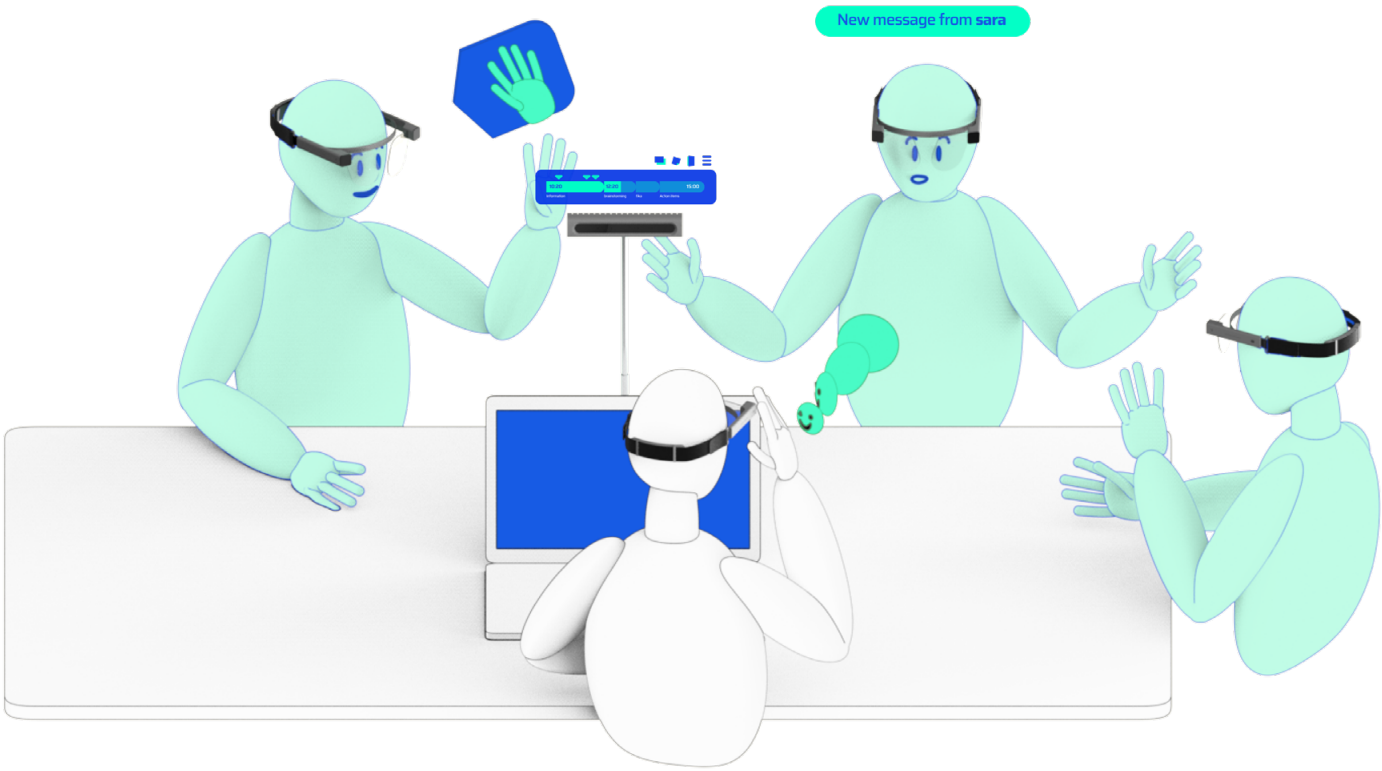

Hollaboration

Degree Project for MFA in Design
Jason Pi & Zahra Ghiasi

LUND UNIVERSITY
LTH
FACULTY OF ENGINEERING

Hollaboration (envisioning the future of hybrid meetings)
Jason Pi and Zahra Ghiasi
Degree Project for Master of Fine Arts in Design, Main Field of Study Industrial Design,
from Lund University, School of Industrial Design
Department of Design Sciences
Examiner: Senior lecturer Andreas Hopf
Supervisor: Senior lecturer Charlotte Sjödell
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Finally, thank you to our parents for supporting us through all these years of education.

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Abstract

This project aims to envision the future of virtual collaboration in the year 2030. Global trends show that ever since the Covid-19 pandemic, hybrid work has become a standard in almost all job sectors, making virtual collaboration crucial for the success of hybrid teams. Although the option to work from home partially or completely has well documented outcomes of higher employee productivity and wellbeing, poorly managed hybrid teams could lead to feelings of disconnection, distrust, and exclusion. Team leaders have had to learn to accommodate the combinations of on-site, off-site, and fully remote employees. After speaking to the individuals working within hybrid teams and ones managing them, we identified the virtual conferencing tools, which hybrid teams depend on for communication, to be key areas for innovation in the coming years. Virtual conferencing technology at its current state fails to capture communication cues like eye-contact, body language, spatial positioning, and layered dialogue, all of which work together to create the fluidity of real-life interactions. At its best, the absence of these cues lead to disengagement or fatigue. At its worst, they can lead to distrust and become a roadblock for creative collaboration. We determined that the use of holograms would allow virtual calls to regain the feeling of face-to-face interactions. Evaluating the technological innovations in augmented reality wearables and volumetric imaging technology, we proposed a concept for a holographic conferencing system that would capture individuals in 3D and place them in their teammates' rooms with the use of augmented reality headsets. For our final outcome, we designed a personal webcam for those calling from home, a larger conference camera for the team members calling in from the office, and an augmented reality headset that would be used in both scenarios.

Introduction

As a side-effect of the pandemic, coupled with younger generations' changing attitudes towards life and career goals, flexibility in work is now one of the top priorities for employees when searching for a job. More flexible working hours, locations, and a more balanced work-life balance are here to stay.

Though the benefits of hybrid work are apparent, like greater levels of employee productivity and overall happiness, there are also added challenges that companies must solve in order to get the most out of this work setup. These challenges are known as the 5 C's: communication, coordination, connection, creativity, and culture. From our own research, the one problem that seems to be at the root of the challenges is communication.

Although the use of messaging and conferencing applications allow for swift and efficient communication, interactions become limited by this desire for brevity. The small talk that happens between work related interactions often gets cut out, and work relationships adopt a less personal tone. Spontaneity and creativity also suffer, as most interactions have to be intentional. From our conversation with a startup founder, the barriers posed by digital mediums remain as the main reason he refuses to let their team go fully hybrid.

We wanted to figure out a way to make virtual interactions as fluid and rewarding as in person ones, while maintaining the efficiency and functionality of web based meetings.

Literature review

What is the future of work?

To gain a better understanding of the state of the work and the emerging trends within the industry, we consulted surveys conducted by institutions like Gallup, McKinsey & Company, and Cisco.

McKinsey's American Opportunity Survey

McKinsey's American Opportunity Survey surveyed 25,000 Americans in spring 2022 about their working arrangements and how the shift to more flexible work has affected their lives.

1. When offered, almost everyone takes the opportunity to work flexibly

2. Men and younger employees were more likely to be offered remote-working opportunities

3. Digital industries demand work flexibility

4. A flexible working arrangement ranked third amongst reasons for job hunting, behind a search for better career opportunities and greater pay

5. Amongst people aged 18 - 38, mental-health has become a larger issue when working remotely

Collaborative interactions fall into three categories.

Virtual In person Other mechanisms

	Interaction	Suggested Format	Purpose	Characteristics	Outcome
Decision making	**Complex or uncertain decision**		Make uncertain, hard decisions	Most complex, hard decisions Quality debates	Decisions for complex issues and actions
	Cross-cutting routine decision		Make routine decisions	Standard set of routine decisions Well-defined protocol for approvals Most time spent on exceptions or escalations	Routine decisions
Creative solutions and coordination	**Innovative session**		Identify innovative solutions	Innovative problem solving Usually half-day sprint Solutions to be brought into a decision meeting	Potential innovative solutions—preparation for a decision meeting
	Routine working session		Coordinate actions Get input Crowdsource ideas	Round-robin Usually short	Considerations and next steps
Information sharing	**One-way**		Share information	No interactions required Other effective mechanisms; eg, memo, email, podcast, vlog, Slack-based town hall	Awareness of new information
	Two-way		Share information and answer questions	Interactions (eg, Q&A) required to be successful	Awareness of the new information and concerns and questions addressed

McKinsey & Company

Not all virtual meetings are treated the same: some are meant for listening, while others are meant for active participation. Managers must figure out what type of meeting is best to have virtually and which to have in person.

Gallup: Future of Hybrid Work

Gallup surveyed 140,000 US employees after the Covid-19 pandemic about their experience, needs, and future plans regarding to work.

1. Employees prefer hybrid over fully remote work because they still need to feel connected to their co-workers and their organization

2. In a hybrid environment, communication and team-building are crucial for highly independent teams, with neglect of leading to erosion of culture amongst remote workers

3. Productivity, flexibility within framework without ambiguity, and connectivity between team members all make hybrid work more engaging

Cisco Global Hybrid Work Survey 2022

A study conducted by Cisco in 2022 surveyed 28,000 full time employees around the globe across 27 different markets and various industries. Notably, this study leaves out the US respondents.

1. Managing and maintaining high levels of trust will be crucial as workers adapt to more hybrid or remote arrangements

2. The top three challenges to hybrid work are a weak or unreliable internet connection, a distracting work environment, and feeling disconnected from work colleagues

3. 65.2% think that less than half the virtual meetings they attend are productive

4. Virtual meetings may surprisingly help with strengthening employee relationships

5. 73.2% of respondents say companies need to rethink culture and mindset to make hybrid work truly inclusive

Take-aways

1) Remote work is here to stay, and a significant portion of employees expect a hybrid work arrangement in the future

2) The top reasons employees prefer hybrid work include avoiding commuting and having personal freedom in their work and a better work-life balance

3) The future workweek will likely involve a mix of autonomy and structure, depending on team interdependence

4) Trust, flexibility, technology, and supportive management are crucial for the success of remote and hybrid work

5) Companies need to actively shift their culture to become hybrid-first

Interviews

What do the stakeholders think about hybrid work?

For our interviews, we looked to cover a broad spectrum of roles and working environments.

We spoke to a start-up founder within an incubator, a remote worker within a hybrid team, and then a manager on a hybrid team.

Startup founder

“My top three problems? Money, money, and money”

generation: Baby Boomer
location: Sweden
company: electronics startup
position: founder / CEO
work arrangement: mainly in-person, hybrid as needed

1. Remote arrangement isn’t feasible when the people, methods, and ideas are all new

2. Remote work makes it hard to be spontaneous

3. Biggest problem has and always will be money

4. Working in between disciplines and diverse backgrounds, communication through virtual platforms becomes grounds for miscommunication and lack of creativity

Remote worker

“It’s difficult to put in the time to socialize when the rest of the team is in a different city”

generation: Z
location: US
company: large tech company
position: developer
work arrangement: fully remote and hybrid team

1. Likes the being able to manage own time

2. Their team is experienced with remote workers, and accommodates their demands for efficient and effective communication

3. When coworkers are in different location and have completely different backgrounds, it becomes difficult to socialize with them

Hybrid manager

“Meeting in person at the end of the project, I just felt that it would’ve been so much easier communicating if I knew she was this nice”

generation: Z
location: US
company: large consultancy
position: healthcare manager
work arrangement: projects start remote and move on-site

1. In-person meetings at the start of a hybrid work arrangement help to break ice and ease communication

2. In-person interactions build trust, which is crucial to forming long term business relationships

4. Social interactions can help manager learn more about problems and complaints, and deeper understanding of team members

5. For some, it can be difficult to speak up and be heard in virtual meetings, it’s up to the managers to recognize and include members

Take-aways

Key benefits of hybrid working arrangements

1) Employees can manage their own time better
2) Virtual meetings can be more efficient than in-person ones when done correctly
3) Employees can be more casual when calling from home

Downsides of hybrid working arrangements

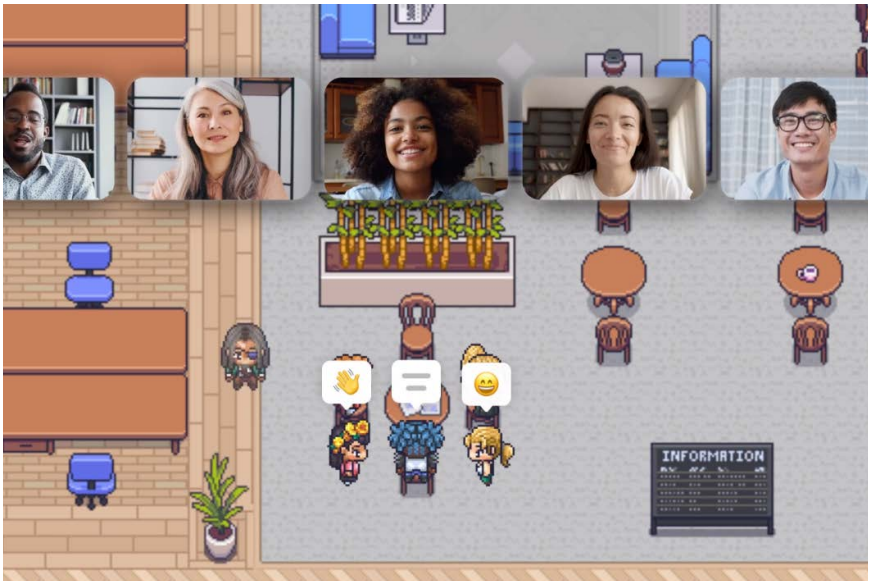
1) Successful collaboration takes careful planning and coordination
2) Lack of spontaneous interactions
3) Hard to develop trust through purely virtual interactions
4) Managers need to actively try to include remote workers
5) Virtual calls lack real world conversational cues

Market research

How can we make virtual meetings feel more like to face-to-face interactions?

Virtual meetings lack certain conversational cues found in face-to-face interactions, like eye contact, body language, and the overlap of voices. Additionally, being present makes spontaneous interactions like catching up in the hallway or grabbing a coffee between meetings easier. Virtual meetings tend to stick to the script, and efficiency is favored over small talk. Zoom fatigue can be caused by the unnatural qualities of virtual meetings, and can be a reason why people are more eager to get off a call than to stay on to get to know their coworkers a little better.

2D virtual offices



Gather Town allows hybrid teams to navigate a 2D office to collaborate and hang out.

At the very lowest level of immersion lies the 2D virtual office space. One example is Gather Town, which uses a 2D representation of an office, either referencing the real space or creating a completely virtual one. Users can navigate around the virtual space to enter meetings, chat with colleagues, or just work in the presence of others.

This type of platform introduces spatial audio and attempts to bring back the fluidity of real-world interactions. However, the major downside is that the experience is simulated, and movements, orientation, and interactions have to be controlled by secondary inputs which demand an additional cognitive load. Having to navigate this virtual environment can become more of a hassle than a perk. It also doesn't address the lack of eye contact and body language, as individuals are still displayed beside their avatars with their 2D webcam feed.

pros:

- low barrier
- low tech requirement
- spatial sound

cons:

- lack of immersion
- added complexity of navigating virtual environment

Virtual reality conferencing

Meta's virtual conference room places teams in full offices setups, complete with a whiteboard, large screen, and round table

At the end of the spectrum of immersion lies virtual environments completely simulated in virtual reality (VR). A major player in this space is Meta. Along with their headsets, Meta also has advertised virtual workrooms as a part of the Meta Horizons platform. Individuals using the Meta's VR headsets can be transported into digital meeting rooms as custom avatars, complete with hand and facial tracking.

pros:

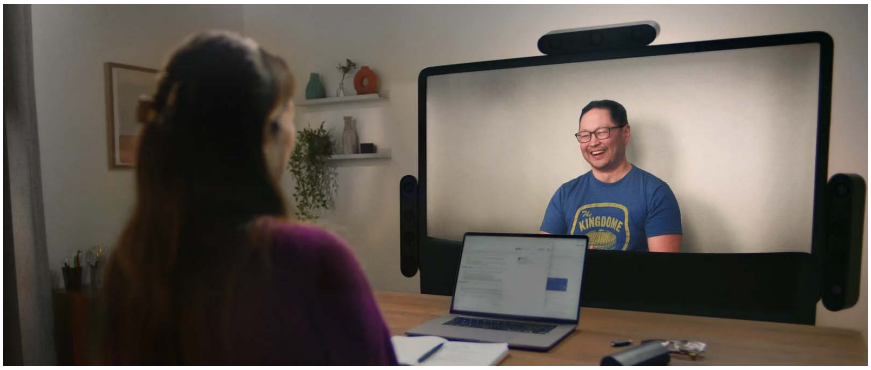
- less hardware required
- less data to transfer, computation can be done on cloud
- no spatial computing
- fully immersive

cons:

- can't capture true to life
- can get a little creepy
- unable to see real person behind VR
- disorienting
- barrier of entry

Hologram booths

Cisco's system uses a camera booth to capture users, and Magic Leap's AR glasses to display users as holograms. The booths are meant for single-person use.



Google's Project Starline utilizes a complete setup of cameras to capture users and a 3D screen to display them. Only one person can be in front of the display, as the cameras use head-tracking to simulate a 3D image on-screen.

In the middle lie holographic conference booths, blending the virtual and physical world. These are the most recent inventions of the group, both Cisco and Google's projects having been announced in the spring of 2023. They are self-contained video capturing and displaying systems, utilizing large arrays of cameras and depth sensors to capture individuals in front of their setup. The key difference between Cisco and Google's approach is in the method of display. Cisco's system relies on preexisting augmented reality (AR) goggles manufactured by Magic Leap to project holograms of individuals in space. Google, on the other hand, opts for a full 3D display that utilizes head and eye tracking to create an illusion of depth for the user. These however require large, expensive hardware that is only suitable for 1 on 1 interactions.

pros:

- enclosed system
- no need for extra equipment
- natural and less uncanny

cons:

- large, expensive setup
- not portable
- not scalable

Take-aways

1) Fully simulated users and environments allows for simpler hardware, but can lead to discomfort over long periods of usage and may further hinder trust

2) Holograms can bring us closer to a face-to-face experience, but current solutions lack scalability and can’t accommodate remote workers

3) A system utilizing smaller cameras alongside independent head mounted displays could enable a more larger holographic meetings, whilst making individual setups easily deployable

Design brief

What is the problem?
The technological limitations of virtual meetings can lead to ineffective, non inclusive, and fatiguing interactions.

Who does this impact?
Small, interdependent hybrid teams that require close communication and collaboration.

Why is this important?
As hybrid work becomes the norm and more meetings move online, it is essential to retain the aspects of in-person interactions that foster creativity and connection between co-workers.

What is our solution?
A holographic conferencing platform that could replicate the feeling of face-to-face interactions while maintaining the advantages of virtual meetings.

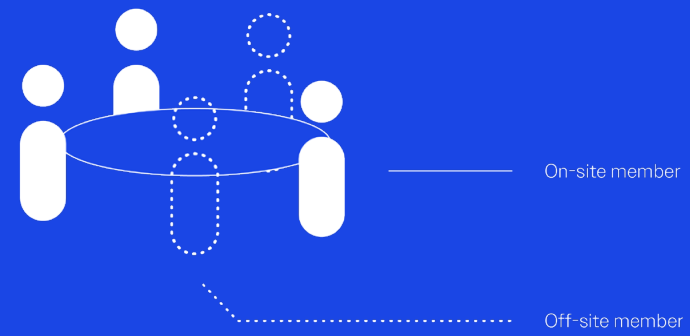
Design a system that could:

1) Capture multiple on-site employees within the same room

2) Capture off-site employees working from their own homes

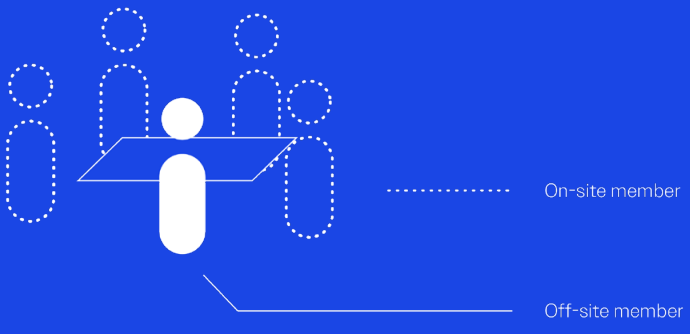
3) Display the members in AR so both parties feel like they’re in the same room

4) Utilize software tools to help make meetings more effective



On-site view

Members joining the meeting on-site will be able to see off-site employees within the room in full scale.



Off-site view

Members joining in from home will see their team projected at their home office table.

A brief history of holograms

The history of holograms is intertwined with that of telecommunications.

Ever since the conception of long distance communications, technology has inched towards fully replicating face-to-face interactions from afar. Holograms, which have long been cemented in works of science fiction, have always been a destination without a clear path. However, recent innovations in capturing and displaying have made this dream within reach.

Technically speaking, the glowing volumetric image in science fiction movies isn't really a hologram. True holograms are 3D images produced by a process of capturing the interference pattern of light waves within a sheet of film. For the purpose of this document, we'll refer to volumetric images as holograms, as they're generally called as such by the general public.

Hologram timeline

1935
Sci-fi author Weinbaum describes first AR goggles

1901
L. Frank Baum first recorded reference of overlaying data over real world

1951
Isaac Asimov first to reference the hologram in science fiction series Foundation

1860s
English scientist John Pepper popularizes Pepper's Ghost

1947
Dennis Gabor discovers method for creating true hologram

1968
Sutherland and Sproull create the first AR/VR headset

1870

1876
Alexander Bell invents the telephone

1960
picturephone
At&T creates two way office video conferencing system

1930
At&T demonstrate 2 way comm

Telecommunications timeline

2030
Holographic video calls

2016
Microsoft Hololens hits the market

1977
Princess Leia appears as a holographic transmission in the first Star Wars film

2014
Google Glass hits the market

1980
term “Augmented reality” is coined

2013
Oculus Rift becomes first commercially accessible VR headset

2030

1990s
internet
first webcam
first desktop video conferencing program CU-SeeMe

2000s
smartphones with cameras, Skype, 3g and 4g enabling facetiming with iPhone 4 in 2010

1984
PictureTel
first commercial video codec for more efficient video data transmission

1992
Polycom SoundStation conferencing speaker that enabled both parties to simultaneously speak and be heard

2020
Covid pandemic pushes companies to go virtual
Zoom, Bluejeans, Microsoft Teams used for education and in corporate

What are we proposing that's new?

The use of AR and VR headsets to project simulated people and objects directly into users' vision has been a very practical way of creating holograms.

Currently, live-streaming individuals captured by 3D cameras, or *holoportation*, can only be achieved in extremely controlled settings novel use-cases. Despite this, the recent resurgence of interest in AR driven by all of the main players in tech have brought developments in AR and volumetric capturing technology that promise to make both more practical and accessible in the coming years.

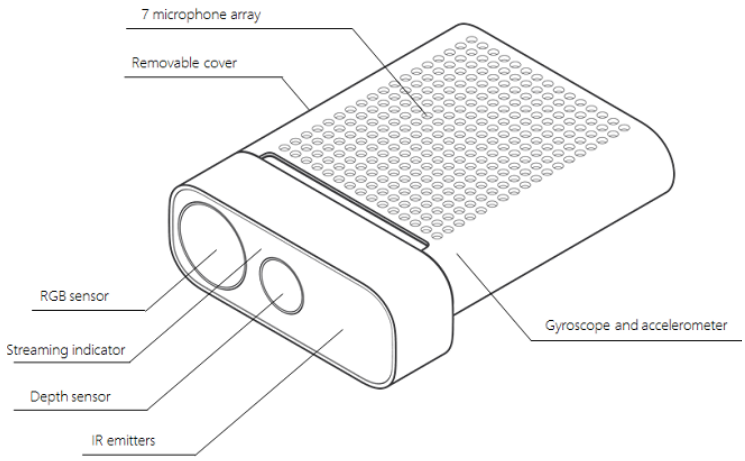
Building upon these emerging technologies, we hope to propose a realistic concept for holographic conferencing in the year 2030.

Camera technology

How do current technologies capture depth?

Conversational cues like eye contact, body language, and the ability to overlap speech can all be replicated by capturing and relaying spatial information in real time. Depth cameras are used to accomplish this task. However, current setups can be costly and require extensive calibration. We investigated the capabilities of the technology and proposed a more feasible solution.

Depth cameras



The Microsoft Kinect Azure utilizes a single RGB camera and ToF sensor to provide high quality depth maps

A single Microsoft Kinect camera live-streaming a volumetric captured face

Microsoft's latest version of their Kinect, the Kinect Azure, is sold as a depth camera for robotics and 3D content creation. A single Kinect camera can create a serviceable volumetric representation of a person. In the image above, you can see a person being captured this way. The sides of his face are blurry, as the single RGB camera on the Kinect fails to capture the sides and back of the subject. This can be solved with the use of multiple cameras, as we will see in the next section. However, what's becoming more promising is the use of machine learning algorithms to recreate missing parts of the face, enabling even simple iPhone cameras to create lifelike 3D models.

Ukrainian President Volodymyr Zelensky being streamed in 3D

Depthkit's tutorial for the optimal home volumetric streaming setup

Volumetric imaging studios often use depth cameras developed by Microsoft and Intel, rigged up and calibrated within a controlled environment. The ones selling studio time are overkill for what we're trying to accomplish, with some of them using over 20 cameras within a greenroom to generate 3D assets for movies, video games, or to stream high profile figures like Ukrainian president Volodymyr Zelensky (top). Companies like Depthkit provide software and hardware kits to help users build their own home studios for volumetric capturing. This photo (bottom) shows a formidable setup used for capturing one person in 3D to be streamed via video call.

Comparing imaging technologies

Sensor Selection Considerations

Robot Task	Suitable 3D Sensor(s)	Decision Factors	Notes
Short-range obstacle avoidance	Stereo CMOS HDR CMOS Structured Light Active Stereo	Ambient Lighting Unexpected Obstacle Types Host Compute Host Power	HDR sensors may be required in environments with very bright sunlight, or very low light conditions
Mid-range navigation	Time of Flight (ToF) Stereo CMOS HDR CMOS	Ambient Lighting Host Compute Host Power	Wider baseline stereo sensors used for mid-range navigation may not be able to provide short-range obstacle avoidance.
Long-range navigation	Time of Flight (ToF)	Ambient Lighting Host Compute Host Power	ToF sensors used for long-range navigation will need to be coupled with another sensor for short-range obstacle avoidance.
Object detection/identification	Stereo CMOS Active Stereo	Sensor Resolution Site Bandwidth Data Compression Ambient Lighting	Machine learning systems that are fed with photographic images to create classifiers will respond best to CMOS-equipped sensors.
Object/surface inspection	Structured Light Active Stereo	Sensor Resolution Site Bandwidth Data Compression Ambient Lighting	Black and/or shiny surfaces will impede structured light sensors; active stereo sensors are a better option for these scenarios.
3D modeling	Structured Light Stereo CMOS Active Stereo	Sensor Resolution Site Bandwidth Data Compression Ambient Lighting	Black and/or shiny surfaces will impede structured light sensors; active stereo sensors are a better option for these scenarios.

The chart compares different depth sensors and their strengths and weaknesses.

A full body scan can enable novel effects like re-orienting the model in 3D space, but for a face-to-face conversation, we really just need one camera to capture the front of a person from eye level.

Comparing different types of depth sensors, we choose to use four ToF sensors coupled with four color cameras for the conference room for higher resolution and 360 degree coverage. For the home camera, a stereoscopic duo of RGB and infrared cameras captures the front and sides of the user in full color with depth information.

Camera hardware requirements

Personal webcam:

1) stereoscopic RGB cameras
2) stereoscopic depth sensors
3) microphone array
4) adjustable height
5) privacy features
6) glasses charging dock

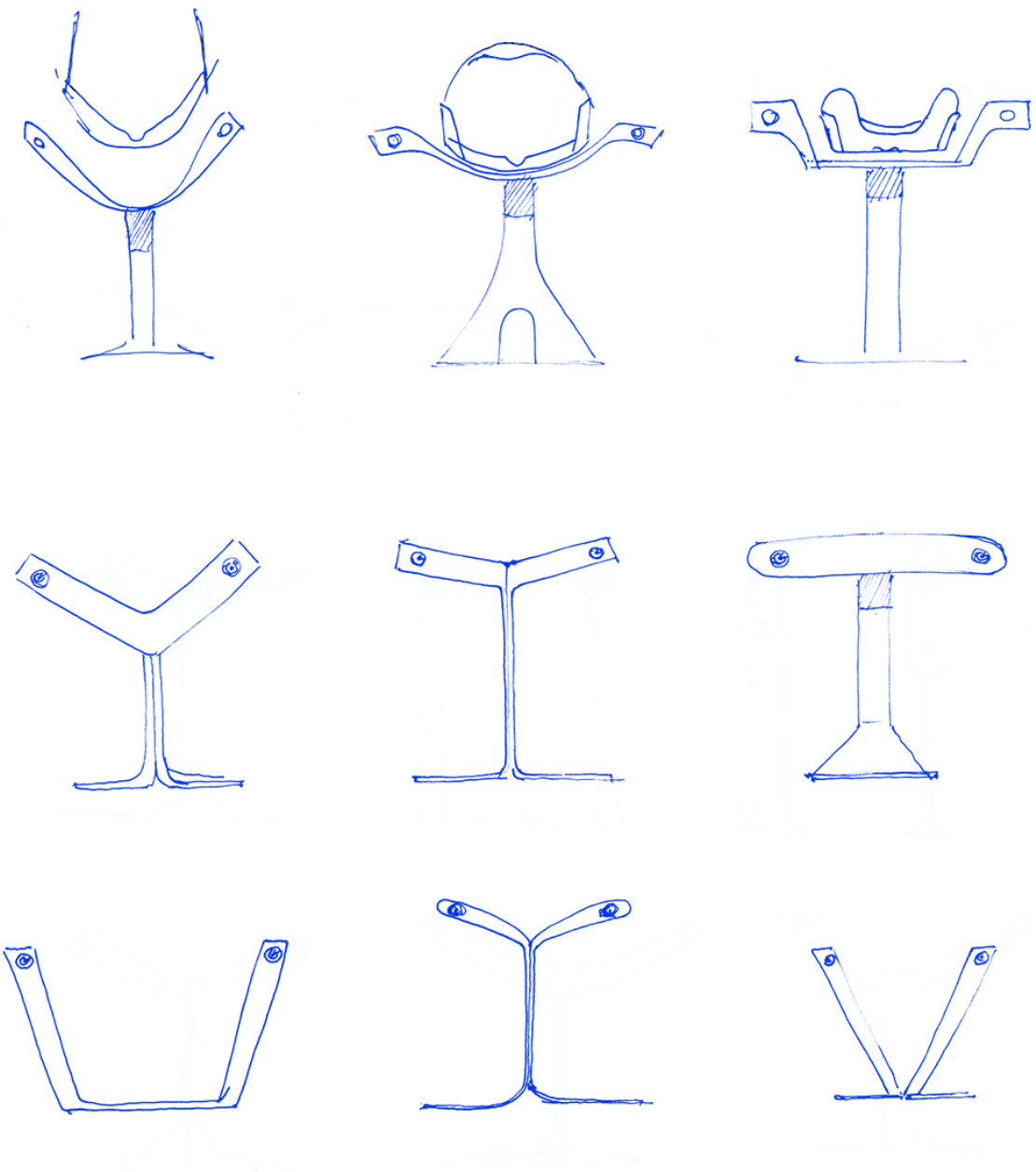
Office conference camera:

1) 4x wide-angle cameras
2) 4x ToF sensors
3) microphone array
4) adjustable height
5) privacy features

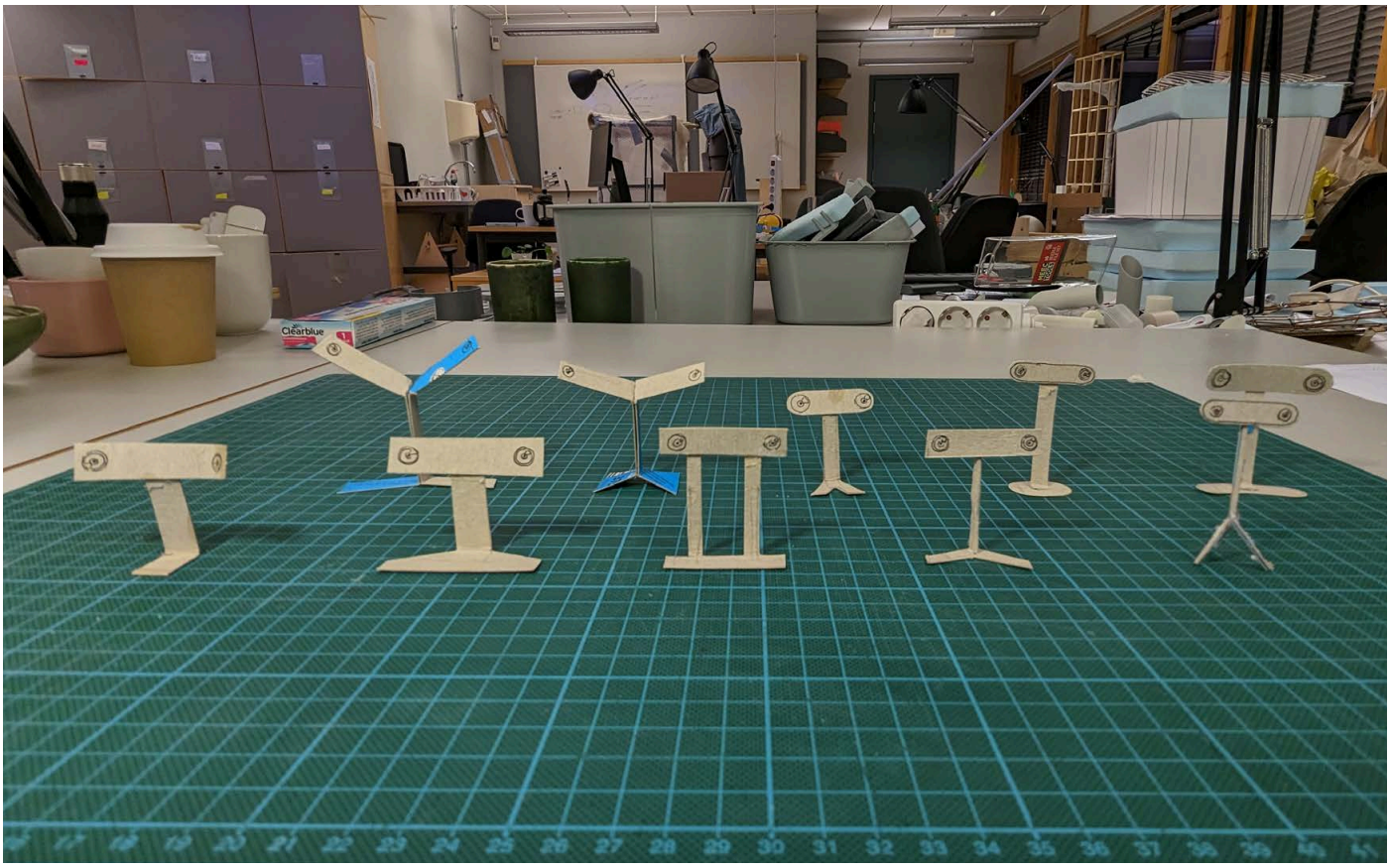
Camera design

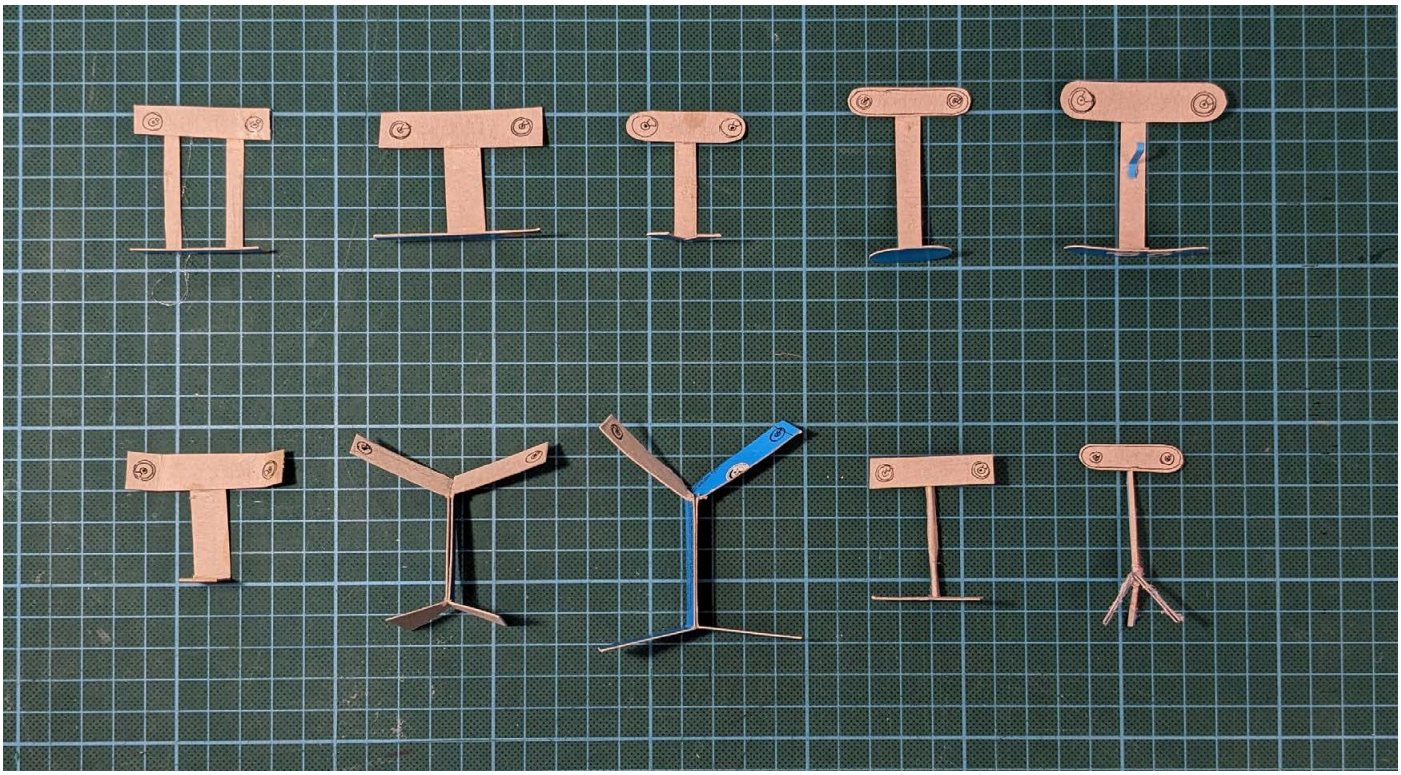
How can we develop a distinct identity for the cameras?

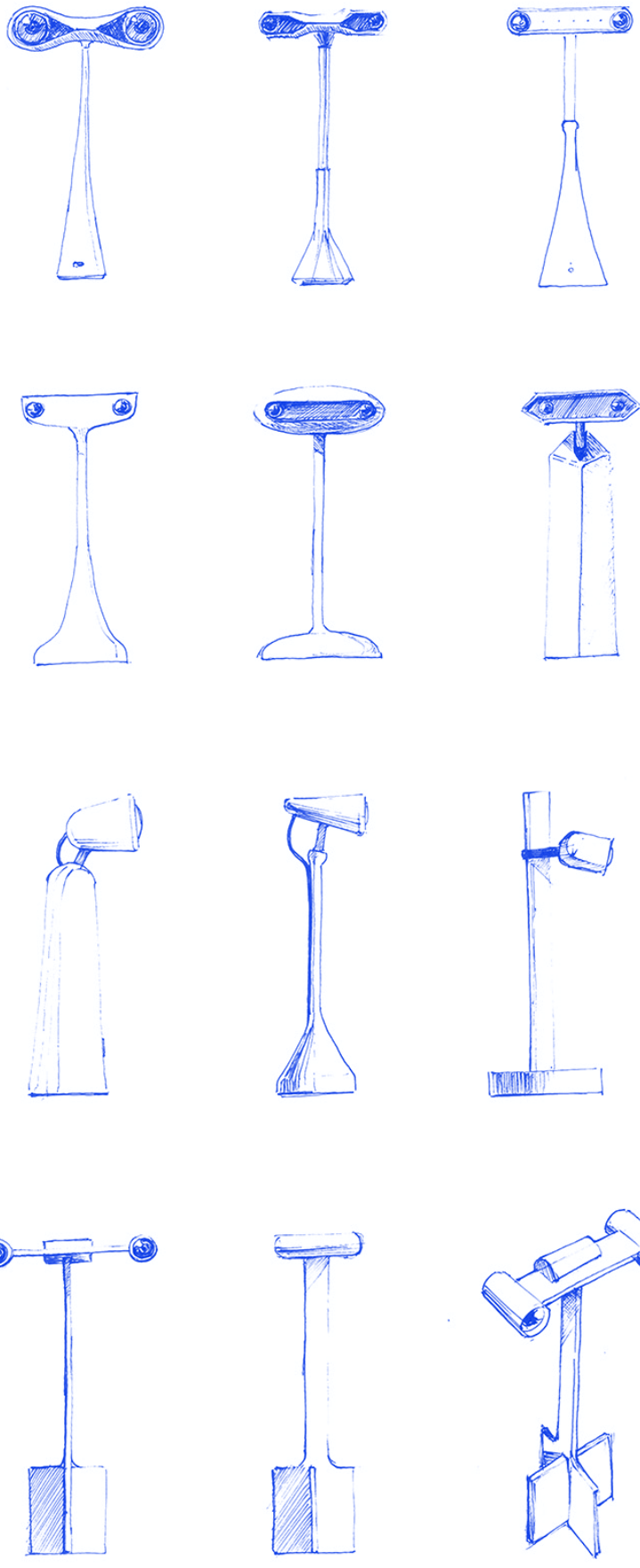
The corporate design language can be a bit bland sometimes. Given our brief of making a product suite for the near future, we wanted to add a bit of character to our designs with the use of bold forms and highlight colors.

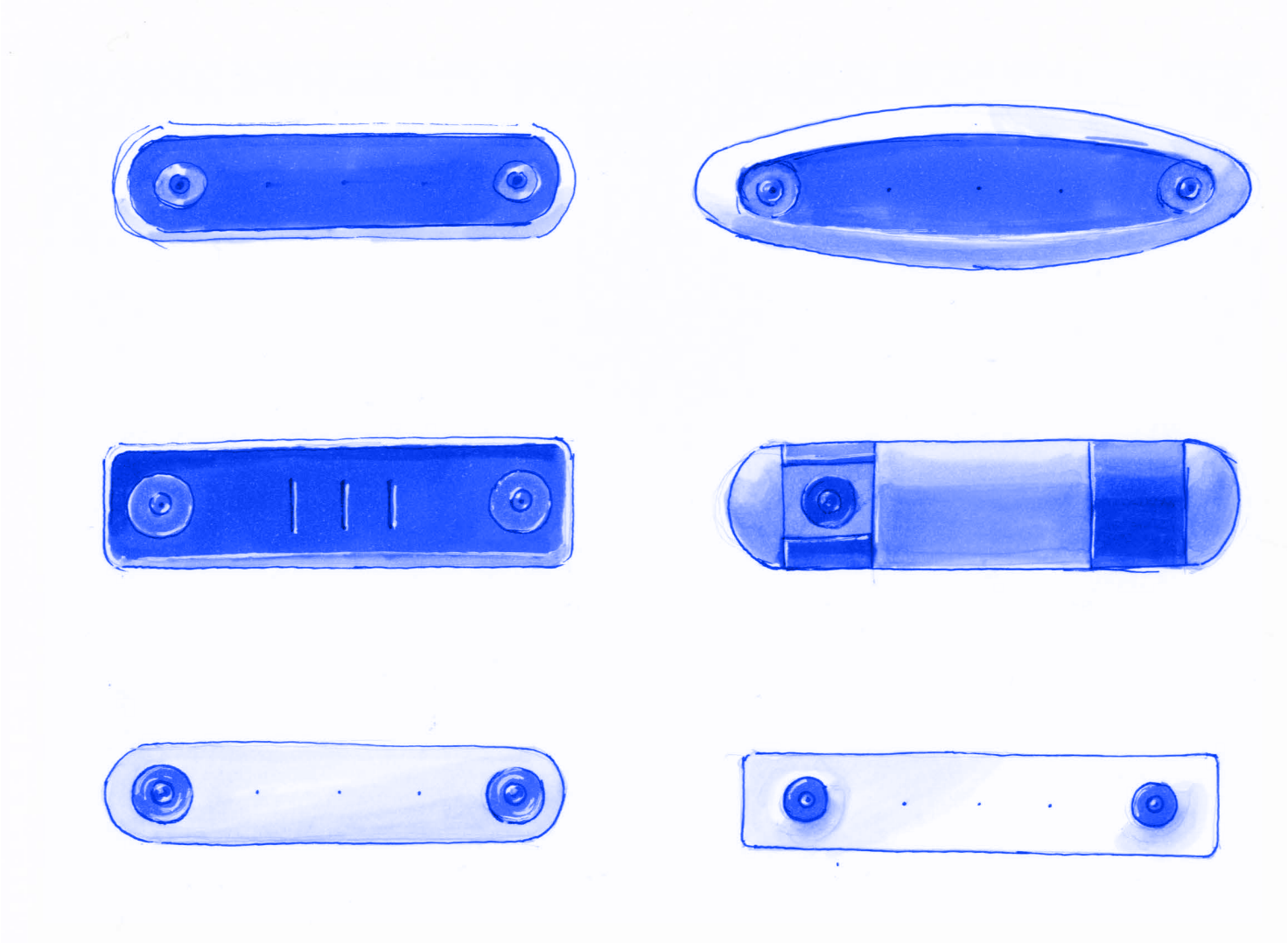


We explored some novel forms that would enable a stereoscopic camera setup without taking too much space on the table.

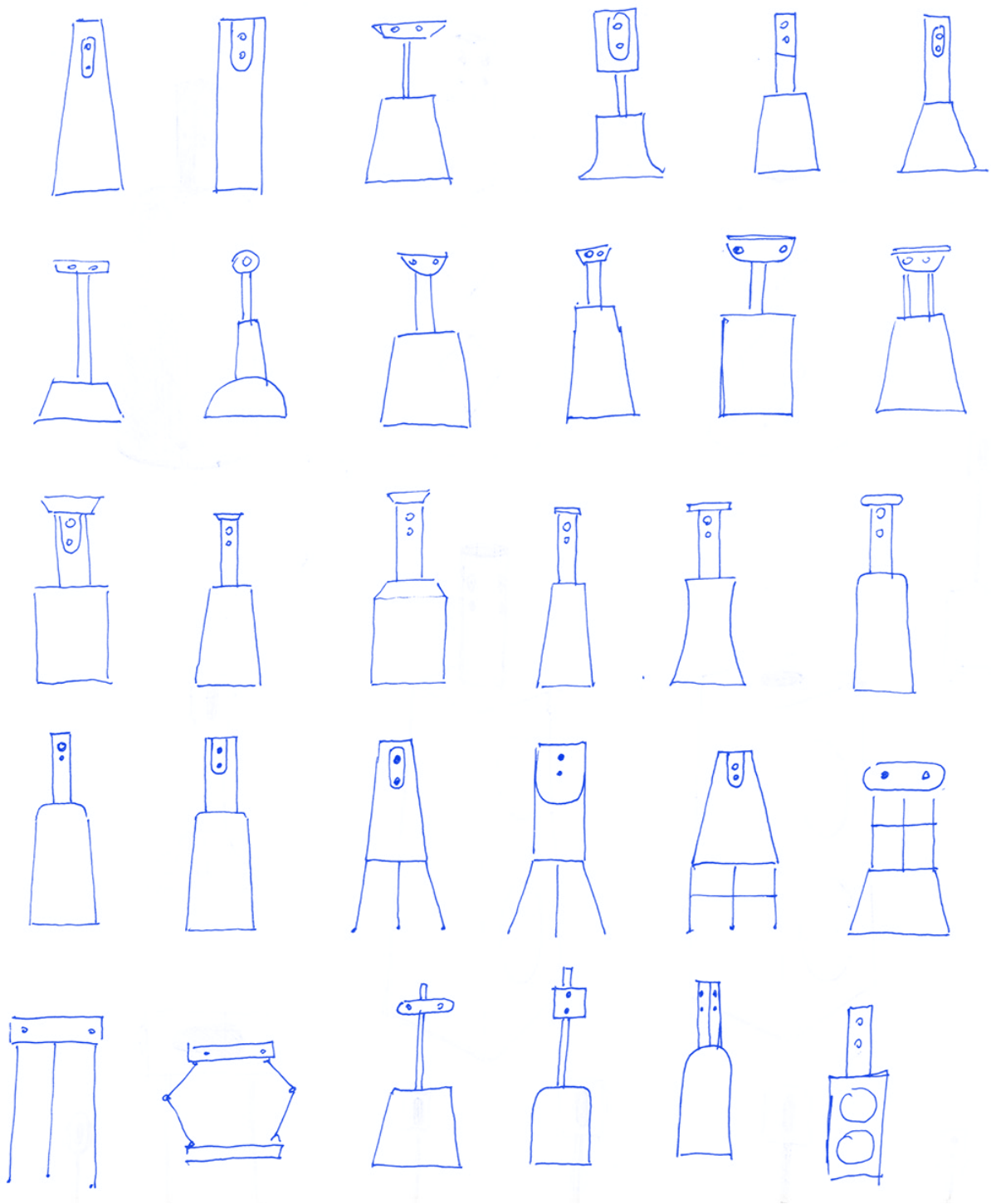

Clearblue





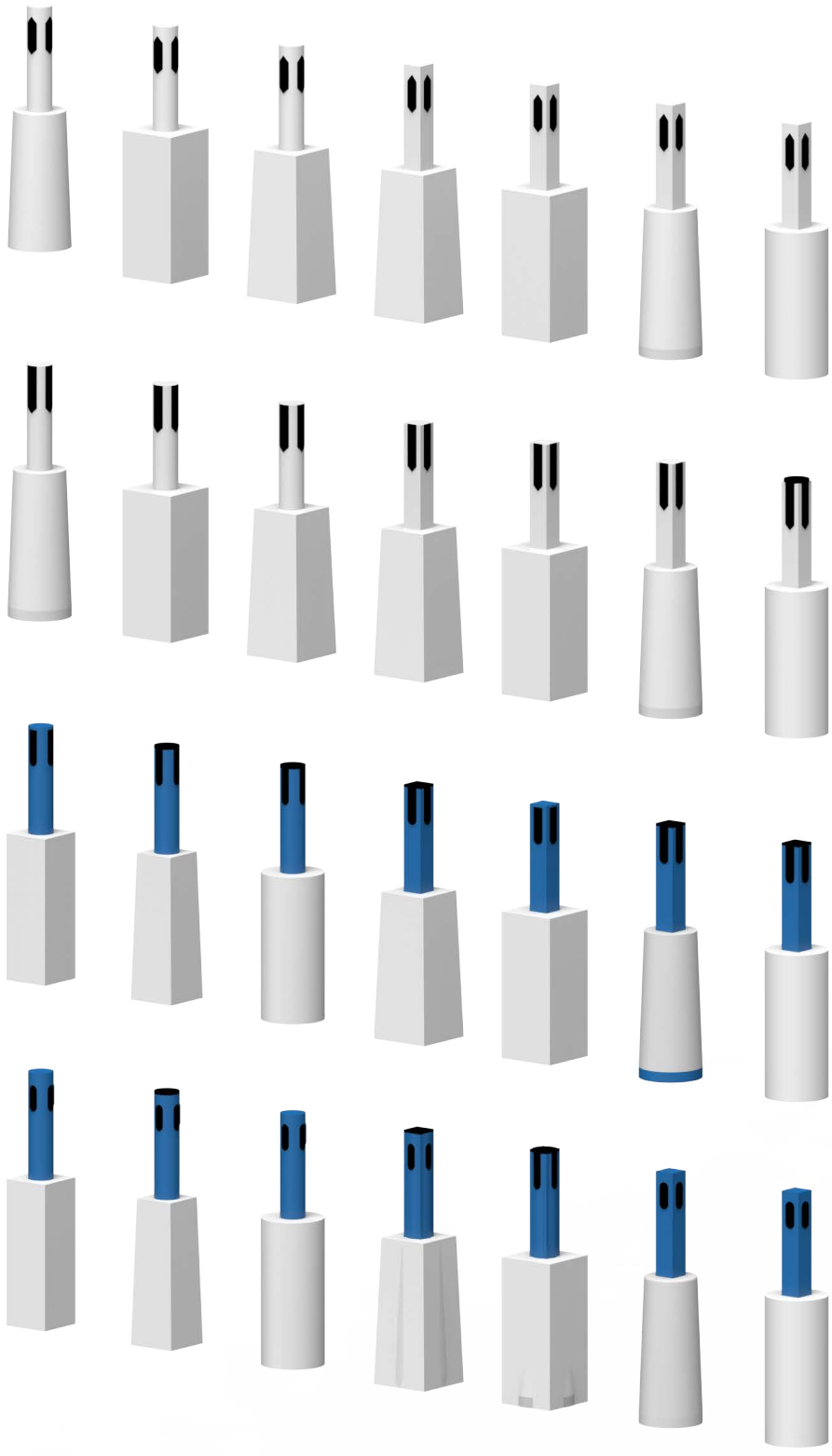


Initial sketches of the home camera explored how to maintain a streamlined form while incorporating a wide stereoscopic camera setup.

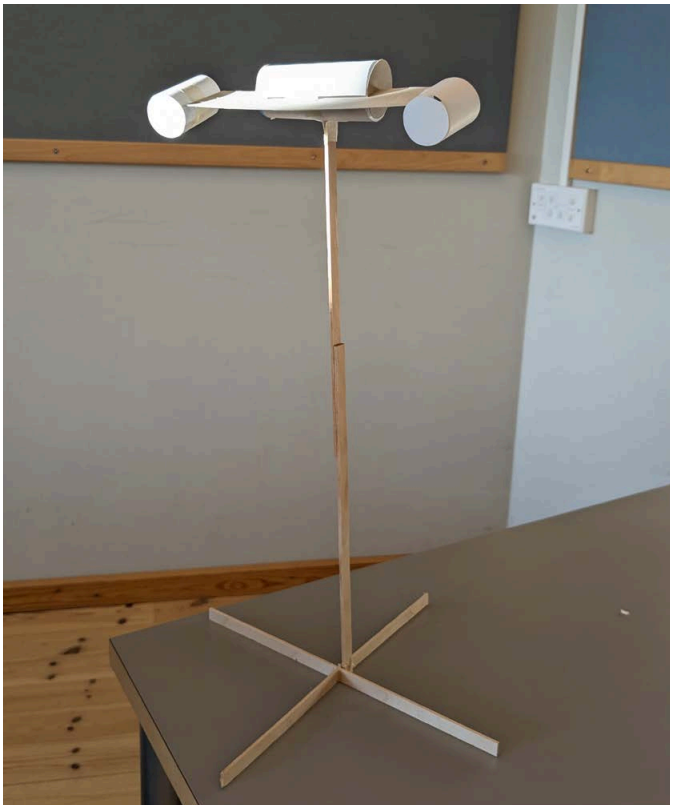


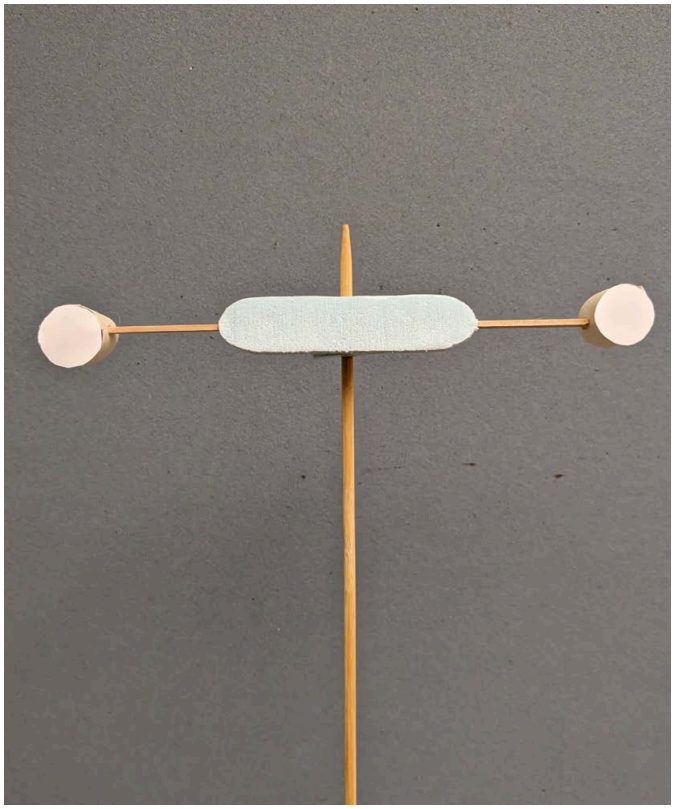
Our main concern for the conference camera was its large footprint, as it has to capture users at eye-level from the center of the table, Sketches for the conference camera explored different ways to reduce its height when not in use.

A key feature is the adjustability of the cameras. The home camera slides along a rod, being fastened in place with a clamp.

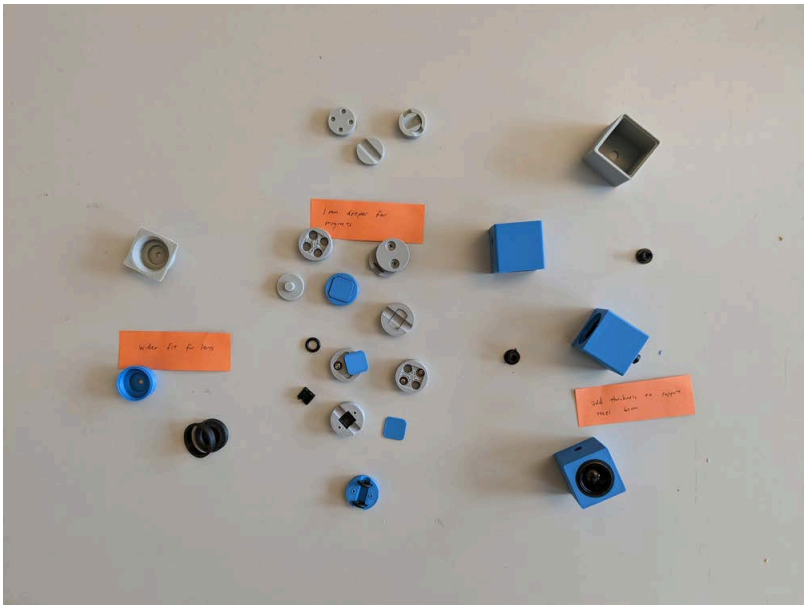


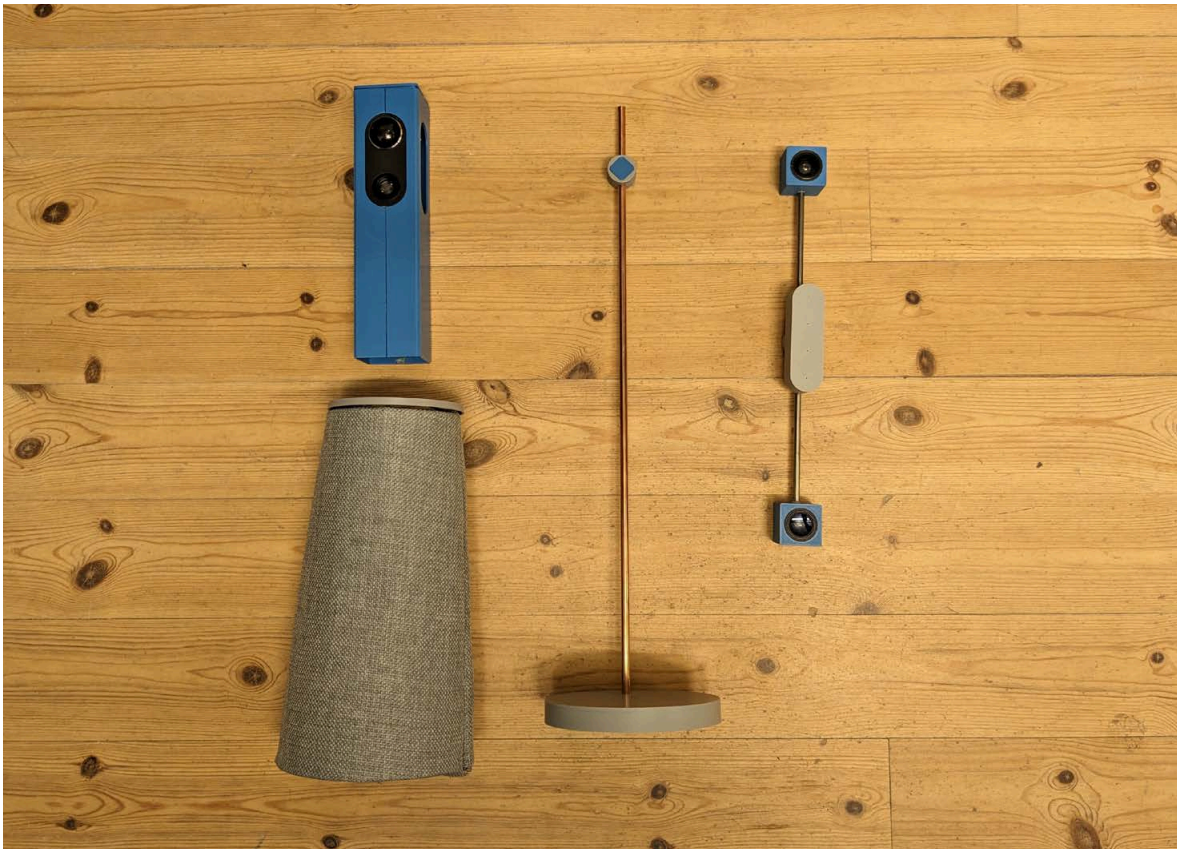
The office camera raises and lowers its imaging head into the main body that also houses the speakers. By hiding the camera when not in use, it allows for added privacy and a reduced footprint when not in use.





The home camera needed to adapt to different users' home office setups. The height should be adjustable and removable to be attached on monitors if desired. Privacy is also an issue at home, so we designed the cameras to rotate and face away from the user when not in use.





After 3D printing and assembling our first design, we realized that the products looked a little too toy-like. We decided to redefine our design language to better fit the target group.

Camera redesign

1) Discard exaggerated geometric shapes

2) Reduce moving components to favor a compact and robust design

3) Reduce colored elements for a more corporate aesthetic

4) Find a clear design language to unify product family

Design Language

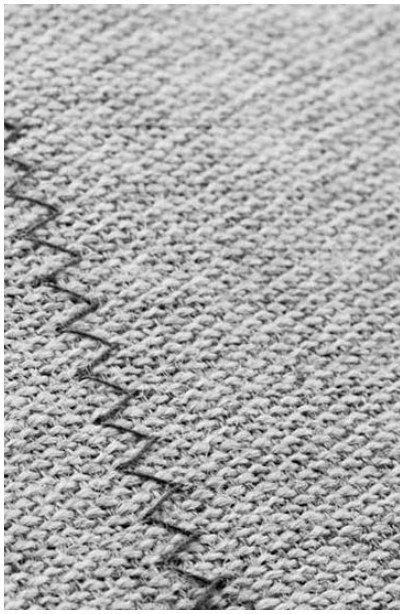
Jabra Panacast
Traditional corporate design, all black with intimidating cameras.

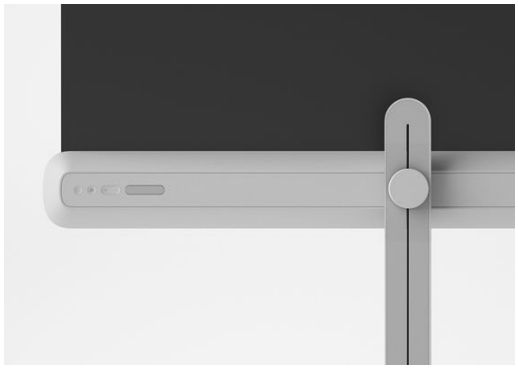
Logitech Sight
More modern minimalist approach. Sleek, could be sold as a consumer product.

Cisco Quad Cam
A friendlier look, with mesh speaker covers and a unimposing design.

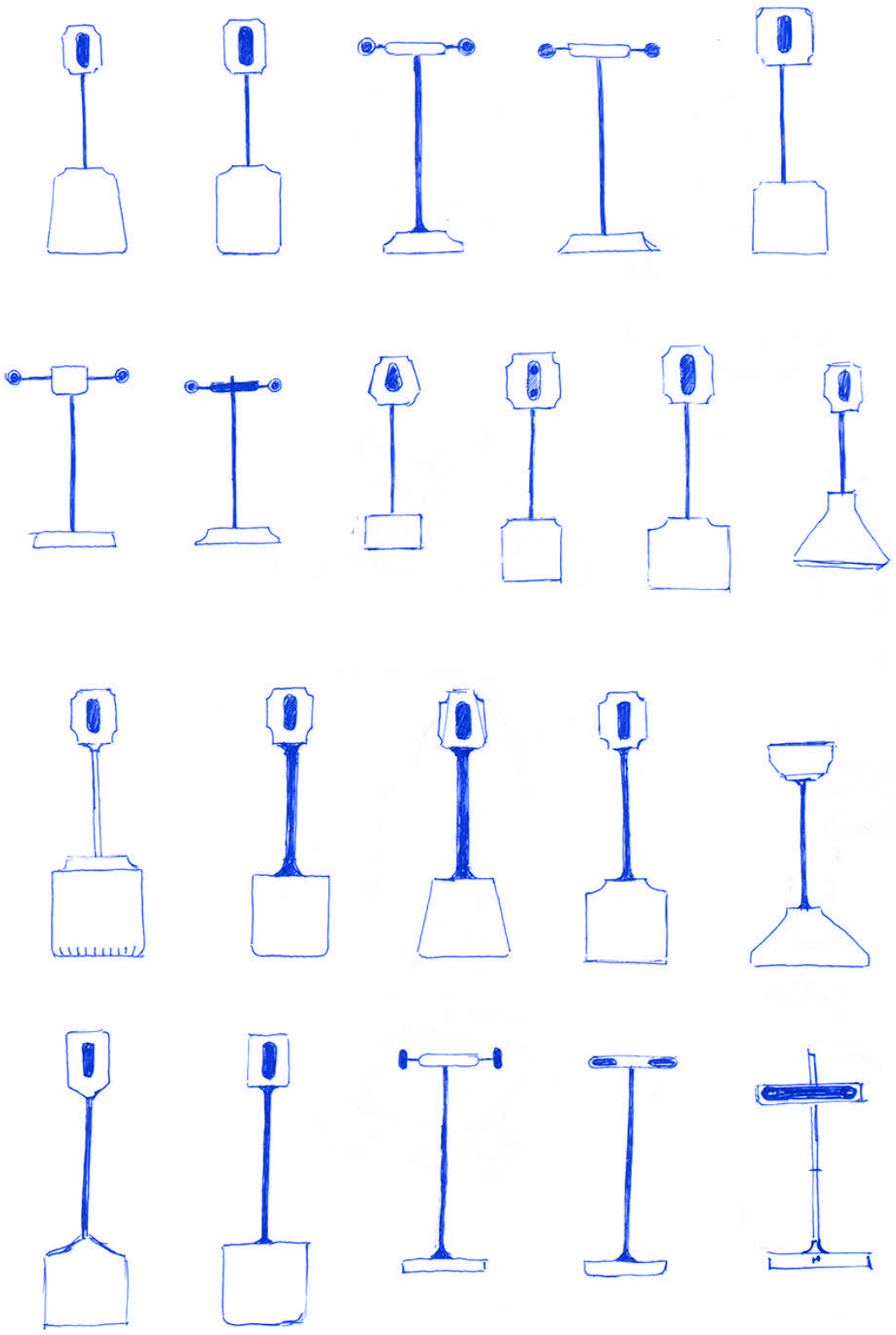
Meeting Owl 3
The quirkiest of the bunch, with LED eyes that serve no function aside from making it cute.

Color and material inspiration

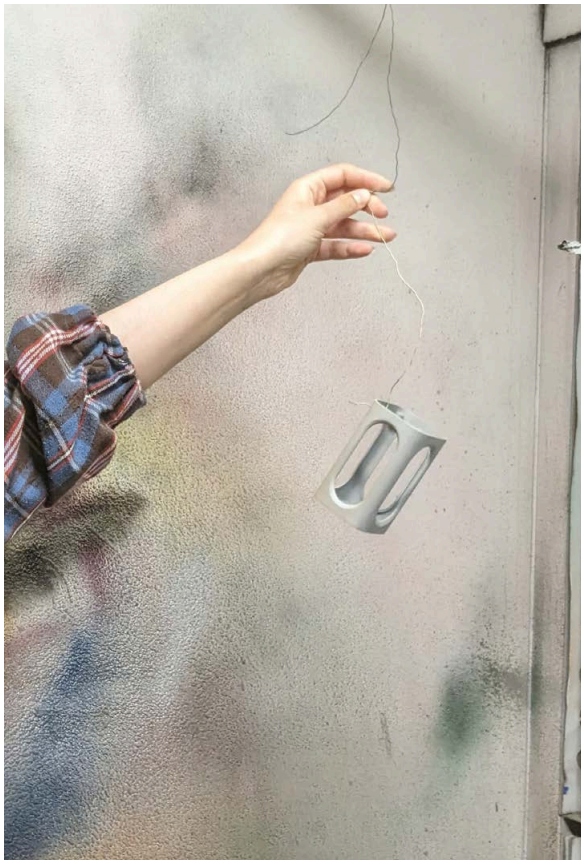




The design language for our product line should be clean, friendly and professional.

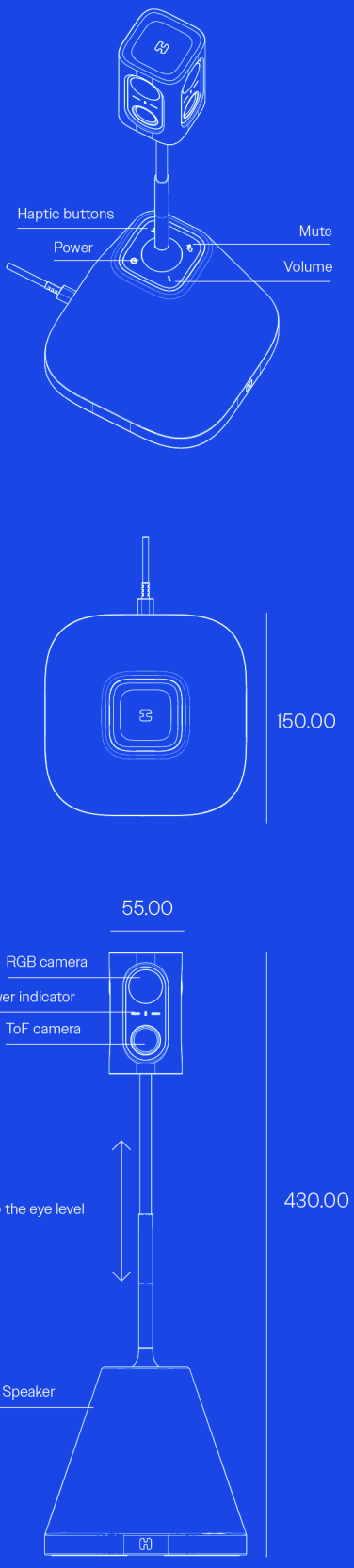


We reduced the bulkiness of the previous design replacing the main body with a telescoping aluminum rod.

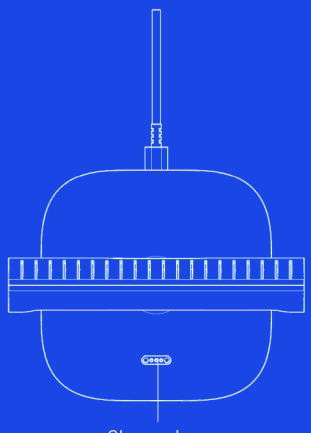


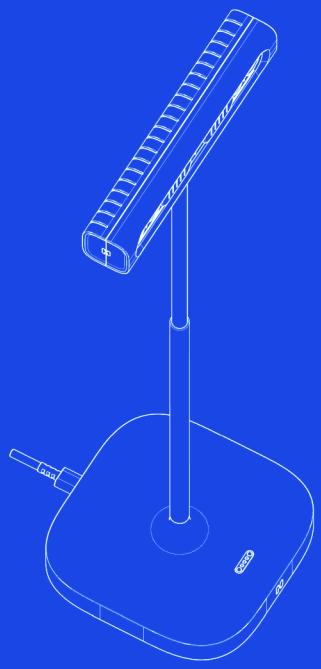
Printing, sanding, painting, and final assembly of the conference speaker prototype. The prototype uses a clamping system to stretch the speaker fabric over the base.

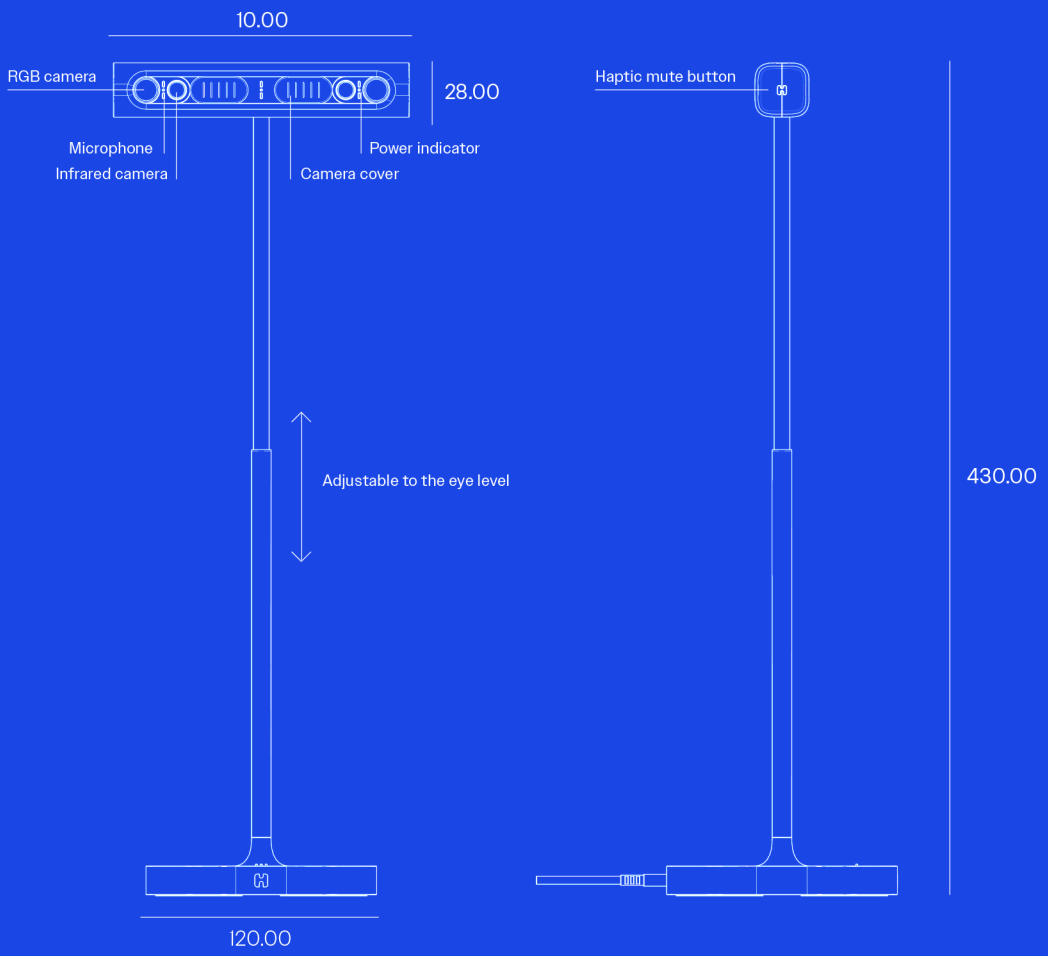
Hollaboration Office Camera



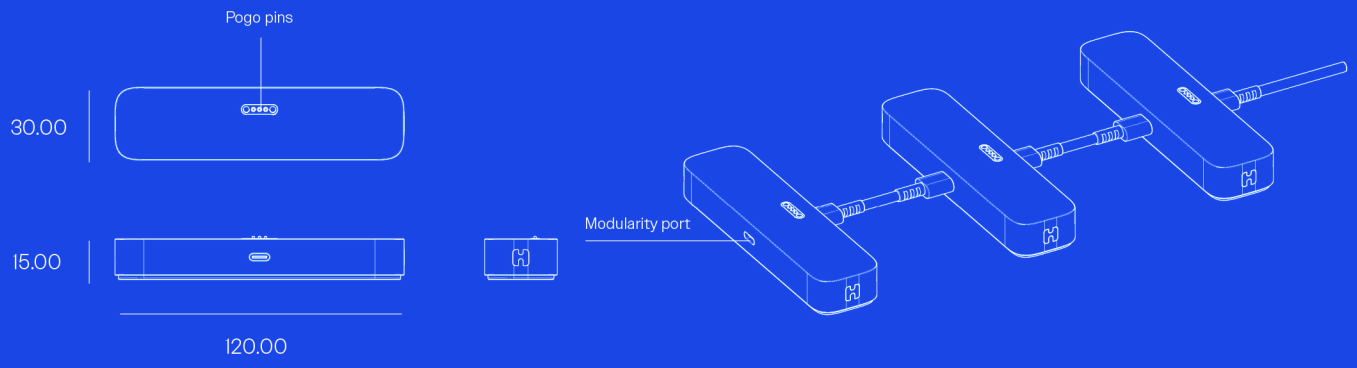
Hollaboration
Home Camera

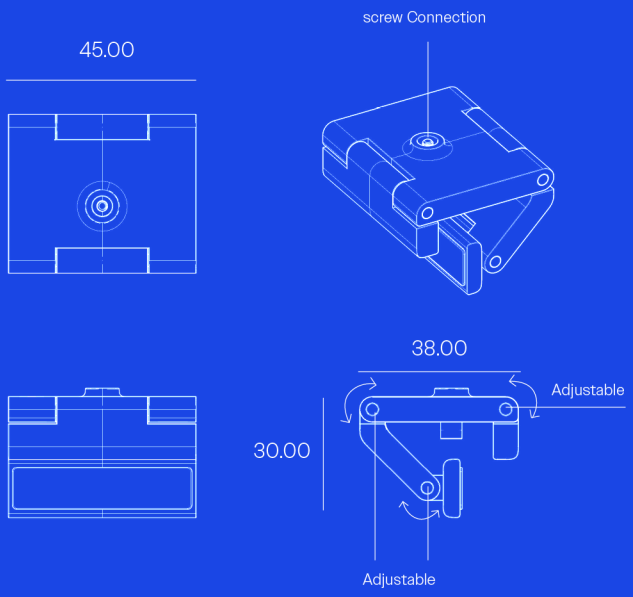




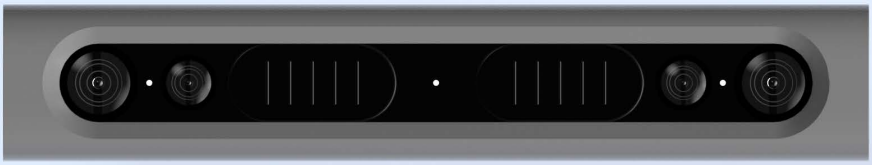


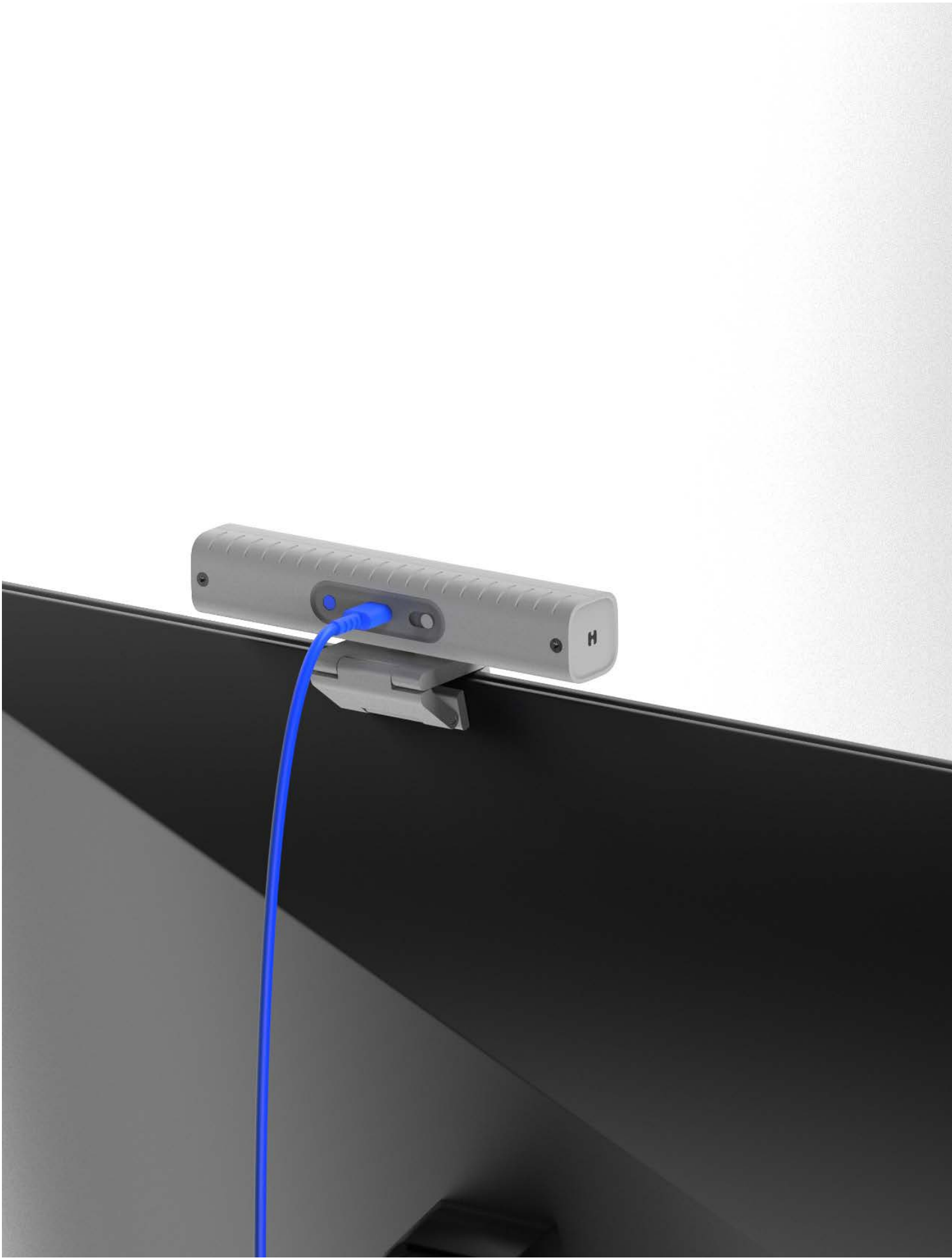
Office Stackable Charger

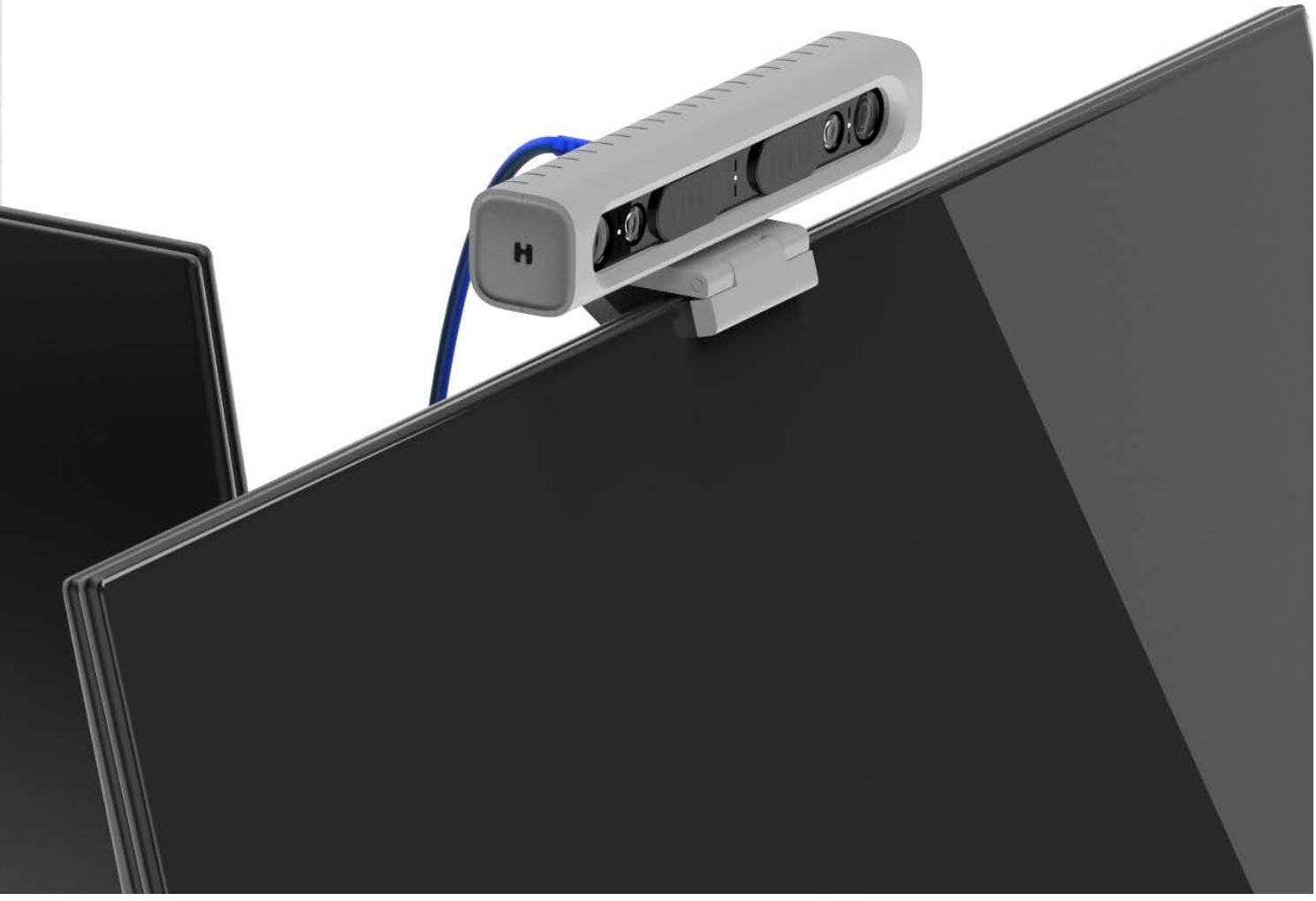




Monitor Mount





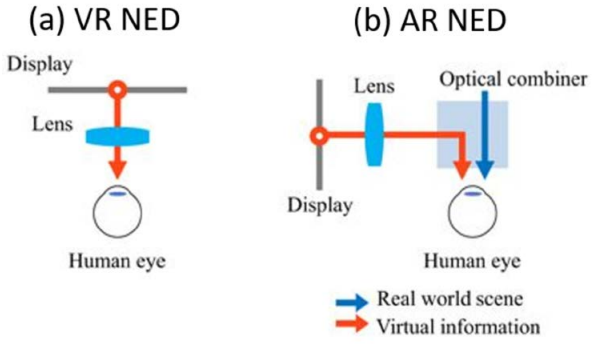


AR display technology

How do current AR technologies work?

By utilizing a system with head mounted displays, the meetings could support much larger groups. The size of the meetings could also be easily scalable, as individuals just have to bring their headgear, and no change has to be made to the capturing setup. Additionally, with reducing cost and size of individual devices, these could be provided for each employee to have at home.

Head-mounted displays



Diagrams showing the differences between VR and AR optics

Head-mounted displays (HMDs) are mainly separated into two classes, virtual reality (VR) and augmented reality (AR). VR headsets completely cover the users' eyes, with the primary goal being immersion. Because they simulate entirely new environments, VR devices don't need to reference the user's real surroundings. AR, on the other hand, sacrifices immersion for transparency in order to display a layer of information above the real world. Many applications are focused aiding and describing operations within the real world.

The technology and industry around VR has already had time to mature, but AR hardware still has a long way to go. One barrier of entry is the price and accessibility of AR devices, leading to both consumers and developers having had a hard time getting their hands on one.

The challenge with AR largely lies in the dream that one day they would look just like prescription glasses. However, unlike VR, AR can be far more computationally demanding as it may need to display images that respond to the real world environment.

General purpose AR devices have not been developed yet due to the significant trade-offs between different display technologies and features. The light-weight glasses-like AR devices like Oppo Air 2 are limited to a HUD-like functionality for data snacking, similar to the Google Glass that debuted in 2013. In order to fit in head tracking, environment and object mapping, gesture control, in addition to a full color display, products end up looking like the Microsoft Hololens. Even so, a bulky device isn't an issue when used for limited sessions on a factory floor.

For now, AR doesn't need to be general purpose, and the prioritized functionality demanded by the use case will directly impact the implementation of AR. Factors that we are considering are facial visibility, color reproduction, FOV and prescription compatibility.

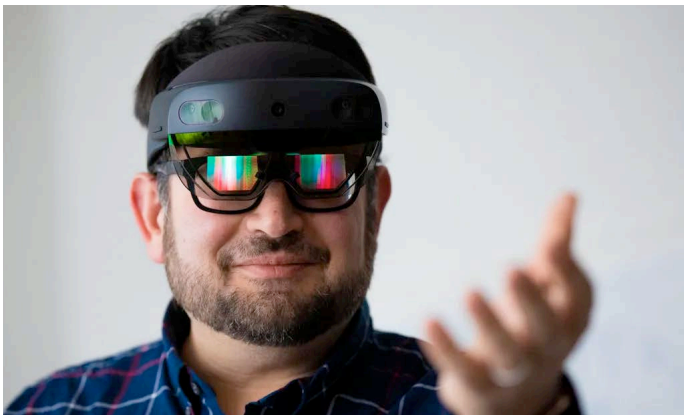
Oppo's Air 2 concept looks like what people wish AR glasses would look like, but it can only display a HUD in monochrome green

Microsoft's Hololens 2 is the most advanced AR device for industrial use in 2023

Facial visibility

Facial visibility is probably the most important feature when choosing the display technology. We want as much transparency as we can get when it comes to facial expressions, especially the eyes.

However, HMDs inherently require us to place a device on a user's head with some optics directly in front of their eyes, so there are certain design elements we cannot avoid. With that being said, we have a choice as to where to place the bulk of the design, and how to leave the front of the face unobstructed. The main features that reduce facial visibility are eyeglow, lens transparency, and obstructing components.



The Hololens 2 utilizes waveguides, but their choice of laser beam scanning as their projection method causes extreme eyeglow

Magic Leap's devices tout having impressive contrast and clarity, but the polarization makes it infeasible for industrial purposes

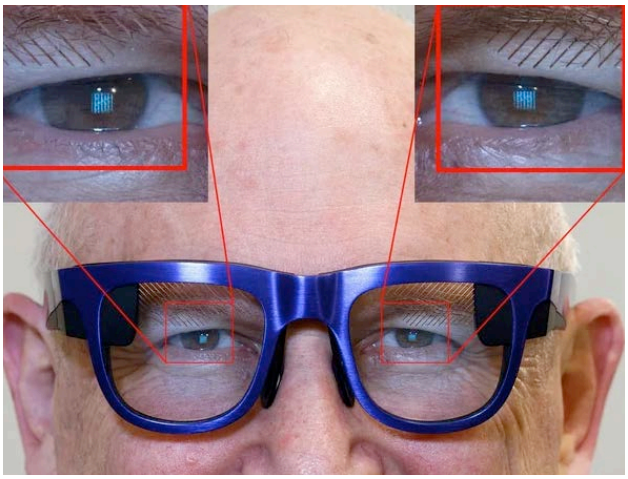
Comparing optical technologies

Birdbath optics

Birdbath optics utilize a traditional display source, coupled with reflecting elements that combine the light from the display in addition to real world light. With each reflection leading to a significant light loss, birdbath designs have to incorporate a polarizing layer to allow the projected image to be clear even in room lighting. There is an issue of image ghosting and frontal projection of the displayed content.

Waveguides

Waveguides can use diffractive or reflective elements within a lens to guide light from a projector into the user's eyes. These are the newest technology and most difficult to manufacture, so are still the most expensive of the three. Because light is reflected or diffracted within the lens material itself, the image projectors can be coupled directly to the material and maintain an extremely compact form factor. Frontal projection is more limited but still an issue in some implementations, and a much smaller FOV.



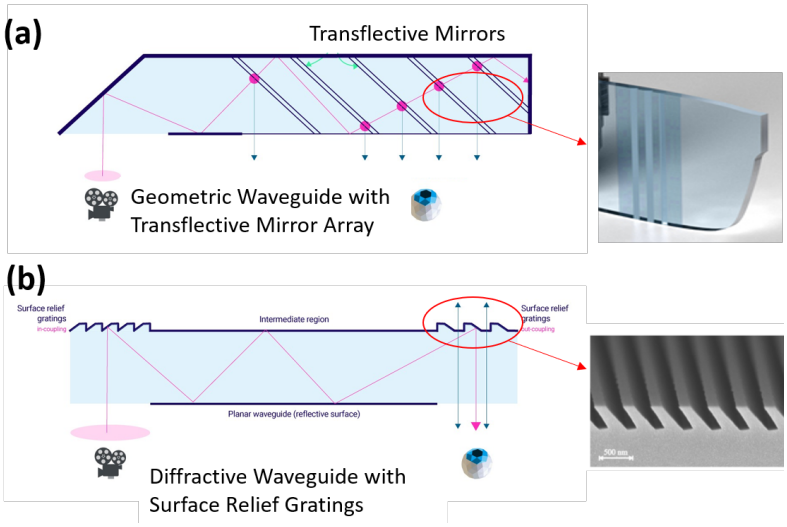
Lumus's waveguides have the lowest eyeglow and frontal projection on the market right now, sacrificing brightness and contrast

Xreal's devices use birdbath optics and have considerable frontal projection, but it's primary usage for home entertainment make these less of an issue

Waveguides (diffractive vs reflective)

Two of the main kinds of waveguides being developed are diffractive and reflective waveguides. Diffractive waveguides are the more popular of the two as of now, and can use surface relief gratings or holographic gratings to diffract the light. The technology is transferable to mass production and can be made relatively cheap.

However, due to the diffraction angles of different light frequencies, red, green, and blue channels are split up and need to be combined to form the image in the user's eyes. This process also leads to significant eyeglow and rainbow artifacts.
Reflective, or geometric waveguides, use embedded mirrors within the lens to reflect the complete image into the user's eyes. The image produced is of a higher quality and with little distortion and artifacts. The manufacturing process of reflective waveguides is much more complicated, and the resulting image size and FOV are smaller than those created by diffractive waveguides.



Structural differences between (a) reflective or geometric waveguides, and diffractive waveguides

Other factors to consider

Field of view

Due to the limitations of current technologies, the field of view is generally in the range of 30 - 50 degrees, with some sacrificing clarity and image uniformity for a high FOV. Higher FOV isn't always desirable in an AR device, as industrial applications may want less immersion for safety reasons. For our scenario, we want people to be able to see individuals in their peripheral view, and to speak to multiple people without having to constantly turn their head, so a higher FOV is desired.

Prescription compatibility

The device must be compatible with most wearers' eyes. Some display technologies require prescription to be embedded within the optics and some can be worn over glasses. Some technologies also have smaller eyeboxes, or the volume in which an eye can perceive a clear projected image. This means that devices need to be tailored to their eyes. Refer to Focals by North, an AR smart glasses company acquired by Google in 2020, who required users to go in person to one of two locations to have their face scanned and measured.

Projection technology

For the projection technology, we have to choose something that's compatible with waveguides. The most common are Digital Light Processing (DLP), Liquid Crystal on Silicon (LCoS), and Laser Beam Splitting (LBS). DLP uses micro mirrors and a rotating color wheel to project color. Benefits are a small form-factor and high contrast, but DLP suffers from a rainbow effect when displaying videos. LCOS uses a similar principle of projecting an image, but instead uses liquid crystal lattices to filter the light. It is being used due to its small form-factor and cheap price. LBS uses a laser and a mirror to scan across the user's retina, and results in high contrast, high brightness, and an image that is always in focus. However, LBS can result in visible scan lines and has to be tailored to the individual user. A fourth, and emerging technology is microLED, which is smaller than all of the above and promises to have higher brightness and picture quality. However, they are only available in green right now, so are therefore unable to recreate full colored images.

AR glasses hardware features

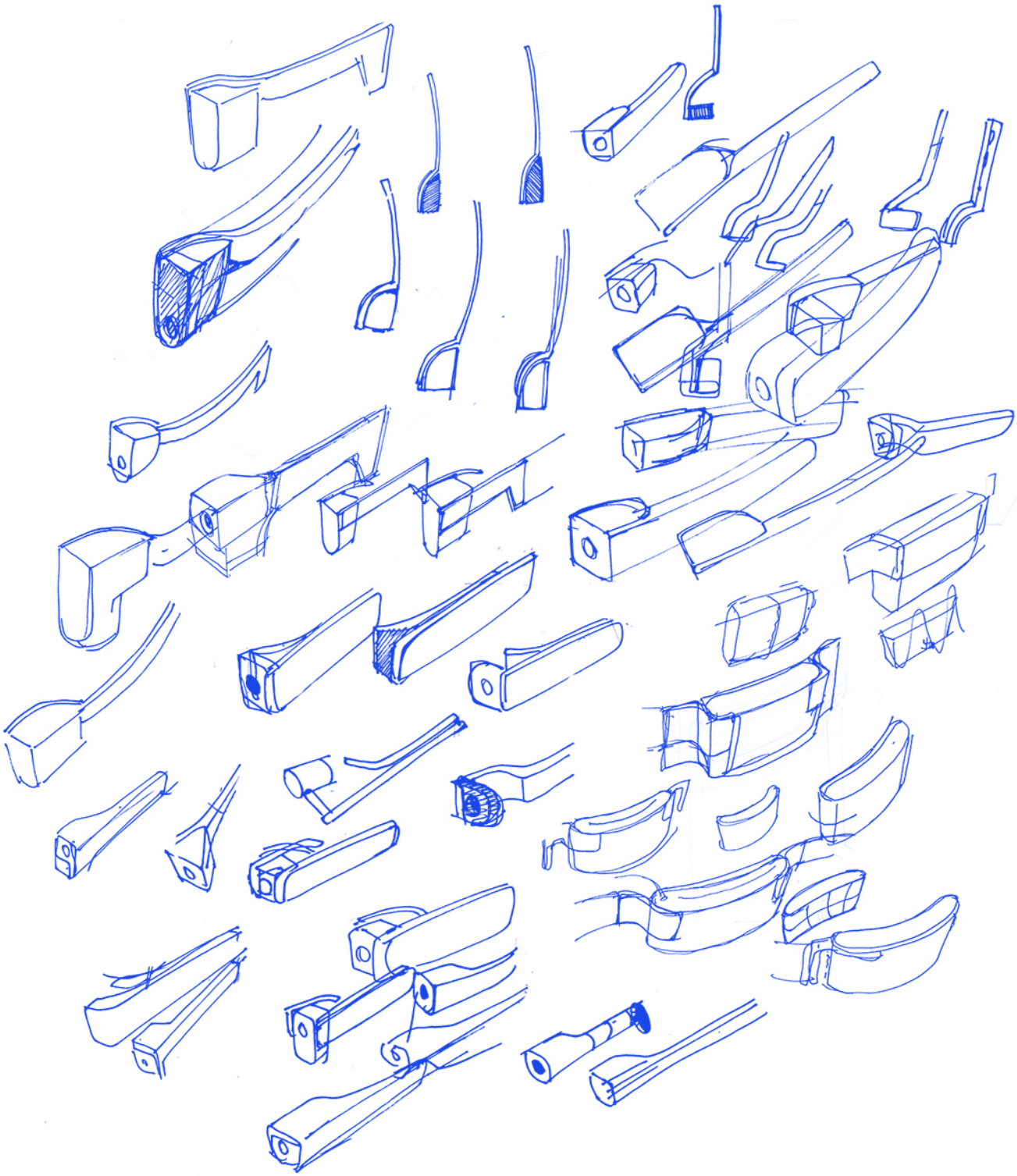
We chose waveguides for their compact form and low facial obstruction. Refractive waveguides, although currently more expensive than diffractive waveguides, produce barely any eyeglow and are bright enough to forgo polarization in the lens. Most projector technology will work with refractive waveguides, but we're going with LCoS because of their brightness, compact size, and price.

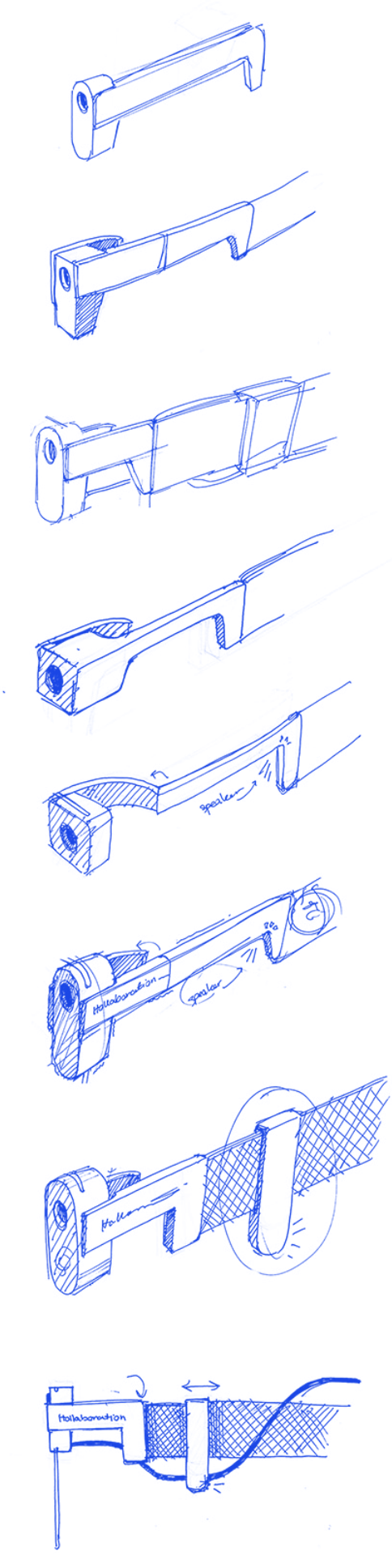
1) reflective waveguide
2) LCoS projector
3) stereoscopic cameras for positioning and gesture control
4) LiPo battery
5) haptic and button inputs

AR Glasses Design

How can we propose a futuristic yet probable design for the glasses?

The glasses were the most difficult of the three products to design since the technology involved is still in its infancy, making it difficult to predict how AR devices would look in five to ten years. Our priority for the glasses was to maximize facial visibility and comfort, while creating a compact footprint based on our knowledge of existing electronic components.

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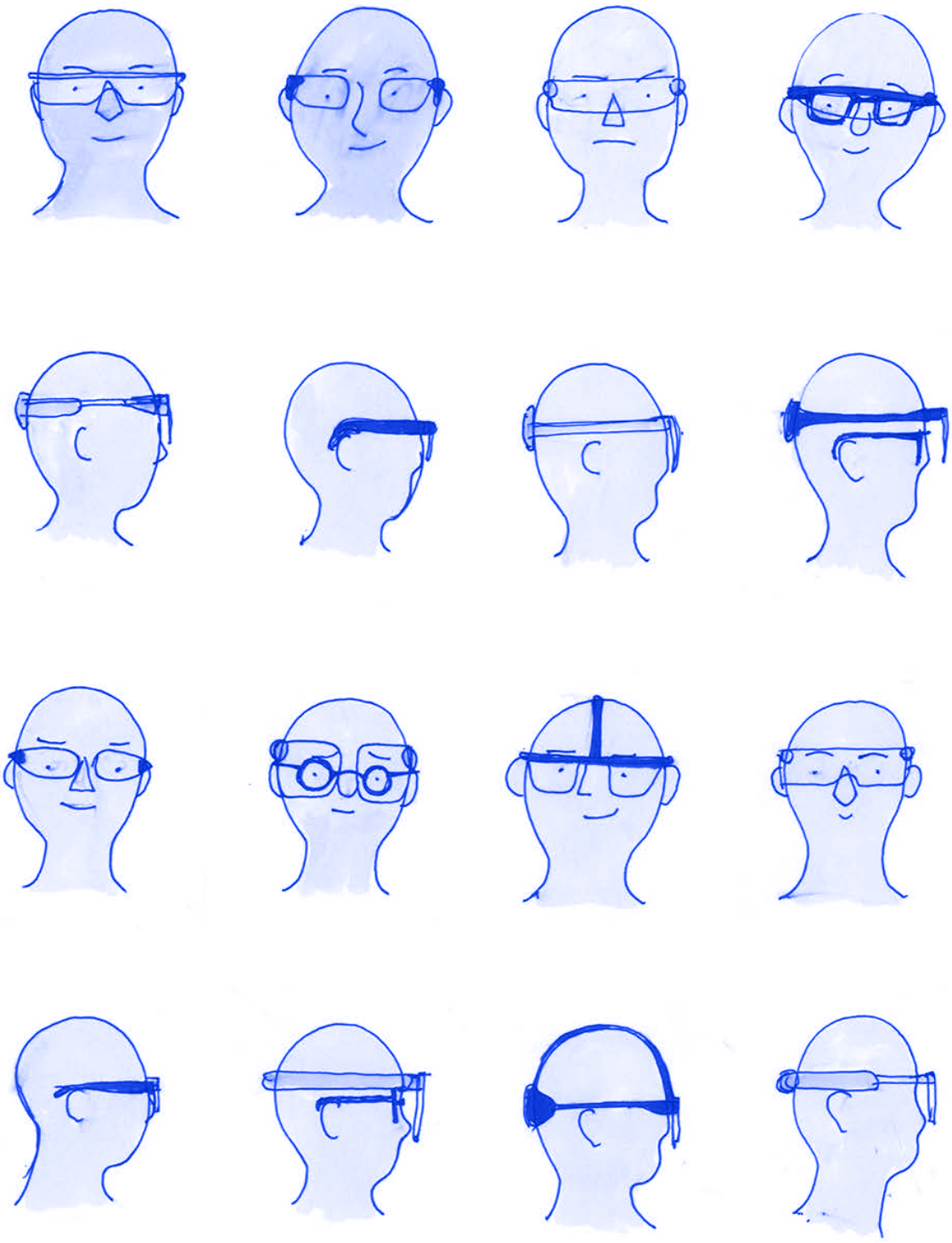
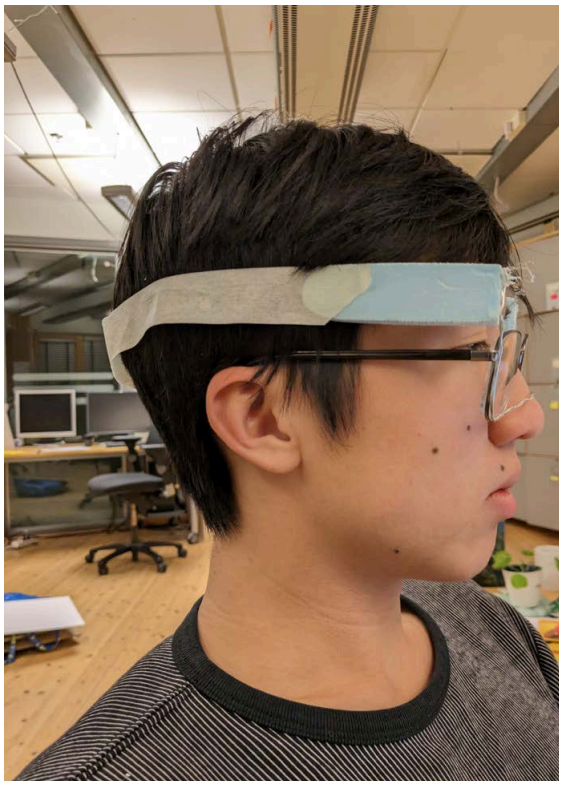
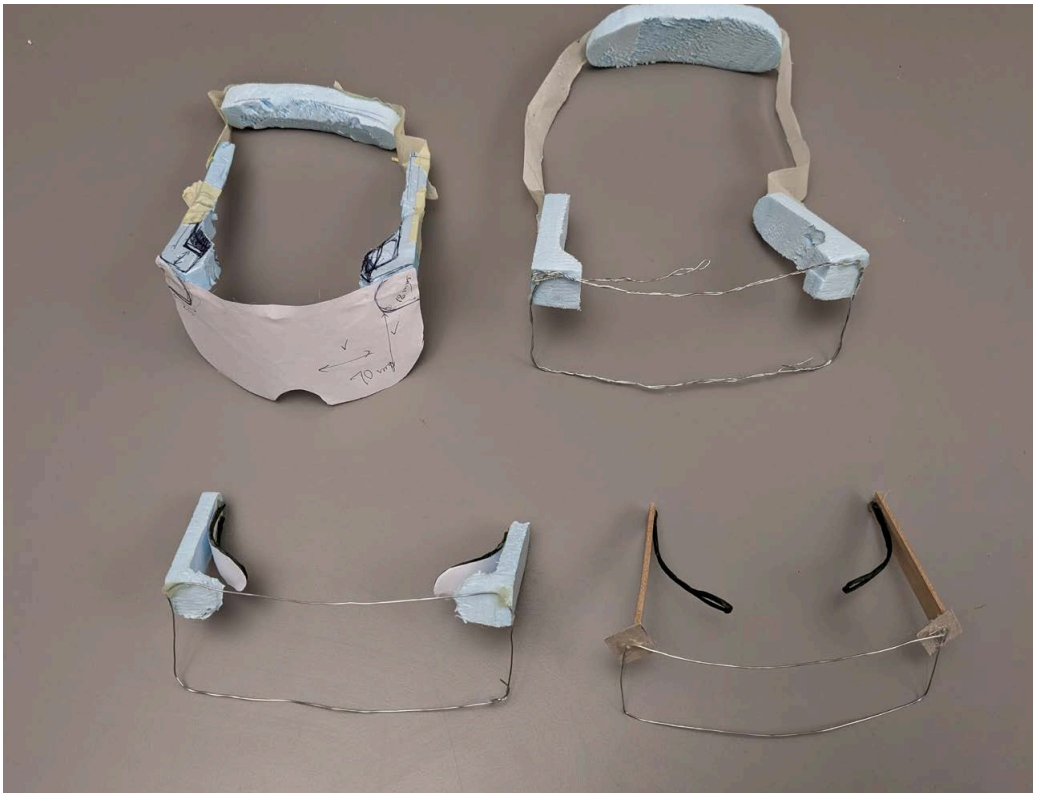
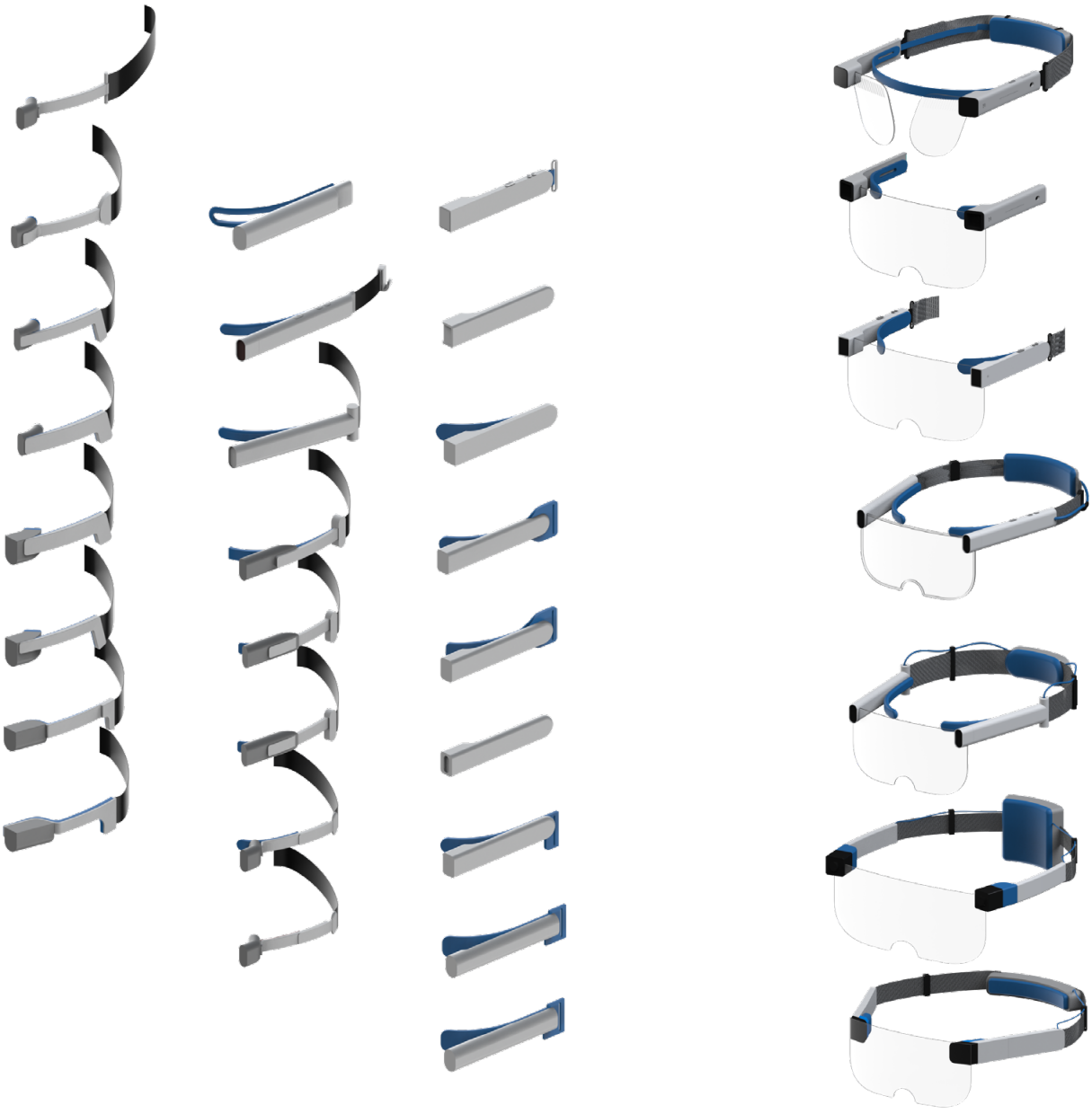


Early sketches and ergonomic studies prioritized glasses facial visibility, designing the structure users' eyes and eyebrows wouldn't be obscured

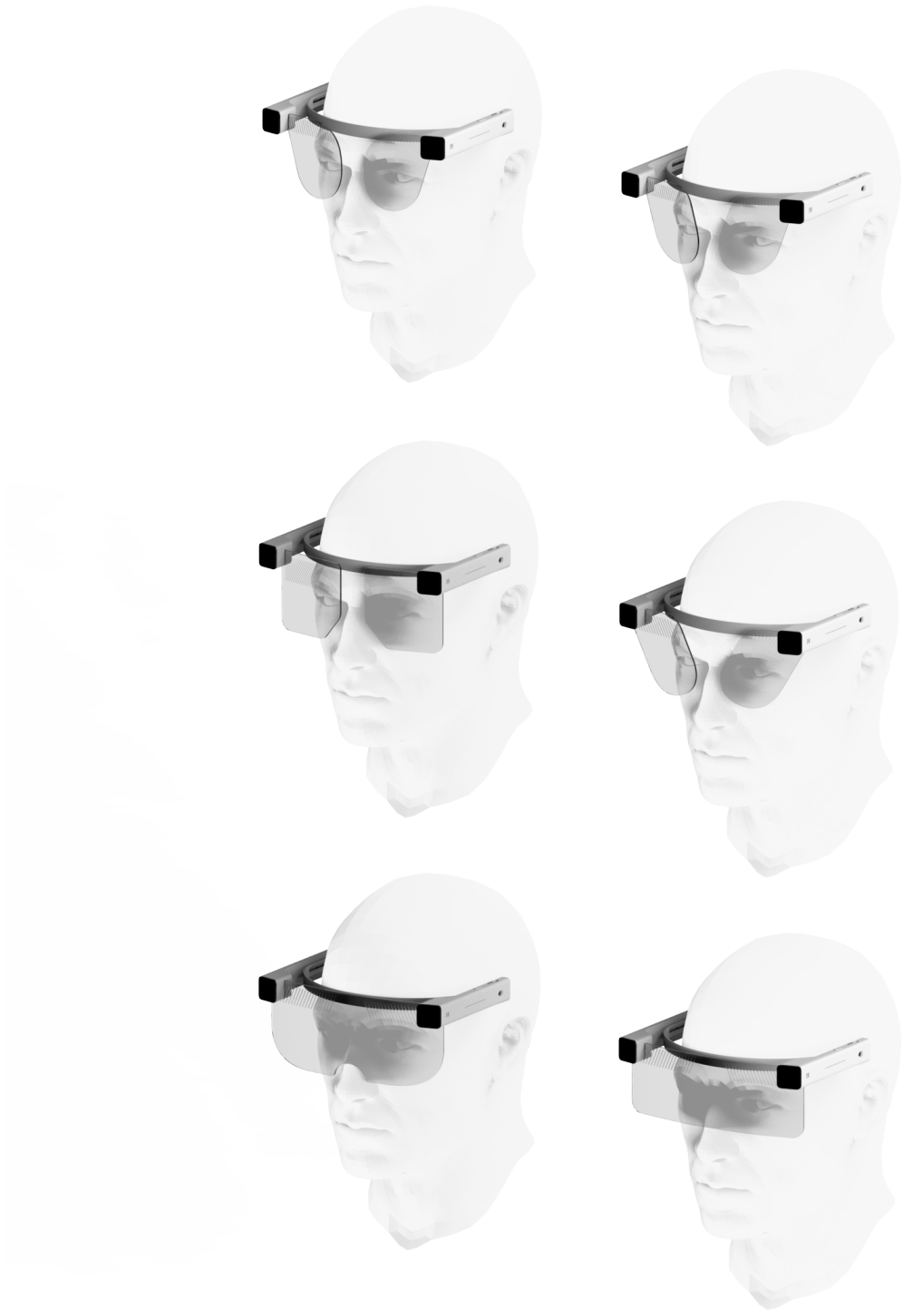




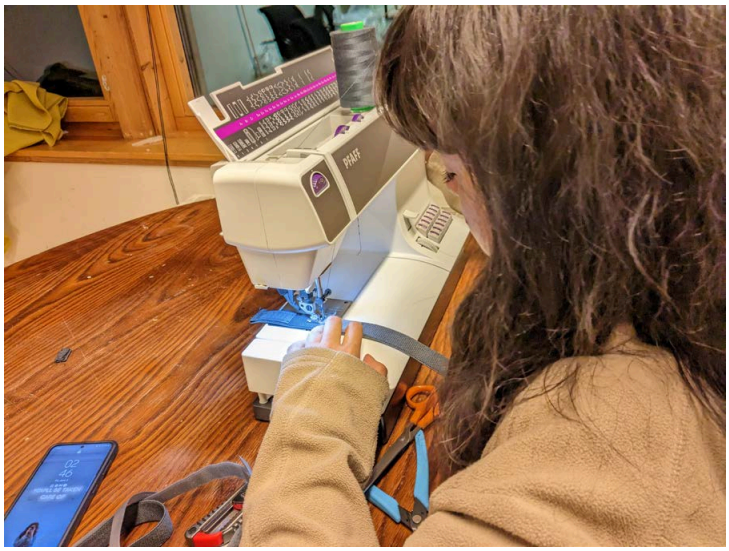
We built foam and wire models to explore the ergonomics and folding mechanism of the device.



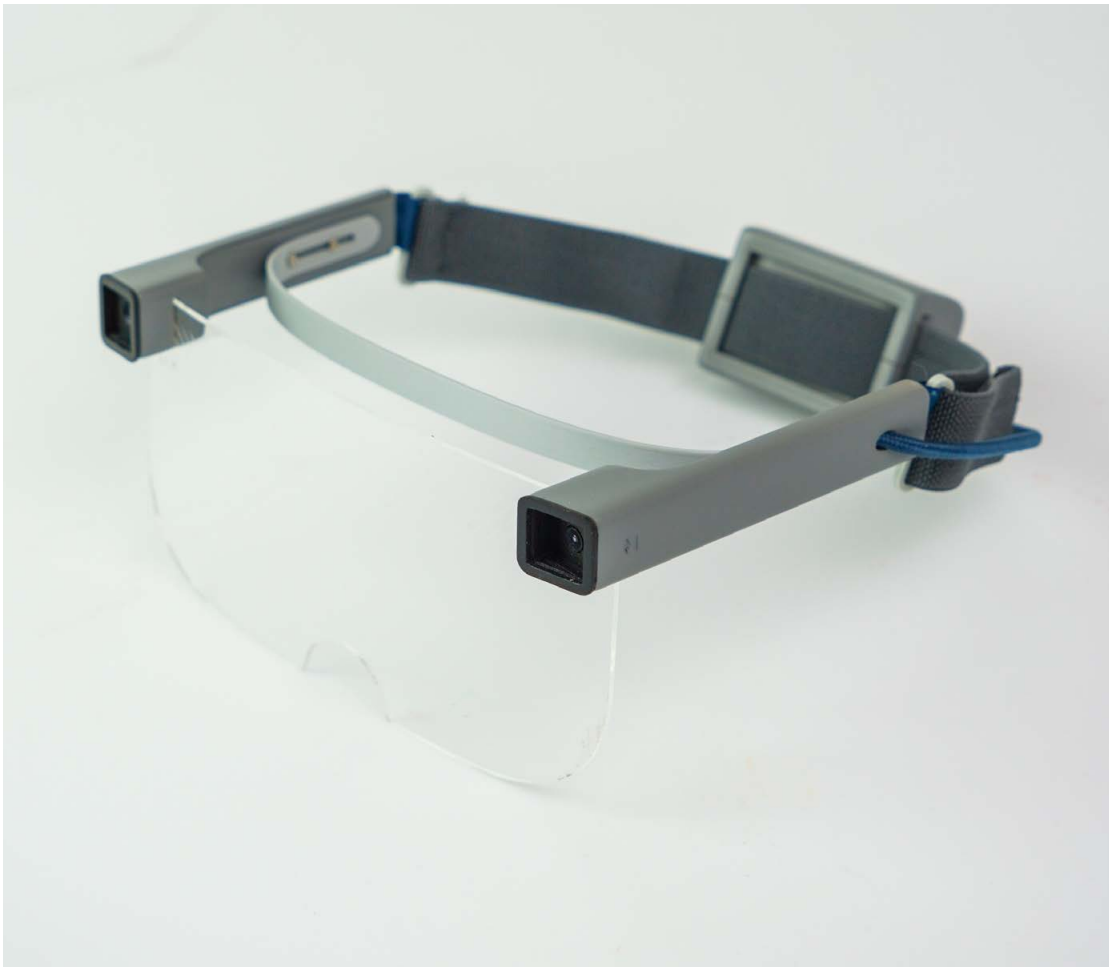
Form studies in 3D exploring the connection between the projector, brace, and arm of the glasses.

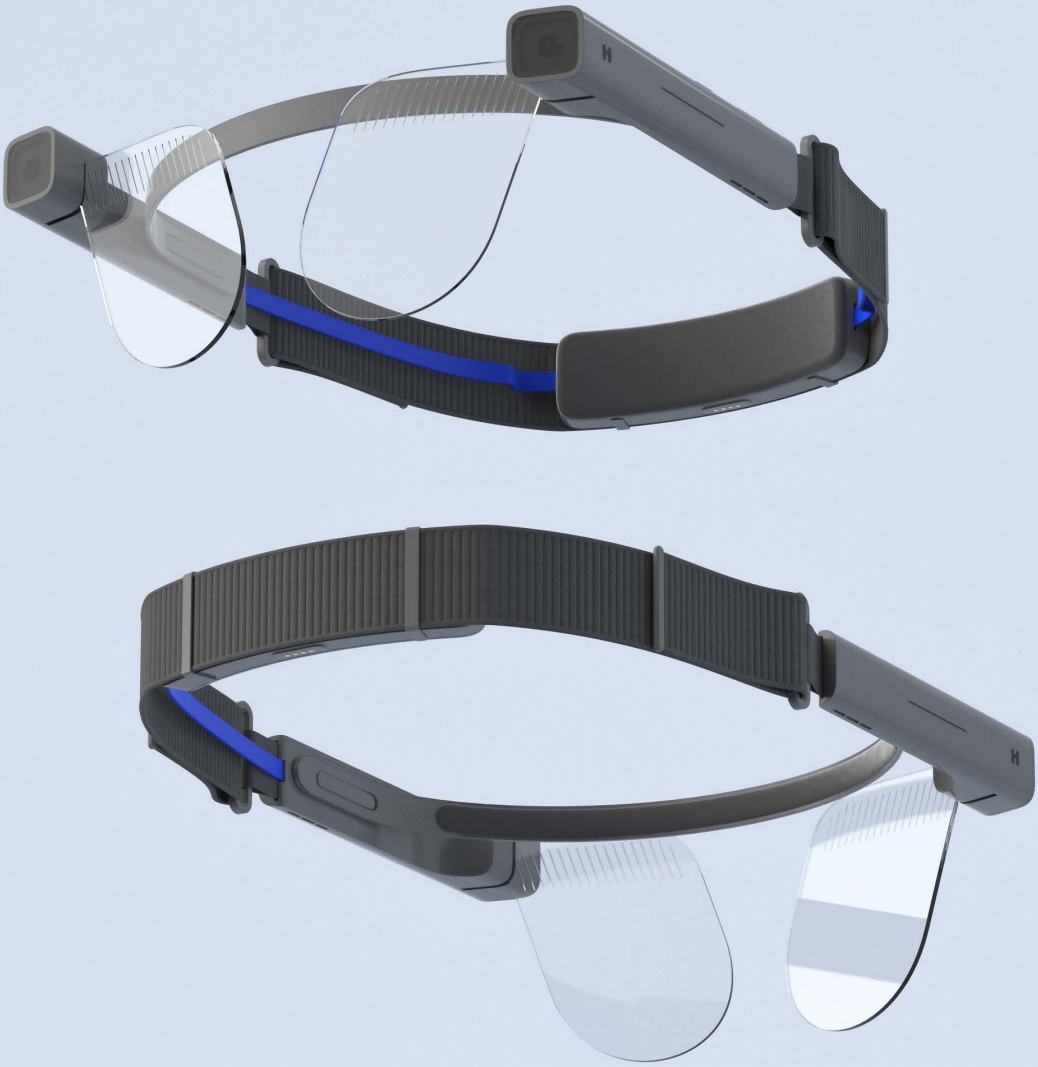


We ended up using a continuous head brace to split the lens into two parts. This allowed for a much more streamlined form and greater flexibility to accommodate different head shapes and sizes.

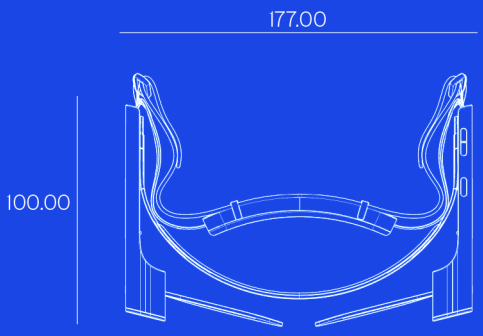


We 3D-printed the plastic components, and sanded and painted them to achieve a final polish. Velcro strips were sewn onto an elastic strap for adjustability.

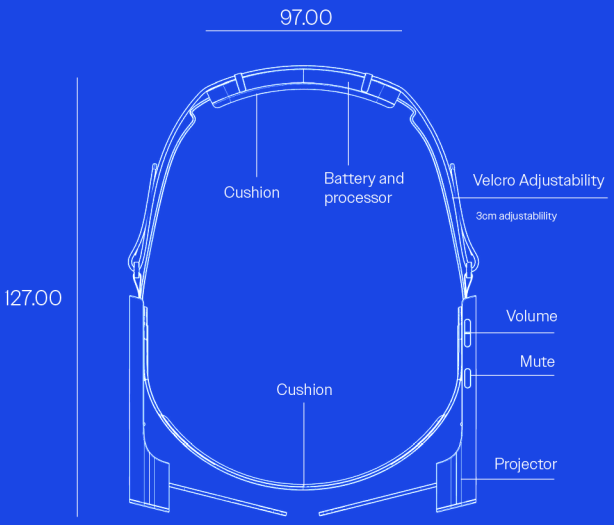


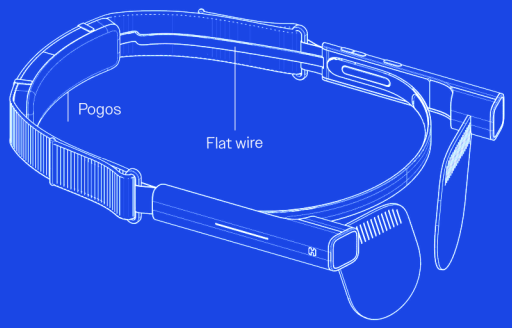


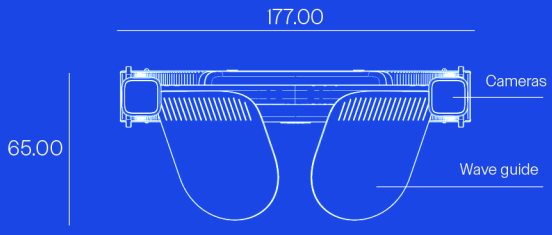
Hollaboration
AR Glasses

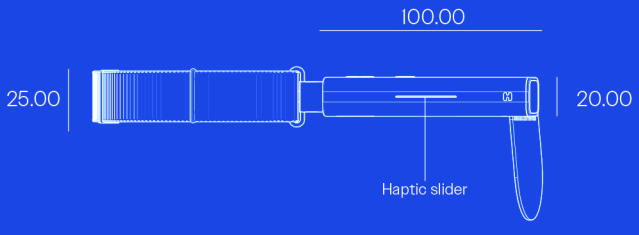


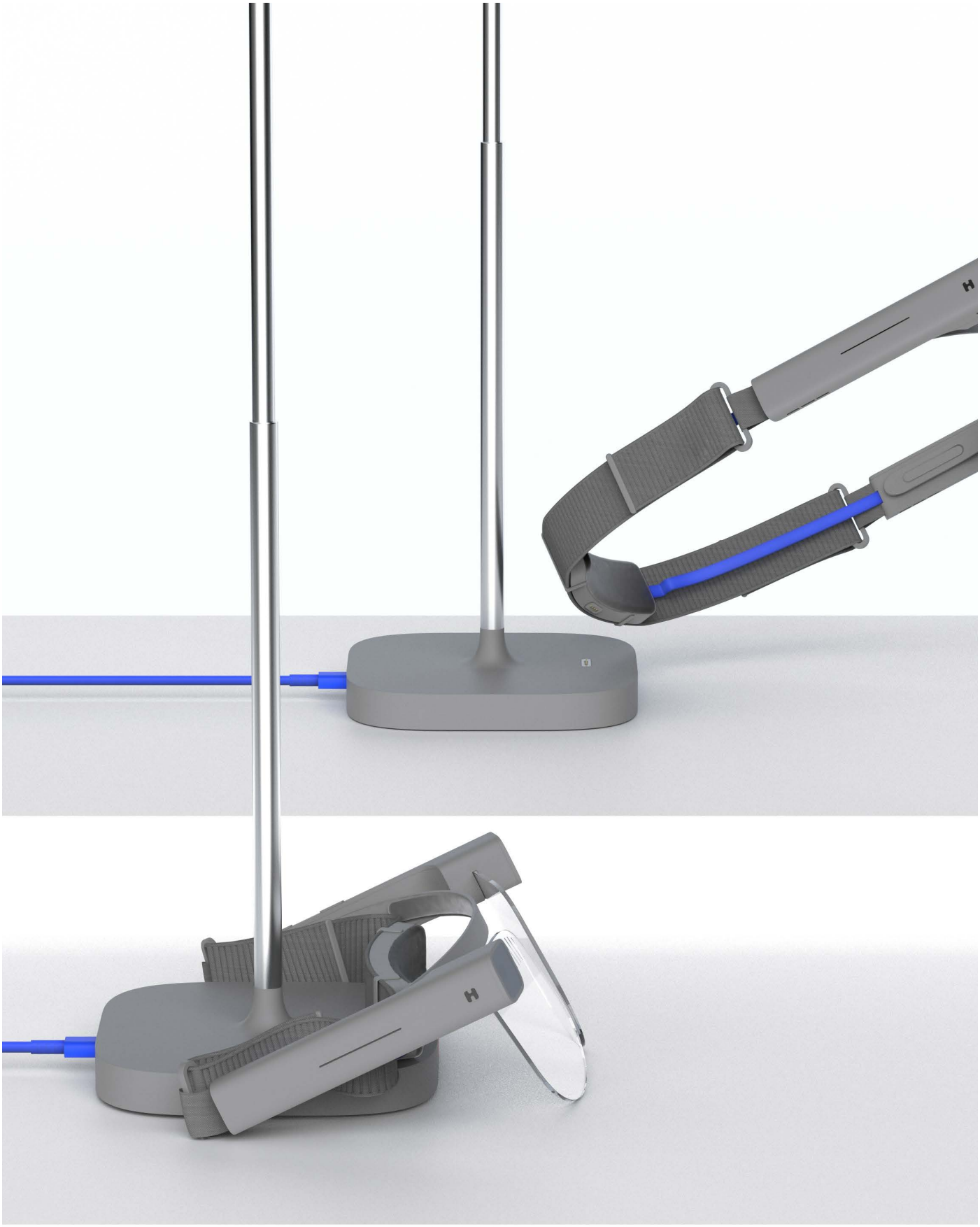
Compact form for charging and portability

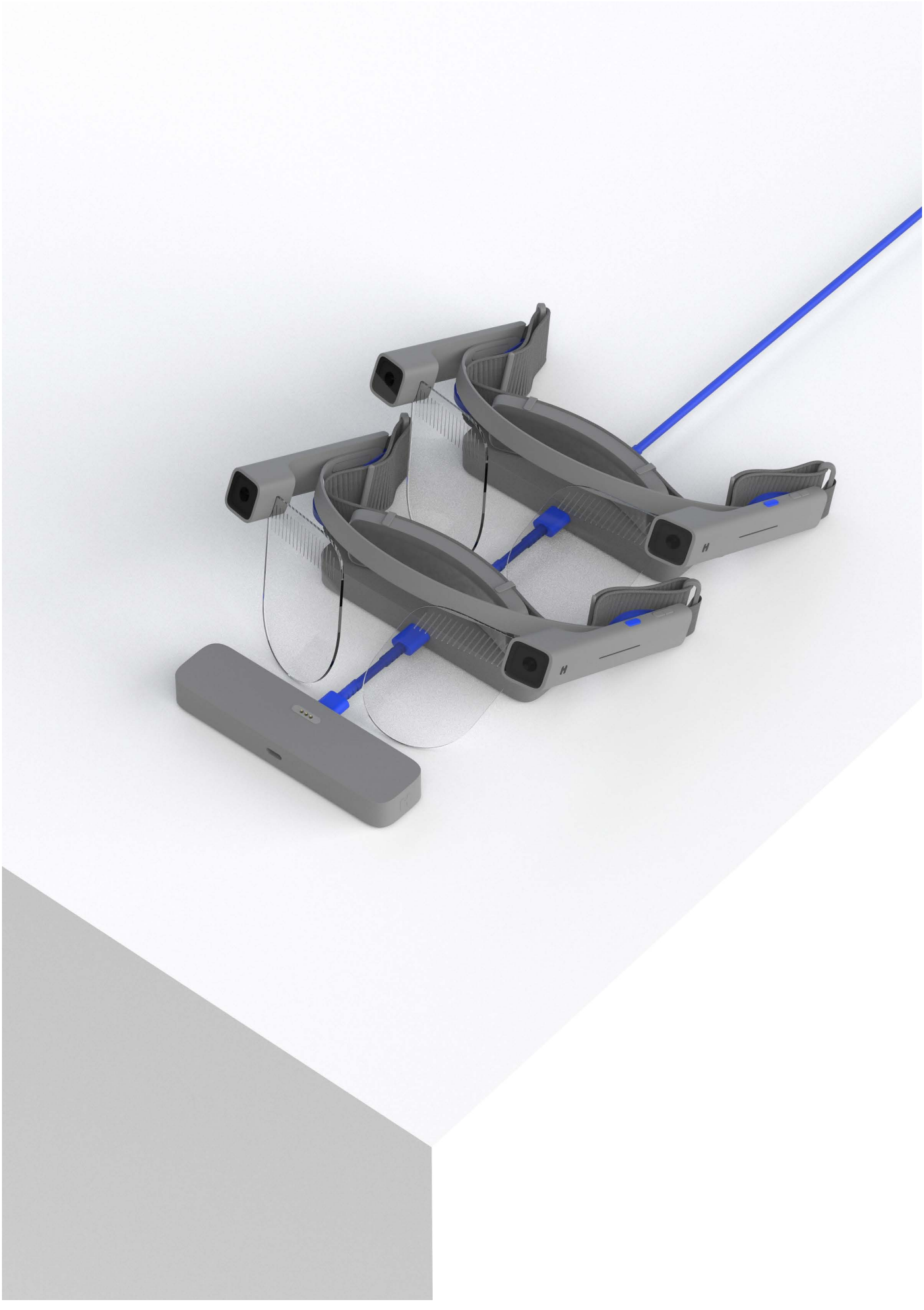










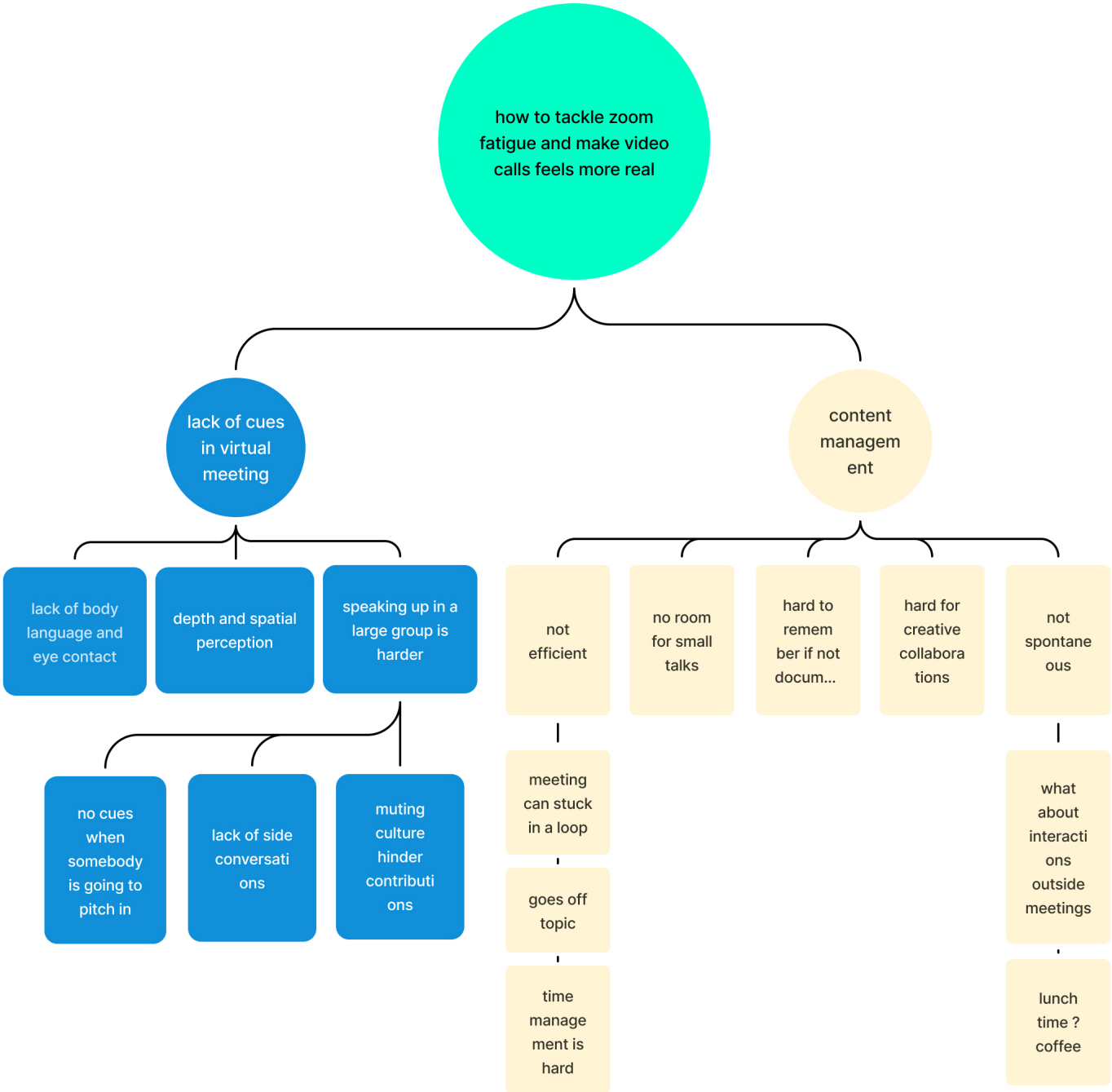


Software overview

How can we make virtual meetings even better?

While we aim to replicate the feeling of face-to-face interactions with the use of holograms, having the meetings virtually enables us to introduce digital features to communication and productivity.

user research



By utilizing AR technology and having the meetings on a virtual platform, we saw an opportunity to enhance the meeting experience and push the boundaries beyond what current solutions were capable of.

Benchmarking

Meeting apps...	Adobe connect...	Livestorm	Ring centeral	Webex	Whereby	Clickmeetings
USP	backstage	Scheduling tools...	share age...	real-time translation	customisation	Highlight the presenter's stream
	custom layouts	Custom branding	meeting summaries, topics, video highlight reels, keywords, and transcripts	Gesture recognition	emoji reaction	Meet now
		Shadowing	presentation mode	note taking		Scheduling tools
			auto follow			
			Team huddle			

benchmarking for ai online meeting management tools

AI apps	jamie	otter	sembly	avoma
USP	summarising after the meeting	adding comments, highlighting key points to the live transcript	time-stamped notes and bookmarks	Scheduling & Agenda Templates Agenda Collaboration & Sharing
	translation	captures and inserts slides into the meeting notes	meeting summaries	Live Bookmarking Collaborative Note-Taking
		summarising after the meeting	meeting library....	talk-listen ratio...
			Voice commands	scoring them and coaching your team
			Voice identificatio...	
			Meeting insights	
			Meeting insights	

VR meeting rooms

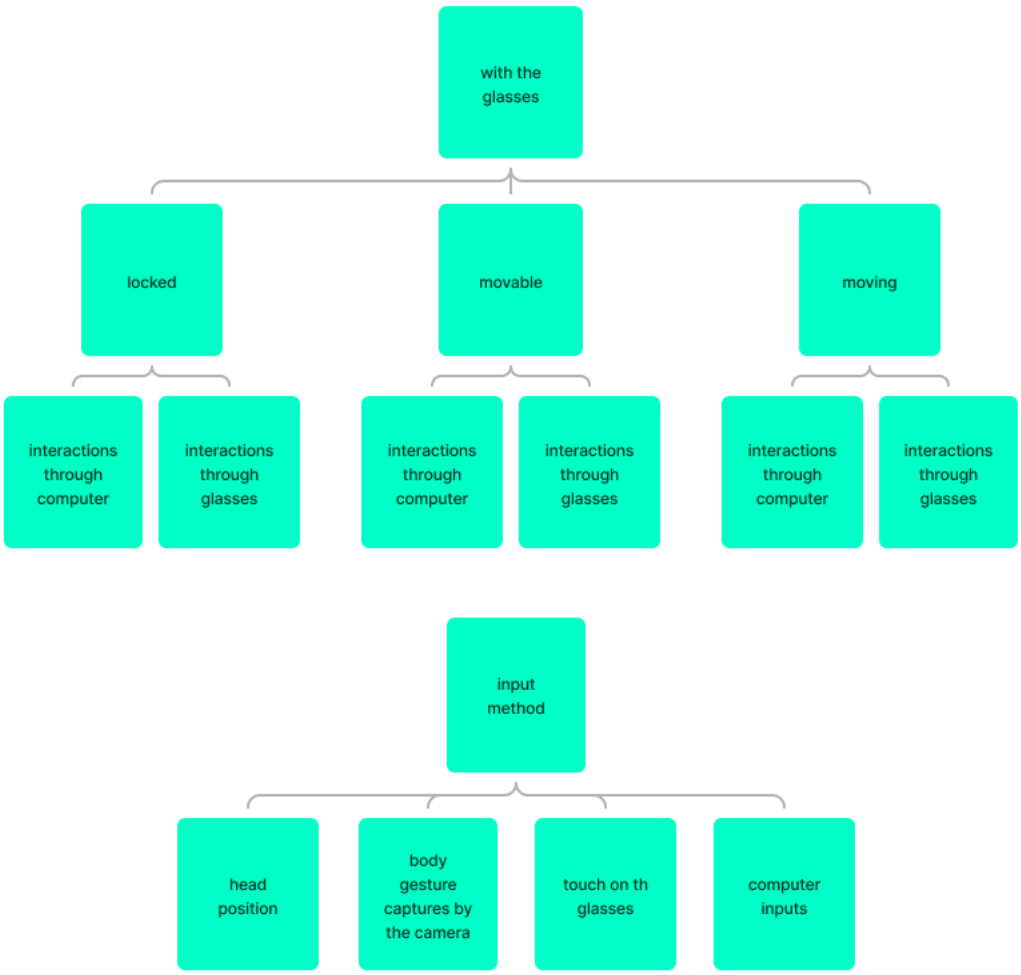
desktop conn...	rooms	tools	Real world mi...
multiple screens	interactive and customisable meeting rooms and objects	team building activities	facial expressions
screen sharings	matching the room with agenda and ro...	collaboration tools: white boards and notes	instant avatar making from selfie
keyboard detection	room breakdowns		special audio
remote screen	mixed reality to have the pesron in your room		Private Audio Zones

The concept of VR meeting rooms is still in its early stages and most platforms still have a relatively low user base. The main features offered by these apps are still quite similar across the board.

Designing for AR

Before delving into the design phase, we considered the placement of different elements in AR.

In order to maintain a seamless and efficient user experience, we decided not to rely on unresponsive hand gestures to control the AR elements. Instead, we opted to use a tactile sensor on the sides of the AR glasses, and we would use head position to target elements. Additionally, the depth cameras work in conjunction with the on-board sensors for more accurate positioning. We limit the functionality within the AR UI to the most essential features, and leave the rest to the companion app on the laptop / phone.



Software features

1) Meeting timeline and agenda creation

2) Smart annotating and summarizing

3) Highlighting hand-raises, waving, and clapping

4) Sending AR emojis for reactions

5) Breakout rooms and easy extension of meetings for chats

6) Inputs controlled by combination of physical and digital buttons and gestures

Software UX

How will the software and hardware elements interact?

We began by mapping out the user journey before, during, and after a hybrid collaboration session. We then created a storyboard to illustrate the entire AR meeting experience. Additionally, by creating a user journey with all the physical and digital actions, we were able to identify and create the necessary buttons on the hardware and in the application.

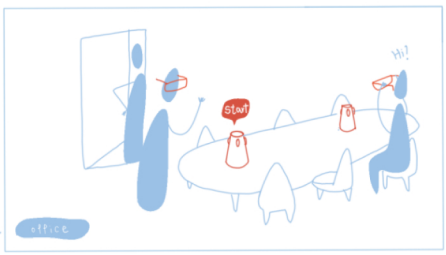
Journey map

	joining		having the cal		
	on site	off site	human interactions		
how its been done	join the call or the room, choosing a place to sit	join the meeting room online by the app or link	lack of eye contact makes it uncomfortable	body languages are not readable	in a in-person meeting emotions are expressed but online people don't unmute just to do that, they would use emojis
what to consider	thinking about how to involve online people	they don't know how they are positioned in the room	who is looking at me? not any eye signalling	did he notice me clapping for him?	showing your intended emotion without unmuting
with holloboration	go in the room with the glasses on and select start	put on the glasses and turn on the camera and see the upcoming meetings	with hologram you can have normal eye contact	people get notified of interactions that are not in their view	both online and offline people can use emojis to express certain feeling without unmuting
what is considered	virtual people would be included as people there	where to sit?chose a place to sit as a normal onsite meeting	how to have clean image? the cameras and ai complete each other for having a 3d image	not missing others intentional body gestures to show agreement or disagreement with the speaker	how to be more interactive without excessive interaction
ux	tap on glasses select start icon on the top of cameras it can recommend a seat to sit that give better view to online people	ar/locked tap and slide on glasses shows the room and empty sits on the screen appear as a hologram	movable/ locked tap on glasses eye contact is completely visible because of limited vision in case of need for signalling, by looking at the person and tapping the side of the glass, it pok the person	movable some intentional body gestures like clapping, high five, thumbs up and down, hand rising, will have a pointer at the side of the glasses	movable/ locked tap and slide on glasses by looking at the person and touching the glasses, then sliding between emojis, send it to the targeted person. shows with an effect and will be pointed on the side of the glasses

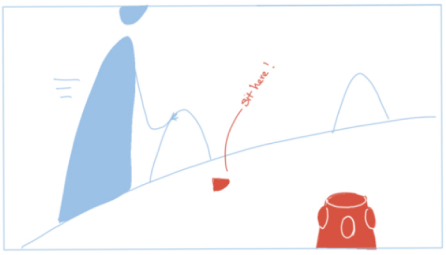
having the cal

human interactions	Breaks	productivity		
private massaging is hard if people are not individually on the call and reading it would look distracting.	online people are left out from outside of the meeting conversations	taking notes manually or using the transcript highlight are not efficient and distracting	going off topic and time management is harder when its hybrid	screen sharing and presenting depend on the screens limitations
trying to not miss the conversation while tell your colleague smth important	feel less connected to your colleges	not missing points ,avoid looping the conversation and repetition	how to keep people on the track and go on the plan without giving hard feelings	how to be involved in the conversation and follow the presentation
people send each others private messages	hubs at eatery or other part of office that let online people join their colleagues for food or coffee	conversation mind map forms itself and people add points to it from each other conversations	agenda helps to have better idea of timing and conversation progression	screens are sharable in numbers and appear close to each person
instant massage to intended person	how to follow your colleagues around	how bullet points can be categorised, explored and edited real time	how the conversation in going regard the agenda and how much has been achieved	where to put them ?
movable/ locked	locked	locked	locked	locked
tap on glasses and using the laptop or phone	tap on glasses or the app	tap on glasses or using the laptop or phone	tap on glasses or using the laptop or phone	they can share screens and choose how they want it to be shown
you look at the person and touch the glasses and select private message by typing on he phone or screen and it appears as speech bubble	by follow me feature you can chose a person to walk with at the end of the meeting or on breaks	pointing other peoples conversation with touching the glasses	agenda details is shown next to speaker all the time and in connection to the mind map it nudges the people to stay on track	if the person already has a screen it can be chosen to be asked from the person
	once the person join again from any hubs or personal camera you join aswell	the points category are chosen with the sliding		an icon on the screen that shows on which side you wanna have it
		mind maps from previous meetings are browsable		people can comment on it with the help of glasses

Journey map

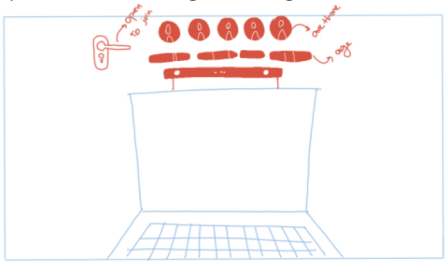


entering the conference room,
by putting on the glasses they could see the start button on the top of the camera

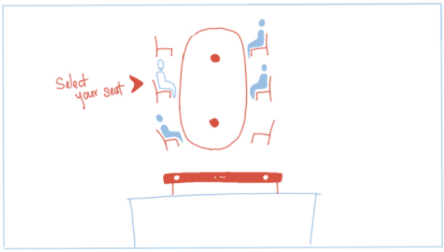


picking the seat,
they can see the sign for seats to sit. these seats are placed Infront of hologram colleagues.

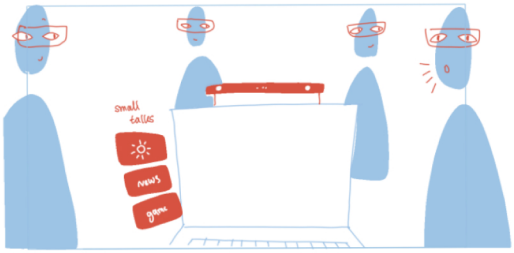
remote employees,
get the notification and then put on their glasses.



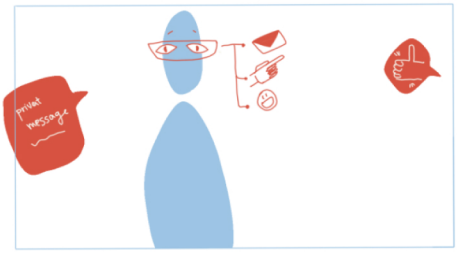
having the glasses on,
they can see a preview of meting and some information about it.



before finding themselves in the room,
they can chose where to seat, next to who.

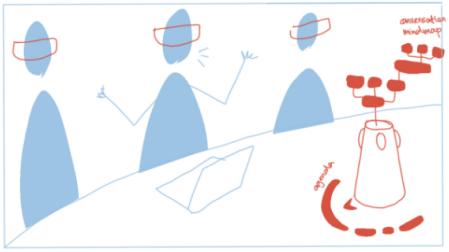


He enters the room,
See peoples hologram arranged like real in person meeting, there are tools for each part of meeting.

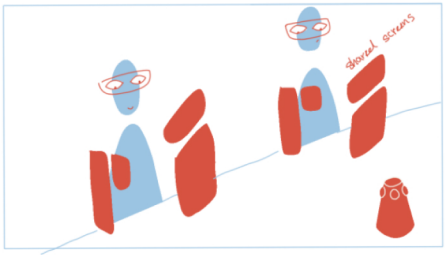


by looking at his colleague and touching the glasses, private messages and emojis would pop up and he can send reactions.

when someone talking,
important points can be pinned with one tap.



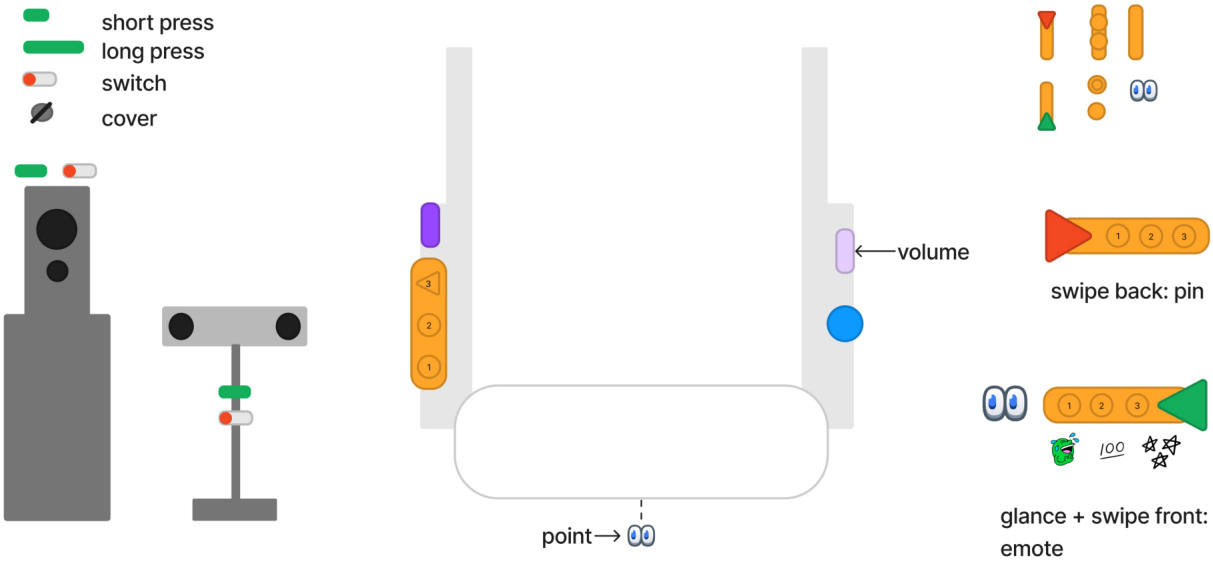
during the meeting, the progression of discussions are showed n agenda and conversation mind map.

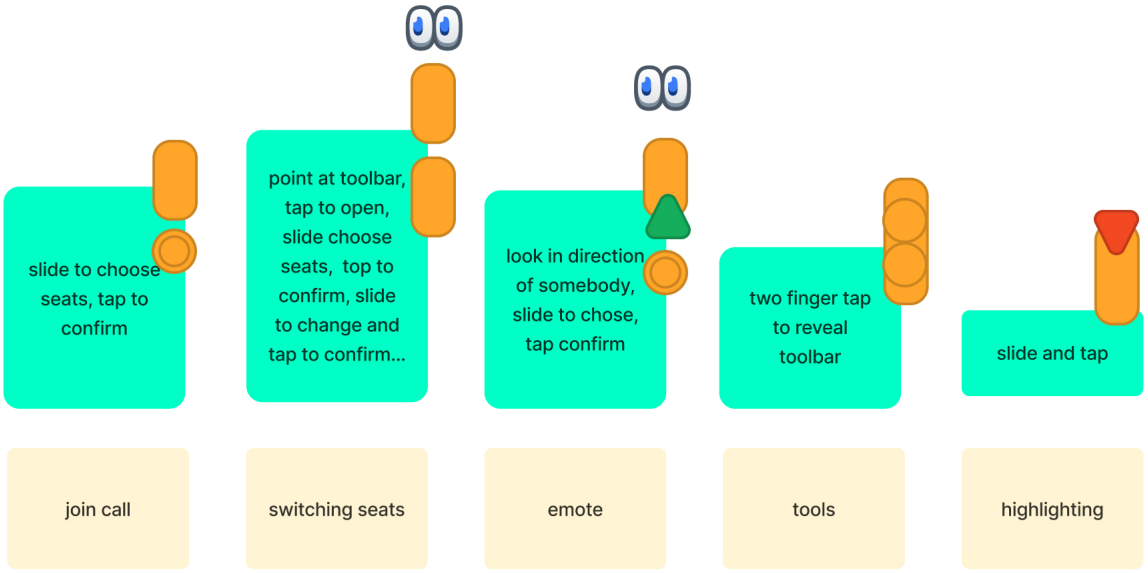


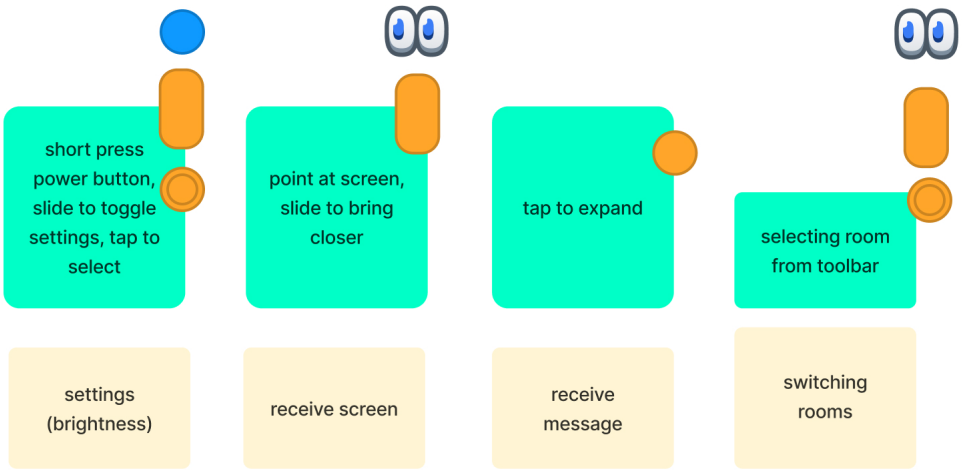
screen share would be more convenient and personalized,
they can be put in different ways.

for breaks or after meetings,
remote people can be involved as onsite employees

Physical Interface

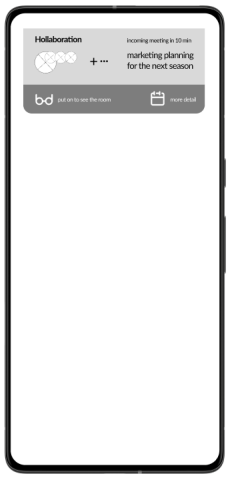






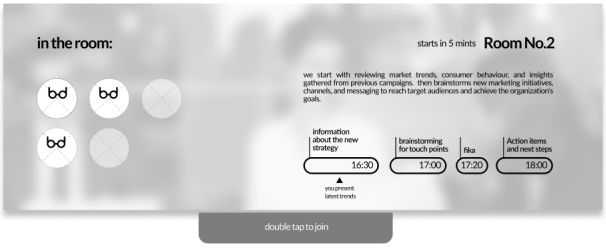
Wireframing

notification



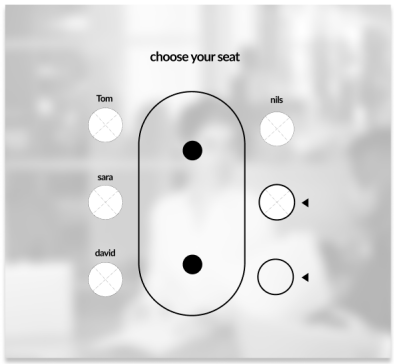
put on the glasses

meeting info

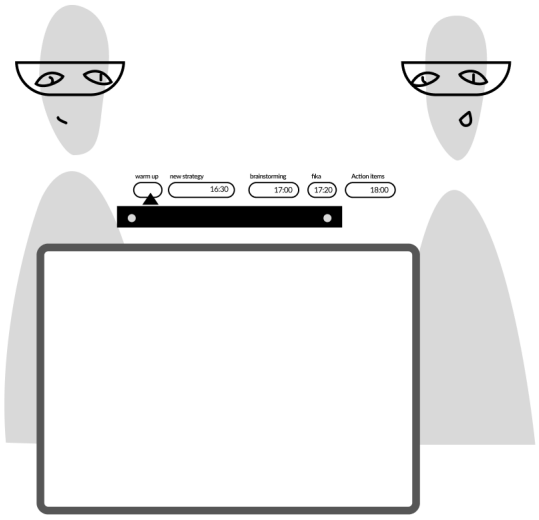


placing

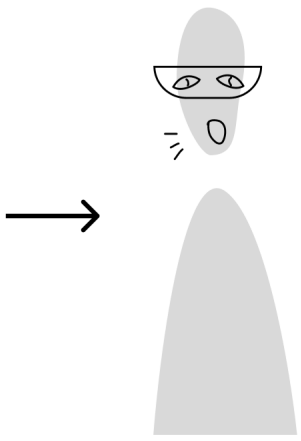
join the meeting



During the meeting



the meeting info get minimalised to an agenda bar and remains throughout the meeting



slide on left handle to chose between categories
tap to pin on the bar

Conversation highlighting

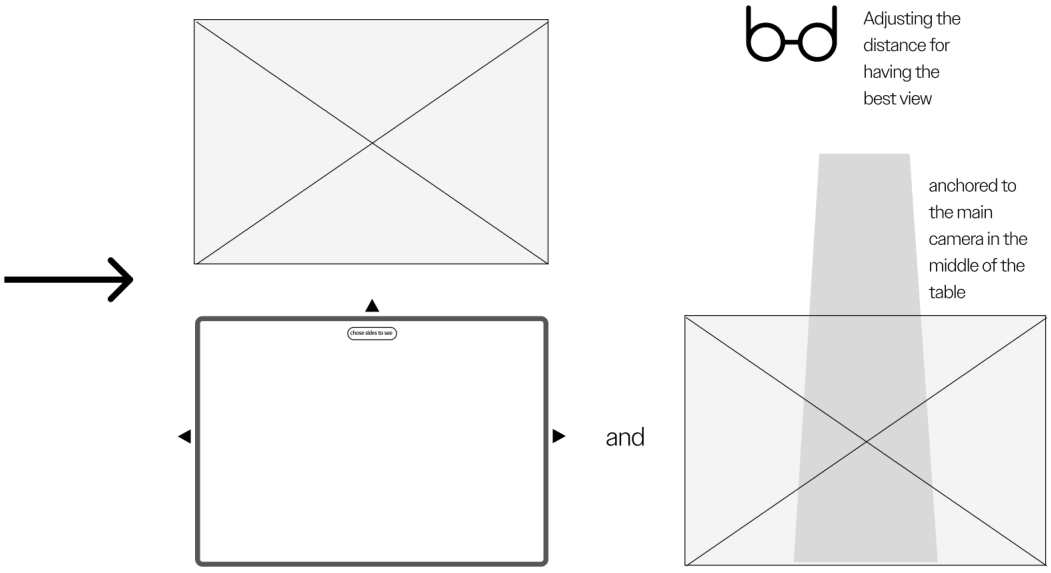
slide on right handle to chose between emojies
tap to send

Sending emojies

screen share

When sharing screens, users can choose to share either their current screen or make multiple screens and then share.

To view the shared screens, users with a screen in front of them can choose to display it on their device or next to it. If they don't have a screen, the shared screen is anchored to the camera and can be adjusted for optimal viewing distance.



After meetings

tap on hold on the irght handle to active follow me feature

this feature that allows users to seamlessly continue conversations with colleagues by joining them through other office cameras, such as in the cafeteria or other rooms, without scheduling additional meetings or interrupting their ongoing activities.

breakout rooms

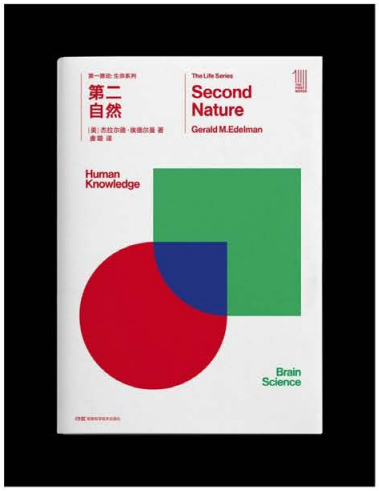
Software UI

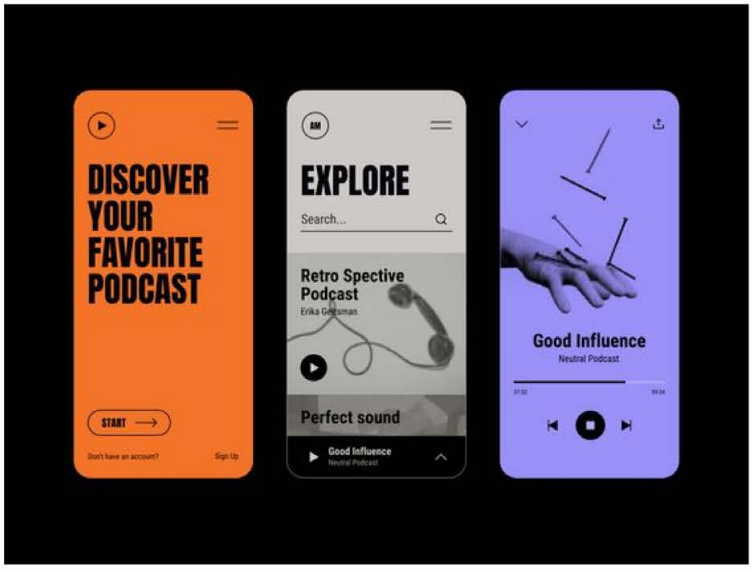
What should an AR application look like?

While designing UI elements for AR, we had to be aware of the transparency of elements and consider how they interacted with the hardware devices. We integrated design cues from our physical products into our digital elements, while contrasting the two by using brighter colors.

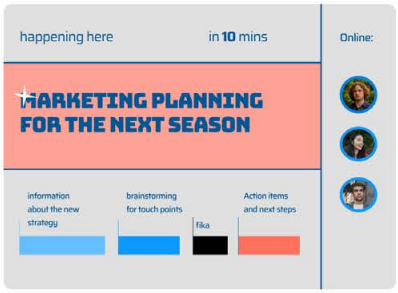
Visual exploration

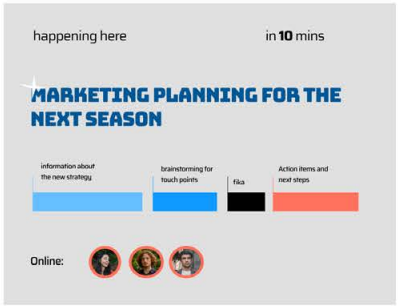
Style inspiration

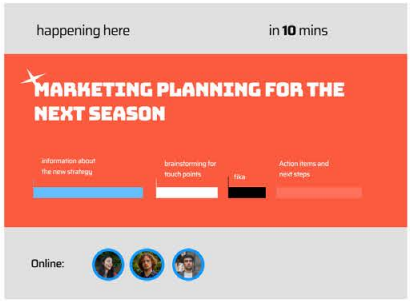


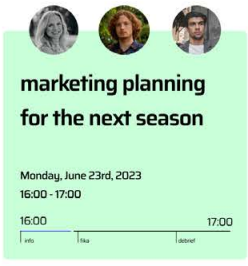


Style variations







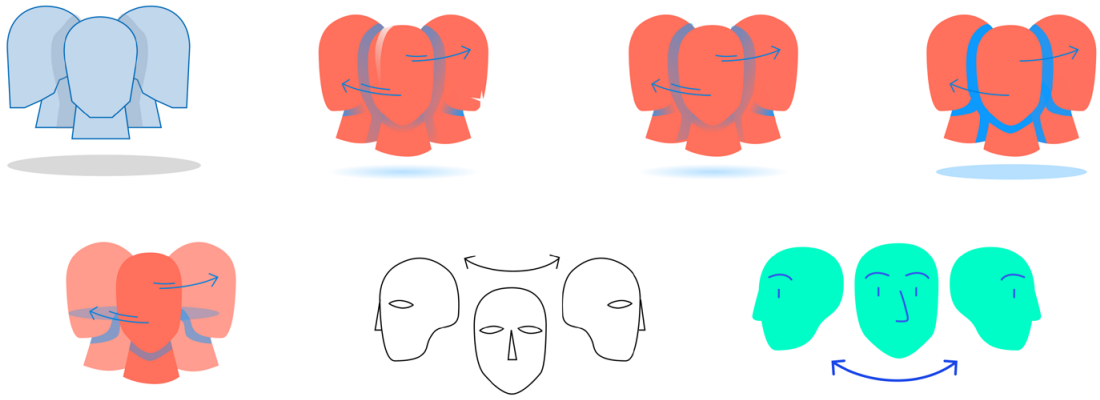


Color inspiration

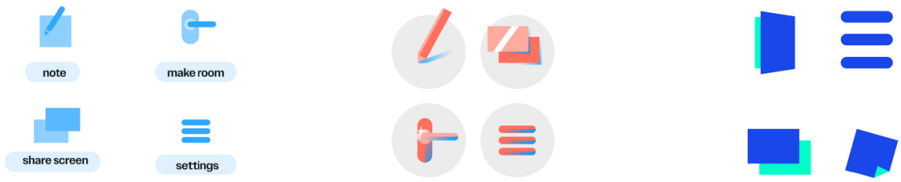
Color variations

Element variations

Illustrations

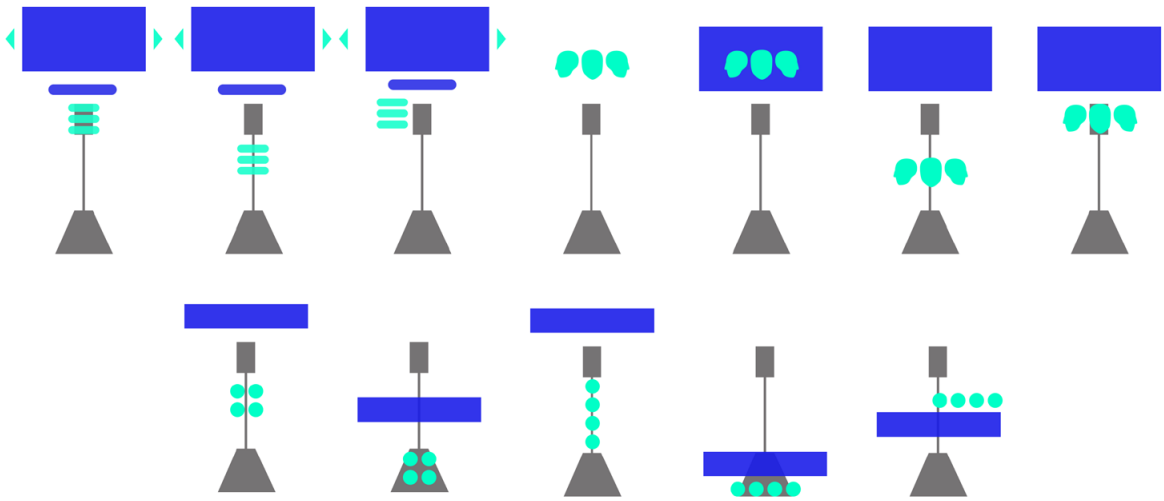


Icons



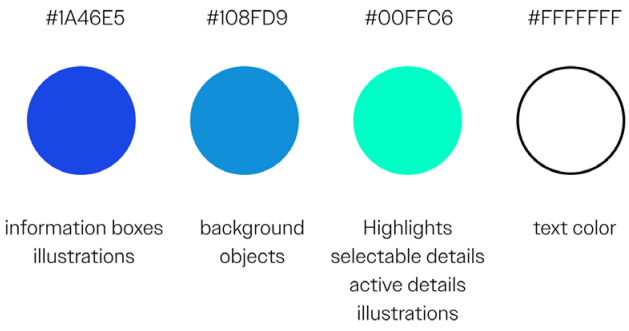
Details

Positioning



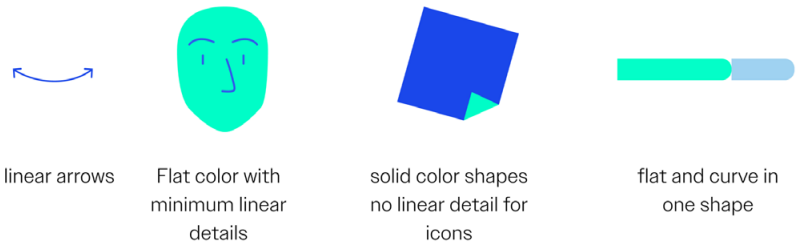
Final elements

Colors



Shapes

Illustrations



Fonts

BUNGEE
HEADERS FONT

Saira
Main info and command font

Main info and command font

Main info and command font

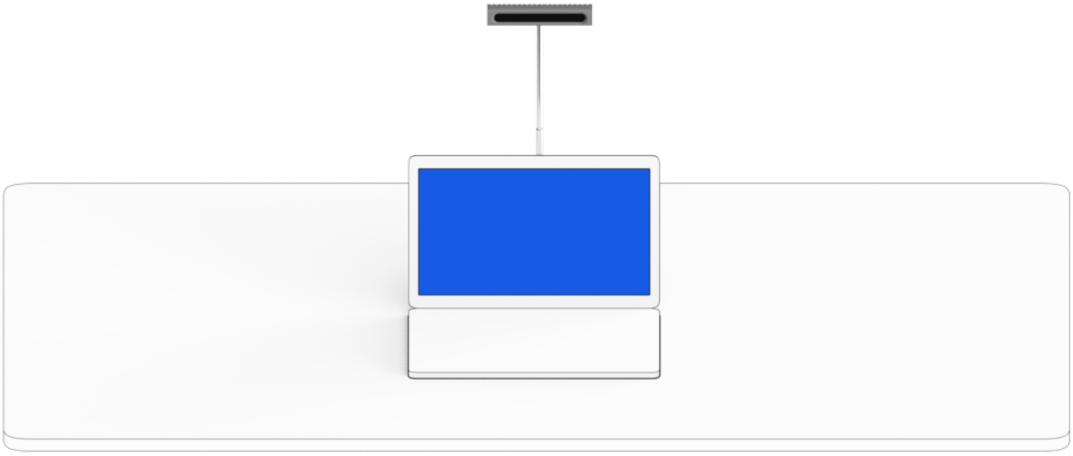
Main info and command font

Hollaboration product scenario

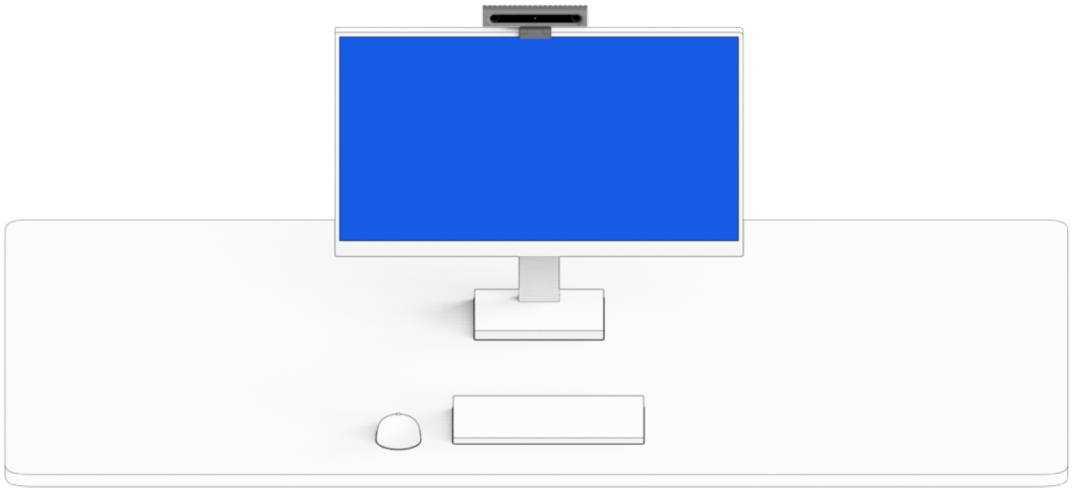
Let's Hollab!

Home setup

Camera stand allows for more flexible placement



Clip can be used for more permanent setups



The home camera can adapt to the user's preferred home office setup. It could be positioned on its stand or attached to monitors with a clip.

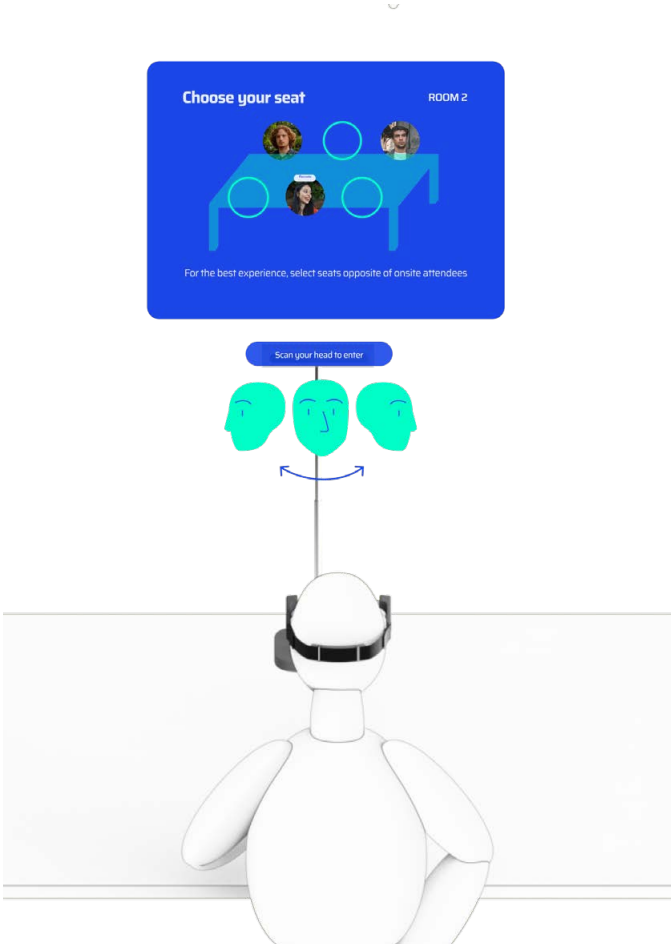
Office setup

Camera should be placed in the center of the group

The on-site camera can be placed in multiple meeting rooms within the office. Depending on the size of the table or group, more cameras can be added to capture a better image.

Joining from home

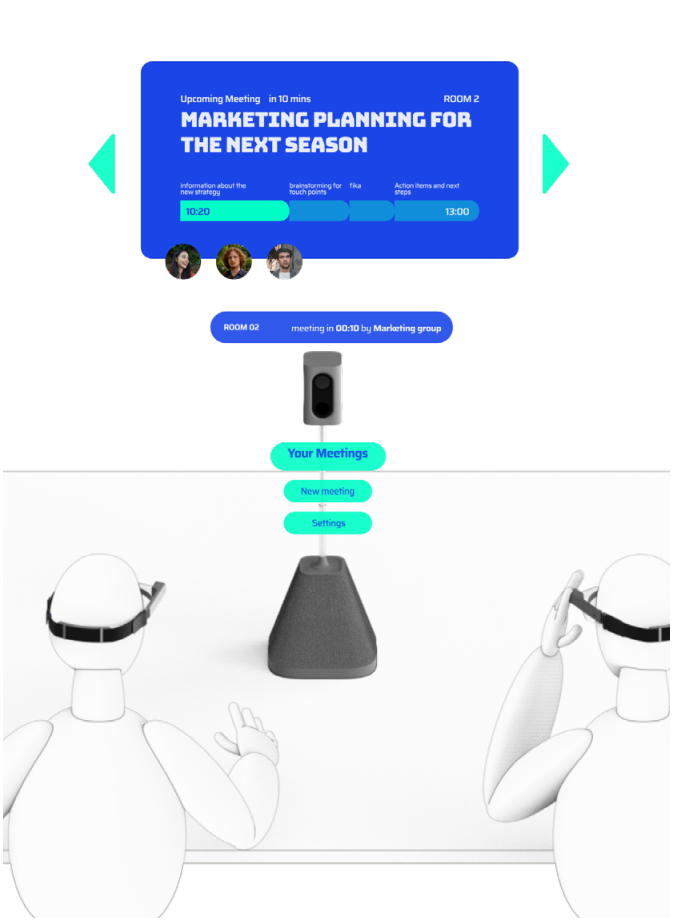
Selecting the meeting



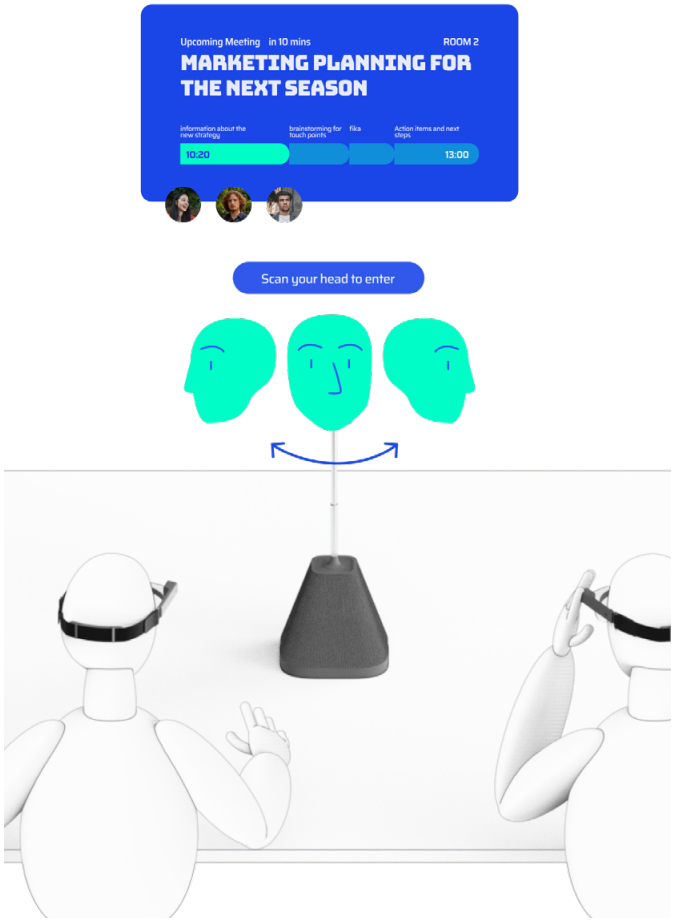
Picking the seat and scanning face to calibrate 3D reconstruction

Members joining in from home are prompted to choose their seats based on the arrangement of on-site employees. By referencing the on-site location, the holograms can retain spatial positioning of the on-site employees and suggest seating arrangements for an optimal experience. If all members are remote, seating can be freely chosen.

Joining from the office



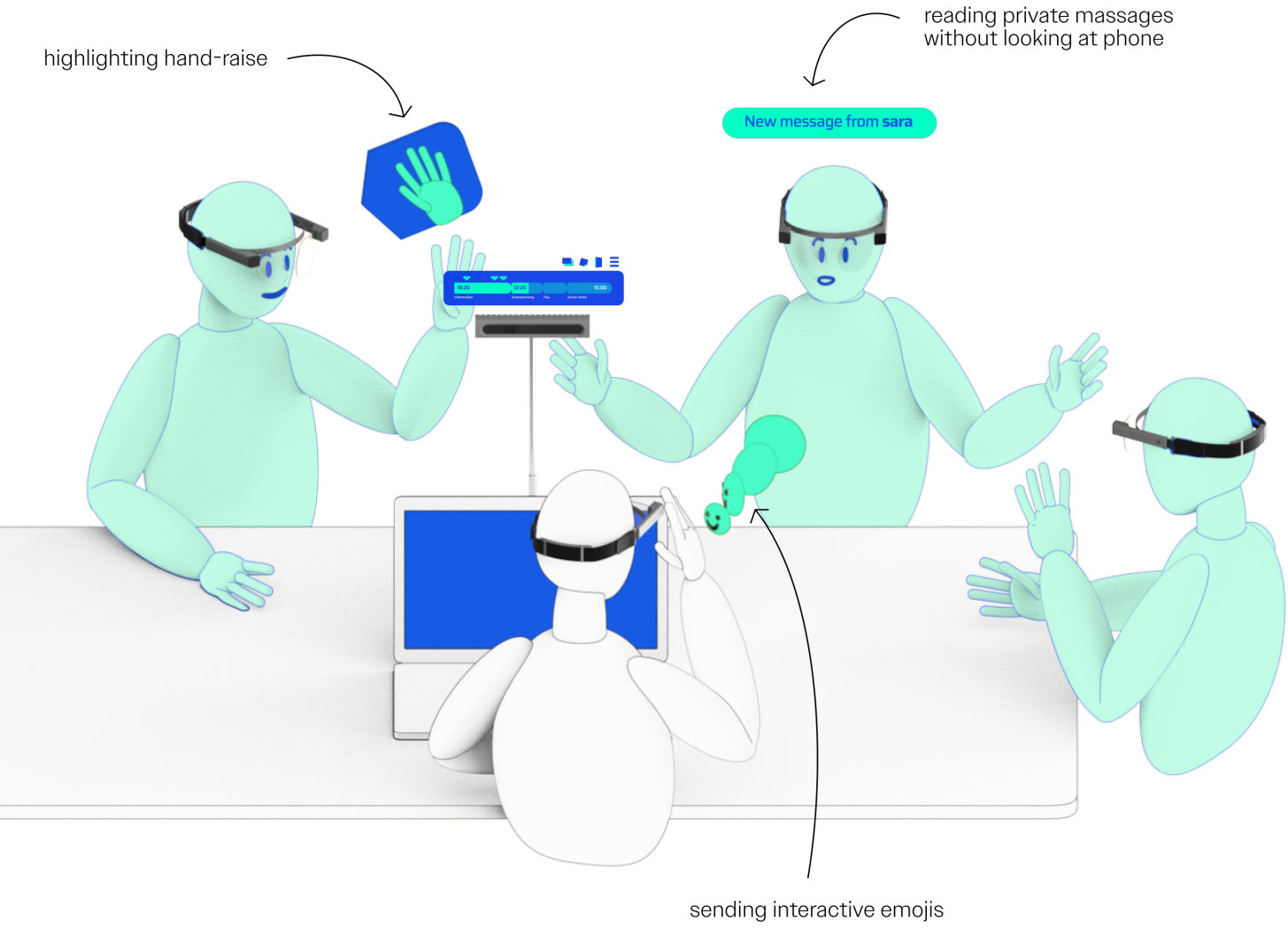
Selecting the meeting



Scanning faces to calibrate 3D reconstruction

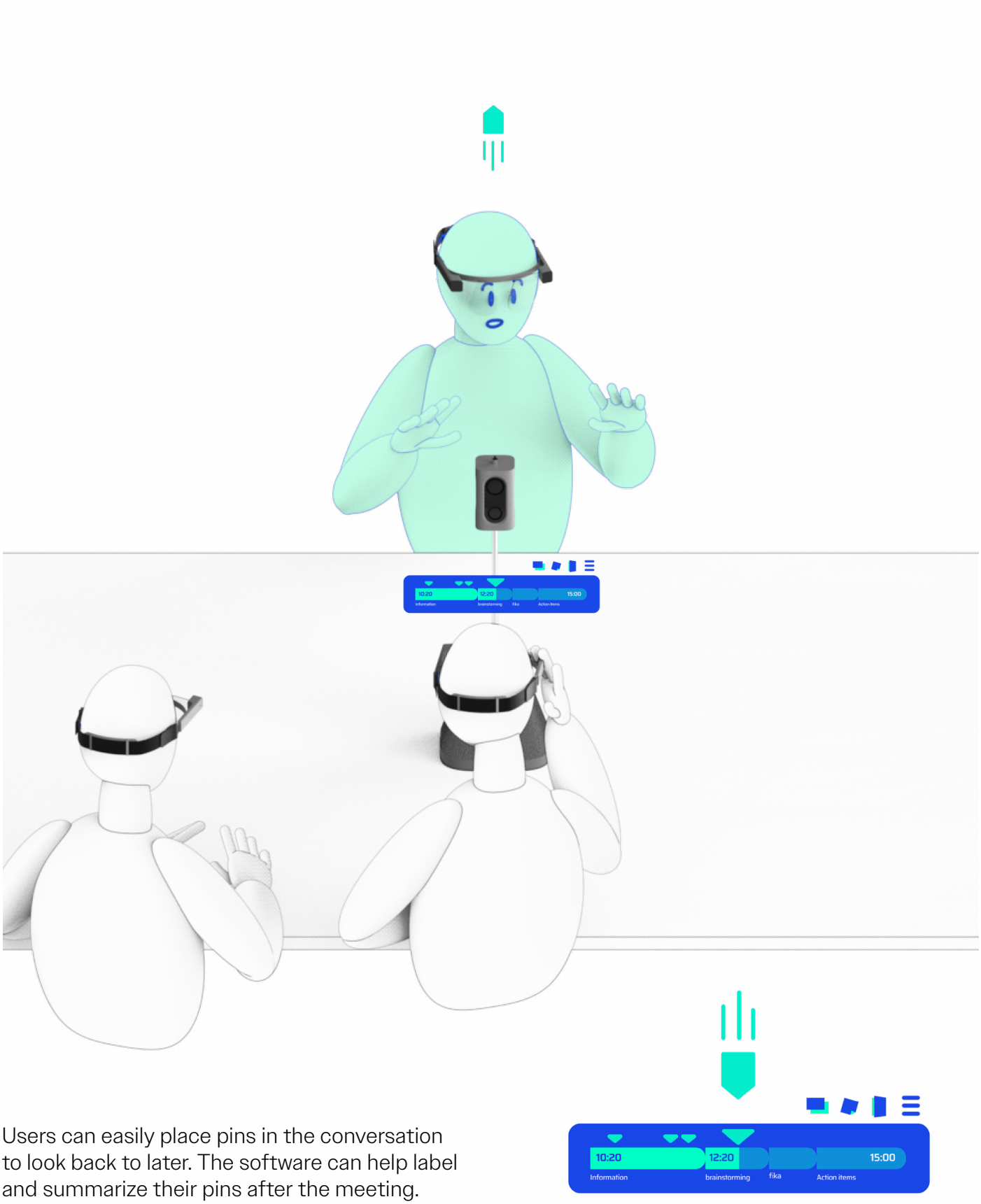
Members joining from on-site locations will be prompted to adjust their seating as needed to accommodate off-site members. Users can quickly turn their heads to sign into their accounts while wearing public headsets. This also helps the camera build a more accurate model of the user's face in real time with the help of AI prediction software to fill in occluded sides of the face.

Nonverbal communication



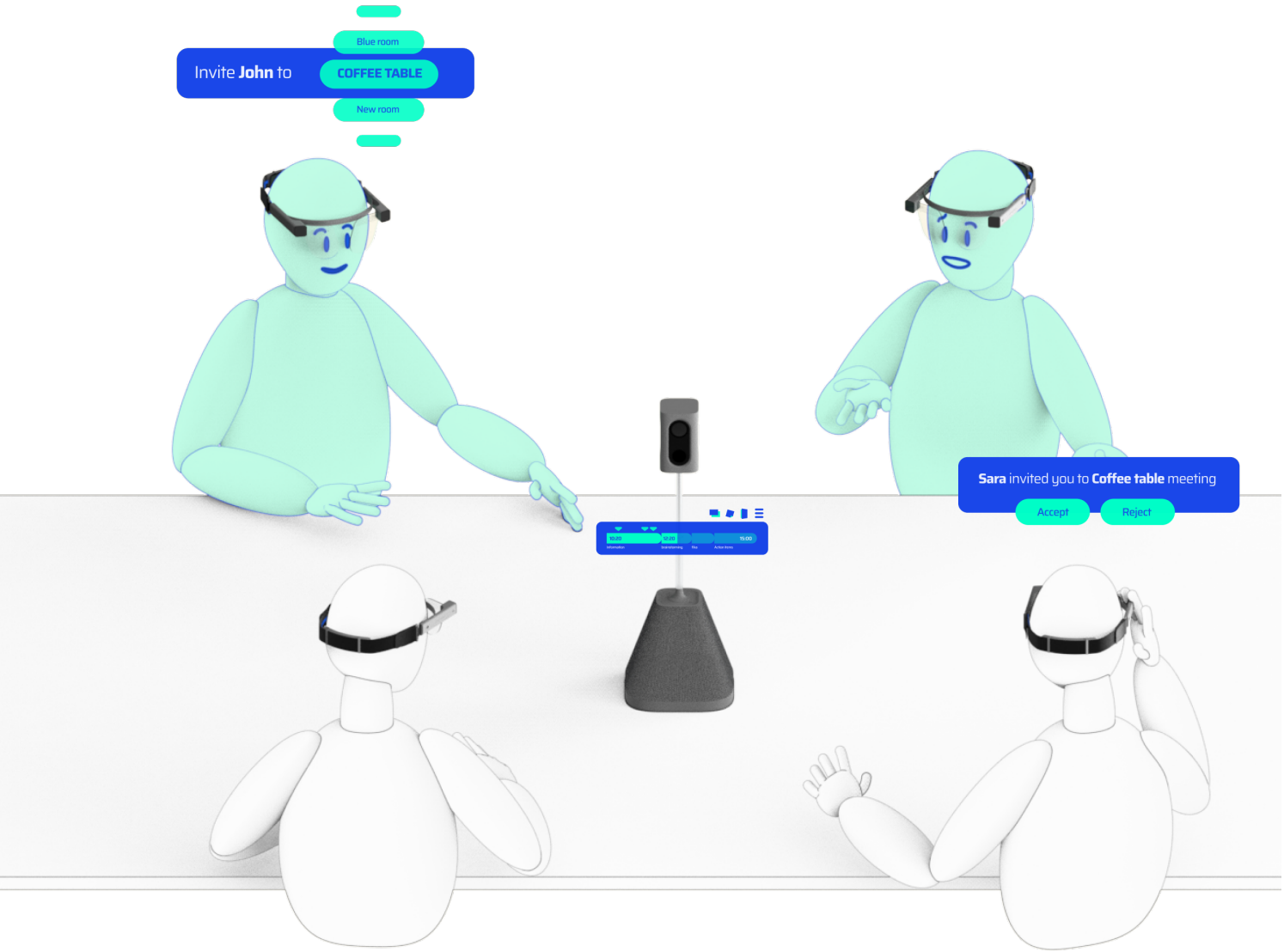
By adding highlighting gestures and allowing people to send emojis, we can make the holographic meetings more inclusive and engaging when group sizes get larger.

Pinning the conversation



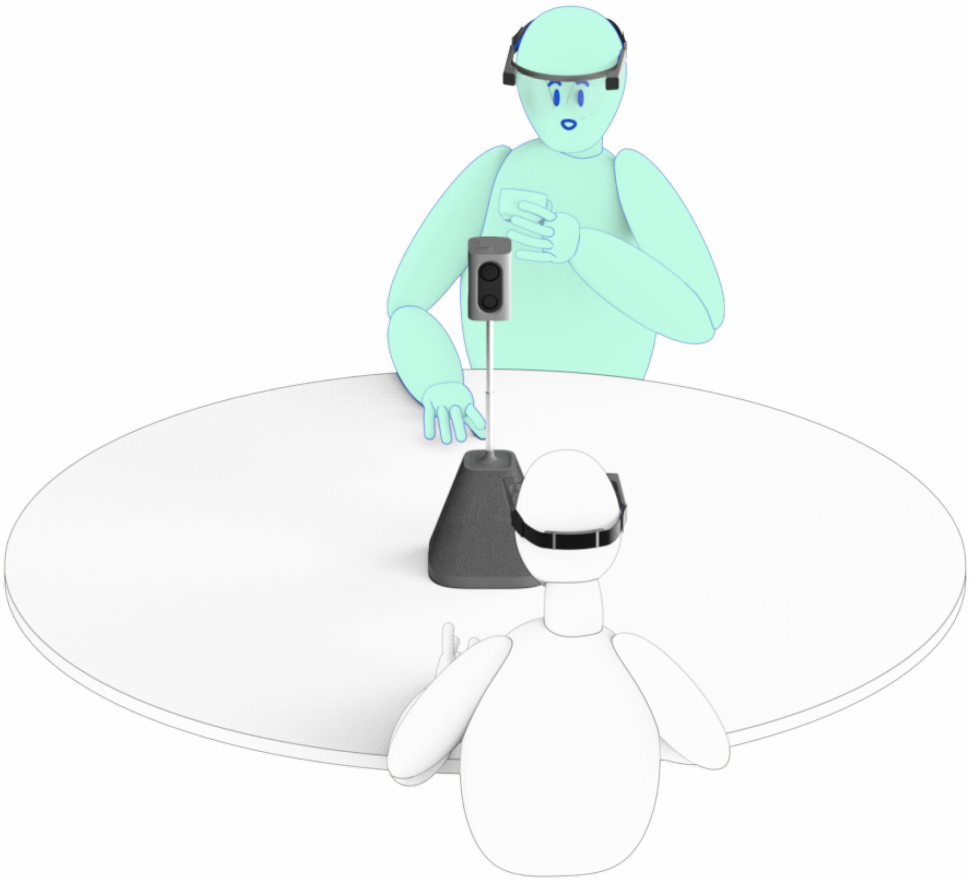
Users can easily place pins in the conversation to look back to later. The software can help label and summarize their pins after the meeting.

Extending the conversation



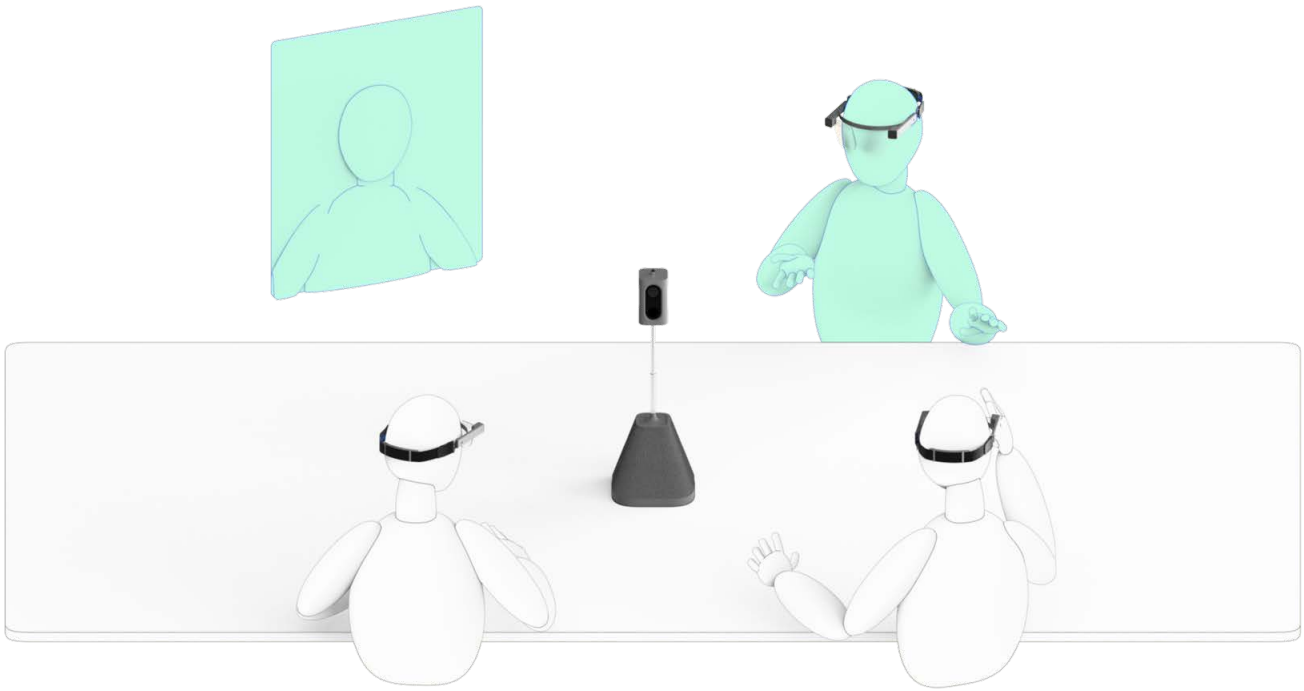
With more natural feeling conversations, hybrid meetings could be less fatiguing and more engaging. To help members easily extend conversations beyond the scheduled time, users can easily create new meetings and bring others along.

Hubs around the office

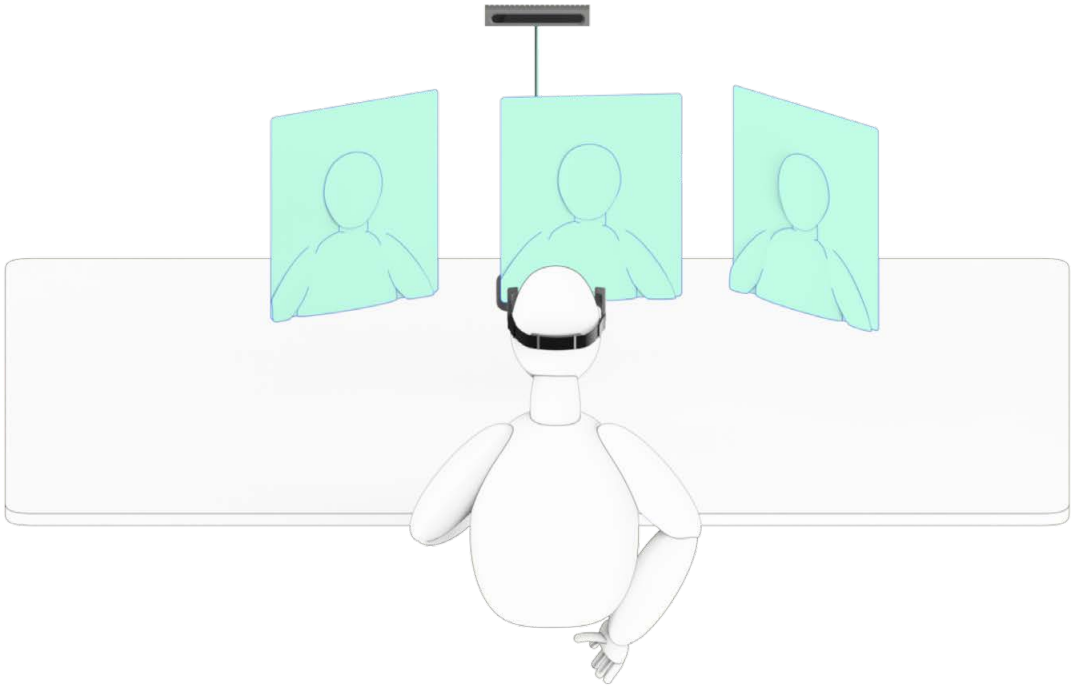


By placing hubs around the office, Hollaboration becomes more than just a tool for meetings, but a way to check in on a teammate or chat over a drink during happy hour.

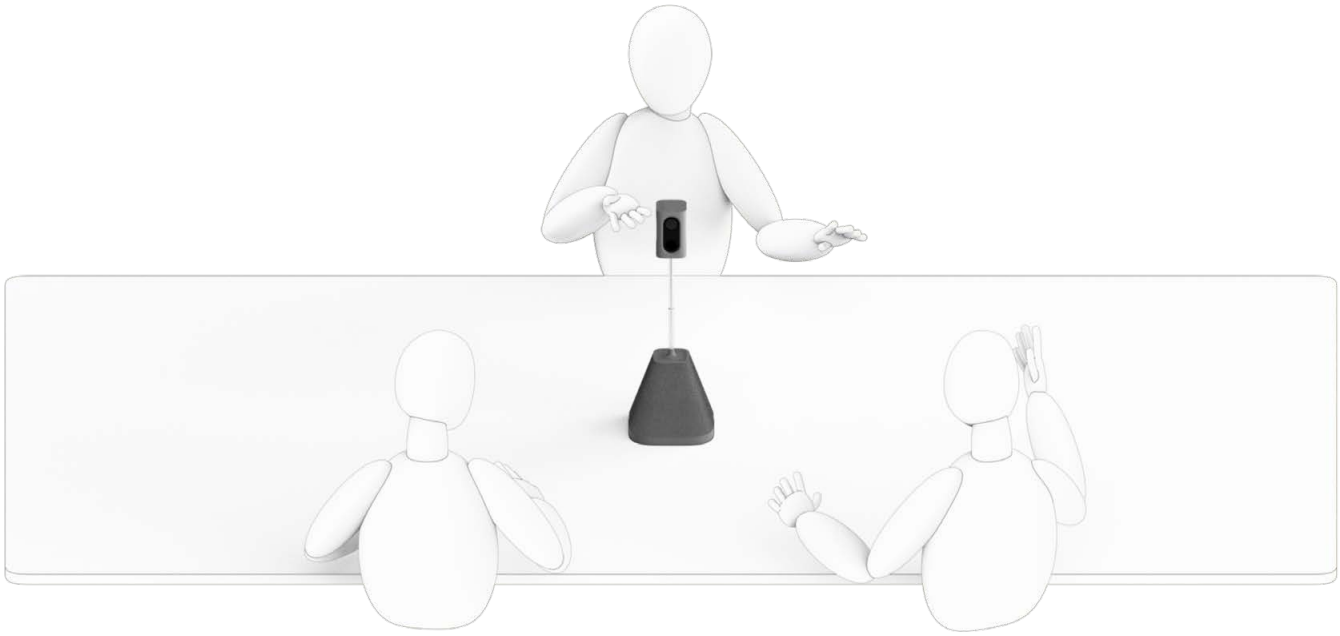
System fall-back



To accommodate users without the Hollaboration hardware like clients or external consultants, the conferencing platform can support different levels of connectivity. Users can call in with just audio or a regular webcam feed, being represented as a virtual screen within the room.



When joining traditional 2D virtual meetings, the headset can still be used to view attendees in a larger scale as separate virtual screens.



Without the headsets, both cameras can be used for traditional video conferencing.

Reflection

Throughout our project, we underwent significant idea changes, transitioning from e-waste reduction to user-centered hybrid workspaces and ultimately focusing on the future of virtual collaboration. This led us through three distinct design processes, providing a breadth of knowledge and a deeper understanding of the challenges involved in solving such formidable problems. We also recognized the importance of starting a design with the problem rather than working backward with a solution.

The greatest challenge we faced while designing the products for our Hollaboration concept was creating a realistic product for the near future. Although we didn't develop functional prototypes, it was crucial to ensure that our designs were grounded in reality. However, the rapidly evolving fields of AR and volumetric capturing make it unclear which implementation will prevail in five years. Unlike smartphones, which have established consensus on design and components, AR glasses designs are still exploring the optimal setup of projector, display, and computing capability. Various combinations currently serve niche use cases, and experts agree that general-purpose AR is still at least five to ten years away.

Another underestimated challenge was designing three distinct and entirely new devices alongside a software interface within a tight timeframe. Each product presented unique challenges that we had to address. Despite these hurdles, we conducted extensive research, including technology exploration and expert interviews, resulting in a speculative proposal grounded in informed predictions about technological capabilities and trends.

Given the opportunity to revisit this project, we would prioritize conducting user interviews earlier in the process and carefully consider the scope of our proposals to ensure timely completion within the project's timeframe.

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