linear) to showcase the current position in the interaction loop.



A decision tree is used to visualize the state machine logic, showcasing each step in the interaction loop.

Fine-tuning the layout of the decision tree so as not compromise the readability of the text.

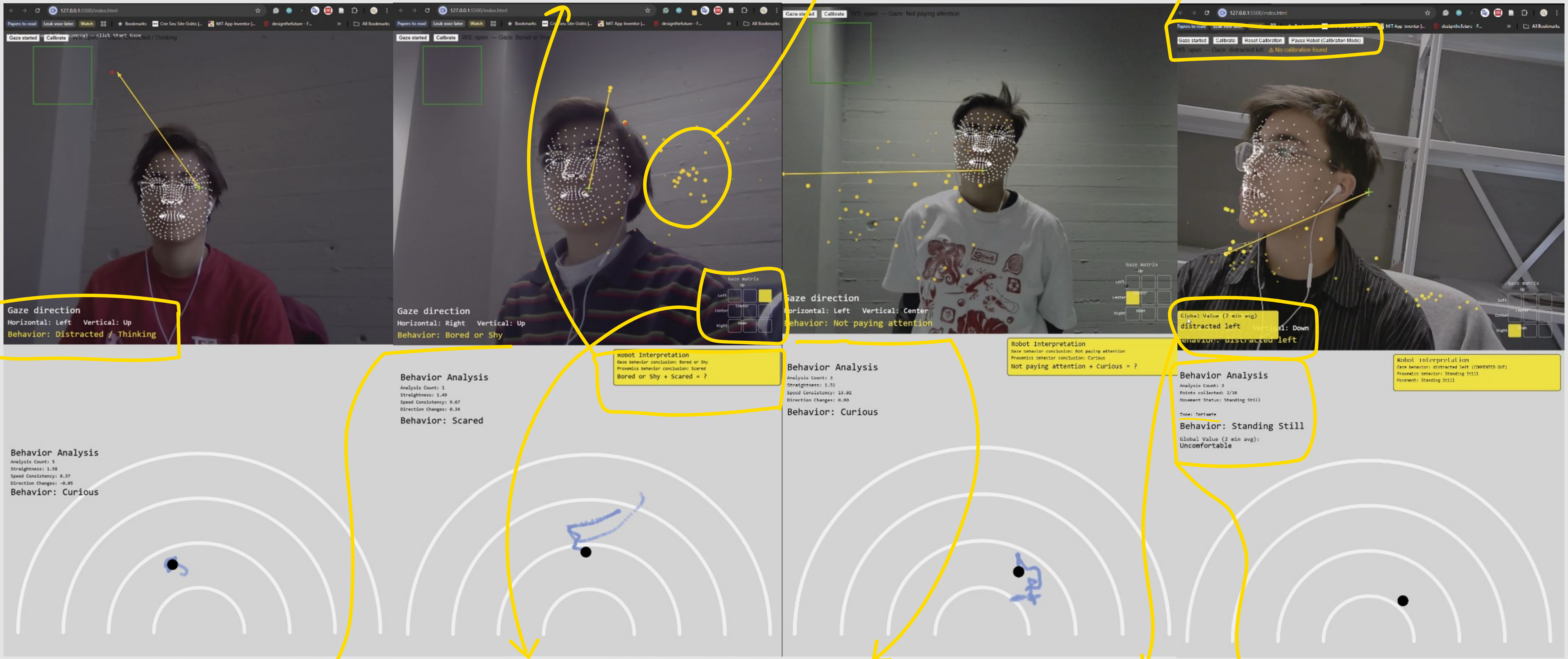
Synchronization between the state logic robot and the visual of the interaction loop (action box). Since people on the screen side can’t see the interaction, the action box showcases the reaction of the robot.

The WebGazer API outputs raw 2D screen coordinates (x, y) in pixels. These were then derived to directional labels (ex: left up).

Output box/robot final interpretation showcasing the combination of both sensors. Having trouble with how to add up/making a conclusion of the two sensor outputs.

Showing gaze trail (data points collected to make reading).

The tracking kept having to be recalibrated (erased everytime the webpage was refreshed). Therefore now it is saved in browser's localStorage (client-side only), but stays on the local machine.



Showcasing doubt/uncertainty in how the social cues is interpreted.

Verbally outputing the gaze direction (ex: right, up) was hard to follow. Therefore a 6x6 matrix showcasing the gaze position was made.

The gaze interpretation labelling were made less emotive; instead of "shy", it was read as "not paying attention", due to the difficult meaningful attribution to the data options.

To communicate the average gaze behavior during the whole interaction (around 2 minutes), a global value is calculated.

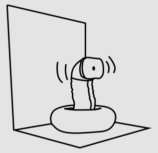
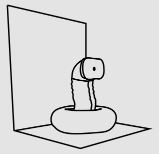
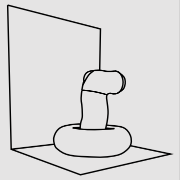
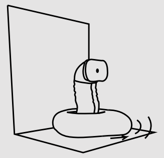
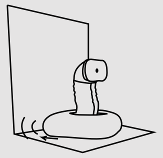
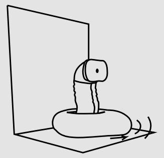
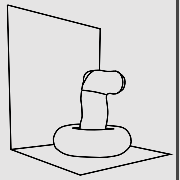
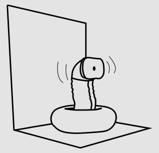
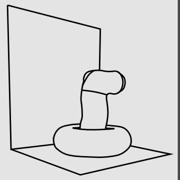
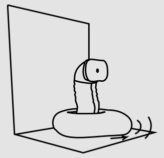
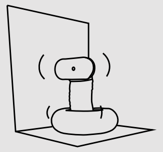
Based on Hall's Proxemics theory [26], three zones exist; robot reacts in social/intimate, using filtering to deal with unstable values when standing still.

Interaction Loop

Iteration 1

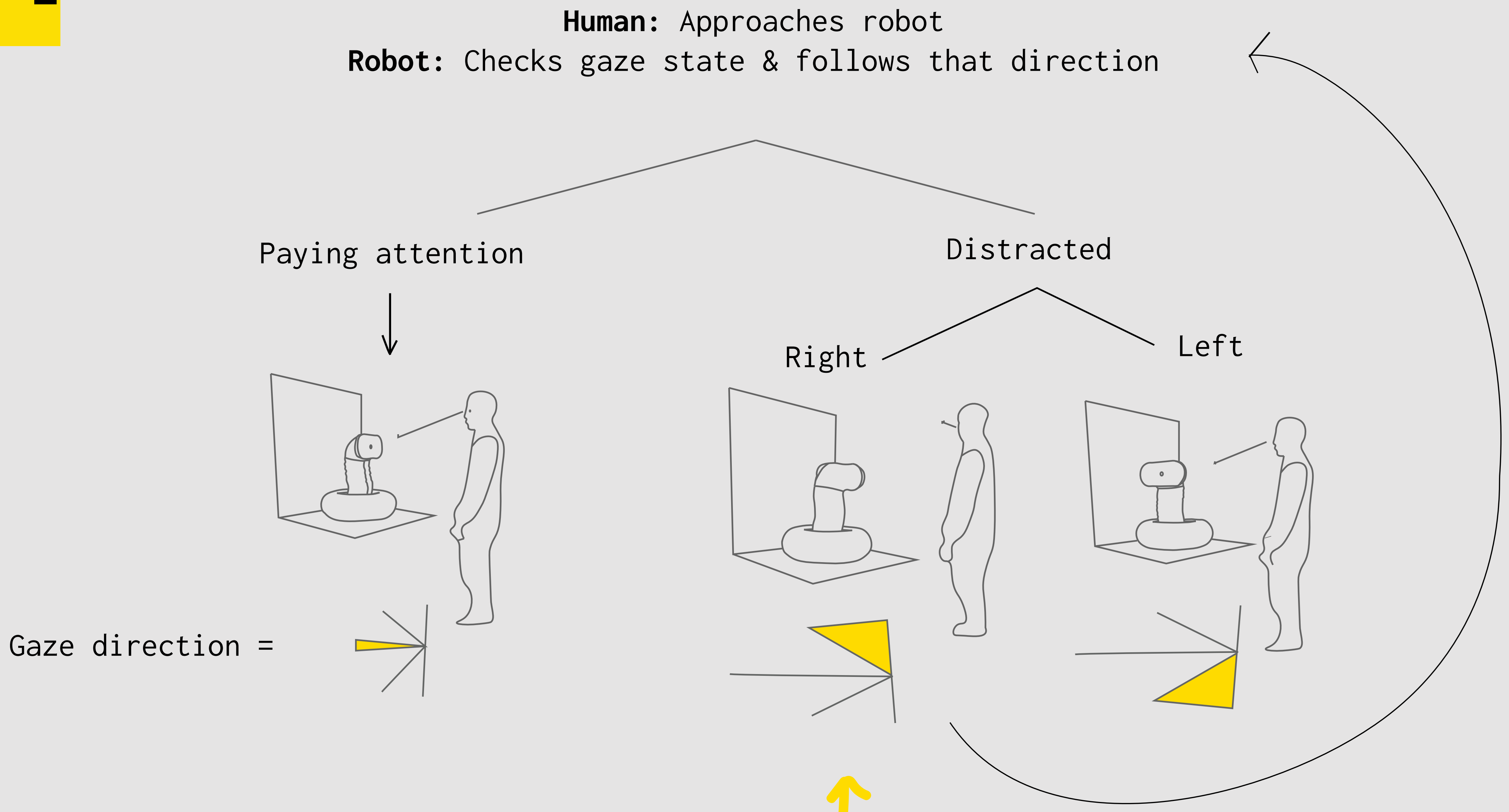
Gaze observation

Radar observation

	Thinking/ distracted	Another person	Paying attention	Ignoring	Looking at actuation	Bored/shy
Angry	"I don't feel seen, are they mad at me or someone else? Shaking/ turning to get attention 	"Is there a conflict arising between these two people?" Freeze 	"Are they angry at me? What did I do?" Run away, neck turns away and stays there 	?	"Is my reaction making them mad? Is it okay for me to be mad?" Shame, finish actuation and then see reaction 	"They are impatient. I am disappointing them?" Base moves away 
Scared	"I want to sooth them, they are feeling scared? Base moving towards user to sooth them 	"They are frightened of the person coming our way?" Slow turn away/uncomfortable 	?	?	?	?
Curious	"Are they distracted?" Slow shaking to get attention 	"They are more interested in the other person" Fast turn away/ Feeling rejected 	?	?	"Are they interested or will they look/walk away?" Doubting, actuation only 	?
Uncomfortable	?	"They are more interested in the other person" Turning to warn other person 	?	?	?	?

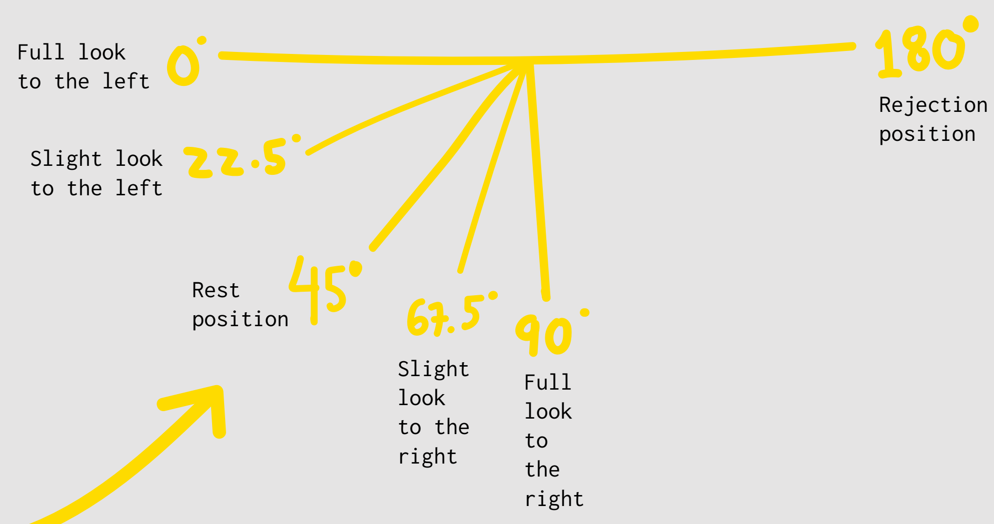
Reflection on the interaction loop:
The first draft of the interaction loop used the same structure as the "Motion and Emotion" project. The interaction structure includes independent pathways for each emotion prediction. Using the addition of the observation of one sensor with the other, the designer's intuition was used, using the existing actuation outputs as mapping elements.
As previously mentioned in the "Background" section, the interpretation "lens" of a socially anxious being was used.
Inspired by the P3 of user study #2, when suggesting thought bubbles, which are commonly used in comics, is the combination of these observations. However, a key limitation is how to add up sensing meaning. For example, what does the combination of being bored and curious mean?

Iteration 2

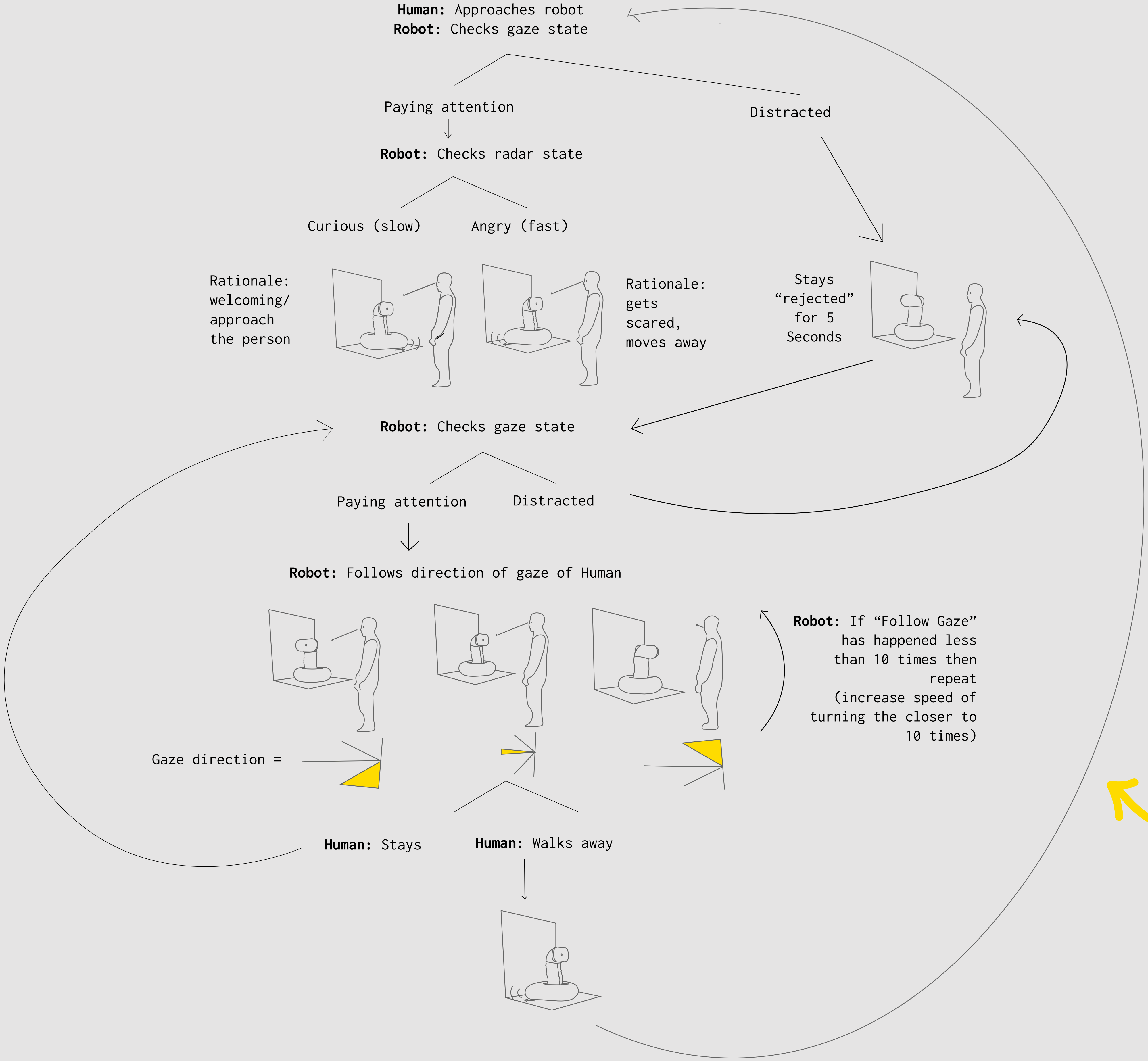


Due to prior limitations, a temporal, segmented approach was used instead of an additive one. The radar sensor captured initial user intentions, influencing later interactions, while the gaze sensor guided immediate responses. This balance between predictability and complexity maintains engagement and curiosity through delayed reactions (interaction guideline #4). Addressing a key limitation from User Study #1, Maker Days, and Demo Day, improving the robot's slow reactivity became a central project priority.

Reflection on the interaction loop:
When testing a simpler version of the interaction loop, refining the action of following the gaze direction of the user, the reaction of only looking left or right was underwhelming. Therefore, intermediate positions were used to showcase a slight look to the right or left. Although this was tricky due to the little range of motion of the non-continuous servo, therefore the following allocation of positions was made.



Iteration 3



The follow gaze was done 10 times, it showcases impatience and anxiety by accelerating in turning speed the closer to the 10 times it is. The follow gaze function shows the robot wondering why and what someone is looking at. Due to the exhibition at Demo day being predicted to be quite crowded, a fixed amount of times of the follow gaze function was set, since interactions are quite short at these exhibition and wanting to provide the full interaction loop within 1-2 minutes.

Reflection on this interaction:
The main limitation is that the gaze following reaction occurs late, potentially losing initial visitor engagement and making responses less noticeable. A better approach would start with the most engaging interaction, then introduce rejection unexpectedly. Reactions currently remain uniform regardless of visitor behavior. Introducing variations based on interaction length, movement within social zones, or other actuation possibilities could let each visitor leave a "trace," enhancing personalized, dynamic experiences.

Due to the time consuming software development to make ideated interaction loops experientable, the choreographing or acting out the interaction loop versions helped test out timings, the order of the interaction loop, and natural/intuitive reactions of the user.

User study #3: Expert interviews

To validate the project through the three fields it intersects, the following experts were interviewed:
Ali Paikan: CTO at LuxAI (a social robotics company that developed QTrobot, designed to support education for children with autism and other special needs)
Teije Oudshoorn: Developer engineer at Studio Drift (an art & technology studio which makes kinetic and interactive installations manifesting natural phenomena and their hidden properties)
Piyakorn Koowattanataworn: PhD candidate of critical design research at IT University of Copenhagen (ITU), conducting research on trust and loss of control for health informatics
More details on the demographics, experts contacted, and procedure of this user study can be found in Appendix A.
Several shared themes emerge across the expert interviews; these are outlined below.

Theme #1: Making the invisible visible
Oudshoorn agrees that people constantly misread one another's nonverbal cues, often without realizing it, and suggests this robot can function as a mediator that brings these unconscious mechanisms to the surface. Paikan frames this as a form of theory of mind, which is the human ability to understand that others have different mental states from our own, which helps predict and interpret the behavior of others [5]. He says that by giving the robot its own cognitive biases, users are confronted with how they themselves might be perceived differently than they intend. All three experts see value in revealing this perspective. Oudshoorn even proposes recording interactions and replaying them to users, allowing them to confront the "mirror" between their intent and the robot's interpretation, and to reflect on where this miscommunication happens.

Theme #2: Ambiguity vs intuitiveness
Ambiguity and interpretive openness were repeatedly emphasized as important experiential qualities. Koowattanataworn referred to ambiguous design [11] as a way to provoke reflection instead of a fixed and prescribed meaning. She positions "Through Your Eyes" within critical and speculative design, where the robot's sensitive, easily rejected personality and lack of instructions encourage user projection. Oudshoorn warns against interactions that are too straightforward and predictable. When an installation's logic is immediately clear, users reduce it to a game or a button, therefore missing its conceptual intent. Instead, he argues that leaving some mystery and ambiguity allows visitors to construct their own meaning. The choice to give the robot an anxious, exaggerated personality is similarly intentional. As Koowattanataworn notes, a strong affective stance makes it easier for people to react and position themselves, whereas a neutral robot would likely fail to provoke engagement or reflection.

Theme #3: Transparency of technical processes
Koowattanataworn stated that showing the robot's internal reasoning allows users to compare its "lens" to their own. Oudshoorn resonates with this approach, pointing out that, unlike human interactions, the installation can give a peek into each other's minds. He suggests that post-interaction reflection can be stimulated by showing users how the robot interpreted their behavior versus what they intended. Paikan acknowledges that in real-world therapeutic robotics, interpretation of emotional and body cues is often avoided due to privacy concerns and ethical constraints. Regardless, he sees educational value in the project, where the robot can act as a low-stakes social mirror for practicing grounding, gaze awareness, and backchanneling.

Theme #4: Context influence on perception
Framing and context are identified as shaping how the work is experienced. Koowattanataworn notes that subtle cues such as the name of the project, explanatory text, and spatial arrangement influence user expectations. Oudshoorn similarly observes that when an installation is framed as art, ambiguity is accepted, whereas a research framing leads visitors to

User study #3: Expert interviews

seek accuracy and measurable outcomes. Moreover, cultural context also shapes interpretation; as Koowattanataworn points out, behaviors like looking away or maintaining distance carry different meanings across cultures.

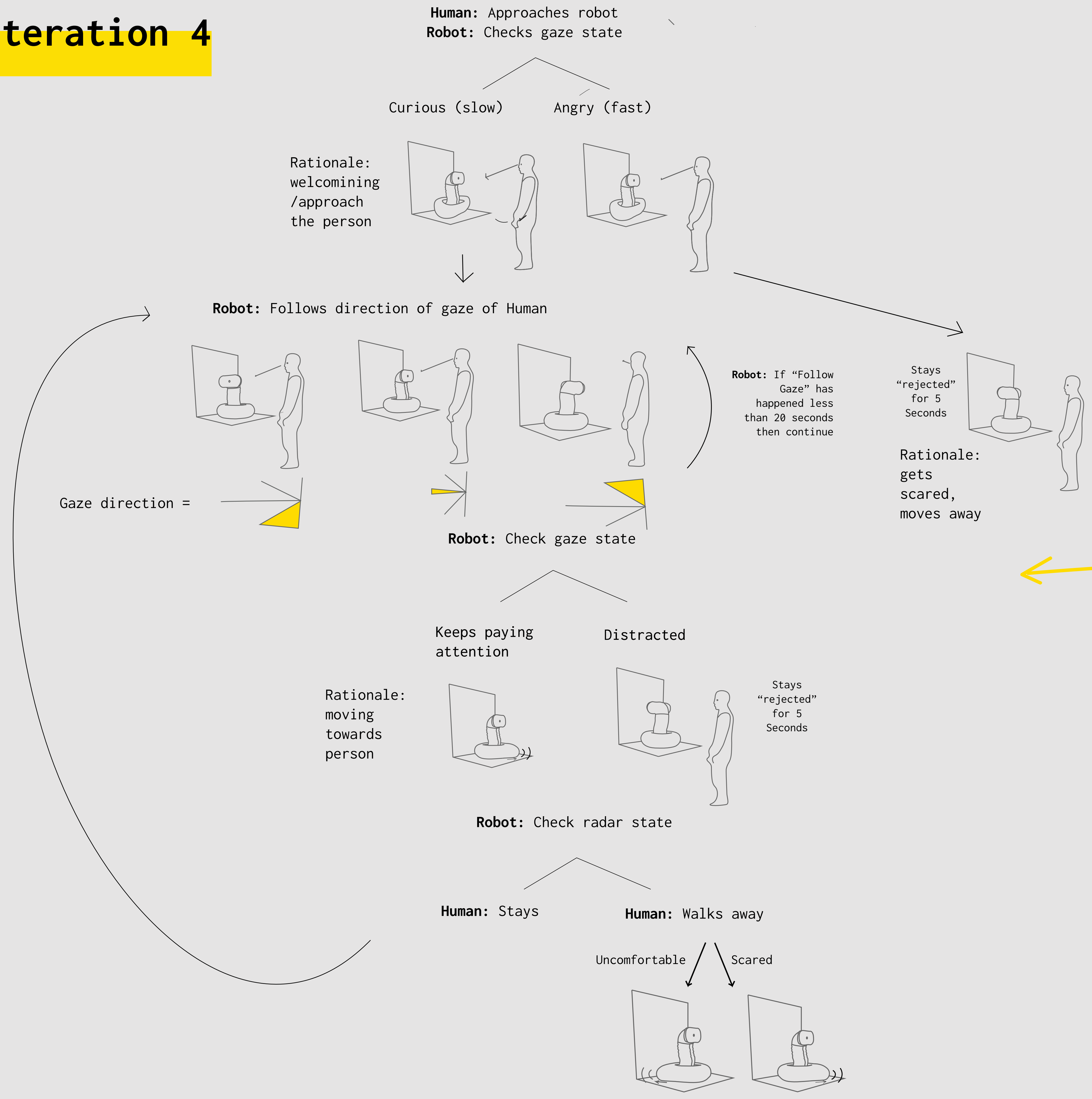
Theme #5: Temporal dynamics

Oudshoorn highlights that social interpretation unfolds over time: initial reactions can later shift as meaning emerges. “Through Your Eyes” collapses this temporal complexity into rapid judgments, mirroring both machine inference and human cognitive bias. Experts suggest future iterations could treat time as a design material, allowing interpretations to evolve rather than resolve instantly.

Together, these insights position “Through your eyes” as a reflective system that leverages ambiguity, transparency, and embodied interaction to illustrate how meaning is constructed through social cues and cognitive bias.

Image 35: Logo of IT University of Copenhagen
Image 36: Logo of Studio Drift
Image 37: Logo of LuxAI

Iteration 4



Reflection of interaction loop
The robot's "personality" is socially anxious and negative, reacting with surprise when visitors pay attention to it, surprising visitors, and integrating the rejection loop described in the section "Background". The follow-gaze function balances latency and accuracy: it reacts immediately but sacrifices some precision, as accurate gaze tracking requires multiple samples, delaying response. Immediate reaction was prioritized, so gaze direction accuracy was partially compromised to maintain interaction responsiveness.

User Study #4

User study #4 was conducted to examine robot perception, instinctive interaction behaviors, and user experiences of ease, engagement, communicated meaning, and reflections arising from the interaction. See Appendix A for the demographics and procedure used.

Data collection and analysis:

From the semi-structure interviews, thematic analysis [2] resulted in four main themes.

Theme #1: Misinterpretation

While seeing the visualization, P3 & P4 wondered if the robot's readings referred to the user or the robot's feelings. P1 and P3 described the visualizations as both accurate and exaggerated. All participants felt misinterpreted when labeled "angry" or "distracted," often second guessing their own feelings. These moments were experienced as funny or unsettling. These misreadings led P1 and P3 to reflect on how easily social cues are misinterpreted in everyday interactions.

Theme #2: Emotional Projection

When the robot rejected participants, it triggered various emotional responses. P2 and P4 experienced it as feeling ignored and felt sad, while P5 found it funny. After this rejection, a clear contrast emerged between P2 and P5: P2 empathized with the robot, perceiving it as shy or anxious, while P5 experienced rejection as humorous or rude if imagined in a human context. These reactions demonstrate how minimal movement and gaze behaviors can evoke social emotions and projection.

Theme #3: Personality

All participants defined the personality of the robot, some as shy, anxious, or sassy; others as cute and intelligent. Associations with animals or symbols (ex: snake, worm, Discord logo) were made, suggesting an instinct to categorize the robot through familiar metaphors, often linked to the idea of needing to build trust. Regarding its intent, P2 and P3 found the uncertainty about the robot's intent both intriguing and frustrating.

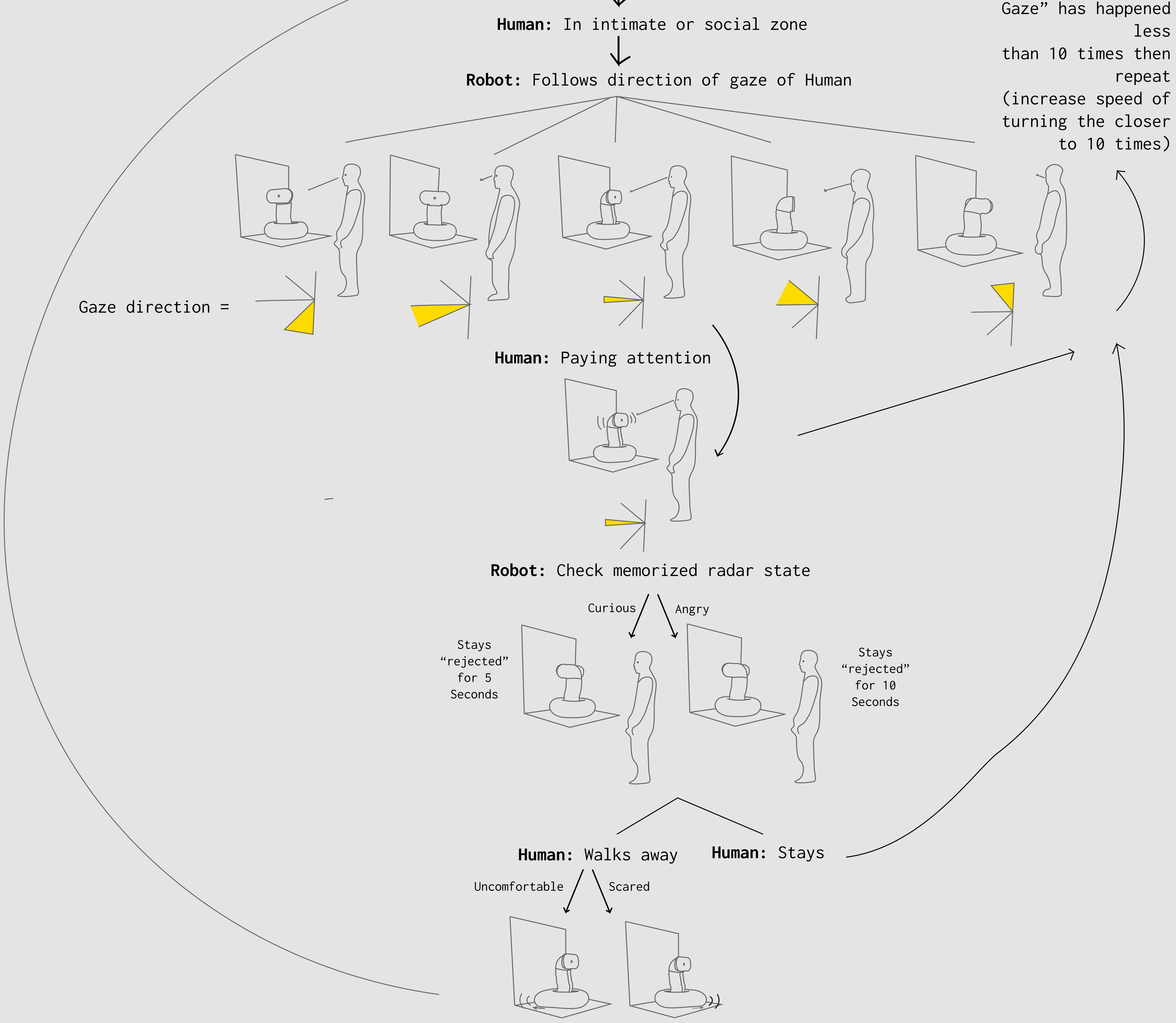
Theme #4: Reflection on social cue lenses

The interaction prompted reflection among P1, P3, and P4 on their own social cue lenses, particularly regarding eye contact, rejection, and assumptions during social interaction. P2 and P3 emphasized that social cues are ambiguous, culturally sensitive, and easily misinterpreted. A key reflection from P3 revealed how gaze aversion caused by their shyness is often misinterpreted as rudeness, suggesting a crucial mismatch between intention and perception, which the project successfully tries to mirror. All participants found the installation relevant for making inner worlds visible, sparking conversation, and increasing self-awareness.

Reflection of the researcher:

From the researcher's observations, there was uncertainty around the sensing modality, distance to have from the robot, and responsiveness, which affected engagement. Improvements were identified: increasing base movement speed, reactivity, and visualization clarity. The improvements suggested during this study, which were integrated into the final prototype, are illustrated in the sections "Interaction Loop" and "Visualization".

Iteration 5



The final interaction loop integrates the following interaction guidelines.
#1: "Negative characteristics can be used for emotional connection between the visitor and the artifact." By embodying the rejection loop of people with social anxiety.
#2 Technical malfunction can add an element of unpredictability, which fosters a sense of agency of the prototype.
The compromise of the gaze being reactive, but therefore not always accurate.
#4 The interaction must remain easily understandable, reactive, and predictable while offering enough complexity and varied feedback to ensure users feel their input has a meaningful, evolving effect. Balance between layered interaction, radar observation being used at a later stage of interaction (delayed reaction), and the immediate reactivity of the follow gaze function.

Form

Form evolution

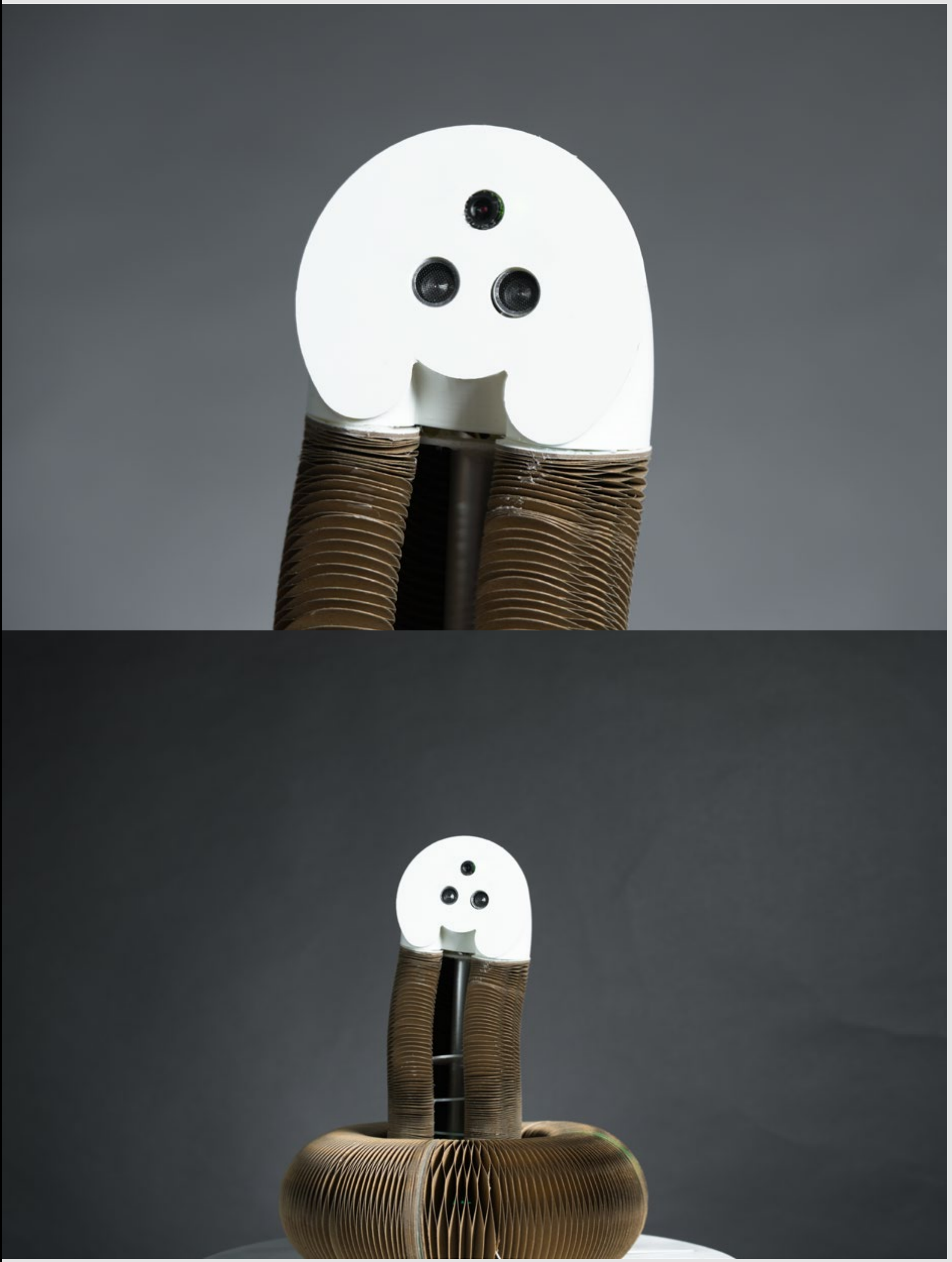


Image 36 & 37: Final form of the project “Motion and Emotion“

Image 38: Final form of the project “Through your Eyes“

The robot's physical form is intentionally abstract in order to avoid anthropomorphic features while maintaining expressiveness and allowing personal projection. By analyzing current social robots ranging from companion animals to humanoids (Image 40), this robot proposes a novel aesthetic, between minimalism, transparency about sensors, and materiality. The “cyclop" aesthetic features a singular front-facing camera with a slot-shaped opening, providing feedforward of gaze direction while reducing anthropomorphic associations and accurately reflecting sensing capabilities.

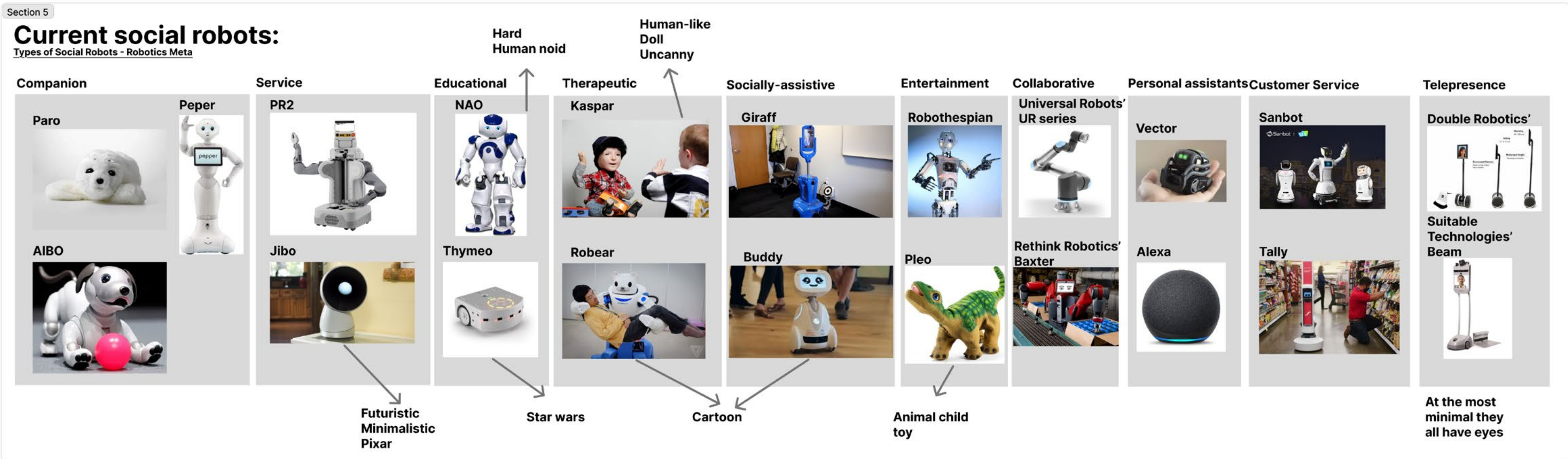


Image 39: First iteration of changes. Here the “Motion & Emotion“ form is the same except for only having on “eye“ since now only a camera was needed.
Image 40: Benchmarking of aesthetics of social robots, organizing them by purpose and annotating their aesthetics [1, 17, 18, 72-90]

Form giving process

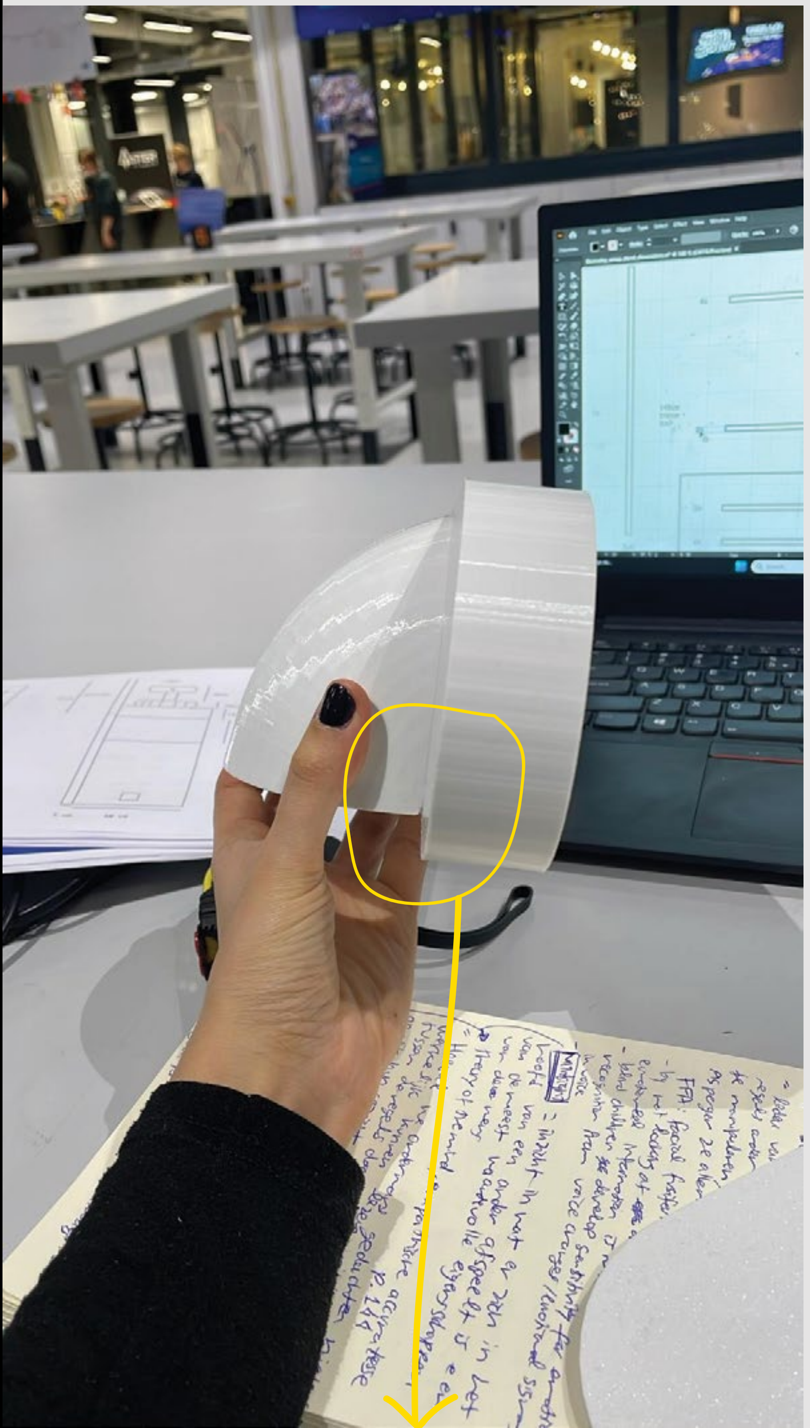
The form of the head of the robot and its neck evolved in shape due to concept changes and changes in the sensors used. Also, the perceptual limitations of the M2.1 prototype influence the further development of its shape.

The **first sketch** proposes the robot to be integrated into the base without a neck. This design was inspired by people referring to it as shy and as an animal that can hide itself. The **second sketch** integrates a collapsible neck to communicate between a state of trust or a state of refuge and adds more degrees of freedom for programmable actuation. Also, the head shape is a slot to better convey the orientation the camera is looking in, giving a better indication if the user is in the field of view.

The **third sketch** ideates on the shape of the stand of the prototype, proposing a better shape flow between the base and stand. The **fourth sketch** stems from a change in sensing, adding the radar and two cameras (one for gaze tracking and one for facial expression tracking). This direction was abandoned because the radar needed to be in a still position to work reliably, being embedded into the electronics casing, and the second camera was not needed due to software integration.

The **fifth sketch** was ideated when the system's sensors changed to only one camera. Therefore, the “face” of the robot changes to a “cyclop” shape instead of the previous trilocular “face”. The **sixth sketch** tests how to connect the slot head to the arced neck and integrate the cyclop “face” with the slot shape. A limitation was the angle of the camera being upwards instead of directly facing the user.

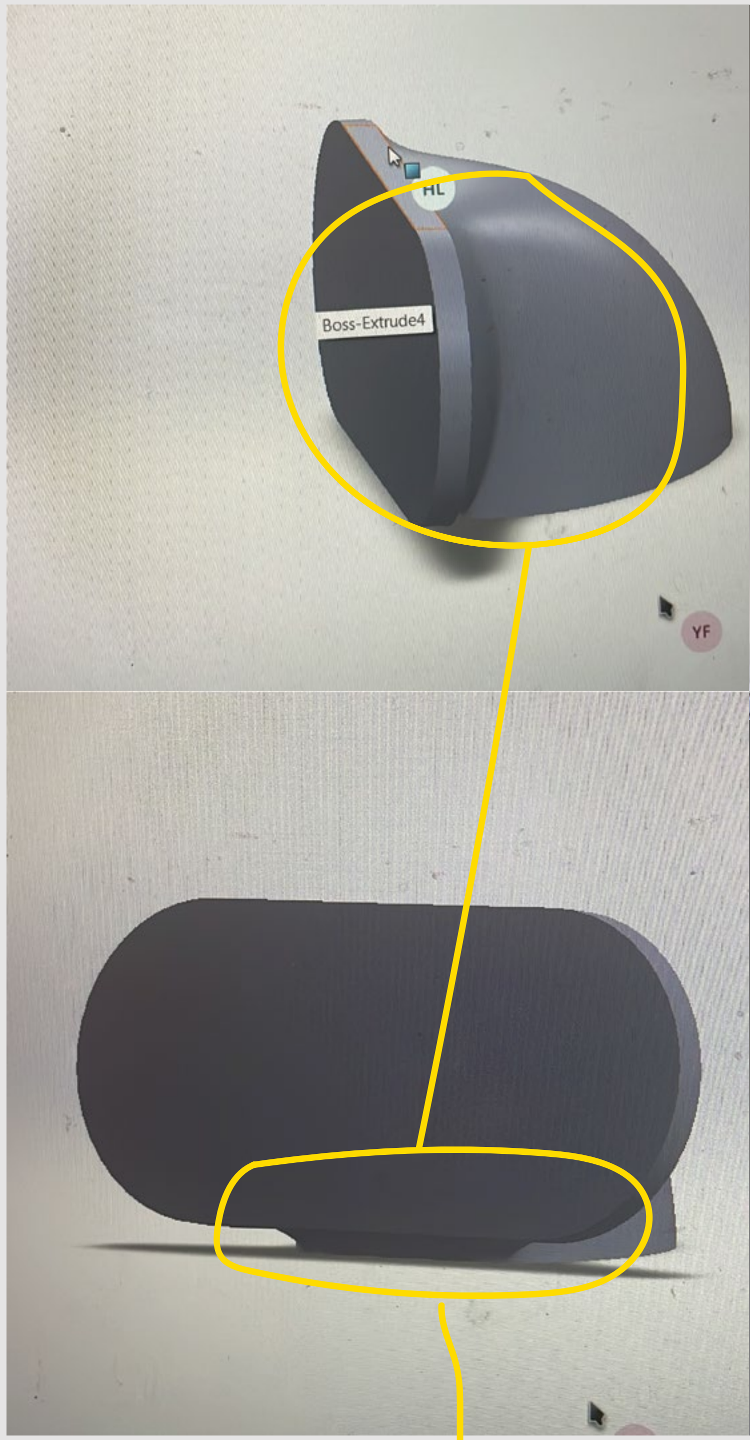
The **seventh sketch** iteration shows the shape transition between the “neck” and the “head” in a linear manner. Making the aesthetic more bulky and matching traditional robotics aesthetics. The **final sketch** uses circular lines to connect the “neck” to the head, producing a more organic and modern aesthetic.



Front

Side

Side



The first 3D printed iteration had no flow between the “face” and the neck, not achieving the desired organic aesthetic.

To achieve this organic flow, the “face” needs to be higher than where the attachment starts.

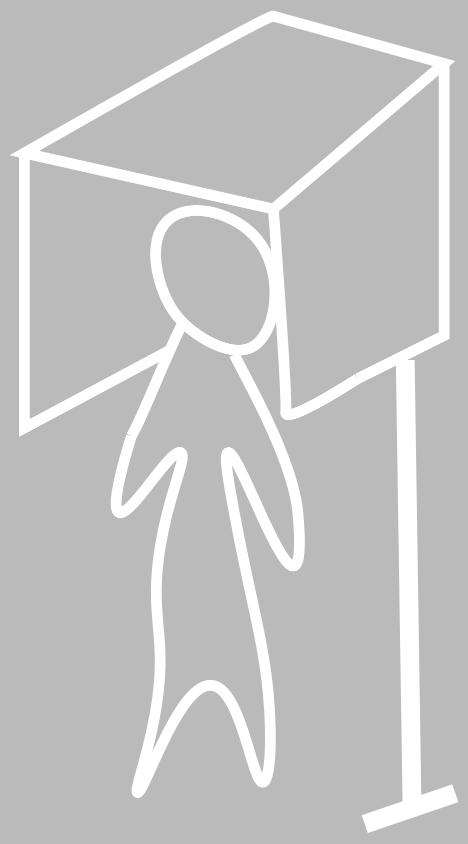
Using SolidWorks for 3D modelling, and with the help of a colleague, the organic flow was accomplished. The new slot shape provides a visual feedback of the direction of the gaze of the robot and consequently a feedforward of the field of view of the camera.

Stand

Stand

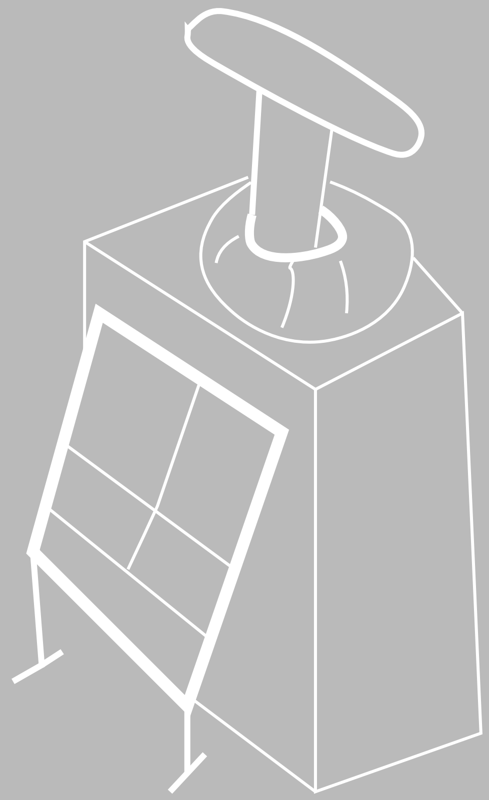
- With the start of the ideation of the stand form the following requirements were set:
- A 1,5 week build timeline
- adaptability for future dimension changes
- easy access to electronics for troubleshooting
- a sturdy structure to support 5 kg of mechanics/electronics and 3 kg of horizontal monitor pull
- aesthetic connection between the robot and visualization side
- The stand needs to position the robot’s camera at eye level for an average-height visitor (1.75 m) and maintain separation between the robot and visualization sides, so social cues could only be read through the robot’s perspective

Image 41: Demoday stand of the project “Motion and Emotion“. The neck of the robot kept dismounting or tilting sideways. The base where the electronics were was not integrated with the rest of the stand.

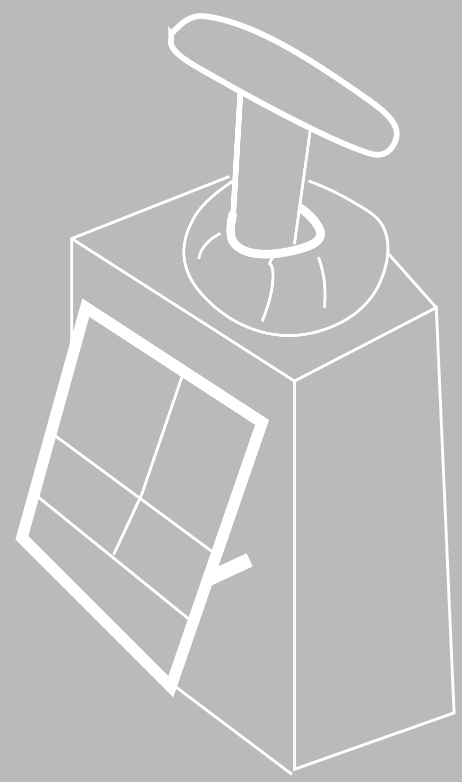


The initial stand forms separated the visualization and robot stands. This was because the starting point of the prototype already had a mid-fidelity casing for the robot.
The above concept shielded the person on the visualisation side from seeing the person on the robot side.

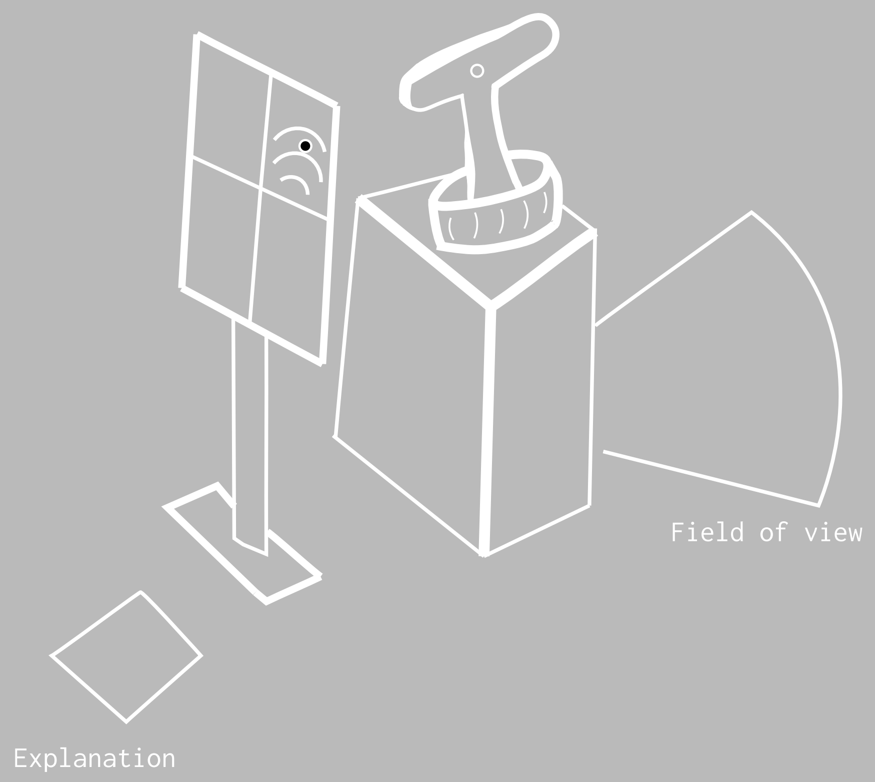
This concept is a simpler stand for the visualization, putting the monitor on a tripod like stand. Here the gaze direction of the user is downwards which doesn't allow interaction between the two sides. However, having the same gaze direction on both sides of the installation is more interesting and consistent.

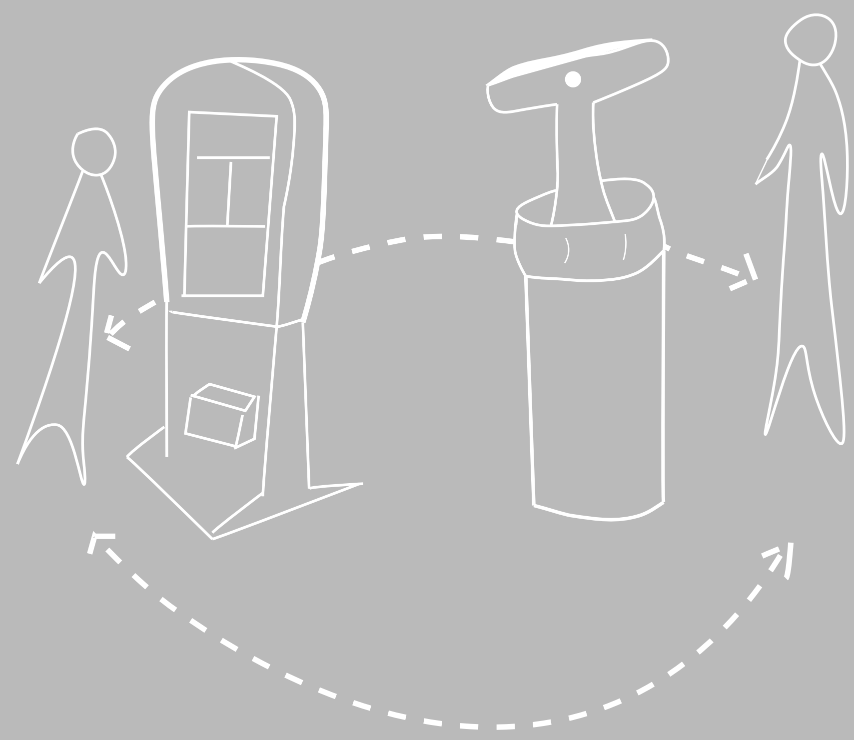


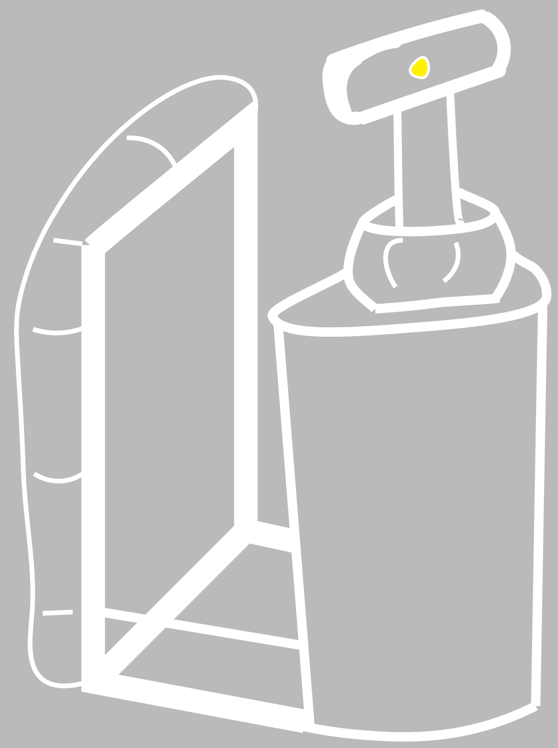
This concept combines the robot and visualisation parts. Due to the weight of the monitor, attaching it directly could make the robot casing fall over.



This concept attaches the monitor to the robot stand. To deal with the risk of the stand falling over a 3Kg, counter weight should be placed inside the stand.



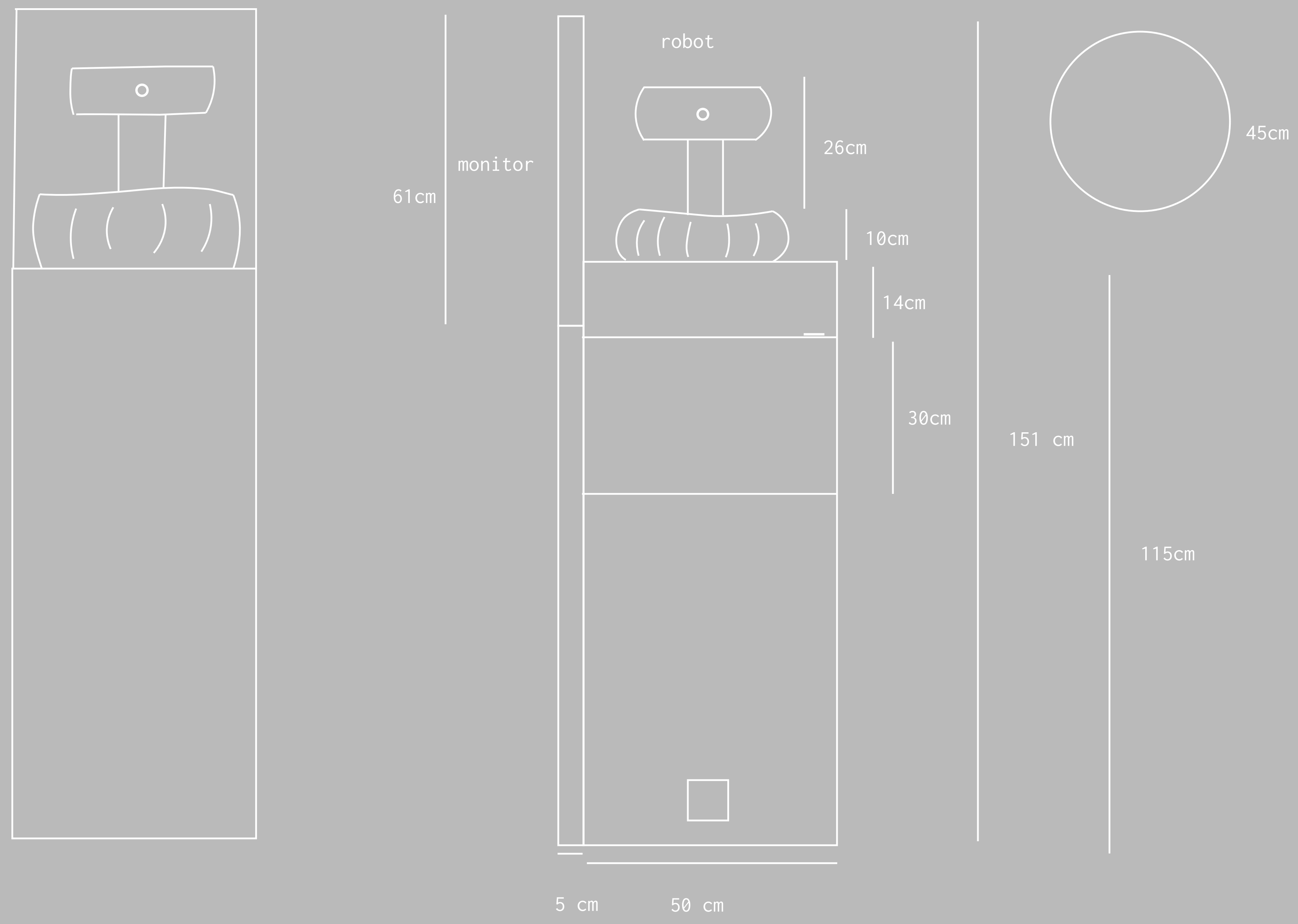




This concept proposes the setup of the installation with an indication of the field of view of the camera to guide users and an explanation of the concept on the visualization side. To not risk a weight imbalance of the system, the monitor is separated from the robot stand.

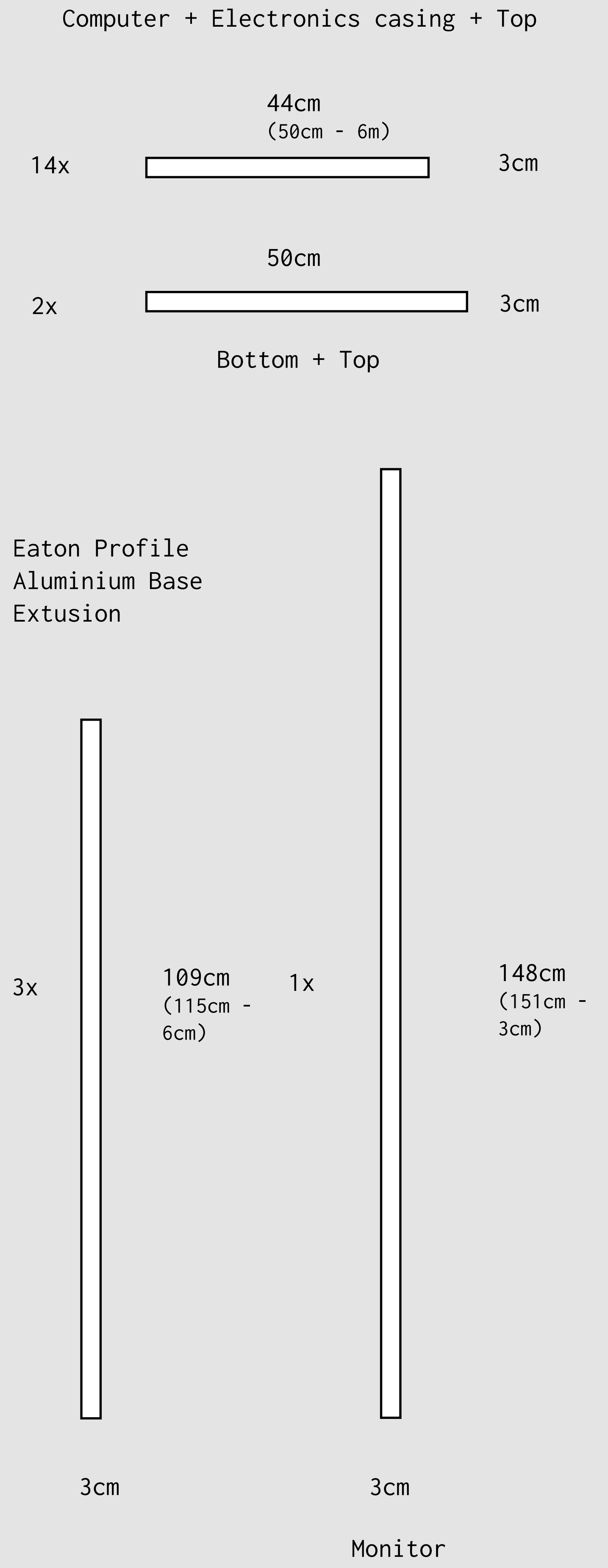
This concept tries to use the circular shape of the robot base on both sides by rounding the frame of the monitor. Additionally, a box with questions to trigger reflections of the audience is placed under the visualization. The experience is defined as having two unique experiences (bi-directional).

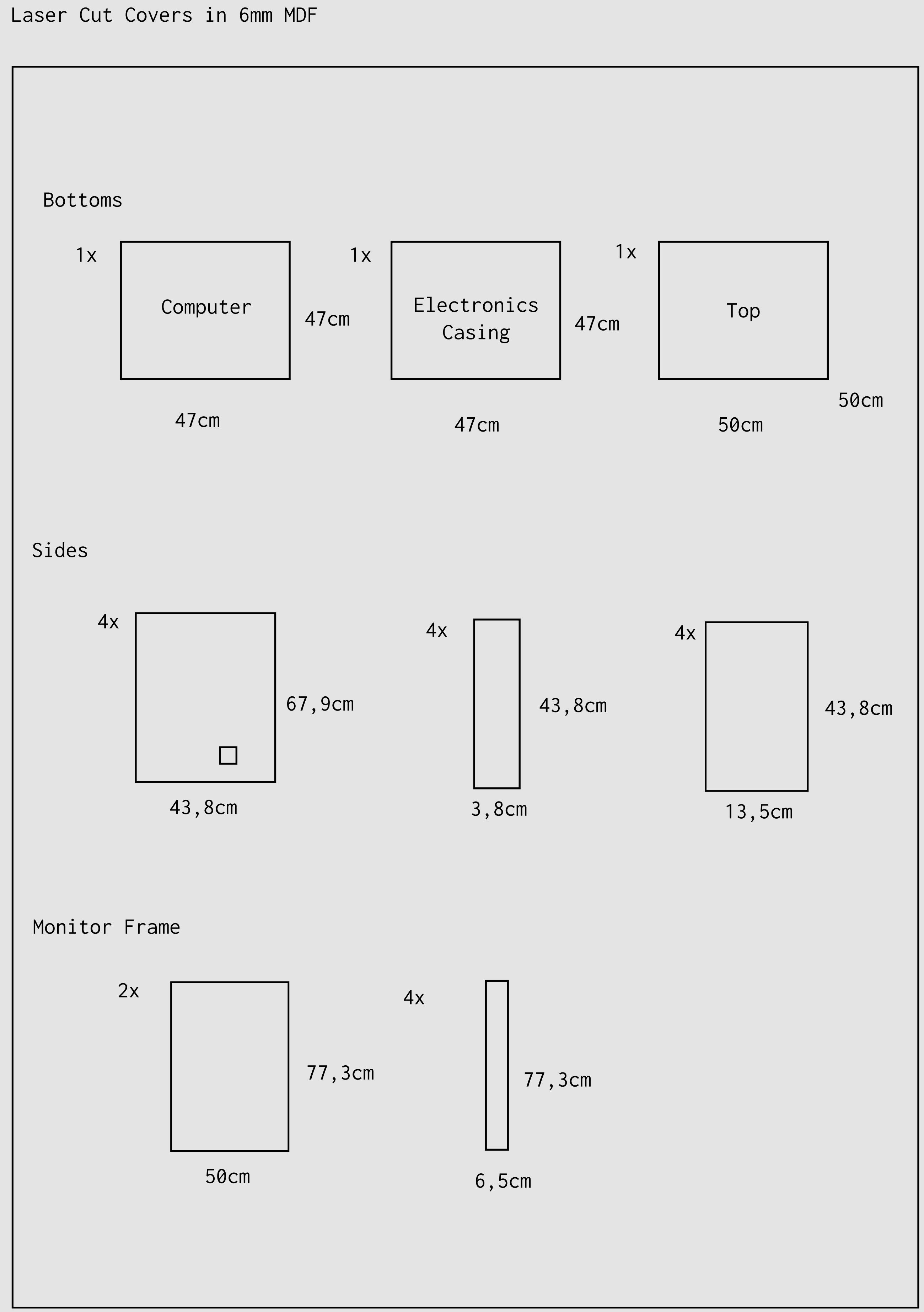
However, separating the two stands limited the aesthetic cohesiveness of the installation. Therefore, the same cardboard material as from the robot base is used as a frame around the monitor. Additionally, to deal with the weight disbalance the weight support is on the ground, not on the robot stand.



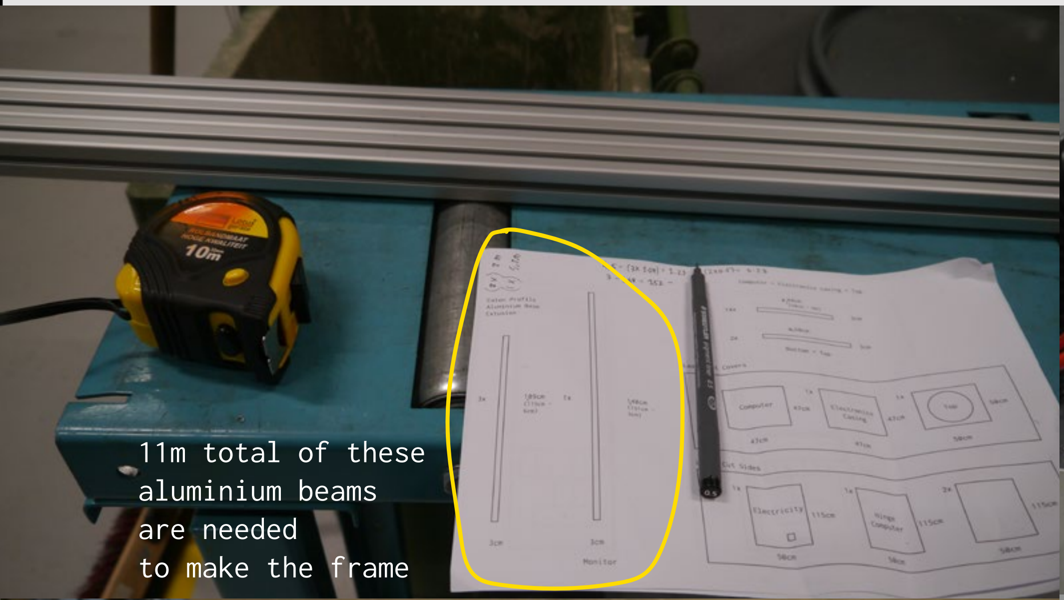
Edwin van den Einden, a mechanical engineer from TU/e's Innovation space, recommended a 30cm aluminum beam to counterbalance the 3kg monitor. This allowed the seamless integration of the monitor into the robot frame. This final design aligned the rectangular monitor with the robot's form, creating a visually cohesive installation.

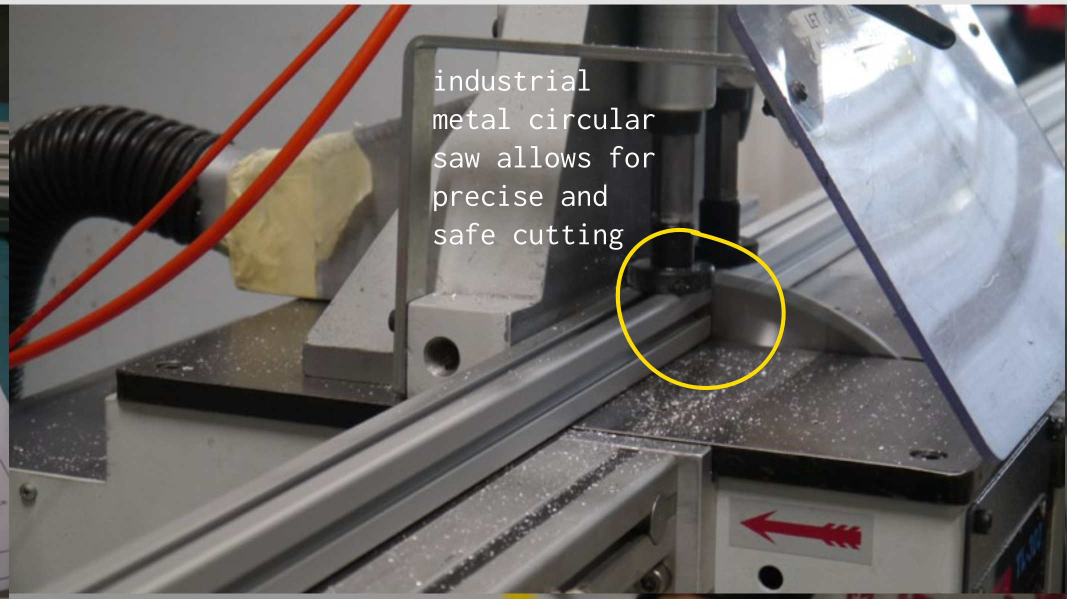
Technical drawings were developed after testing different heights using an adjustable table to evaluate the perceived hierarchy and interaction with the robot. The final height was chosen to match the robot's eye level for average-height users (1.75m), accounting for diversity in visitor heights, to provide a generally consistent experience. Above are the technical drawings.

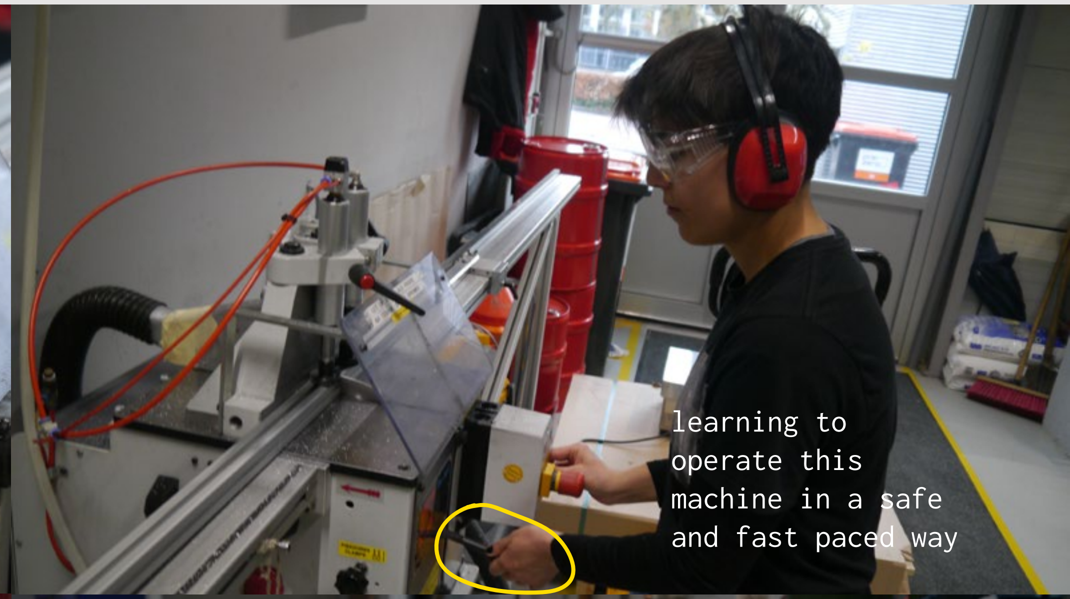




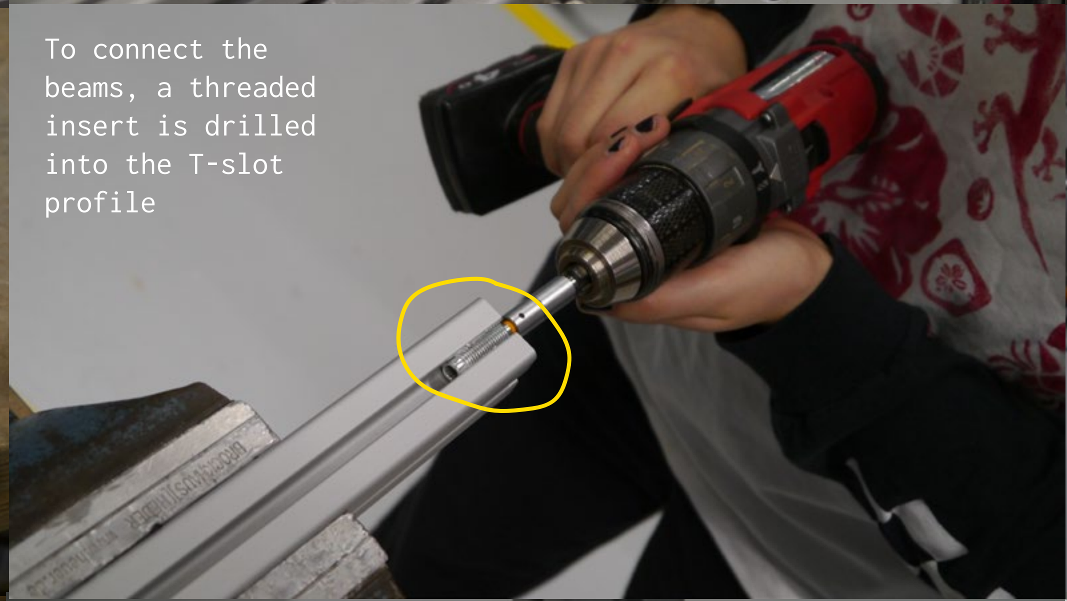
After the dimensions were defined, a list of the needed materials was specified. The chosen materials were 3cm Aluminium T-slot Profile beams (11m in total) for the frame and 6mm MDF, which was later spray-painted white, for the sides.


11m total of these
aluminium beams
are needed
to make the frame

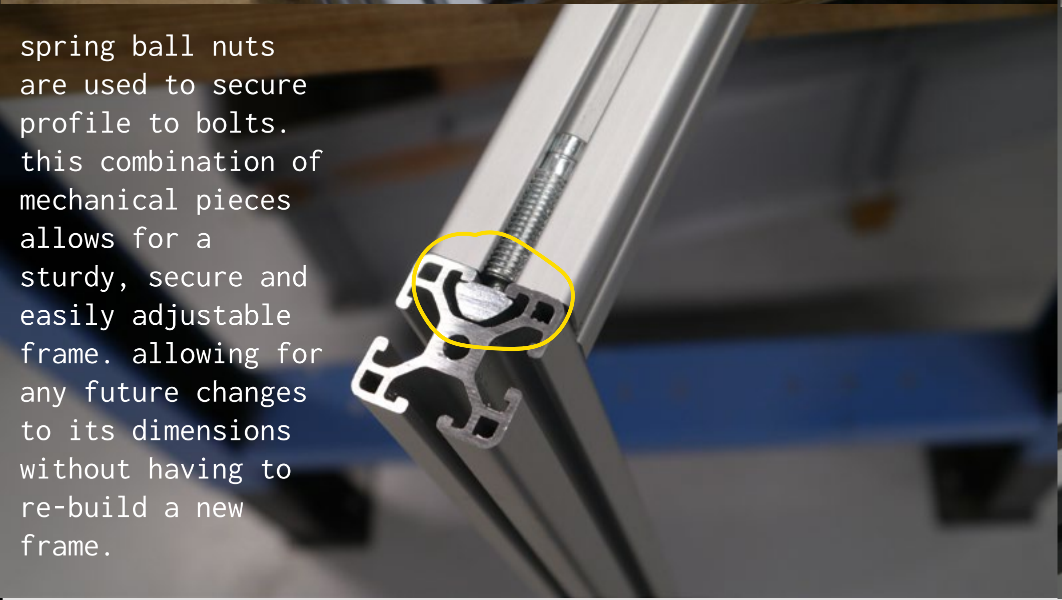

industrial
metal circular
saw allows for
precise and
safe cutting

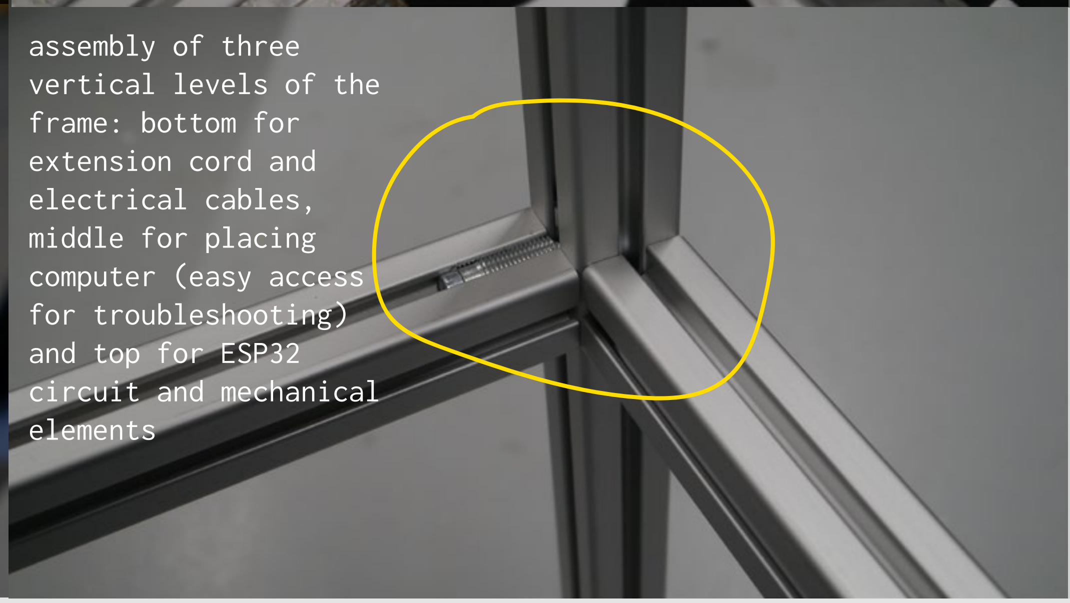

learning to
operate this
machine in a safe
and fast paced way

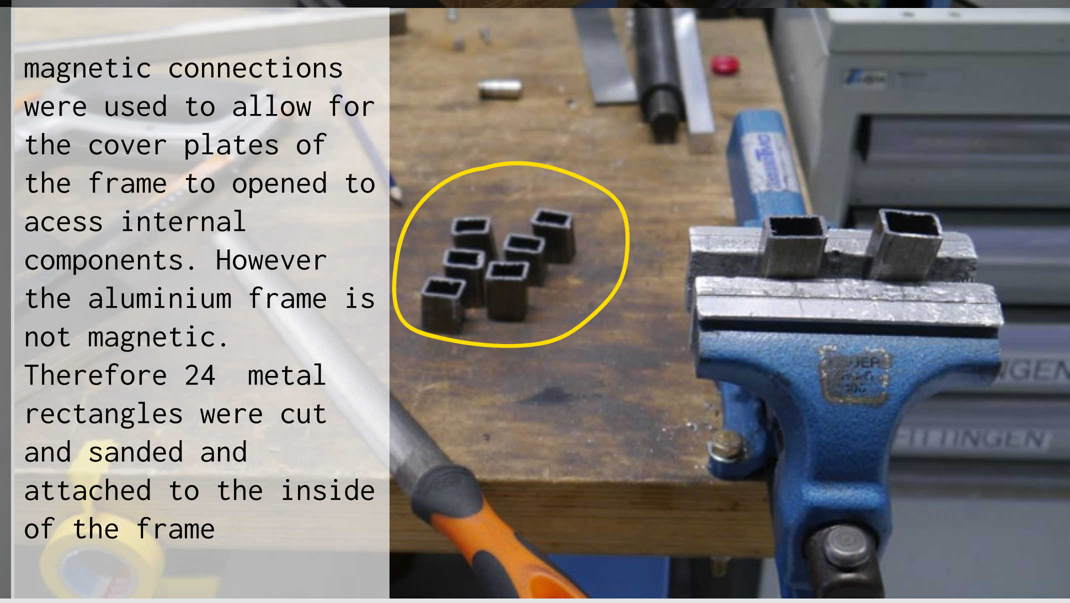

these aluminium beams
have a T-slot profile,
allowing for
simultaneous vertical
and horizontal
connections


To connect the
beams, a threaded
insert is drilled
into the T-slot
profile


connection between beams
through flat head bolts.
It's important to align
everything precisely to
not result in skewed
pillars later on

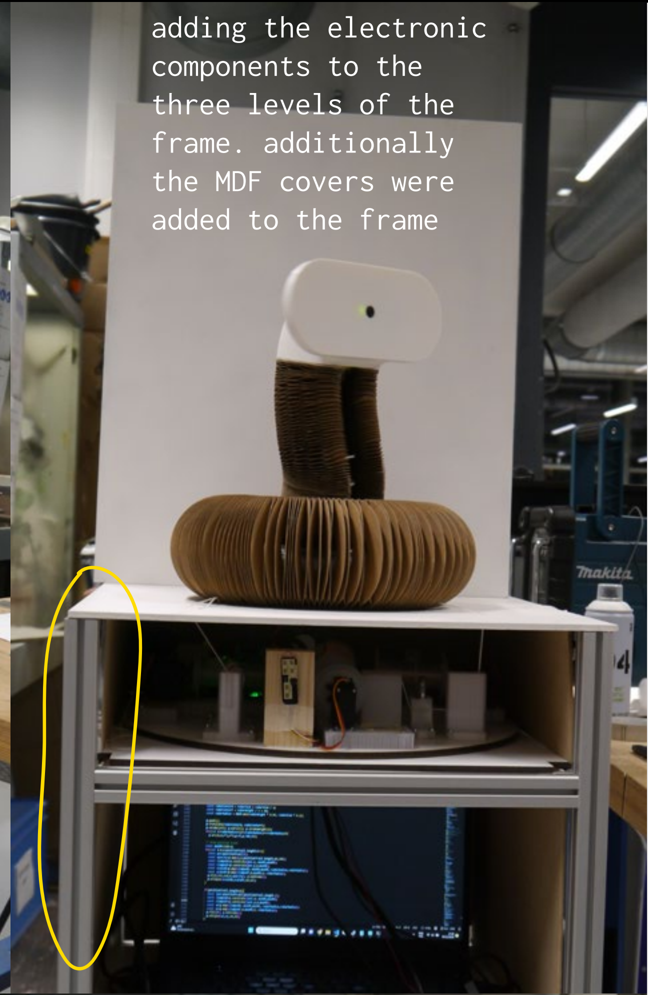

spring ball nuts
are used to secure
profile to bolts.
this combination of
mechanical pieces
allows for a
sturdy, secure and
easily adjustable
frame. allowing for
any future changes
to its dimensions
without having to
re-build a new
frame.


assembly of three
vertical levels of the
frame: bottom for
extension cord and
electrical cables,
middle for placing
computer (easy access
for troubleshooting)
and top for ESP32
circuit and mechanical
elements


magnetic connections
were used to allow for
the cover plates of
the frame to opened to
acess internal
components. However
the aluminium frame is
not magnetic.
Therefore 24 metal
rectangles were cut
and sanded and
attached to the inside
of the frame

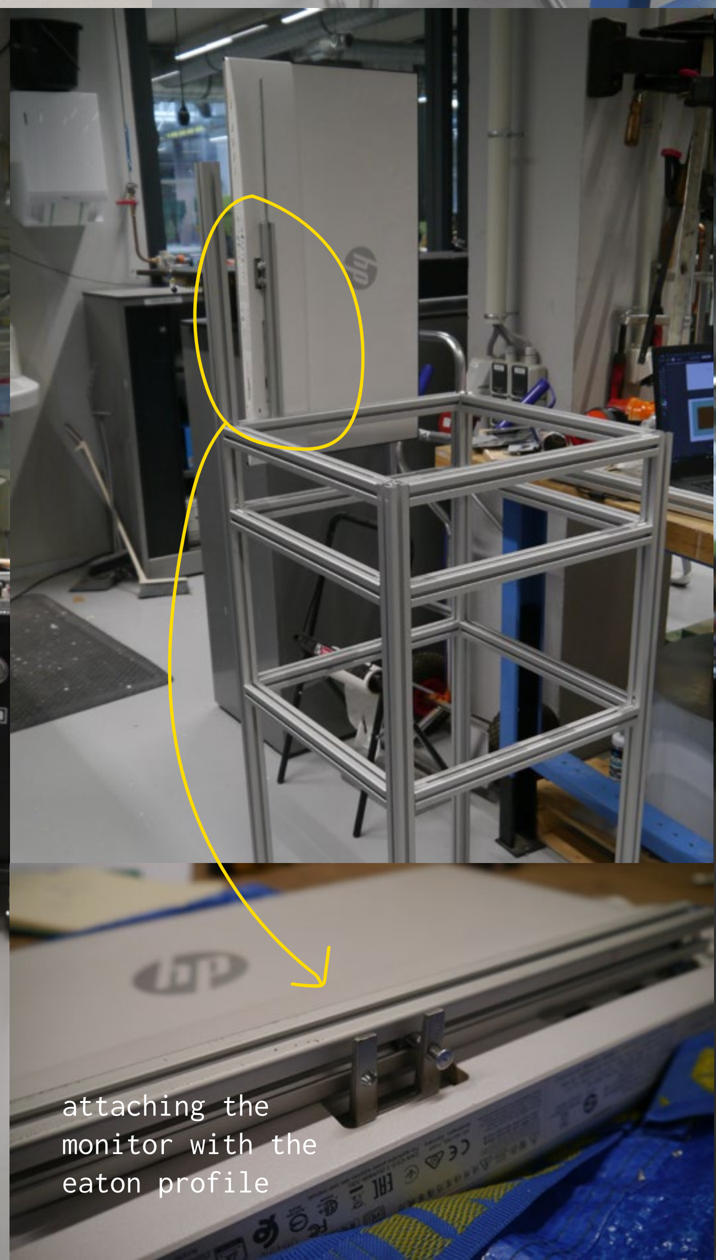
assembling the frame

assembling the frame

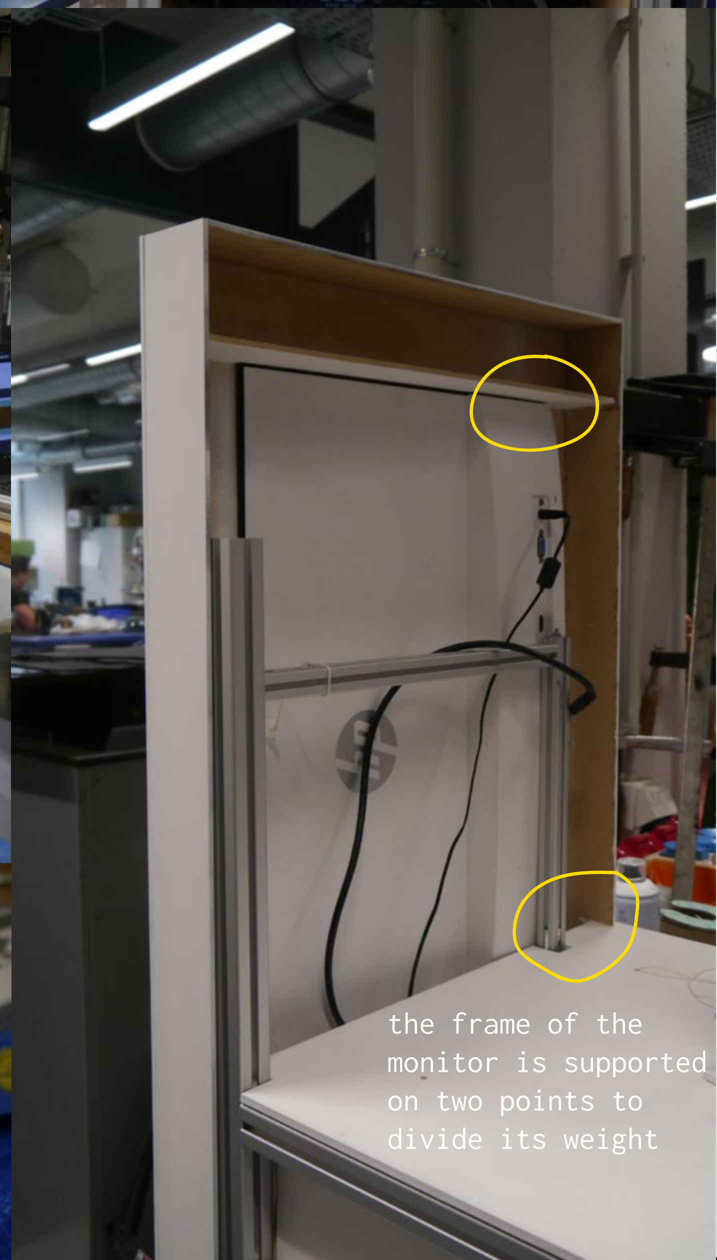


adding the electronic components to the three levels of the frame. additionally the MDF covers were added to the frame

testing the visualization on the frame



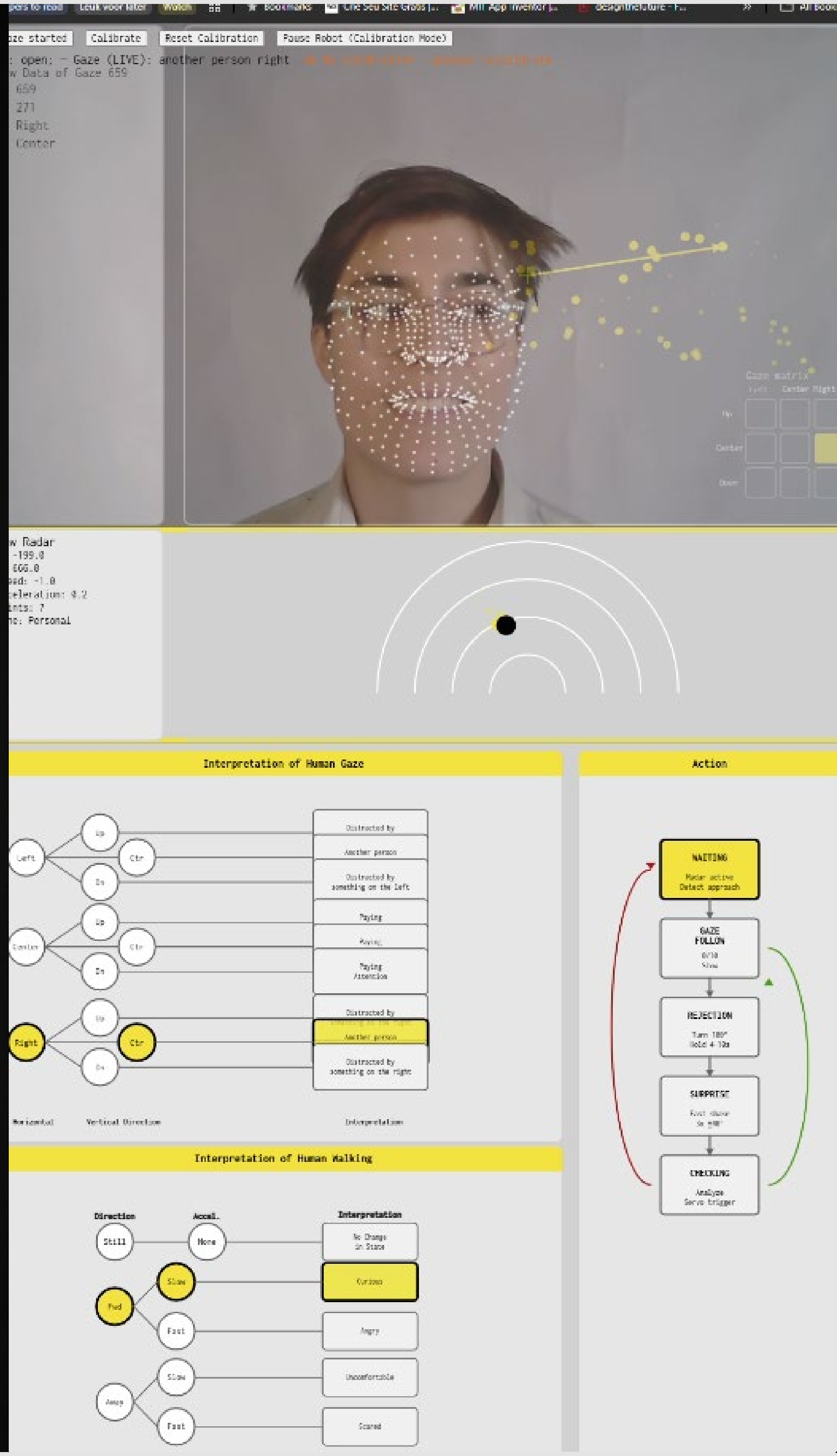
attaching the monitor with the eaton profile



the frame of the monitor is supported on two points to divide its weight

Final Prototype

Final prototype. Photography by Sem Jordaan



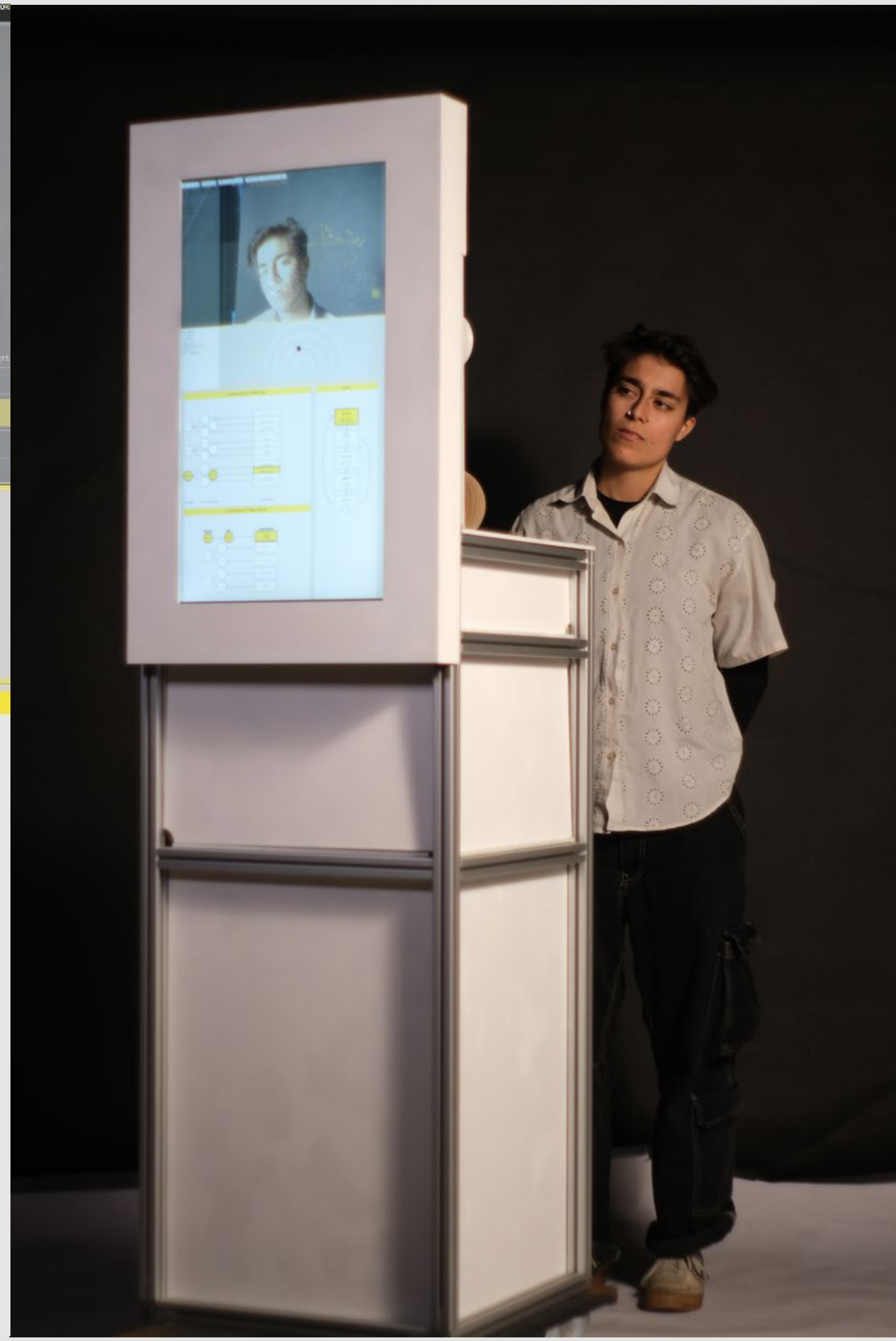


Image 42: Robot side of prototype
Image 43: Visualization side of prototype
Image 44: Close up of visualization

Final prototype. Photography by Sem Jordaan

Image 45 and 46: Pictures of the final prototype.

Final Video

https://www.youtube.com/watch?v=yDE2gL6etPw&themeRefresh=1

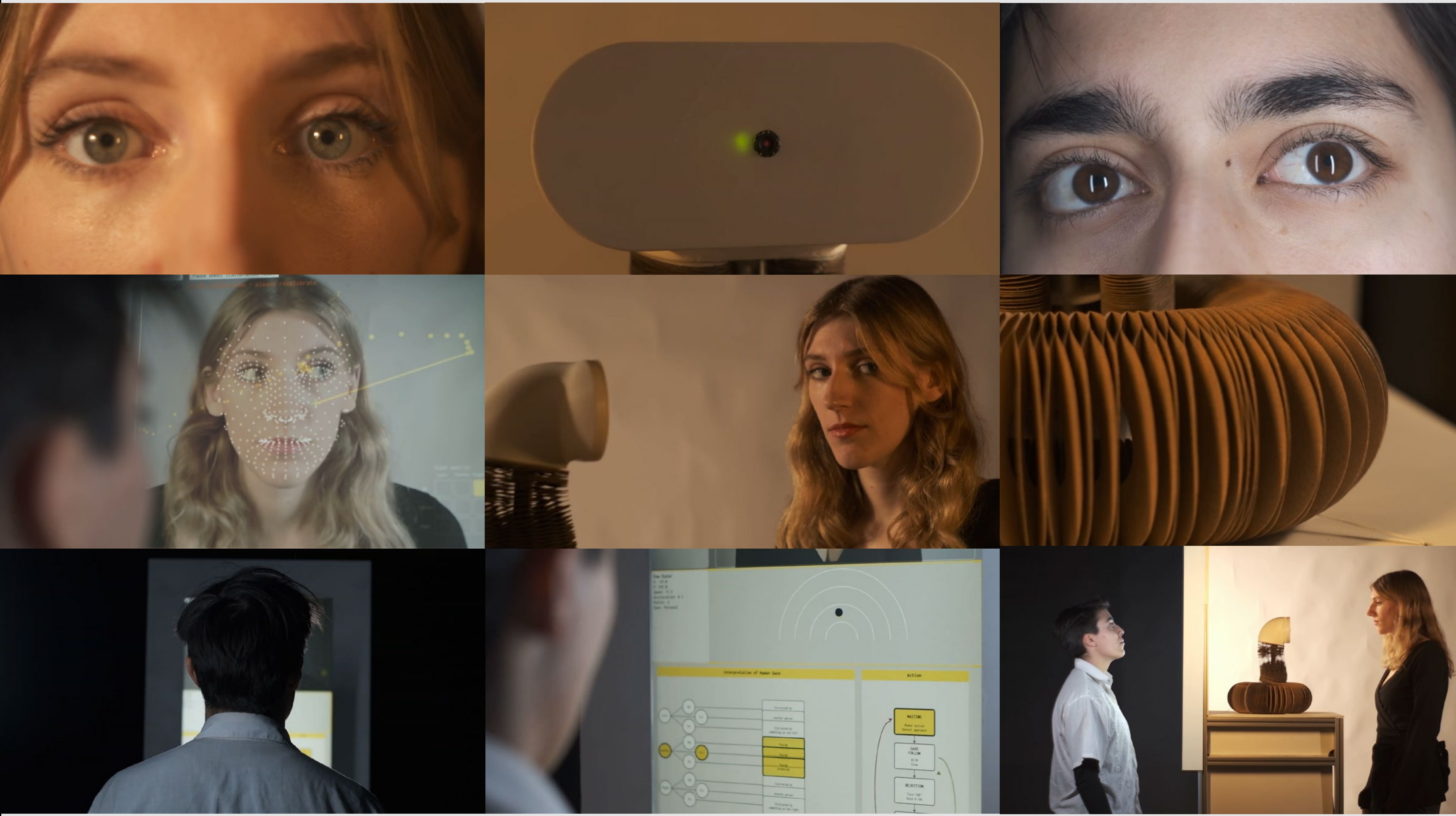


Image 47: Stills of video demonstrating final prototype. Cinematography by Sem Jordaan, editing by Hanna Loschacoff and acting by Sofie Medema and Hanna Loschacoff

Demoday Impressions

Demoday Impressions

The Demoday highlighted insights from the final prototype of “Through Your Eyes”, which proved more robust than the earlier “Motion & Emotion” version, performing reliably both technically and physically.

Social dynamics

Visitors on the robot side often missed the visualization screen unless prompted by others, whereas starting at the visualization side offered a direct link to the robot.

When both sides of the installation were occupied, a “performance” occurred; new visitors were more likely to approach, having already witnessed the interaction’s effects. This led to a collaborative “game” where users on the robot side would ask the observer on the visualization side, “What is it perceiving now?” to test the robot’s accuracy. A particularly interesting moment of engagement occurred in “rejection” mode, when the camera unexpectedly included bystanders, turning them from observers into active participants.

Perception

While some visitors found the artifact cute, funny, or curious, others described it as anxious or creepy. This split was most evident in gaze-following; while many felt a direct connection, others perceived the robot as looking around randomly or being “shy.” Those who felt tracked often interpreted the robot’s behavior as

Image 48, 49, 50 and 51: Demoday interactive setup with two above average height visitors. One of which has to lower myself to fit the field of view of the robot.

Demoday Impressions

“making fun” of them. A clinical psychologist noted that this gaze-following emulates grounding, the communication process that signals mutual attention. Specifically, the robot’s behavior mirrored backchanneling (ex: nodding or rhythmic responsiveness), suggesting applications for ASD therapy or social anxiety training, where users can practice reading and reacting to social cues in a controlled, role-playing environment.

Improvements

Future development should refine the robot’s form to reflect sensing modalities and camera limits and consider long-term interaction design.

Industry validation

Glow Labs: Phillip Ross (Director of Glow) expressed interest in the designer doing a project for Glow Labs, recognizing their skillset as a fit for their multidisciplinary innovation hub. A follow-up meeting is scheduled for late February to present initial concepts for the combination of light and robotics.

Check Appendix F for the digital correspondence.

Tech Kicks: Rian Dings (Director of Tech Kicks) proposed the possibility of using the installation in their educational workshop about emerging technologies.

Check Appendix F for the digital correspondence.

Innovation Space: Mark Scheffer (digital and IT strategy lead) proposed a second version of the prototype to serve as a greeting robot for the Innovation Space entrance. This iteration would integrate gaze detection with Google Gemini to provide verbal, context-aware output.

Image 52: Logo of Glow Eindhoven
Image 53: Logo of TechKicks
Image 54: Logo of Eindhoven University of Technology Innovation Space

Discussion

Discussion

This project shows how visualizing a robot's social interpretations turns human-robot interaction into a reflective mirror, exposing cognitive bias, uncertainty, and social meanings.

Implications

Within interaction design, this project illustrates how psychological and social science theories can be translated into physical, experiential installations. Abstract values such as transparency, ambiguity, and discomfort are given form through visualization and kinetic expression. Sensing and actuation are being combined to allow for emotional expressivity. The interaction guidelines developed through the design process offer a blueprint for similar projects, the process log, design reflections, and an open-source GitHub repository [24] support replication, critique, and continuation by other designers.

In social robotics, the project contributes as an alternative to dominant anthropomorphic or utilitarian examples. It's minimal, non cute aesthetic proposes a robot that allows for awkwardness, rejection, and misunderstanding. Creating an alternative to status-quo emotional dynamics of caring or efficiency-driven designs. Also, positioning the robot as a reflection tool, similar to applications in social role play, psychoeducation, and therapeutic contexts. Insights from user studies further contribute to understanding how such robots are perceived and experienced.

Limitations

Several limitations shaped the generated findings. Since user studies were conducted primarily with Eindhoven University of Technology students and exclusively with Caucasian participants, this restricted demographic diversity. Thus, its evaluation does not address known biases in computer vision systems, which perform less reliably on underrepresented groups. Reinforcing broader concerns about AI bias and the systematic privilege of certain bodies by sensing technologies.

Methodologically, qualitative user research and autoethnography are inherently interpretive and subject to researcher bias [59, 60]. Decisions regarding data collection and interpretation inevitably shape the resulting insights.
To make social cognition theories tangible, the system simplifies and exaggerates complex psychological constructs.

Although this was effective for engagement, validating this translation with psychology experts would evaluate its accuracy and psychoeducational value. Additionally, expert interviews were conducted remotely via video demonstrations; in-person sessions would generate more experience-based insights.

Regarding the sensing technology used, gaze tracking was easily affected by lighting conditions, glasses, skin tone, and calibration. These sensitivities became conceptually meaningful because they reveal how AI systems are never neutral. Moreover, how the sensing data was interpreted relied on Western norms of proxemics and eye contact, risking cultural and neurotypical bias.

Accessibility emerged as a further limitation. The fixed height of the prototype excludes wheelchair users and young children, revealing how physical design choices can unintentionally exclude certain bodies.

Future developments

Future iterations could increase participant agency by allowing users to manipulate how the robot interprets cues, making bias itself an interactive parameter. Longer interaction periods with visible data trails could reveal evolving patterns over time, while additional modalities such as haptics could enrich the interaction loop. Evaluating the system in psychoeducational contexts, particularly relating to social anxiety or autism spectrum experiences, remains an important next step. Addressing the previously mentioned limitations by conducting user studies with diverse demographics, using computer vision models which were trained on diverse data sets, and making the stand adjustable in height. Finally, developing the prototype into a customizable research platform could support broader human-robot interaction studies beyond this project.

Conclusion

Conclusion

This final master project set out to explore how experiential interaction design can propose alternative ways of understanding ourselves and others by making social cognition tangible. Through a Research through Design approach [58], the project addressed the research question by making social interpretation, cognitive bias, and misreading experiential. Turning abstract psychological concepts into embodied experiences.

“Through Your Eyes” presents a socially anxious robot that interprets gaze and proxemics through a biased lens. By visualizing its reasoning, the installation showcases subjectivity, uncertainty, and cognitive biases in social interaction.

While the installation has clear limitations: computer vision ethnic bias, accessibility constraints, and cultural specificity, these shortcomings also reinforced the project’s conceptual point by revealing the bias of sensing systems. Through user studies, expert interviews, and public exhibitions, the installation showed that it provoked reflection. This suggests its potential within experiential, psychoeducational, and critical design contexts.

This project demonstrates how experiential design can be used to make social cognition tangible and showcase how social understanding is formed, interpreted, and misinterpreted.

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//Department of Industrial Design at the Eindhoven University of Technology, thank you for all that you have taught me, all the amazing students and staff I've met and all the inspiration and advice everyone has given me. There is a really special community here, I hope it continues to be so original and free. I really appreciated the educational format, the trust and freedom that was provided me. Also thank you for those that have built this department, education and curriculum. And thanks to Eindhoven for being the home of my student adventures.

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A special thanks to Pauline, Saar, Miguelito and Papa.

Finally, I dedicate this project to Lidia Serras, that would have loved to hear about it.

Appendix

Appendix table of contents:

Appendix A: User study #1

User study #1
Goal:
User study #1 was conducted with the prototype “Motion & Emotion” with three strangers to identity improvements, perception and experience, side it had not yet been tested. Strangers were asked since the project had only been presented in a industrial design department context, broadening the perspectives of the project.

Procedure
The procedure of the study evolved a 3 minute interaction with the robot without any explanation, followed by questions about what the project is about, how the robot is perceived and how they felt while interacting with it and feedback on the interaction. Afterward, an explanation of the project and system was given, followed with the opportunity to interact with the robot again and simultaneously being questioned further and open to the feedback of participants.

Questions:
- What thoughts/feelings do you have?
- How would you characterize the emotional expressivity/personality of the robot?
- How would you describe the user (aesthetic and sensorial) experience?
- What do you think of the interaction?
- How do you feel about being emotionally sense? Did you feel it was trying to understand you?
- Did you see your emotions reflected in its movement?
- How did you feel in relation to the robot? (intimate, scared, calm)
- How do you feel about products sensing your emotions in the future?
- How could this prototype be improved?
- How do you think how different people react to this system what it reveals about them? How could these observations be made?
- What context/application do you see it have a meaningful contribution to?
- What capabilities could a social/emotionally intelligence robot have?
- What do you see as the main opportunities and obstacles of this technology?
- Ideas of social dynamics I should explore? (ex: getting ignored by one person)
- Any comments/tips/improvements

Appendix A: User study #2

User study #2
Goal:
The second study was done with four Industrial Design students, using participatory design research methods [33] , to propose alternative visualizations of the data and gain insights into its experience. The motivation to do this user study was due to the designer having little previous experience with front-end development and data visualizations, design colleagues were asked to participate in the decisions. Additionally, the designer bias of the visualization being intuitive to understand was a crucial limitation of developing the visualization alone. The user generative method [33] was balanced by providing a start point (draft visualization) since its easier to trigger new ideas and provided feedback if there is an example instead of a blank canvas. Also to communicate the idea better and let it be experiential.

Procedure
They were asked to do a think-aloud method, to shorten the designer interpretation of participants reactions and their internal interactions, to not get lost in translation. They were then interviewed about their interpretation of the system, feelings and feedback Then a participatory user generative method [33] was used, when they were asked to sketch and/or collage a new visualization, either using a template of the elements of the draft visualization they were presented with or proposing a totally new visualization, a visualization of how the robot interprets people.

Appendix A: User study #3 (Expert interviews)

User study #3
Goal:
Expert interviews [34] provided complementary perspectives from a critical design researcher, a CTO from a social robotics company, and an art and technology design engineer working with interactive installations. These interviews informed both conceptual framing, industry perspective and practical interaction strategies. Gaining interaction design insights of the critical design research and the art & tech installation, and gaining more insight into current developments in social robotics. Evaluating my concept's potential for psychoeducation, a tool for critical reflection and as an engaging, interactive and experiential art installation. Sage Research Methods - The SAGE Encyclopedia of Qualitative Research Methods - Semi-Structured Interview). These experts were from the following fields: social robotics, art & technology and critical design research.

Demographics:
Participant recruitment was done via LinkedIn and at DDW, and interviews conducted online. Tellart, Studio Drift, LuxAI and the IT University of Copenhagen (ITU).

Procedure:
A brief introduction of myself, followed by an explanation and video demo of the project, and then a semi-structure interview about the project (refer to the question list on the next page).

On the right are the social robotics companies and academic experts I contacted.

Robotics companies (Expert interview)

Name	**Expertise**	**Contacted**	**Response**	**Output**
Tinybot	Social robots for older adults	☑	☑	No time for interview
Pall robotics	Humanoid for logistics, health, retail and education	☑	☐	
EngineerArts	Humanoids for education, healthcare and hospitality	☑	☐	
Furhat	Research platform robot + AI	☑	☐	
LuxAI	Social robotics for autism	☑	☑	Interview

Academic experts

Name	**Expertise**	**Contacted**	**Response**	**Output**
Madeleine Ganon	Creative robotics: new futures for human-robot relation	☑	☐	
Golan Levin	New forms of reactive expression	☑	☑	Was not available
Behnaz Farahi	Empathetic relationships between the human body and its surrounding environment.	☑	☐	
Angelique Spaninks	MU curator	☑	☐	
Piyakorn Koowattanataworn	Critical Design, trust in healthcare tech	☑	☑	Interview

Appendix A: User study #3 (Expert interviews)

Question per companies of the expert interviews:

Questions for Piyakorn Koowattanataworn:

Expertise: embodied experience design, critical design, relationship between control, trust and physiological sensing

• What are your initial impressions/thoughts?
• How does this relate to your work?
• How can I best communicate this or design the robot interaction?
• How does my work relate your work?
• How can I improve my project? What would you change?
• What are you most curious about when I deploy this prototype? What would you want to research/investigate with it?

• In your Breathe Kritisk installation, you use discomfort as a resource for reflection. How do you calibrate the level of discomfort to keep visitors engaged rather than causing them to disengage? What lessons from this could apply to my socially anxious robot that rejects users?
• My installation aims to create an emotional arc from curiosity to rejection to reflection. How do you design for moments after discomfort—what strategies help visitors move from feeling uncomfortable to productive reflection?
• Your work questions trust in “objectified truths” from biosensors. Similarly, my project questions the “objectivity” of emotion/gaze detection AI. How explicit should I be about the robot’s flawed interpretation system? Should visitors discover this gradually or know it upfront?
• You worked in health informatics—in that domain, there’s often tension between transparency (showing users their data) and trusting the “black box.” How do you navigate this in artistic contexts?

• Both our projects use critical design to question relationships with technology. Where do you draw the line between productive provocation and frustration that causes visitors to dismiss the work entirely?
• You describe your work as creating “playful discomfort.” My robot is meant to be both playful and anxiety-inducing. How do you balance these seemingly contradictory experiential qualities in practice?

• Given your focus on how we relate to devices that measure and respond to our bodies, where do you see the future of affective computing going—particularly systems that claim to read emotions or social cues?
• If you were to iterate on Breathe Kritisk knowing what you know now, what would you change about how you communicate the “lesson” or insight to visitors?

Additional questions:
• With your background in accessibility design, how do you ensure that embodied discomfort is inclusive and doesn’t exclude certain bodies or experiences? Social anxiety manifests differently across cultures and neurodivergent individuals—how might I account for this?
• Your work questions trust in “objectified truths” from biosensors. Similarly, my project questions the “objectivity” of emotion/gaze detection AI. How explicit should I be about the robot’s flawed interpretation system? Should visitors discover this gradually or know it upfront?

Appendix A: User study #3 (Expert interviews)

Questions for Teije Oudshoorn:

• What are your initial impressions/thoughts?
• How does this relate to your work?
• How can I best communicate this or design the robot interaction?
• How does my work relate your work?
• How can I improve my project? What would you change?
• What are you most curious about when I deploy this prototype? What would you want to research/investigate with it?
• Studio Drift creates large-scale kinetic installations with complex sensor systems (like their drone swarms and moving sculptures). What technical approaches do you use to make sensor interpretation visible or tangible to audiences?
• How do you handle the calibration between responsive behavior and predetermined choreography in Studio Drift's interactive works?
• My "behind-the-scenes" visualization shows raw sensor data and the robot's interpretation logic. From your experience, what makes technical visualizations compelling and comprehensible to non-technical audiences without being overwhelming?
• With your expertise how do you keep people engaged but the interaction intuitive? How do you design interaction loops that remain engaging across repeated encounters? My robot needs to "reject" users but keep them curious enough to explore the visualization.
• What are the biggest technical challenges you've faced in creating installations that respond to human behavior in real-time, and how did you solve them?
• How do you think about the physical relationship between the robot and its "brain" visualization in exhibition space? What layout would create the most meaningful journey for visitors? Blocking view or not?
• What are you most curious about when I deploy this prototype? What unexpected behaviors or visitor reactions would you want to investigate?
• How to make people reflect/spark a conversation?

Appendix A: User study #4: General population evaluation

User study #4
Demographics:
Using the personal network of the researcher, six participants were recruited; however, one cancelled last minute. Five participants took part: a mix of early-career professionals and students, all ex-alumni of TU Eindhoven with varying gender identities. None had prior knowledge of the project concept.

Goal:
The goal was to understand how the robot was perceived, participants' instinctive interaction behaviors, and their experience evaluating ease of interaction and engagement. The study aimed to explore what was being communicated through the interaction and what types of reflections it sparked.

Procedure:
Participants interacted with the robot for two minutes using the think-aloud method [71] , followed by two minutes of experiencing the visualization. Afterwards, a semi-structured interview was conducted to capture experience, perception of the robot and its "lens," suggestions for improvement, perceived relevance of the project, and reflections on participants' own social cue lenses and experiences of misinterpretation.
These conversations centered on participants' interpretations of the robot's "mind," experiences of misinterpretation or rejection, and reflections on social anxiety and blame. To remain open to unexpected insights of users, a semi-structured interview was used being able to adapt the questioning scope. The limitation of this approach is not asking each participant the same question.To analyze these materials, reflexive thematic analysis was used, allowing themes to emerge through continuous reflection between data, theory, and design decisions.

Data analytics:
Data collection consisted of manual note-taking, voice recordings, and observations of participants' interactions. No identifiable or trackable information (ex: names or photos) was collected. No sensor data (camera, radar, or gaze data) was recorded, stored, or transmitted; sensors were used only for real-time interaction and visualization during the demo.

Appendix B: Github (Arduino final code, HTML + Javascript)

Github repository link:
https://github.com/hannaloschacoff/non_verbal_social_cues

Appendix C: ERB form

Instruction page

Consent form ethics v1

This consent form should be used in the following situation:
Your research will be fully *anonymous*, and data obtained from the study will not be traceable to individual participants. Because you will not process personal data, you only need ethical consent from the participants to participate in your study. Therefore, this consent form (*which does include the participant's name*) should be removed as soon as possible, but no later than the end of the study.

When you move your mouse over an italic, underlined and blue *word*, an explanation will appear. This explanation should be removed from the actual document upon completion.The text blocks marked in yellow indicate what information should in any case be completed or where the researcher must select an option. Please share this information within this form in the simplest possible phrasing. The template must be followed as strictly as possible and sub-headings may not be deleted.

Based on this information, a potential participant can make an informed and formal decision concerning participation in the research project.

Integration into web survey etc.
This form can be integrated into an online web survey. This is because consent can also be given through a digital signature or by placing a checkmark.

Assistance and review
For additional support in preparing the consent form ethics, contact your faculty's data steward via this *link*.

Ethical Review Form

(Version 2.4)

This Ethical Review Form should be completed for every research study that involves human participants or personally identifiable personal data and should be submitted to ethics@tue.nl. For more information about how this process works please click here. Please check if you are using the correct form: Ethical Review Form (version 2.4). Please click here to obtain this latest version.

Part 1: General Study Information

1	Project title / Study name	Speculum Sociale
2	Name of the researcher / student	Hanna Loschacoff
3	Email of the researcher / student	h.s.s.loschacoff@student.tue.nl
4	Supervisor(s) name(s) *Additional explanation: Please write down the name of your direct supervisor. You can mention several supervisors if appropriate, but at least one supervisor should be mentioned.*	Stephan Wensveen
5	Supervisor(s) email address(es) *Additional explanation: Please give the email address of the supervisor(s) mentioned in question 4.*	S.A.G.Wensveen@tue.nl
6	Department / Group *Additional explanation: Please specify group if relevant e.g. JADS or HTI*	Department of Industrial Design
7	What is the purpose of this application?	☐ Scientific study ☐ Bachelor education. Course:…………….. ☒ Master education. Course: Final Master Project. ☐ Other (e.g. external, following external regulations):………………………….….
8	Research location *Additional explanation: Where will the data collection take place? On campus, in a company, in public space, online, etc.*	☐ Eindhoven University of Technology campus ☐ Online
9	Start date data collection *Additional explanation: Please state when your data collection will start.* ***Please note that the date has to be in the future. Forms with a date in the past will not be accepted.*** *Please note that you do not have to provide information about your complete (PhD) project, but only on this particular sub-study that you are submitting for approval in this form.*	17 November 2025
10	End date data collection	February 21st 2026
11	Does your project receive external funding (e.g., NWO, relevant for special regulations from funders)?	☐ Yes. Name Funder: ☒ No

Ethical Review Form

12	Which internal and external parties are involved in the study? Think about sharing data or information between TU/e and other universities, commercial companies, hospitals, etc. *Additional explanation: Describe all internal and external parties that are involved in the study or project, including:* • *researchers or research groups at the TU/e who participate in the study;* • *(Researchers at) other universities/institutions that provide data/services, help analyzing the data, etc.;*	Internal parties • Researcher(s): • Supervisor:

Ethical Review Form

	• *(commercial) partners, companies, government bodies, municipalities, consultancy firms, hospitals or care institutions that provide data (e.g., contact details of participants, data for further analysis).* *Indicate which role each party plays: who defines the means and purposes in the study, who will supply the data (external parties?), who will process/handle the data, who will be able to access the data during and after research (only researchers at TU/e or also others)?*	External parties • Other universities/institutions: • Others:
13	Have any special agreements already been made with an external party, such as a Non-Disclosure Agreement (NDA) or a data sharing agreement?	☐ Yes, namely: ☒ No
14	Has your proposal already been approved by an external Ethical Review Board or Medical Ethical Review Board? *Additional explanation: For example, when you are collaborating with another university and the project has been approved by their Ethical Review Board, or when you received a WMO-waiver from a Medical Ethical Review Board.*	☐ Yes ☒ No
15	If yes: Please provide the name, date of approval and contact details of the ERB. Please also include the registered number for your project approval. Additionally, please send in the Ethical Review Form upon which ethical approval was granted together with this form.	
16	If you process personal data that are likely to result in high privacy risks for participants, you need to perform a Data Protection Impact Assessment (DPIA). Have you done this for this or a very similar project? ***Please read the information below: a DPIA is not the same as a regular privacy impact assessment. More detailed questions on privacy will follow in the section below.*** *Additional explanation: A Data Protection Impact Assessment (DPIA) is a formal document that must be drafted under the guidelines of the General Data Protection Regulation (GDPR). Think of research with vulnerable people, high-risk medical research,* *The Dutch DPA (Autoriteit Persoonsgegevens) and our website provides more information about a DPIA.*	☒ Not applicable (no high privacy risks) ☐ Yes (the form is attached to the application) ☐ No

Part 2: Medical study

1	Does the study have a medical scientific research question or claim? *Additional explanation: Medical/scientific research is research which is carried out with the aim of finding answers to a question in the field of illness and health (etiology, pathogenesis, signs/symptoms, diagnosis, prevention, outcome or treatment of illness), by systematically collecting and analyzing data. The research is carried out with the intention of contributing to medical knowledge which can also be applied to populations outside of the direct research population. If your research contains questions about health and health related parameters (such as well-being, vitality, feelings of anxiety or stress) but your research question is not primarily medical, then you can answer 'no' to this question.*	☐ Yes* ☒ No *If yes or in doubt, please contact Susan Hommerson via rdmsupport@tue.nl

Ethical Review Form

Part 3: Use of (medical) devices in the study

1	Does your research include a device? *Additional explanation: A device is a complete piece of physical hardware that is used to compute or support computer functions within a larger system. Devices can be divided into input-, output-, storage-, internet of things-, or mobile device.*	☐ Yes, not self-made ☒ Yes, self-made ☐ No
2	Please describe your device or link to an online description of the device	See Page 20-21
3a	Will you use a device that is 'CE' certified for **unintended use** (meaning you will use existing CE certified devices for other things than they were originally intended for) or use a device that is not 'CE' certified? *Additional explanation: You can find more information about CE certification here*	☐ Yes ☒ No
3b	Please explain to what extent the device was assembled according to relevant standards and provide a risk assessment *Additional explanation: You can find more information about a risk assessment here*	To minimize risks, the device is never used or left on without supervision. In terms of electronic risks, these are minimized since all elements are used with their original power sources.

Ethical Review Form

3c	Do you use a device or software that has a medical purpose such as diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease or injury?	☐ Yes, my device or software currently has a medical purpose ☐ Yes, my device or software could have a medical purpose in the near future ☒ No ☐ I'm not sure

Part 4: Information about the study

1	What are your main and applicable sub, research questions? *Additional explanation: You need to provide at least one clear research question.*	How can interaction with a seemingly "socially anxious" robot be a mirror and facilitator around talking about our own social perceptions? How can the visualization of sensors reading social cues and their interpretation stimulate reflection on cognitive biases? Is the message/goal of the experience well communicated and engaging?
2a	Please check the box that indicates the relevant study population *Additional explanation: Please select which persons are eligible for your study.*	☐ Students ☒ General healthy population ☐ General population with specific feature, e.g., pregnancy, specifically .... ☐ Patients, specifically ……….... ☐ Other,
2b	Age category of participants	☐ Younger than 12 years of age ☐ 12 to 15 years old ☐ 16 to 18 years old ☒ older than 18 years of age
3	Description of the research method (select all that applies)	☒ (Semi-structured) interviews *If you tick one of the above, send the interview/survey questions with this form. Without them the form will not be accepted.*

Ethical Review Form

	Additional explanation: Please specify your research method. Note that you need to provide information about the research method in an additional file that you attach to the ERB form. *E.g., for interviews you provide the interview questions, for surveys you provide the survey questions, etc.*	☐ Group workshops/roundtable discussions ☐ Diary studies ☐ Behavioural observations ☐ Building sensor data ☐ Wearable device (e.g. Fitbit watch, on-skin sensors) ☐ User testing ☐ Pilot study ☐ GPS tracking/location data ☐ Living Lab ☐ Other, namely
4	Describe the procedures, measurements, and stimuli/treatments used in your study. If your study involves multiple stages or methods, please describe each step chronologically. For each stage, specify: • What participants will do or experience • What data will be collected (e.g., surveys, observations, physiological measures) • What tools or materials will be used (e.g., validated scales, prototypes, databases) Note: This helps reviewers understand the participant journey and the rationale behind each method.	ee pages
5	Describe and justify the number of participants and observations for each stage of your study. If different methods or phases involve different participant groups, please specify: • How many participants are needed per method/stage • Whether participants will be involved once or multiple times • The duration of participation per session or overall • Any compensation offered Note: Justify your choices based on the study design, expected data quality, and ethical considerations (e.g., minimizing burden, ensuring informed consent).	User study #1: 4 - 5 participants are enough to gather initial insights of visualizations and get design suggestions. User study #2: 6 participants since that is the minimum for qualitative research about experience User study #3: 3-10 participants however diversity of perspectives is most relevant but ideally 5 participants would be best. For all: Informed consent will be attained as described, the form is attached to this document.
6	Explain why your research is societally important. What benefits and harm to society may result from the study? *Additional explanation: What benefit will the results of your study have to society in general?*	This project is societally relevant because it addresses the growing gap in social understanding and empathy in an increasingly digital and algorithmic world. By using art and technology to visualize how humans and machines misread social cues, it invites reflection on our cognitive biases, emotional assumptions, and fears of rejection. The interactive installation encourages self-awareness, emotional dialogue, and connection between strangers, fostering mental health awareness and social understanding through playful psychoeducation.

Ethical Review Form

7	Describe the way participants will be recruited *Additional explanation: How will you recruit participants for your study? For example, by using flyers, personal network, panels, etc.*	☐ Survey link posted online, e.g., social media platforms ☐ On campus flyers ☒ Personal network ☐ Via a company, namely …………….. ☐ Via a hospital, namely …………….. ☐ Via an organization Eindhoven University of Technology ☐ By a Consortium Partner, namely
8	Provide a statement of the risks regarding data breach, safety or well-being (think about stress, extreme emotions, visual or auditory discomfort) that you expect for the participants or others involved in the study. Explain these possible risks and describe the way these risks are mitigated. Also take into consideration any personal data you may gather and associated privacy issues.	Data breach risks: low, gaze direction data is temporarily/ ephemeral stored for processing on a locally hosted webpage not making it vulnerable to server/cloud data leaks (see pages 20-21). Additionally, a meeting with Data Steward validated the technical safe data handling and its privacy. There won't be any safety risks since I will manage the installation when it is running. There won't be any stress-inducing factors such as strong visual or auditory input.

Part 5: Self-assessment checklist

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1a	Does the study involve human material? (e.g., surgery waste material derived from non-commercial organizations such as hospitals)		X
1b	Will blood or other (bio)samples be obtained from participants? (e.g., hair, sweat, urine or other bodily fluids or secretions, also external imaging of the body)		X
2	Will the participants give their consent – on a voluntary basis – either digitally or on paper? Or have they given consent in the past for the purpose of education or for re-use in line with the current research question?	X	
3	Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator? Additional explanation: Think about doing research on your own students or on your own employees. When there is a dependency or power imbalance between you and the research participants, you need to answer 'yes' to this question.		X
4	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g., children (<16 years of age), people with learning difficulties, patients, people receiving counselling, people living in care or nursing homes, people recruited through self-help groups)		X
5	Will participating in the research be burdensome? (e.g., requiring participants to wear a device 24/7 for several weeks, to fill in questionnaires for hours, to travel long distances to a research location, to be interviewed multiple times)?		X
6	May the research procedure cause harm or discomfort to the participant in any way? (e.g., causing pain or more than mild discomfort, stress, anxiety or by administering drinks, foods, drugs, or showing explicit visual material)		X
7	Will financial inducement (other than reasonable expenses and compensation for time) be offered to participants? Additional explanation: For an explanation of what is considered a reasonable compensation, see the topic participant fees from the HTI group		X
8a	Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people)	X	
8b	If yes: Will you be observing people without their knowledge in public space? (e.g. on the street, at a bus-stop)	X	

Appendix C: ERB form

Ethical Review Form

		Yes	No
9	Will the study involve actively deceiving the participants? (e.g., will participants be deliberately falsely informed, will information be withheld from them, or will they be misled in such a way that they are likely to object or show unease when debriefed about the study)		X
10	Will participants be asked to discuss or report sexual experiences, religion, alcohol or drug use, suicidal thoughts, or other topics that are highly personal or intimate? Additional explanation: Think about your research population. For some participants, particular topics can be considered sensitive or intimate, whereas the same topics will not be perceived as such by other participants.		X
11	Elaborate on all boxes answered outside of the blue boxes in part 5.	uring user study #2 participants can non promptly s are personal information a out t eir e periences it misreading social cues and social an iety o e er all tracea le details ill e remo ed from data collection dditionally, people can also disclose t is information in daily life	

Ethical Review Form

Part 6: Self-assessment on privacy

The following questions (1-11) concern privacy issues, as laid down in the General Data Protection Regulation (GDPR). The Data Stewards and – if necessary – privacy team of TU/e will assess these questions. In some cases, more information is required to assess the privacy risks. If this is the case, you will be notified that the Data Stewards team will contact you.

The GDPR defines 'personal data' as any information relating to an identified or identifiable natural person ('data subject'). Personal data also includes data that indirectly reveals something about a natural person. Personal data can lead to the physical, physiological, genetic, mental, economic, cultural or social identity of a natural person. There are two main categories of personal data: regular personal data and special category personal data.

If you are not sure whether some of these questions below should be answered with a Yes or No, please contact a Data Steward first through rdmsupport@tue.nl.

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1	Will the study involve discussion/collection/processing of **regular** personal data, or will you collect and (temporarily) store video or voice recordings for the purpose of conducting interviews? *Additional explanation: For example, name, address, phone number, email address, IP address, gender, age, video or interview recordings? If you are not sure whether your data contains personal data, please contact the Data Steward Team (rdmsupport@tue.nl).*	X	
1A	**If yes**: Please describe which regular personal data you will collect in this study?	User study #2: age, gender identity, nationality, audio recording User study #3: profession and company, audio recording	
2	Will the study involve discussion/collection/processing of **special category** personal data or other **sensitive data**? *Additional explanation: Examples of special category personal data are race, religion, health information, political views, genetic or biometric data for the unique identification of a person, sexual preference, etc. Health information concerns personal data of the physical or mental health of persons, including the provision of health care. Examples of other sensitive data is information such as communication data, financial records or credit scores, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, criminal records, data of vulnerable persons (children, people with disabilities, refugees), BSN number etc. Please be aware that the use of special category personal data in research requires extra security measurements in order to safeguard the privacy of data subjects and to comply with the GDPR. Processing of this special category data is prohibited, except for specific purposes and under certain circumstances. If you need to process special category data, please consult the data stewards at rdmsupport@tue.nl.*		X
2A	**If yes**: Please describe which special-category personal data and/or sensitive data you will collect in this study?		

If you answered yes to either question 1 or 2, please answer the questions below. If you answered no to both questions, you can skip this part and continue onto part 7. Also, if an answer to any of the following questions is 'yes', please contact a Data Steward at rdmsupport@tue.nl

		Yes	No
3	Will your project involve the processing of personal data on a **large scale**? *Additional explanation: In general, any processing that involves more than 10.000 data subjects should be considered "large scale". However, if the data of approximately 1000 persons (or more) are involved, the data processing may still be considered large scale. In that case, besides the number of persons involved in the study, one should also assess (i) the amount of data collected from these persons taking into account the type/risk level of the personal data, (ii) the duration of the data processing, (iii) the geographic scope or extent of the processing. For example, if you would collect and process data across several European countries with 10+ socio-economic data items of 1200 individual persons for several years in a row, that is likely "large-scale processing". Other examples of a large-scale processing activity are:* • *Monitoring driving behavior of road users on Dutch highways* • *Collecting data of Covid patients* • *A hospital that processes patient data as part of its usual operations*		X

Ethical Review Form

	• *A transport company that processes travel information of people who travel by public transport in a certain city. For example, by tracking them through travel maps.*		
4	Does this processing activity involve the use of new or innovative technologies? *Examples of a new technology: combining fingerprints and facial recognition for physical access control, the use of bodycams in public spaces, the use of new technical methods in conducting research such as AI. This question also refers to new technologies that have not been deployed by TU/e so far.*		X
5	Does your study involve systematic (c.q. automated) monitoring of persons? *Additional explanation: Consider data processing activities that have the purpose of observing, monitoring or controlling individuals, for example in circumstances where the individuals are not aware by whom their personal data is collected and how it is used. Examples of such activities are using camera systems to monitor driving behavior on highways, monitoring email inactivity or employee phone use, certain applications of machine learning and artificial intelligence.*		X
6	Does the study involve collaborations (with third parties) in which data are shared or exchanged in order to link or combine data? *Additional explanation: This may often apply in a collaboration between the university and a commercial party, contract research, etc. It is important to assess this for all data in the entire project, not just your own data. An important consideration in this situation is whether the person whose data is involved could have expected that data from these different databases or sources of information were to be combined. For example, it is less likely for data subjects to expect that databases from different parties will be combined and the results are used for different purposes than one could reasonably expect; this may apply for example in a collaboration between the university and a commercial party.*		X
7	Will the study include data processing activities that prevent data subjects from exercising their rights or using a service or contract? *Additional explanation: Examples include processing operations carried out in public places that people cannot avoid (train station, airport, shopping mall, public university premises, etc.) or processing operations whose purpose is to allow or not allow data subjects to use a service or enter into a contract (examples: by refusing to pay a benefit, not being able to apply for a loan, etc.).*		X
8	Will the study process personal data to score, rank or profile persons? *Additional explanation: Examples: monitoring (highway) roads to give road users a "score" based on their detected driving behavior, a bank assessing its customers based on their creditworthiness, or an organization building behavioral and marketing profiles based on use of their website or navigating their website.*		X
9	Does your data processing include activities that involves composing "**blacklists**" – and, in particular, in relation to sensitive or special category data, such as communication data, financial records or credit scores, genetic data, biometric data, health data, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, etc. *Additional explanation: This situation will not be a common occurrence in research, but you may indirectly be involved in this. In general, this typically concerns processing operations involving personal data relating to criminal convictions and offences, data relating to unlawful acts, data concerning unlawful or annoying behaviour or about creditworthiness, and data which are processed and shared with third parties (blacklists or warning lists, as used, for example, by insurers, hospitality companies shopping companies, telecom providers as well as blacklists relating to unlawful behaviour of employees, for example in the private security or employment agencies, etc.).*		X
10	Will personal data be transferred or shared outside the EU/EEA? EU data protection rules apply to the European Economic Area (EEA), which includes all EU countries and non-EU countries Iceland, Liechtenstein and Norway. *Additional explanation: The GDPR has drafted additional requirements for transfers data outside of the EU/EEA. Typically, additional safeguards must be implemented to protect the personal data of residents in the European Union. For example, if you collaborate with an American, Indian or Chinese university or other third party outside the EU/EEA, you must first check whether this is allowed and under which conditions this is allowed. Another typical example is storage of data on American providers of cloud (storage) services. Please contact the data stewards first to discuss this.*		X
11	Will any raw or anonymized personal data or any other sensitive data or research results from the project possibly be transferred to a high-risk country*? ***High risk countries**: China, Russia, Iran, Turkey, and North Korea. If personal data or other potentially sensitive data is exchanged with one of these countries, or if part of the data processing takes place in one of these countries: **an advice from the Data Protection Officer, the kennisveiligheidsteam (Knowledge Security team), and the CISO (Chief Information Security Officer) is ALWAYS required.***		X

X

Ethical Review Form

Part 7a: Processing of research data

1	Is consent your legal basis for processing the personal data in your study? *Additional explanation: What is a legal basis? One of main principles in the GDPR is to ensure that personal data is processed lawfully, fairly, and transparently. To comply with this principle, the processing of personal data also requires that you have a valid legal basis for the personal data processing activity. In research projects, the legal basis is often but not always consent. However, it is possible that it is not clear or not possible to establish whether to use consent as a legal basis. Some examples where consent may not be applicable as legal basis are covert research, data collection in public spaces, secondary data analysis of existing data, data that are transferred to you by a third party, consent is not possible or would require disproportionate effort, etc. In that case, please indicate which legal basis you think that applies or (preferably) contact a data steward first.*	☒ Yes ☐ No, I will use another legal basis to process the data. Namely, …….. * You can download a suitable template **here**.
2	Where will the data come from?	☐ Data obtained from another party (secondary data use) ☒ New data collected only by my research team ☐ New data collected together with collaborators
3	Which of the following tools will you use to process personal data?	**Surveys** ☐ Qualtrics ☐ Limesurvey ☐ Other, namely …………….. **Interview/workshop recordings** ☐ Voice/video recorder ☐ Phone in a flight mode ☐ MS Teams ☐ Other, namely ……………… **Transcription** ☐ Manual transcription ☐ Microsoft Office software (e.g. Word, Teams) ☐ Other, namely …………… **Statistical analysis** ☐ SPSS ☐ R ☐ Other, namely …………… **Other tools**, specifically………………
4	Where will the data and in particular the personal data be stored during and after completion of the study? If you have already uploaded your Data Management Plan, you can refer to your Data Management Plan.	☒ Onedrive ☐ Research Drive ☐ Network Drive

Ethical Review Form

	Additional explanation: University supported-storage facilities are SURF Research Drive, Ceph, departmental drives (this includes BE Project Drive), and the TU/e instance of Microsoft OneDrive. For most personal data, the use of SURF Research Drive or departmental drives (including BE Project Drive) is required.	☐ Research Manager ☐ Other, namely ………

Part 7b: Safety and security measures

1	Will you pseudonymize/anonymize the data? *Additional explanation: Anonymization: remove all direct identifiers (name, address, telephone number etc.) but also indirect identifiers (age, place of birth, occupation, salary) that, linked with other information, can lead to a person's identification. Anonymization to the point that a data subject is no longer identifiable means that the anonymized data is not considered to be personal data anymore. Pseudonymization: replacing the unique identifier of a data subject with an artificial pseudonym. This means that identification is still possible with the identification key. The identification key needs to be stored securely and separately from the pseudonymized data. If the data subject can be identified by combining data with additional information, the data is also called pseudonymous.*	☐ ☐ No ☒ Yes, since I will not collect names, only in case of expert involvement will I (with consent) collect and use names for the use of specific quotes.
2	Is access to (personal) data restricted? (Select all that apply)	☐ No ☒ Yes, via access control ☒ Yes, via password protection ☐ Yes, access only given to TU/e research team ☐ Yes, access only given to research team, including non-TU/e collaborators ☐ Other, specify……….
3	Who will have access to the data during and after completion of the project? (Select all that apply)	☒ Main researcher ☐ TU/e supervisor(s) ☐ External supervisors ☐ TU/e research team ☐ Other, specify……….
4	Will you store data for future research?	☒ No ☐ Yes, in a public data repository ☐ Yes, in a public data repository under restricted access ☐ Yes, in a TU/e-recommended storage (SURF Research Drive, Network Drive)
5	Will you share data outside the TU/e?	☒ No ☐ Yes, in a fully anonymized form ☐ Yes, raw or pseudonymized data* *If you selected this box, make sure that a suitable data agreement is put in place. You can contact the Data Stewards for support in preparing such an agreement
6	How long will data be stored after the end of the project?	7 year standard retention period

Ethical Review Form

Part 8: Closures and Signatures

1	Enclosures (tick if applicable **and attach to this form**):	☒ Informed consent form ☐ Informed consent form for other agencies when the research is conducted at a location (such as a school) ☐ Text used for ads (to find participants) ☐ Text used for debriefings ☐ Approval other research ethics committee ☒ The inter ie uestions or a description of other measurements ☐ Data Protection Impact Assessment checked by the privacy officer ☐ Data Management Plan checked by a data steward
2	Signature(s)	Date: /1 /2025 Signature(s) of applicant(s): [signature] Date: Signature research supervisor: [signature] *Without both signatures we won't accept the form.*

Appendix C: ERB extra details on user studies, technical setup, data pipeline and how to safeguard privacy during sensing

User study #1: User testing visualizations

Goal: user preferences, thoughts/feelings about design options, gather design suggestions and comprehension of the concept/prototype

User group: Master Industrial Design students with minimal Adobe Illustrator experience

Procedure:

Without or with little previous knowledge of the project participants will first experience one version of the visualization prototype.
2 Followed by some semi-structured interview questions about their experience.
3 Multiple options of the visualizations on the monitor will be shown, participants will express their preferences and change the Illustrator template accordingly. Followed by semi-structured questions a out t e user interface.
Finally the research probe will be explained in total and two final questions will be asked.

Questions:

- ➔ What is your first impression/thoughts of this system?
- ➔ What do you think it is trying to tell you?
- ➔ Which data do you notice? (*Think aloud methodology + observation from researcher*)
- ➔ Is there anything unclear or confusing? Anything missing?
- ➔ Which visualizations do you prefer? 1, 2, 3? Why?
- ➔ Does the visualization seem accurate? Do you notice any biases?
- ➔ How does the system make its data interpretations?
- ➔ Any design suggestions/feedback or comments?

I explain the bigger concept and show a sketch of full experience/with robot

- ➔ How do you relate this visualization to how people read social cues?
- ➔ Does it make you reflect on your own interpretations or assumptions?
- ➔ With the knowledge of the goal of the project, how do you assess the current prototype?
- ➔ How do you see the concept I described back in this prototype?

User study #2: Demo and individual interviews

Goal: Gathering insights on the experience of the installation, learning about what questions and thoughts/reflections arise from it, creating meaning of the work through participant reactions/experiences and observations, design suggestions. Understanding the interpretations, emotional reactions and reflections that arise.

User group: General ealt y population recruited y t e researc er, inter ie ed in a pri ate meeting room at U ind o en

Procedure:

1. ideo recording of t e researc er interacting it t e instlalation is s o n
2 e isuali ation of t e data input are s o n
3 emi structured uestions a out t eir t oug ts impressions of t e installation, reflections on o t ey misinterpret social cues and on t eir cogniti e iases

Semi-structured questions and observations

- ➔ What part of the experience caught your attention first/most?
- ➔ How did the robot's behavior make you feel? (e.g., amused, confused, rejected, curious, uncomfortable)
- ➔ What do you think this installation is about?
- ➔ What are your thoughts/first impression? What do you feel while experiencing it?
- ➔ What questions arise?
- ➔ Do you think the robot has a bias in interpretating the sensors? If so what bias do you notice? If not, why do you think its accurate?
- ➔ Do you think you have biases when reading others social cues? If so, which/why? If not, why not?

User study #3: Expert Interviews

Goal: Gathering insights and reactions of the design installation and its goal from experts in areas of: HCI academia, art & technology and social robotics companies.

User group: Behnaz Farahi, Goland Levi, Pei-Ying Lin, Amy Winters, Piyakorn Koowattanataworn, Tessa Abkoude, Laura a Dima, Pal Robotics, Furhat, Rong-Hao Liang

Procedure:

Showcase video/physical demonstration/interaction loop explaining concept and relevance
2 Asking semi-structured questions

Semi-structure questions (will be adapted per expert/field)

- ➔ What are your first impressions/thoughts?
- ➔ How does this relate to your work?
- ➔ In your view, how effective is it in making invisible psychological processes visible?
- ➔ o do you e aluate t e installations

Explanation of Device

I made a shape changing interface which has a camera connected to a locally hosted web page (running a model for gaze direction detection), a radar sensor measuring proxemics (position of user to interface and speed at which they move), an a AI model which reads facial expressions on Google Collab and several servo motors. Based on the sensed metrics a specific servo motor will move and a visualization on a computer monitor will be shown.

How data is handled safely

Facial expression detection

The facial expressions AI model run on a Google Collab notebook uses my computer's external webcam accessed through my Google Chrome browser. This AI model is a pre-trained foundational model, meaning no new data is used to train it, if only performs inference (detection).Google Collab is a cloud-based Jupyter Notebook service which runs my code on a temporary virtual machine equipped with a GPU.

The process of facial expression detection is the following:

1. The camera stream is accessed through my computer browser (Google Chrome)
2. A single image frame is captured (every 3 seconds) from that camera stream and temporarily stored in the browser's memory, more specifically its RAM (short-term memory of computers for CPU execution). It is then converted into a Base64 string format (which is a text representation of an image of data) and sent to the Google Colab runtime for processing
3. Inside the Colab runtime: the image is decoded in Python from a Base64 string back into a NumPy array (a grid of numbers representing pixel values)
4. The AI model (using MediaPipe and TensorFlow) conducts facial expression detection on that image within the Colab runtime, which runs on a ephemeral Google Cloud virtual machine. The runtime is isolated from other users, automatically shuts down when idle, and deletes all data (files and memory) when the session ends.
5. The detected emotion from the facial expression ("Happy", "Sad", etc) is a text output (string). This string is sent through a private OOCSI (https://oocsi.id.tue.nl/) channel to my locally hosted webpage for visualization and to my ESP32 micro controller. No image or video data is transmitted or saved, only a text label of the detected emotion is shown.

Gaze detection

The gaze detection model uses the open source library "Web Gazer" developed by Brown University (https://webgazer.cs.brown.edu/). The gaze detection is run locally as webpage, by using a local WebSocket server. This server runs on my computer (locally). This local server is also connected to my ESP32 using serial communication (connected through a USB cable). A webcam stream is used through my browser (Google Chrome). It estimates where the user is looking, providing a number array output of the direction (x, y, z) of gaze. WebGazer is always run locally via the Microsoft Visual Studio extension Live Server. No image data is transmitted, stored or processed on external servers. When the browser tab or Node.js server is closed, all data in memory is deleted automatically.

The process of gaze detection is the following:

1. When the webpage is opened a browser request for camera access is asked. The camera stream stays inside the browser's temporary and ephemeral memory and is processed locally using a TensorFlow library .
2. The WebGazer library draws face landmarks to detect where the face of the user is, these are not saved or transmitted anywhere. The WebGazer library analyzes the camera stream in real time for estimate gaze direction. This means it does not take pictures and then analyze the data.
3. Every 2 seconds, based on the gaze directions collected, a classification is made, resulting in a string such as "Distracted". This classification is done in the browser not using any server or cloud components.

Position detection

The position of the user is detected using the radar sensor AI Thinker RD-03D (https://www.tinytronics.nl/nl/sensoren/beweging/ai-thinker-rd-03d-24ghz-radar-sensor-module), this sensor is connected to an ESP32. The data output is a string (x, y, distance and angle). This string is sent to the locally hosted website using a Node.js WebSocket server. When the browser tab or Node.js server is closed, all data in memory is deleted automatically.

How it works:

1. The Node server listens to the serial communication from the radar and send Json messages to the connected client via WebSocket.
2. The browser receives the data and visualizes
3. Communication occurs locally between browser and the Node.js server

Based on the input of the camera a specific servo will move. The other part of the prototype is a monitor display which visualizes the sensor input of the gaze detector and radar sensor. The gaze data is anonymized by only showing the face landmarks/dots and not streaming the camera input.

Appendix C: ERB consent form

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Instruction page

Consent form ethics v1

This consent form should be used in the following situation:
Your research will be fully *anonymous*, and data obtained from the study will not be traceable to individual participants. Because you will not process personal data, you only need ethical consent from the participants to participate in your study. Therefore, this consent form (*which does include the participant's name*) should be removed as soon as possible, but no later than the end of the study.

When you move your mouse over an italic, underlined and blue *word*, an explanation will appear. This explanation should be removed from the actual document upon completion.The text blocks marked in yellow indicate what information should in any case be completed or where the researcher must select an option. Please share this information within this form in the simplest possible phrasing. The template must be followed as strictly as possible and sub-headings may not be deleted.

Based on this information, a potential participant can make an informed and formal decision concerning participation in the research project.

Integration into web survey etc.
This form can be integrated into an online web survey. This is because consent can also be given through a digital signature or by placing a checkmark.

Assistance and review
For additional support in preparing the consent form ethics, contact your faculty's data steward via this *link*.

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Information sheet for research project "Speculum Sociale"

1. Introduction
You have been invited to take part in research project "Speculum Sociale", because you are either a Master Student of Industrial Design, a recruited participant or an expert in the field of HCI or art & technology or social robotics.

Participation in this research project is voluntary: the decision to take part is up to you. Before you decide to participate we would like to ask you to read the following information, so that you know what the research project is about, what we expect from you and how we deal with processing your personal data. Based on this information you can indicate via the consent declaration whether you consent to take part in this research project and the processing of your personal data.

You may of course always contact the Hanna Loschacoff via [*h.s.s.loschacoff@student.tue.nl*], if you have any questions, or you can discuss this information with people you know.

2. Purpose of the research
This research project will be managed by Hanna Loschacoff (h.s.s.loschacoff@student.tue.nl).

3. What will taking part in the research project involve?
You will be taking part in a research project in which we will gather information by:
.
User Study #1: **Visualizations preference**

- A 2 minute demo of the current visualization prototype
- Communicating your preferences between several options
- Changing the Illustrator template or drawing new ideas
- Interviewing you about your experience with the prototype

User study #2: **Individual interviews and demo**

- Thoughts/impressions of installation
- Reflections/dialogue triggered by installation
- Gather information by conducting short semi-structure interviews

User study #3: **Expert interviews**

- Asked about your evaluation of the installation/experience, how it relates to your work and future steps/questions

This study will be completely anonymous, and the data obtained from the study will not be traceable to you.

For your participation in this research project you will not be compensated.

4. Potential risks and inconveniences
Your participation in this research project does not involve any physical, legal or economic risks. You do not have to answer questions which you do not wish to answer. Your participation is voluntary. This means that you may end your participation at any moment you choose by letting the researcher know this. You do not have to explain why you decided to end your participation in the research project. Ending your participation will have no disadvantageous consequences for you

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If you decide to end your participation during the research, the data which you already provided up to the moment of withdrawal of your consent will be used in the research. Do you wish to end the research, or do you have any questions and/or complaints? Then please contact the Hanna Loschacoff via h.s.s.loschacoff@student.tue.nl.

5. Confidentiality of data
The raw and processed research data will be retained for a period of 1 year. Ultimately after expiration of this time period the data will be either deleted or anonymized so that it can no longer be connected to an individual person. The research data will, if necessary (e.g. for a check on scientific integrity) and only in anonymous form be made available to persons outside the research group.

This research project was assessed and approved on X by the ethical review committee of Eindhoven University of Technology.

***** Scroll down for the consent form *****

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Consent form for participation by an adult

By signing this consent form I acknowledge the following:

1. I am sufficiently informed about the research project through a separate information sheet. I have read the information sheet and have had the opportunity to ask questions. These questions have been answered satisfactorily.

2. I take part in this research project voluntarily. There is no explicit or implicit pressure for me to take part in this research project. It is clear to me that I can end participation in this research project at any moment, without giving any reason. I do not have to answer a question if I do not wish to do so.

Name of Participant:

User study #:

Signature:

Date:

Name of researcher:

Signature:

Date:

Appendix C: ERB confirmation email

ERB-form-FMP-Speculum-Sociale 1.pdf

Dear Ethics commitee,
Attached is my ERB with a detailed explanation of the technical workings on my system to guarantee data safety.
I talked with Data Steward Nami Sunami and he validated this was the correct way of safely handling the data of sensors.
Let me know if you have any further questions
Kind regards,
Hanna Loschacoff

Outlook

RE: FMP Hanna Loschacoff ERB

From Severens, Marjolein <m.j.e.severens@student.tue.nl>
on behalf of
Ethics <Ethics@tue.nl>
Date Tue 2025-11-18 11:45 AM
To Loschacoff, Hanna <h.s.s.loschacoff@student.tue.nl>

Dear Hanna,

Your application (ERB2025ID533) with project title “Speculum Sociale” has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

We wish you the best of luck with your research and a pleasant day.

Best regards,

Marjolein Severens
ERB student assistent

From: Loschacoff, Hanna <h.s.s.loschacoff@student.tue.nl>
Sent: maandag 17 november 2025 12:08
To: Ethics <Ethics@tue.nl>
Subject: Re: FMP Hanna Loschacoff ERB

Dear Maartje,
My apologies, attached is the PDF version.
Kind regards,
Hanna Loschacoff

From: Mulder, Maartje <m.j.w.mulder@tue.nl> on behalf of Ethics <Ethics@tue.nl>
Sent: November 17, 2025 8:52 AM
To: Loschacoff, Hanna <h.s.s.loschacoff@student.tue.nl>
Subject: RE: FMP Hanna Loschacoff ERB

Dear Hanna,

Thank you for the ERB application.
To complete this application, we would like to receive the ERB form with also the signature of the supervisor.
We would like to receive it as a pdf file, that’s more convenient for us than a link.

With kind regards,
Maartje Mulder

TU/e

040-2475032
Secretary Integrity and Ethics Office

From: Loschacoff, Hanna <h.s.s.loschacoff@student.tue.nl>
Sent: vrijdag 14 november 2025 18:09
To: Ethics <Ethics@tue.nl>
Subject: FMP Hanna Loschacoff ERB

Appendix D: Full size comparison gaze libraries

	M2.1 prototype	L2CS-Net	LaserGaze	WebGazer
Gaze tracking technique		**L2CS-Net** uses a two-branch CNN architecture with separate classification and regression losses to predict pitch and yaw of head to derive gaze angles from individual frames.	**LaserGaze** processes temporal video data across multiple frames using MediaPipe for facial recognition, dynamically refining gaze estimations for improved stability and accuracy in real-time video stream frames.	**WebGazer** self-calibrates by observing user webpage interactions, training a regression model that maps detected eye features to screen gaze positions.
Setup and libraries	Google Collab: running computer vision on virtual machine	Google Collab: PyTorch + OpenCV	Google Collab: OpenCV + MediaPipe	Local Web Host: API WebGaze + MediaPipe
Data processing		Take picture then make prediction	Live prediction	Live prediction

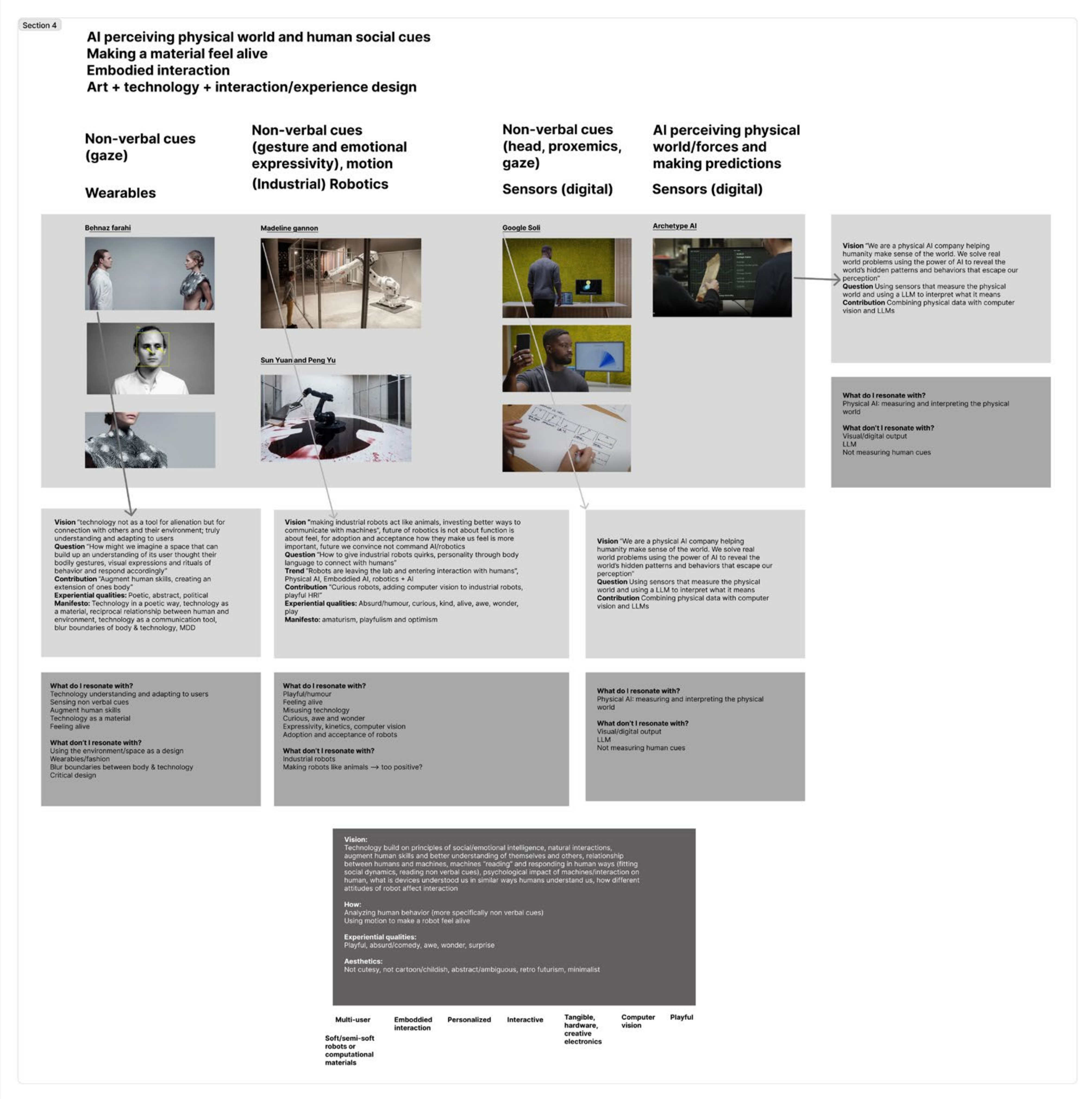
Comparison between L2CS-Net and LaserGaze:

Between L2CS-NEt and LaserGaze the difference is that the former takes a individual picture and makes classifications from it. The LaserGaze method uses temporal classification (using video live stream) allowing for the dynamic refining of the gaze estimation. The gaze direction is estimated depending on the head pose which is not a reliable predictor. Additionally, datasets of computer vision models are particularly sensitive to light settings, camera angle besides the inherent bias in demographics. These parameters can influence its accuracy if these don’t match those found in the deployment data.

Comparison between LaserGaze and WebGazer:

WebGazer was chosen over LaserGaze due to architectural compatibility. LaserGaze's 3D face model approach with affine transformations required Google Colab's virtual machines, achieving only 2-3 fps and frequently crashing. WebGazer uses browser based pupil detection with regression analysis, running locally via TensorFlow.js without requiring a powerful GPU. Its lightweight architecture enabled real-time processing, offline operation, ESP32 integration via WebSocket, and continous calibration, because the robot requiring immidate and accurate predictions.

Appendix E: Full size vision analysis



Appendix F: Evidence of company interest (Glow labs and Tech Kicks)

Hanna Loschacoff • 11:00 AM

Hey Philip,
Ik ben Hanna Loschacoff, masterstudent industrial design aan de TU Eindhoven. We hebben elkaar afgelopen vrijdag gesproken tijdens de demoday. Je had het over Glow Labs en hoe robotica een interessant medium zou kunnen zijn voor een Glow-project.
Ik studeer begin februari af en zou graag verder

Philip Ross
Owner at Studio Philip Ross

Ik studeer begin februari af en zou graag verder praten over mogelijke projecten voor Glow Labs.
Zou je in de week van 16-20 februari tijd hebben voor een gesprek?
Ik kan een korte presentatie voorbereiden over mijn skills/portfolio en misschien ook enkele eerste ideeën over de combinatie van interactieve lichtinstallaties en robotica.
Fijne feestdagen!
Met vriendelijke groet,

Philip Ross • 4:55 PM

He Hanna, Leuk om van je te horen. Ik wou in het nieuwe semester inderdaad een GLOW lab beginnen over robotica en lichtkunst, dus het lijkt me aardig om dan nader kennis te maken. Ik stuur je een meeting request. Daarbij dan wel een slag om de arm want ik zal in januari beginnen en moet dan veel inplannen, maar dan hebben we in ieder geval iets staan. Fijne feestdagen! Gr. Philip

Hanna Loschacoff <hannaloschacoff@gmail.com>
to rian@techmatters.today
Thu, Dec 18, 2025, 10:49 AM

Hallo Rian,

Ik ben Hanna Loschacoff, masterstudent industrial design op de TU Eindhoven. We hebben elkaar afgelopen vrijdag op Demo Day ontmoet. Mijn project heette "Through your eyes" en bestond uit een robot die sociale signalen leest en visualiseert hoe hij deze interpreteert. Het project laat zien dat iedereen een andere bril heeft waarmee ze de sociale signalen van anderen interpreteeren.

Tijdens ons gesprek noemde je verschillende manieren waarop ik na mijn afstuderen aan dit project zou kunnen blijven werken. Als ik het me goed herinner, had je het over samenwerking met onderzoekers van de VU en mogelijk met jouw bedrijf TechKicks.

Zou je de contactgegevens van de VU die je noemde met me willen delen en zou je na mijn afstuderen openstaan voor een gesprek om de volgende stappen te bespreken?

Met vriendelijke groet,

Hanna Loschacoff

rian@techmatters.today
to me

Hi Hanna,

Zeker wil ik je verder helpen.
Wellicht is het goed om ook een gesprek te plannen.
Ik zie mooie kansen voor een project samen met TechKicks en Neuro-onderzoeker.
Daarnaast mag je ook Professor Matthijs Smakman van VU benaderen. Gebruik gerust mijn naam, hij kan je mogelijk ook verder helpen.
Je hebt een hele toffe robot ontwikkeld, ik zie hier ook mogelijkheden in om dit verder mee te nemen in onze plannen.

Wellicht goed om in het nieuwe jaar een afspraak te plannen.

Hartelijke groet,

Rian

Appendix G: Business model of art & technology studios

During Dutch Design Week and through reaching out on LinkedIn, I got to talk with companies I would like to work at. I wanted to best undrstand tat its like working there, the profile they are looking for, design process, and introducing myself as a potential future employee. Additionally, insights into their business model and how projects get started were shared. In the next page a business model is made from these insights.

Expert contacted

Companies (Art & Tech)

Name	**Expertise**	**Contacted**	**Response**	**Ouput**
Fillip Studios	Interactive installations bringing attention to natures phenomeons	☑	☑	**Job application**
Studio Drift	Interactive installations bringing attention to natures phenomeons	☑	☑	**Skills needed, company dynamics Invited for Demoday**
Studio Vouw	Interactive products	☑	☐	**Not a fit in profile, need to be more technical**
Accenture	Research & development, physical AI	☑	☐	**Interesting profile, Skills needed**
Tellart	Immersive museum installations	☑	☑	**What profile they looking for and their design process**

Appendix H: Business model of art & technology studios

The Business Model Canvas

Designed for: Fillip Studios, Studio Vouw, Studio Drift and Tellart

Designed by: Hanna Loschacoff

Date:

Version:

Key Partnerships

Craftsmanship studios:

Craftsmanship studios: to fabricate bigger industrial parts of prototype (such as metal working)
Academic institutions: for collaboration on joint research grants
Curators of museums: to pitch exhibitions and sell to private owners

Key Activities

Sales: pitching concepts to brands and writing subsidy grants
R&D: Experimentation, testing, research, concept development and making with emerging technologies
Production of exhibition: organizing, transporting, setting up installation and on-site maintenance

Key Resources

Human capital: interdisciplinary team of interaction designers, concept designers, creative technologists and researchers
Studio space: to designing, testing out and building prototypes
Portfolio and reputation: through successful public exhibitions and media coverage they build a track record

Value Propositions

For the private sector:
-new engaging ways of selling a product, adversing for it or communicating brand values
-renting or buying art works for companies contributes to their high value reputation when clients come to their office (ex: banks)
-renting or buying art works for private customers can be as a hobby of art collector or as an investment
For the public sector:
-Art & technology studios can propose new alternatives and creative probes to better understand, communicate or deal with a wicked problem. This was serve as inspiration for the academic sector. Additionally, it can be used to communicate research in a tangible, engaging and experiential way.
-Contributing to the cultural and creative sector with innovative ideas and experiences

Customer Relationships

On-site technicians: to ensure long-term functionality and maintenance of work
Co-creation: with brands to ensure satisfaction with end result and company values are included
Collaboration with academic institutions: sharing knowledge on cutting edge and developing projects together

Channels

Design or art festivals
Social media and digital portfolio
Direct sales and studio visits and exhibition site visits

Customer Segments

-B2C companies
-Art collectors
-Academic institutions
-Performance art culture institutions
-Museum and cultural foundations

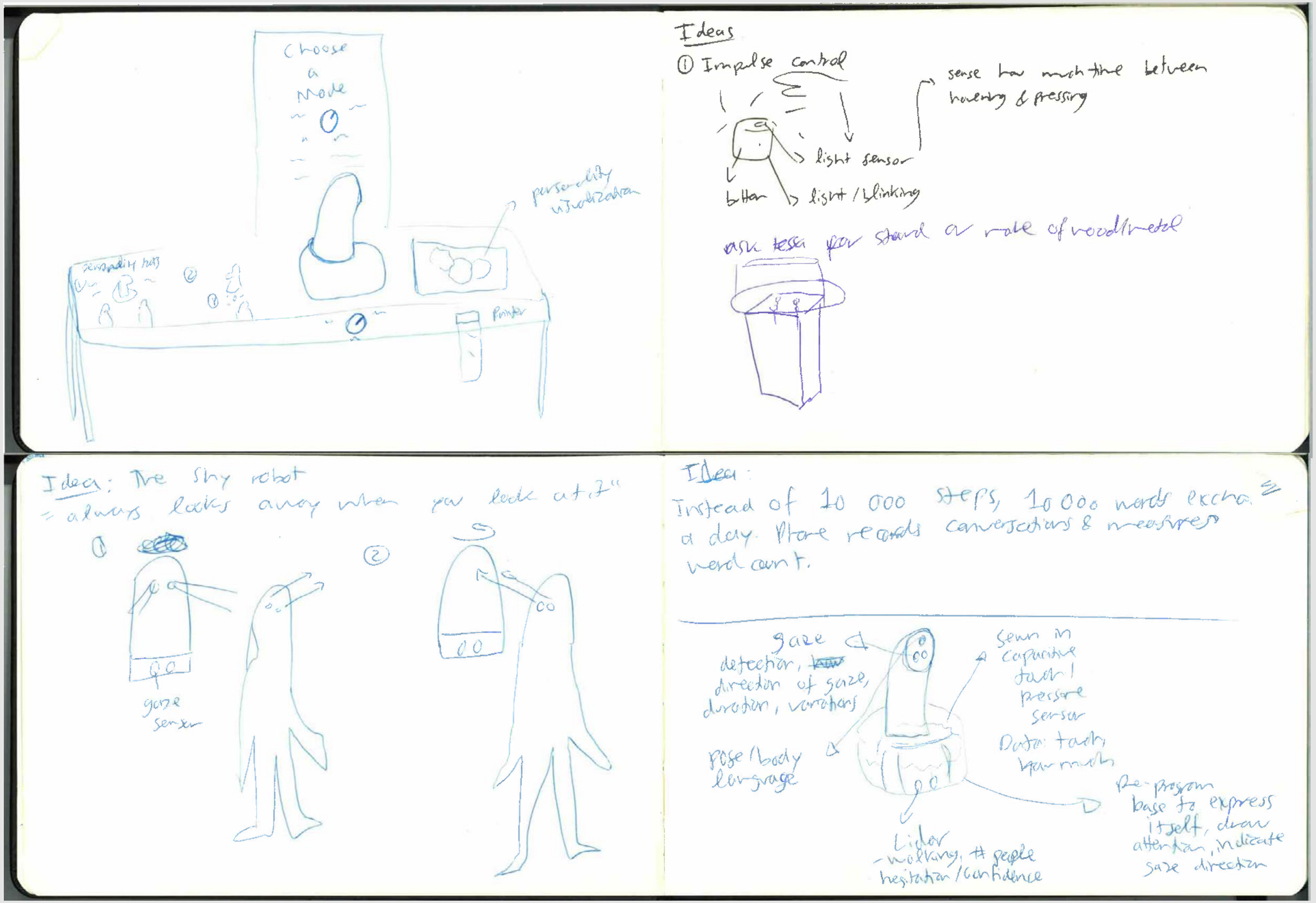
Cost Structure

Labor: designing, development and production (setting up art-works), maintenance technicians (troubleshooting and fixing damage due to transportation or interaction)
Materials
Technology
Graphic design/branding
Transportation
Insurance

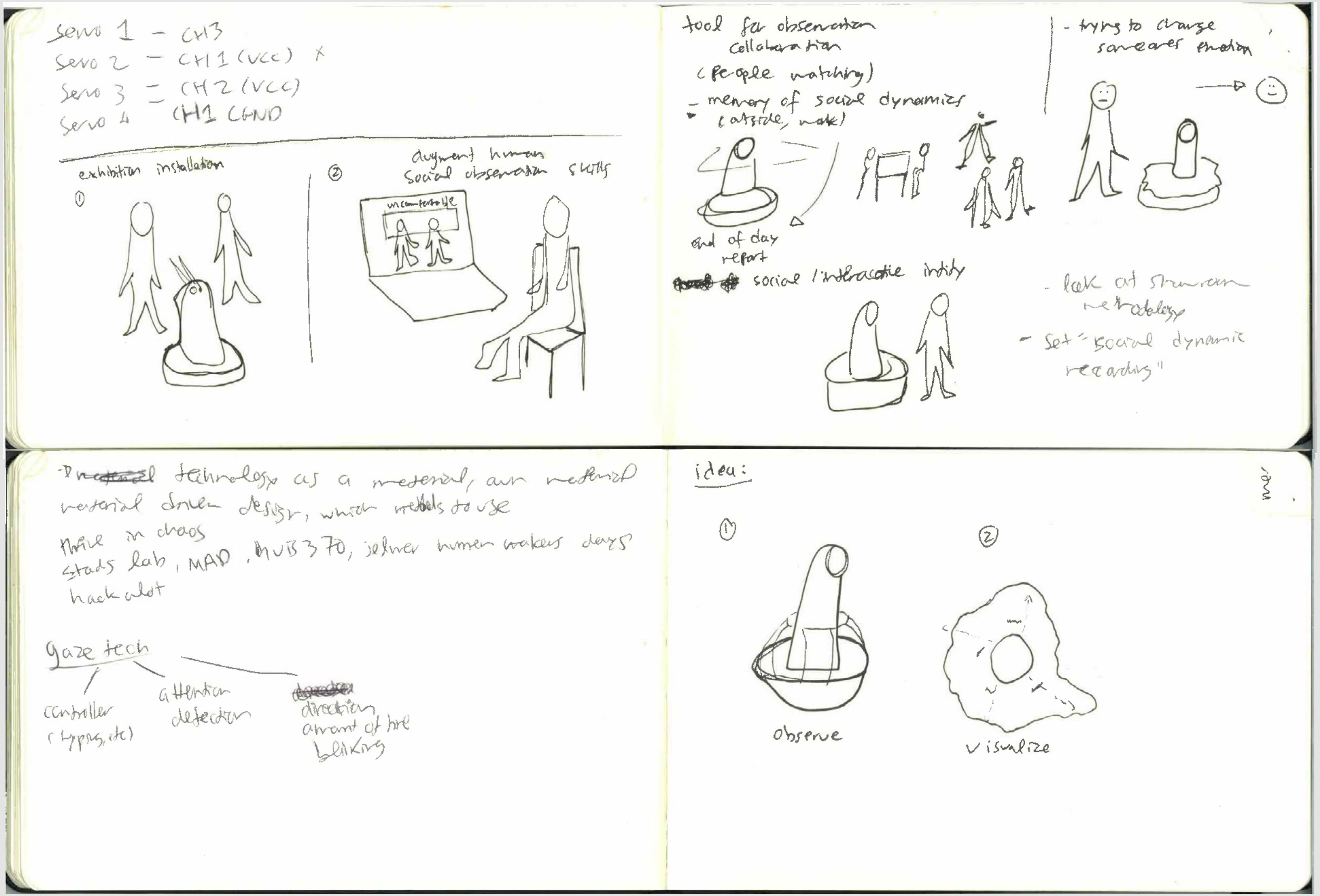
Revenue Streams

Private sector: brand experiences, selling or renting out artworks to private customers or companies, interactive in-store experiences
Public sector: rent out artworks to museums, if work is exhibited at a museum a commission of each ticket bought, subsidies to stimulate the creative sector, subsidies for design and art research or collaborations with academic institutions, collaboration with cultural institutions (commissions from theater companies)

Appendix I: Sketches



Appendix I: Sketches



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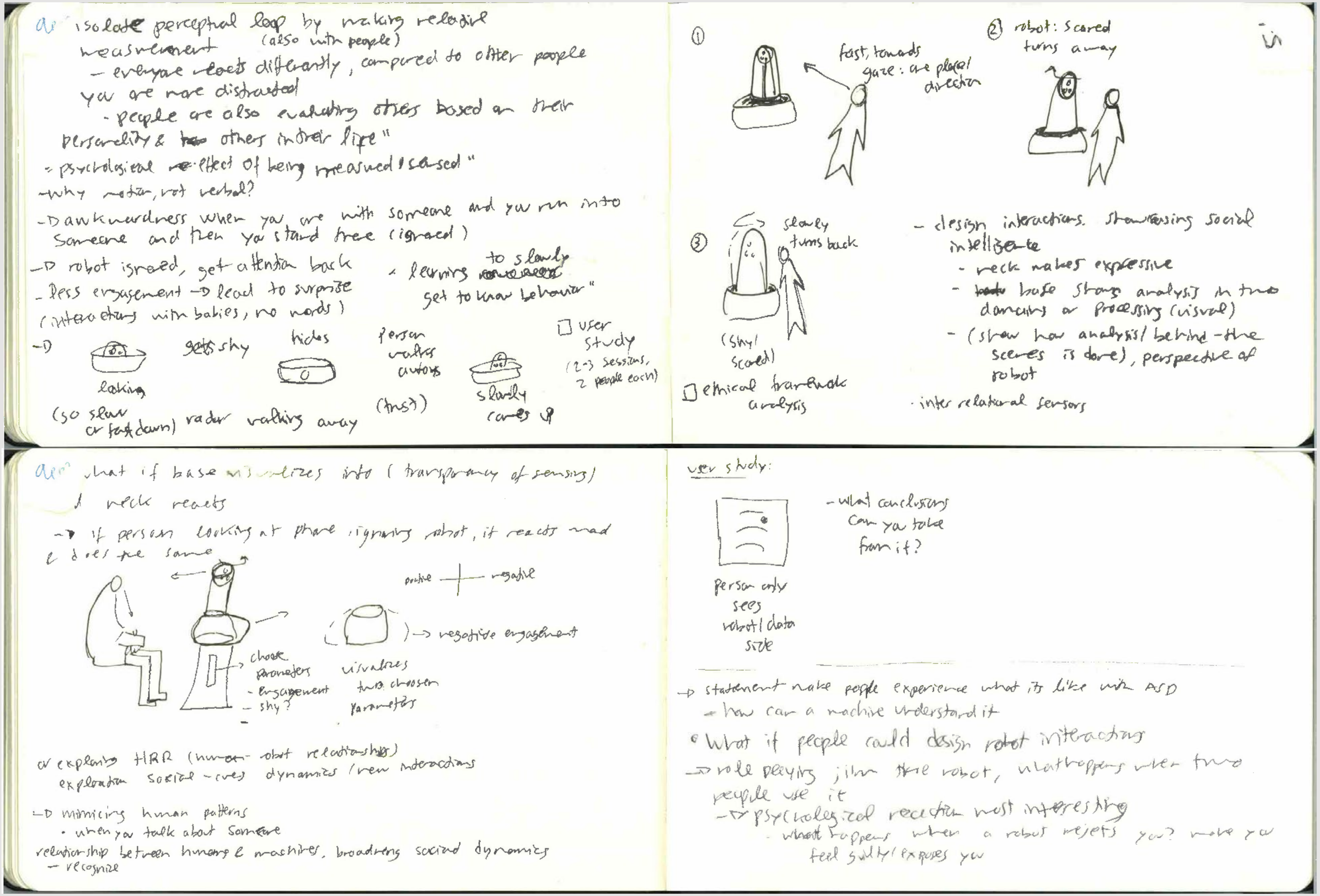

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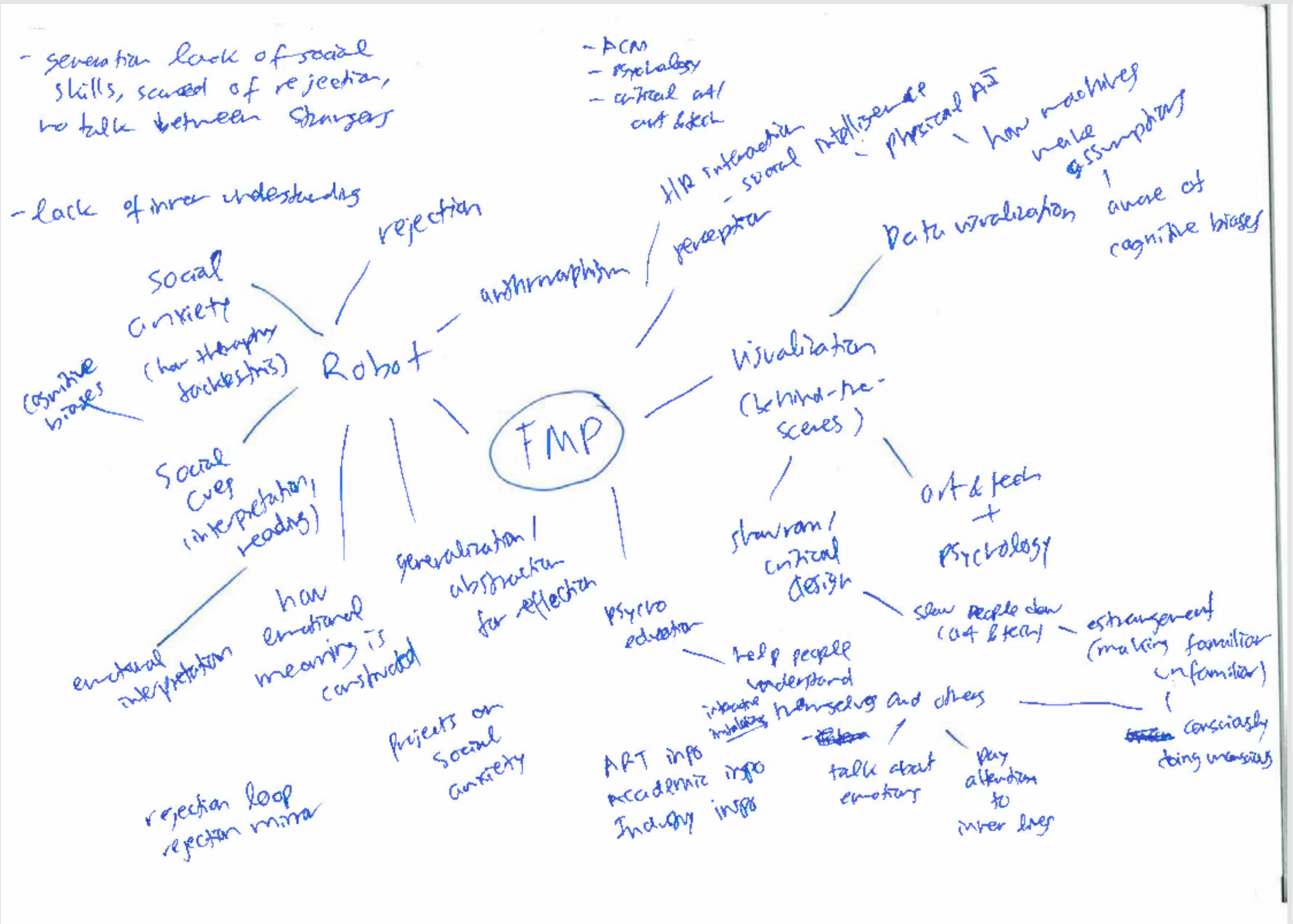

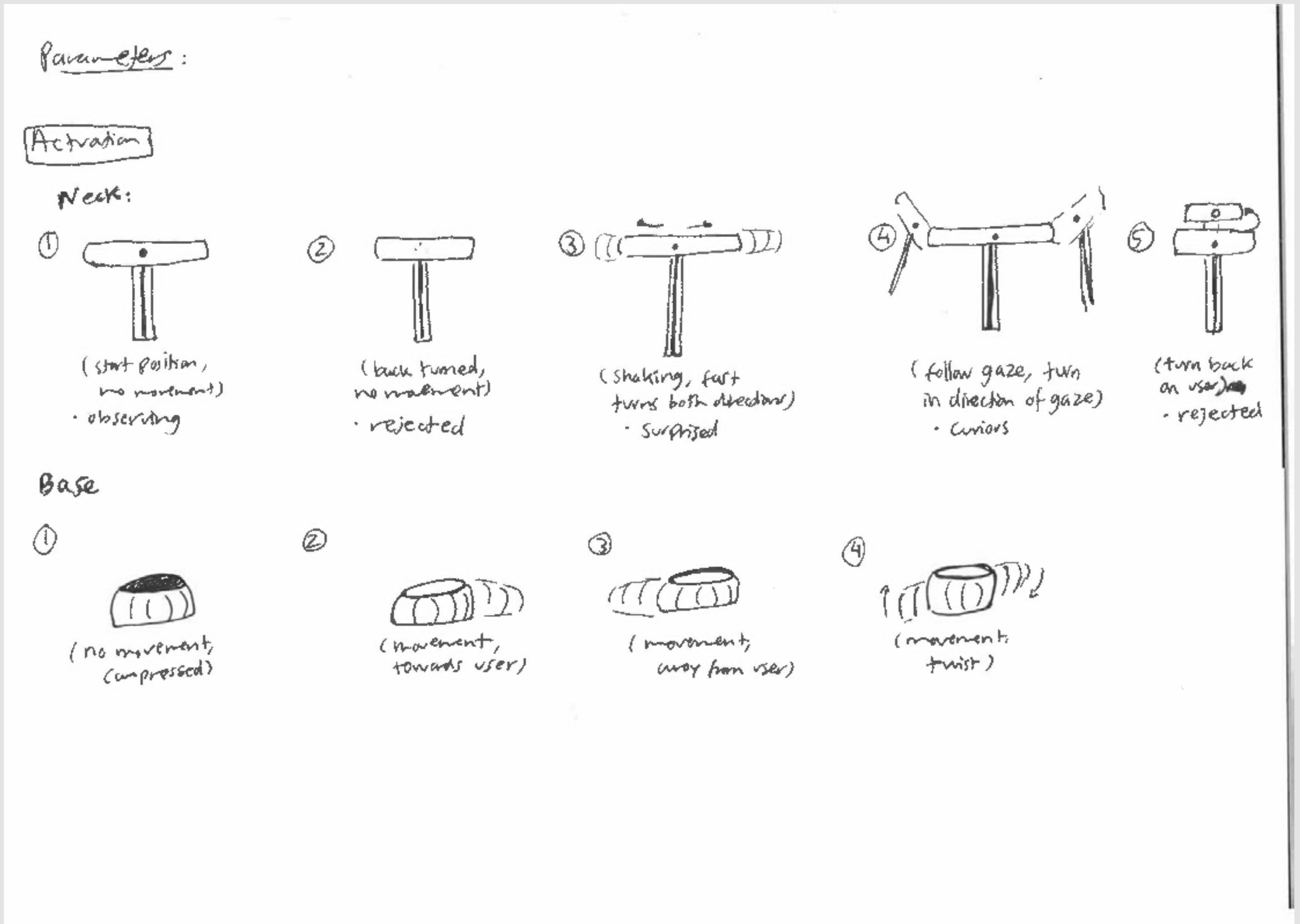

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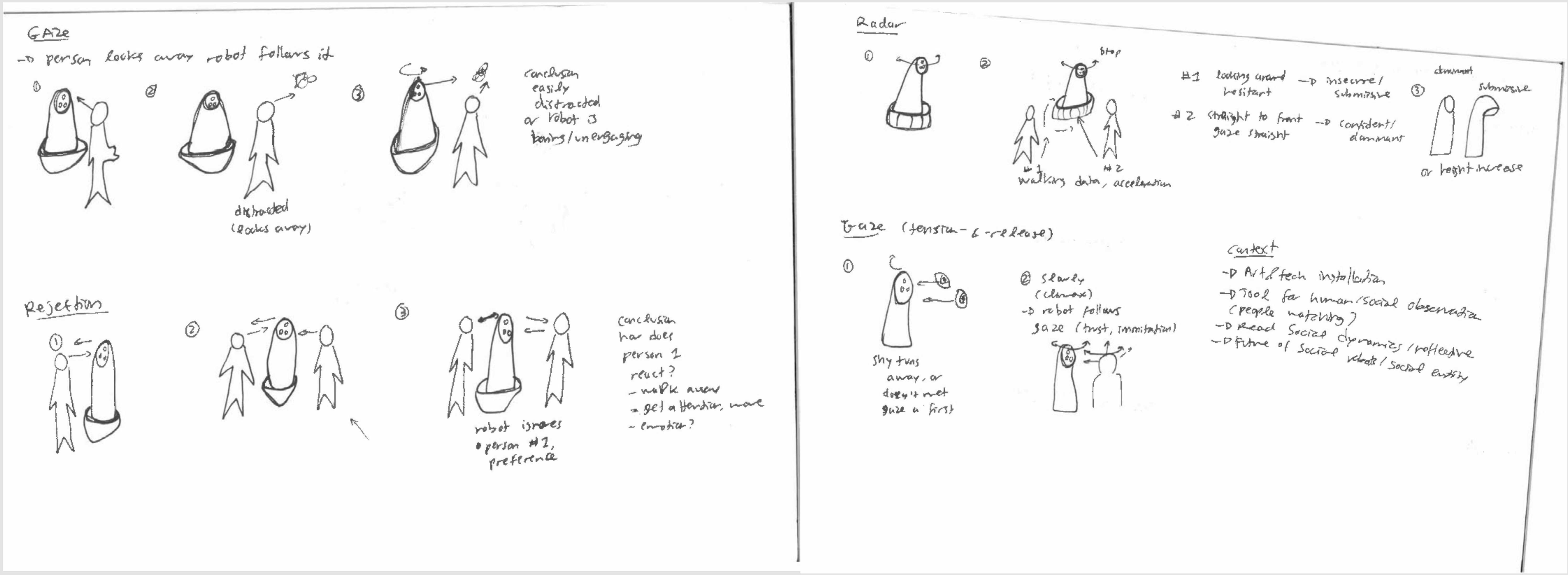

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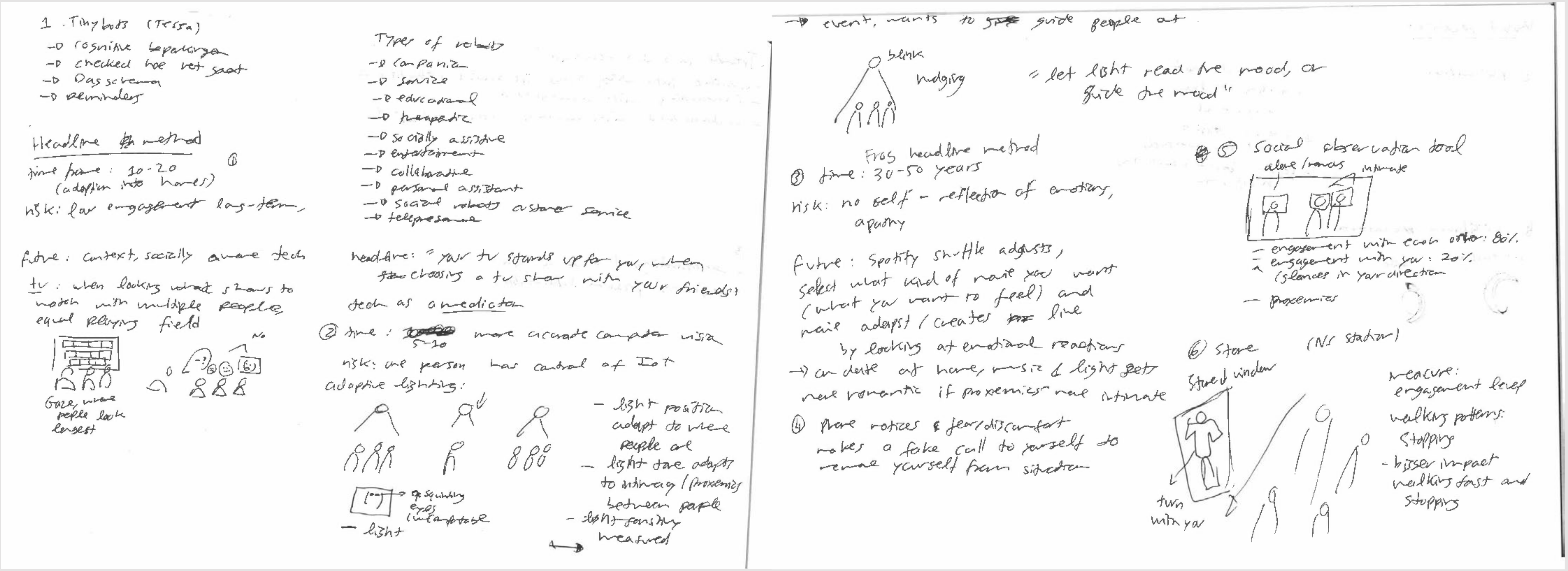

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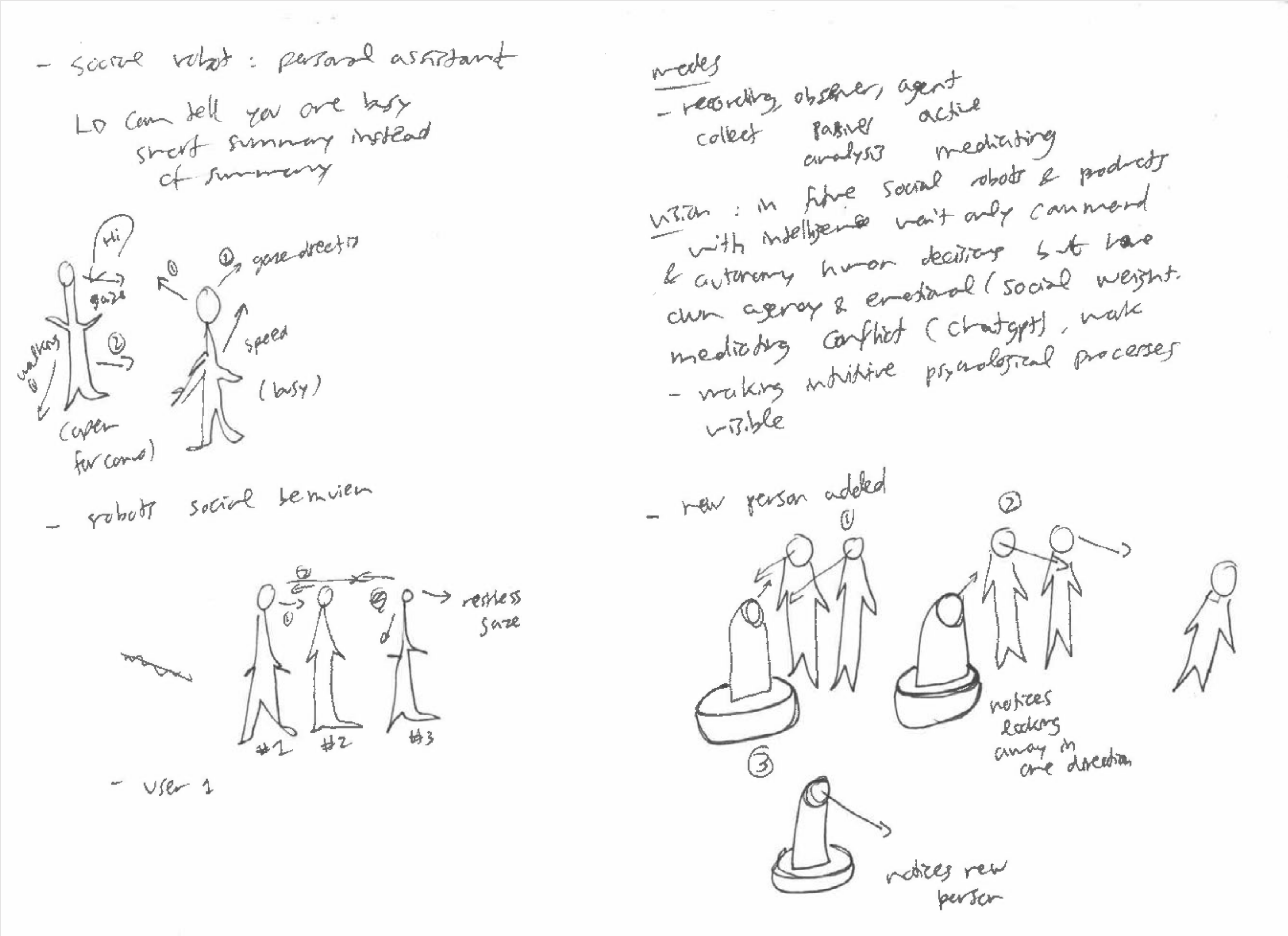

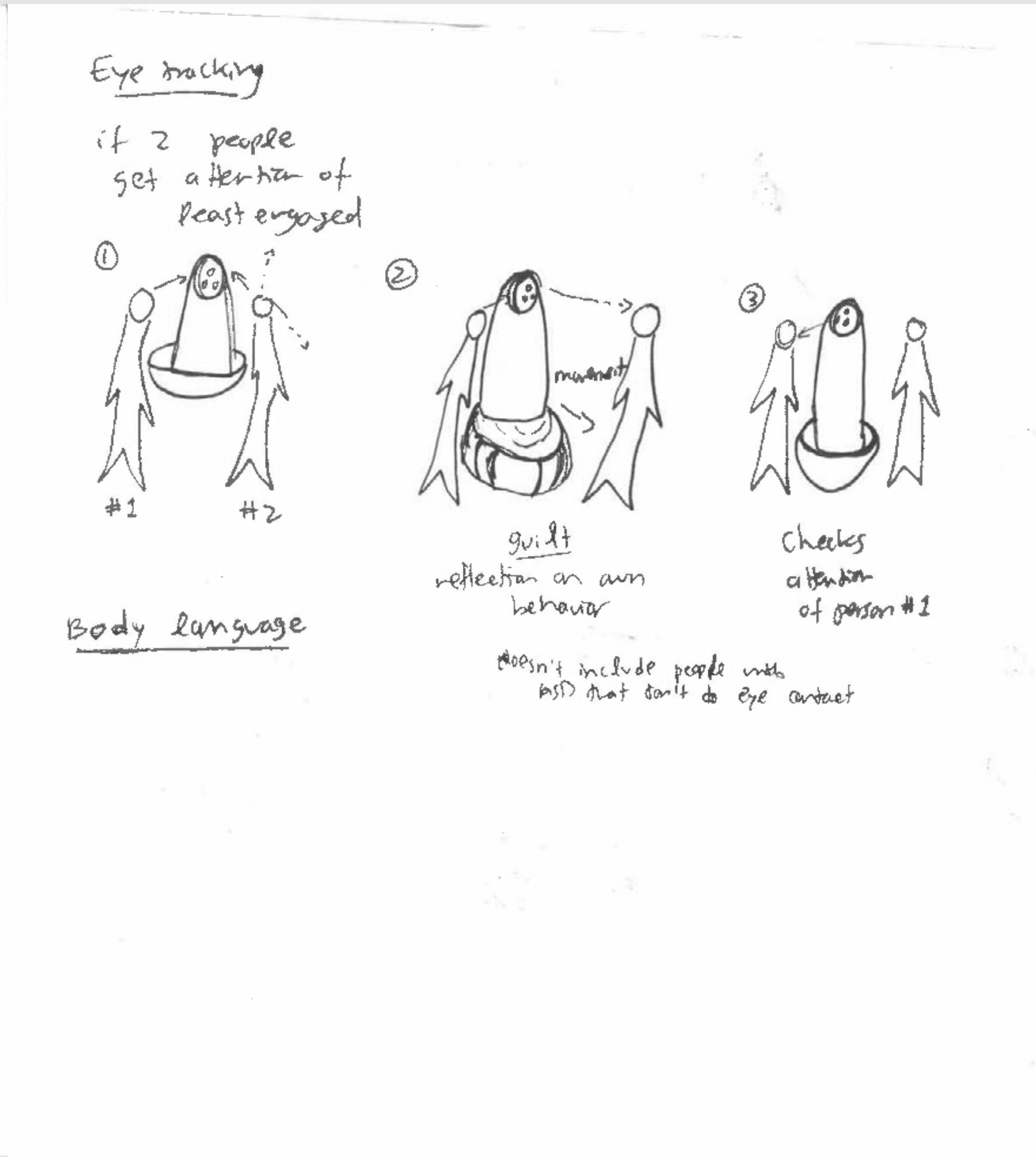

Appendix J: AI Acknowledgement

Finally I want to acknowledge that I have used Claude AI (integrated in the software Windsurf) to explain complilation errors of my Arduino code, debugging Javascript code and hardware. No sensitive data was shared with the AI platform.