

# HEAD-MOUNTED DISPLAY VISUALIZATIONS TO SUPPORT SOUND AWARENESS FOR THE DEAF AND HARD OF HEARING

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Ramani Duraiswami<sup>5</sup>, Dmitry Zotkin<sup>5</sup>, Christian Vogler<sup>3</sup>, Jon Froehlich<sup>1,5</sup>



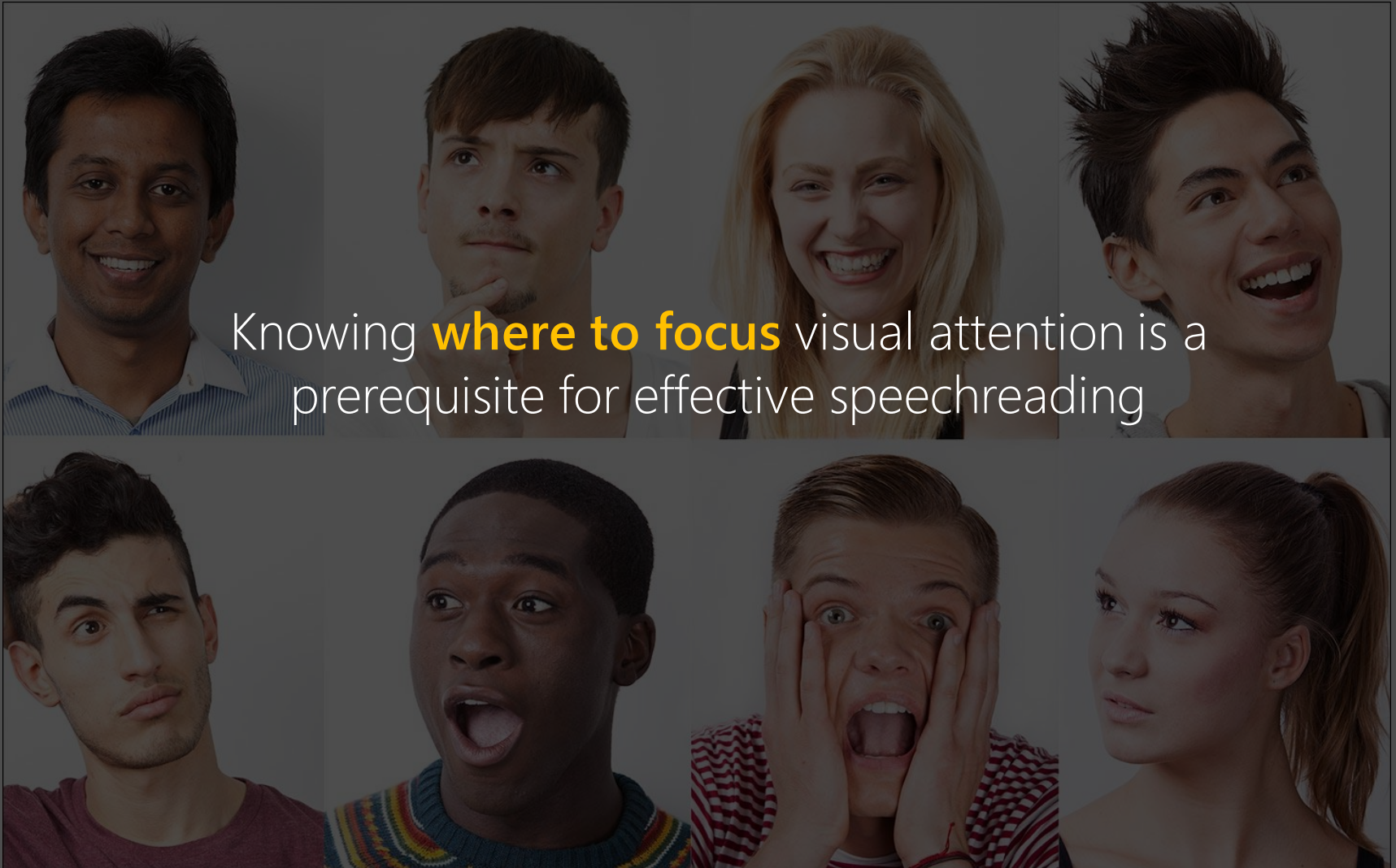
# DEAF AND HARD OF HEARING USE VISUAL SIGNALS

BODY LANGUAGE, FACIAL EXPRESSIONS, LIP MOVEMENT (SPEECHREADING)



# DEAF AND HARD OF HEARING USE VISUAL SIGNALS

BODY LANGUAGE, FACIAL EXPRESSIONS, LIP MOVEMENT (SPEECHREADING)



Knowing **where to focus** visual attention is a prerequisite for effective speechreading



HEARING AID AND COCHLEAR IMPLANT  
DO NOT IMPROVE SOUND LOCALIZATION

# COMMON PROBLEMS IN GROUP COMMUNICATION



# COMMON PROBLEMS IN GROUP COMMUNICATION

## 1. SPEAKER TRANSITION



Video from Study 1: Part 1 (Formative Interview)

# COMMON PROBLEMS IN GROUP COMMUNICATION

1. SPEAKER TRANSITION

2. INABILITY TO FOLLOW SIMULTANEOUS SPEAKERS



Video from Study 1: Part 1 (Formative Interview)

# PARTICIPANTS RESPONSES FROM FORMATIVE STUDY



"I almost always interact with Deaf people. When I converse with hearing people it's usually 1:1 with interpreters." (P4)

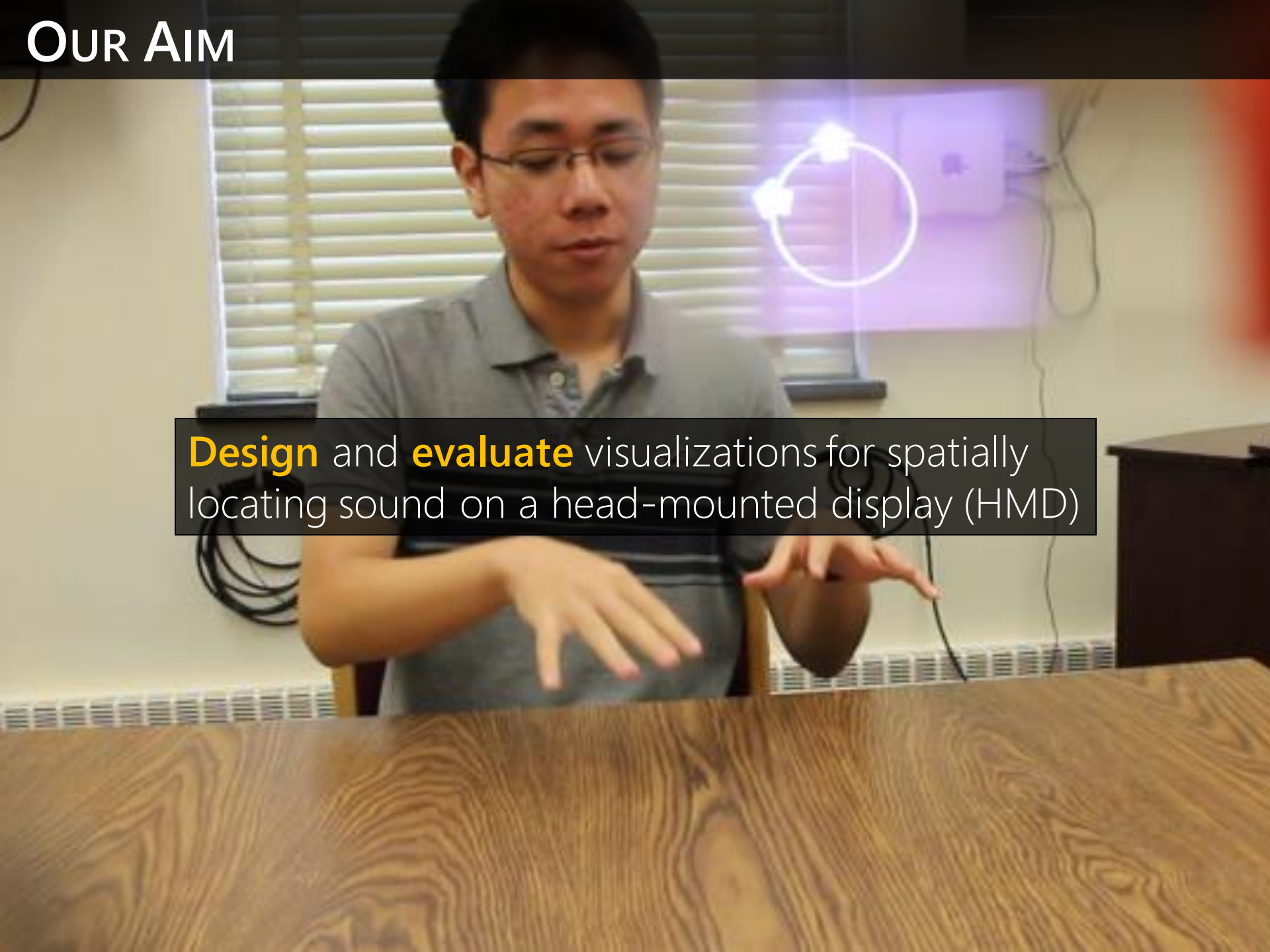
"I usually avoid large groups" (P16)

"If one person finishes talking, I do not know who to look at next—that is my problem because hearing people can hear who the next person is, and what they are saying." (P20)



# OUR AIM

**Design** and **evaluate** visualizations for spatially locating sound on a head-mounted display (HMD)





# Traditional Techniques





Talking pillow...



Pillow

Talking pillow...

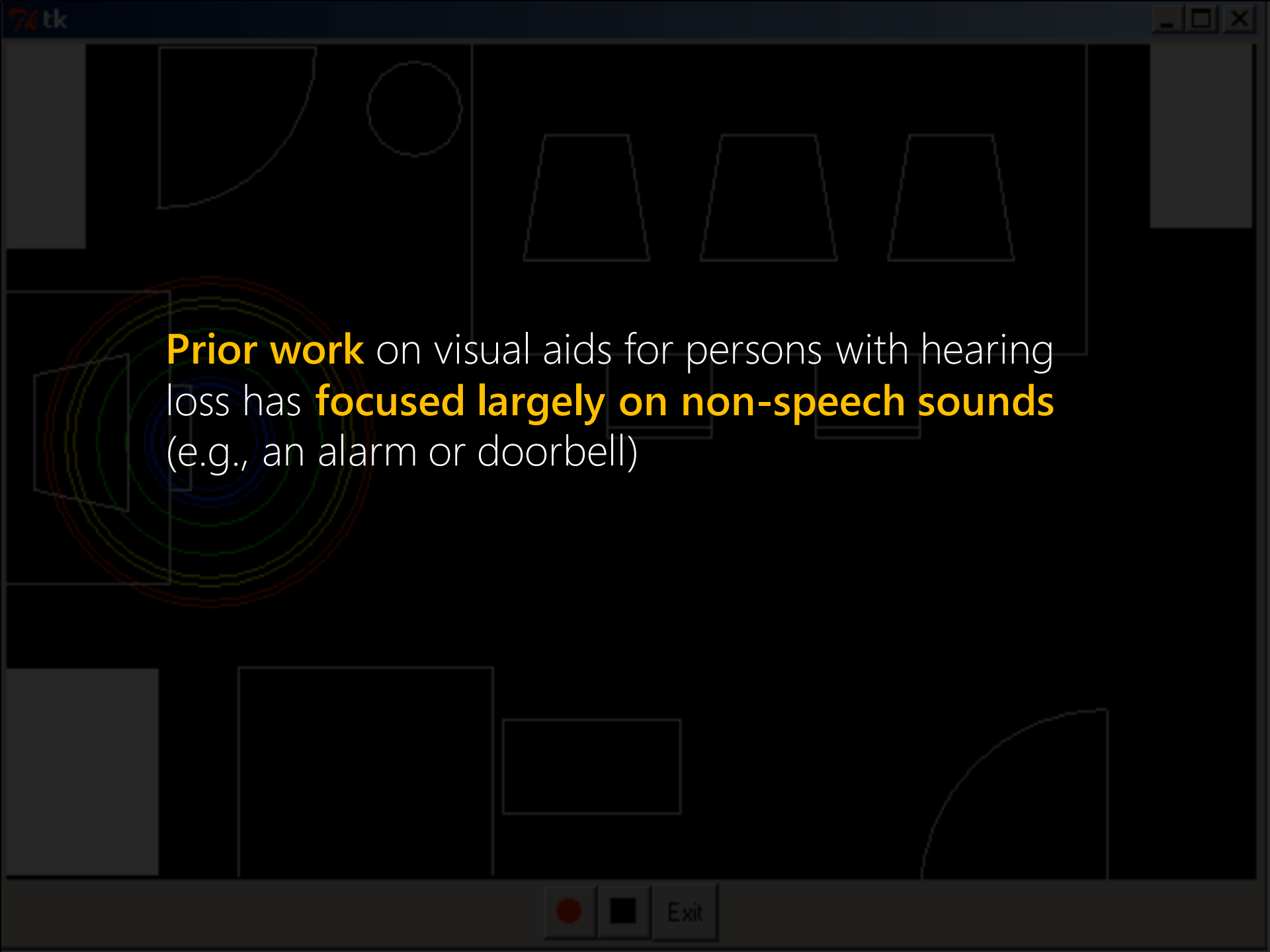


Speaker

Talking pillow...



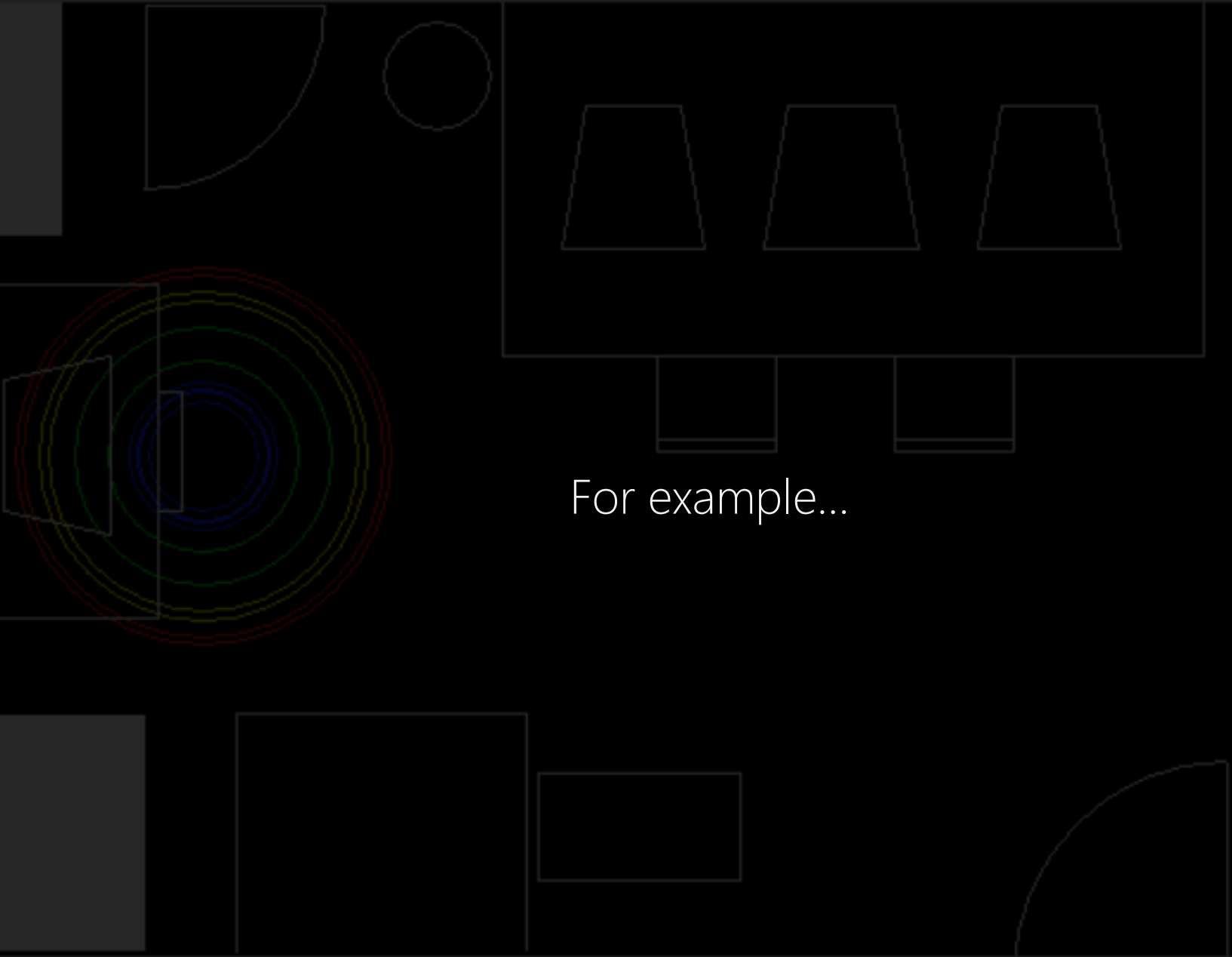
Using interpreter...

A dark-themed Tkinter window titled "78tk" containing various geometric shapes: a quarter-circle in the top-left, a circle in the top-center, three trapezoids in the top-right, a rectangle in the bottom-left, a rectangle in the bottom-center, and a quarter-circle in the bottom-right. A sound wave graphic is overlaid on the left side of the window.

**Prior work** on visual aids for persons with hearing loss has **focused largely on non-speech sounds** (e.g., an alarm or doorbell)

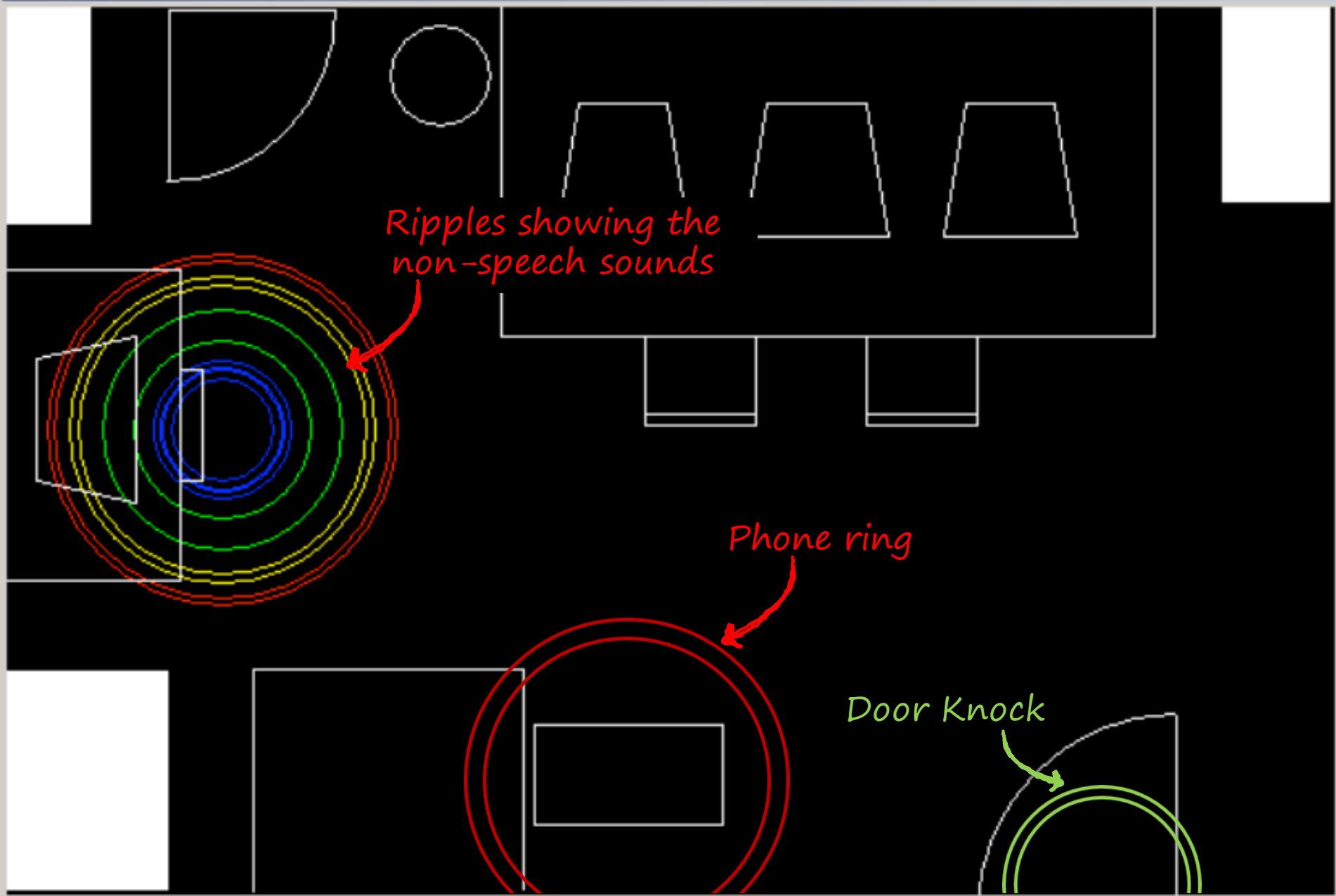


Exit



For example...

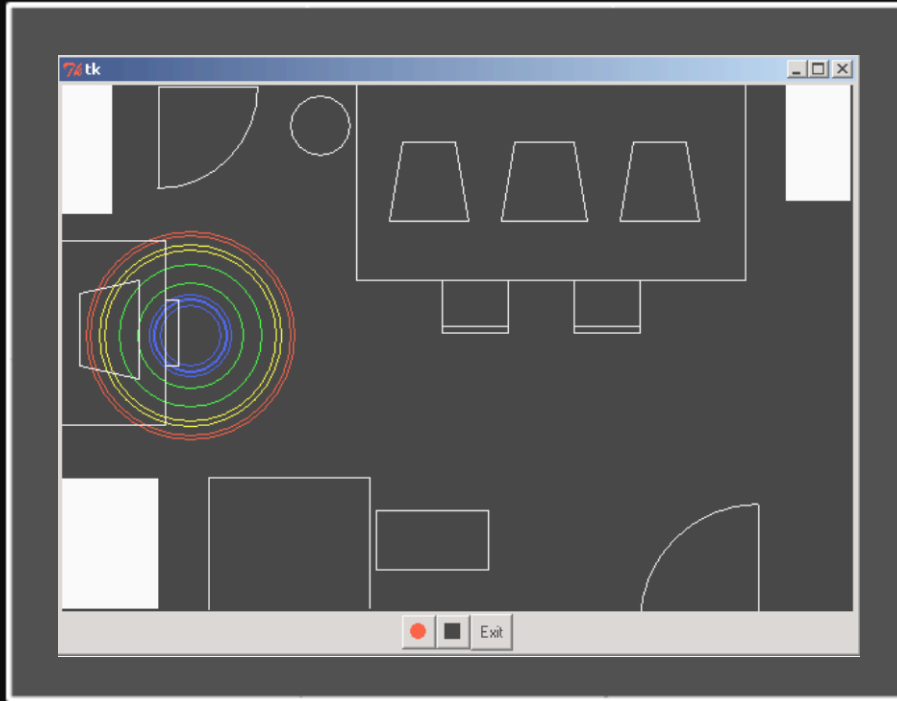






**Prior work** on visual aids for persons with hearing loss has **focused largely on non-speech sounds** (e.g., an alarm or doorbell)

These sounds are presented on **external displays or devices** such as desktops or mobile devices





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These sounds are presented on **external displays** such as desktops or mobile devices

Moreover they **require sophisticated algorithms** to identify sounds, which is an open area of research

# MOST RELEVANT WORK

SOUND COMPASS - KANEKO ET AL., IEEE SMC '13

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SOUND COMPASS - KANEKO ET AL., IEEE SMC '13



Device

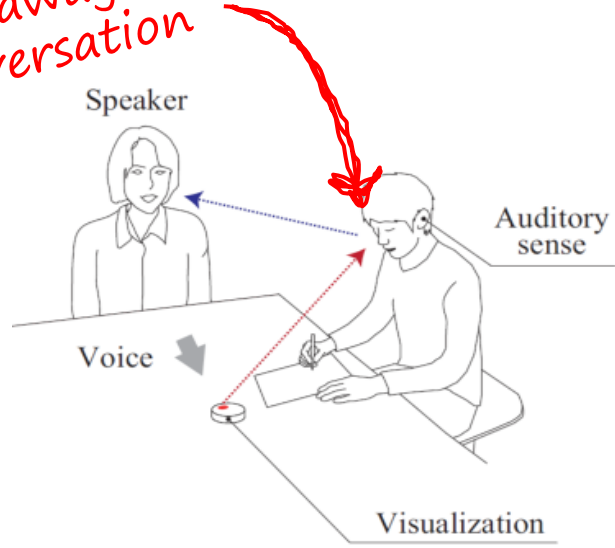


Arm mounted

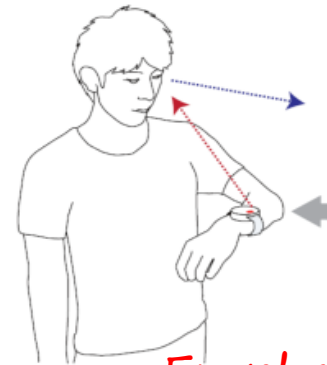
# MOST RELEVANT WORK

SOUND COMPASS - KANEKO ET AL., IEEE SMC '13

*Turns gaze away from the conversation*



Device placed on a table



*Emphasis on sensing, not visual feedback*

Arm-mounted use

# OUR APPROACH: SOUND VISUALIZATION ON HMD

(Please download the powerpoint version to view the video)



OUR APPROACH:  
SOUND VISUALIZATION ON HMD

**1** Increased  
Glanceability

**2** Privacy

**3** Seamlessness

# OUTLINE

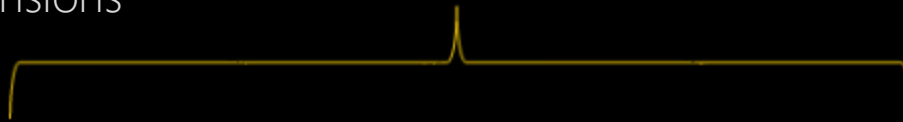
Design Goals  
and  
Dimensions

# OUTLINE

Design Goals  
and  
Dimensions



Study 1



**PART 1:**  
Formative  
Interview

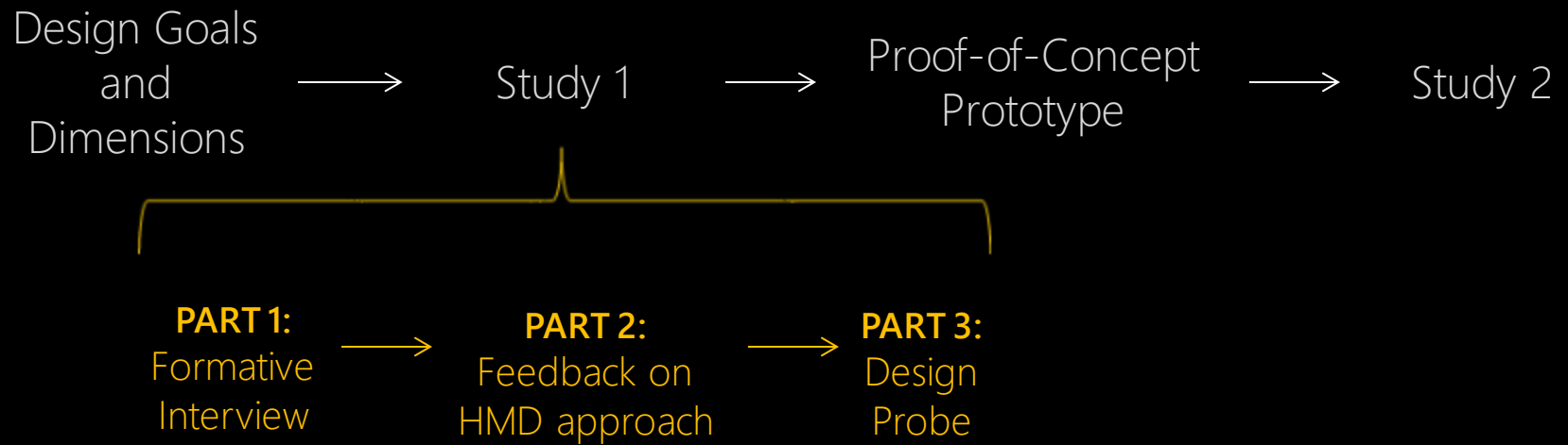


**PART 2:**  
Feedback on  
HMD approach

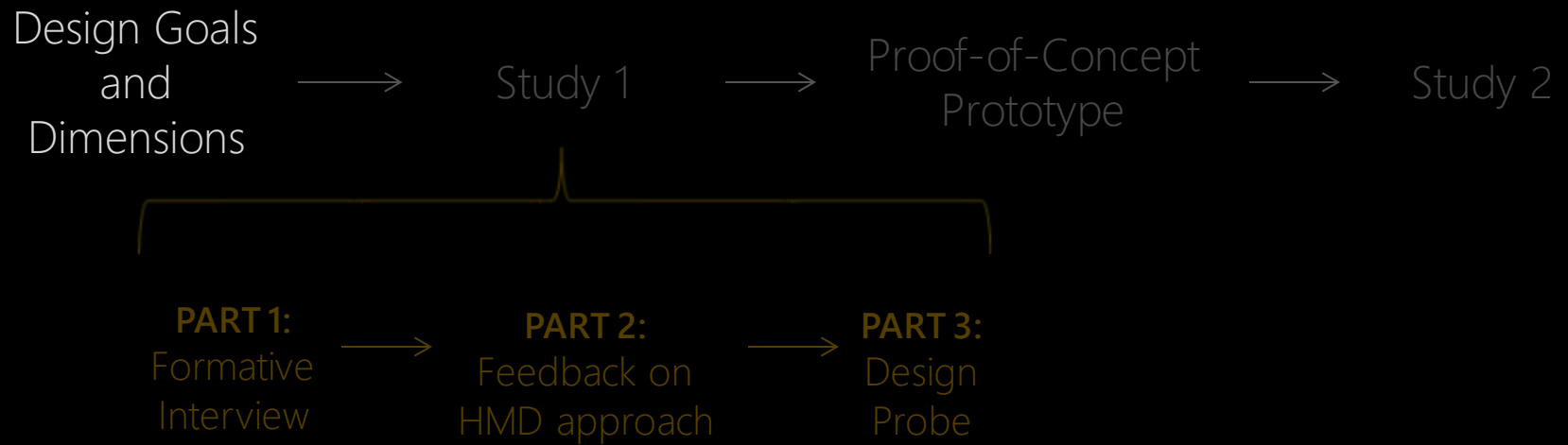


**PART 3:**  
Design  
Probe

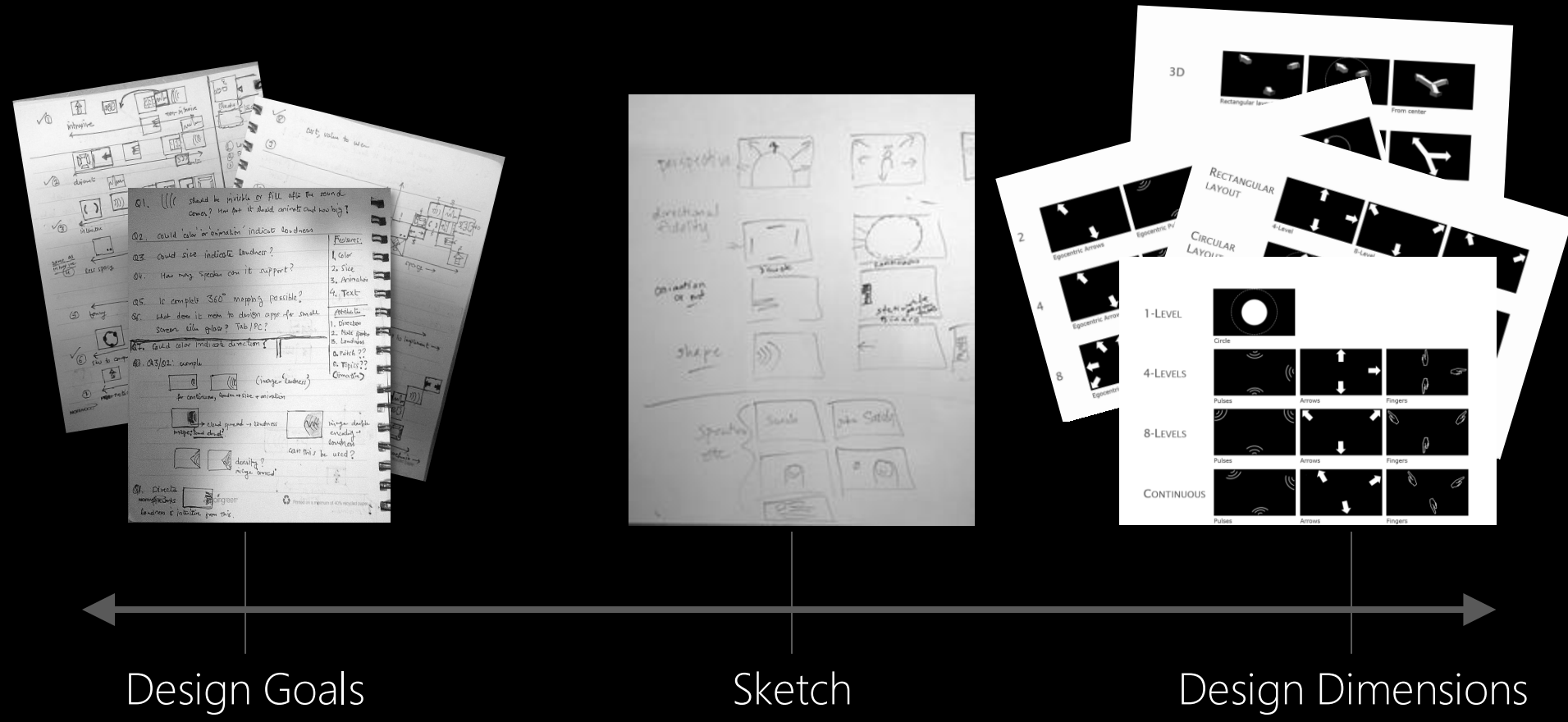
# OUTLINE



# OUTLINE



# Iterative Design Process



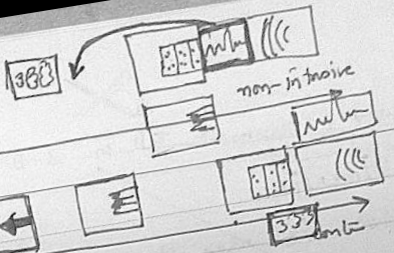
Design Goals

Sketch

Design Dimensions

✓ ①

↑  
intrusive  
←



✓ ②

←  
disrupt



✓ ③

←  
intrusive



same as  
in my use  
④

←  
less space

⑤

←  
fancy



✓ ⑥

←  
sw to control



⑦

←  
notical

NORWOOD

cost, value to user

Q1. ((( should be invisible or fill after the sound comes? How fast it should animate and how big?

Q2. could 'color' or 'animation' indicate loudness

Q3. could size indicate loudness?

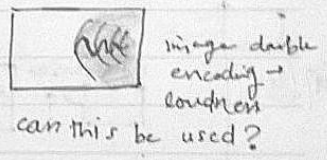
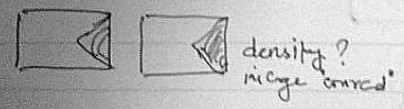
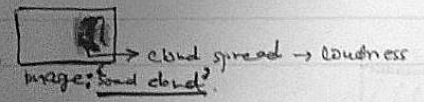
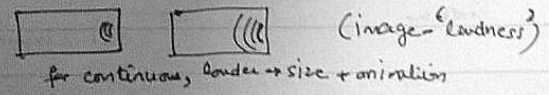
Q4. How many speakers can it support?

Q5. Is complete 360° mapping possible?

Q6. What does it mean to design apps for small screen like glass? Tab/PC?

Q7. Could color indicate direction?

Q8. Q3/Q2: example



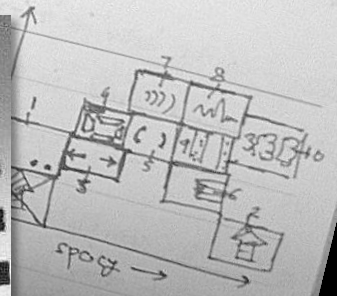
Features:

1. Color
2. Size
3. Animation
4. Text

Attributes:

1. Direction
2. Move speed
3. Loudness
  - a. Pitch??
  - b. Topics??
- (Animation)

Q9. Directa  
NORWOOD  
Bingreen  
loudness is intuitive from this.



to implement ->

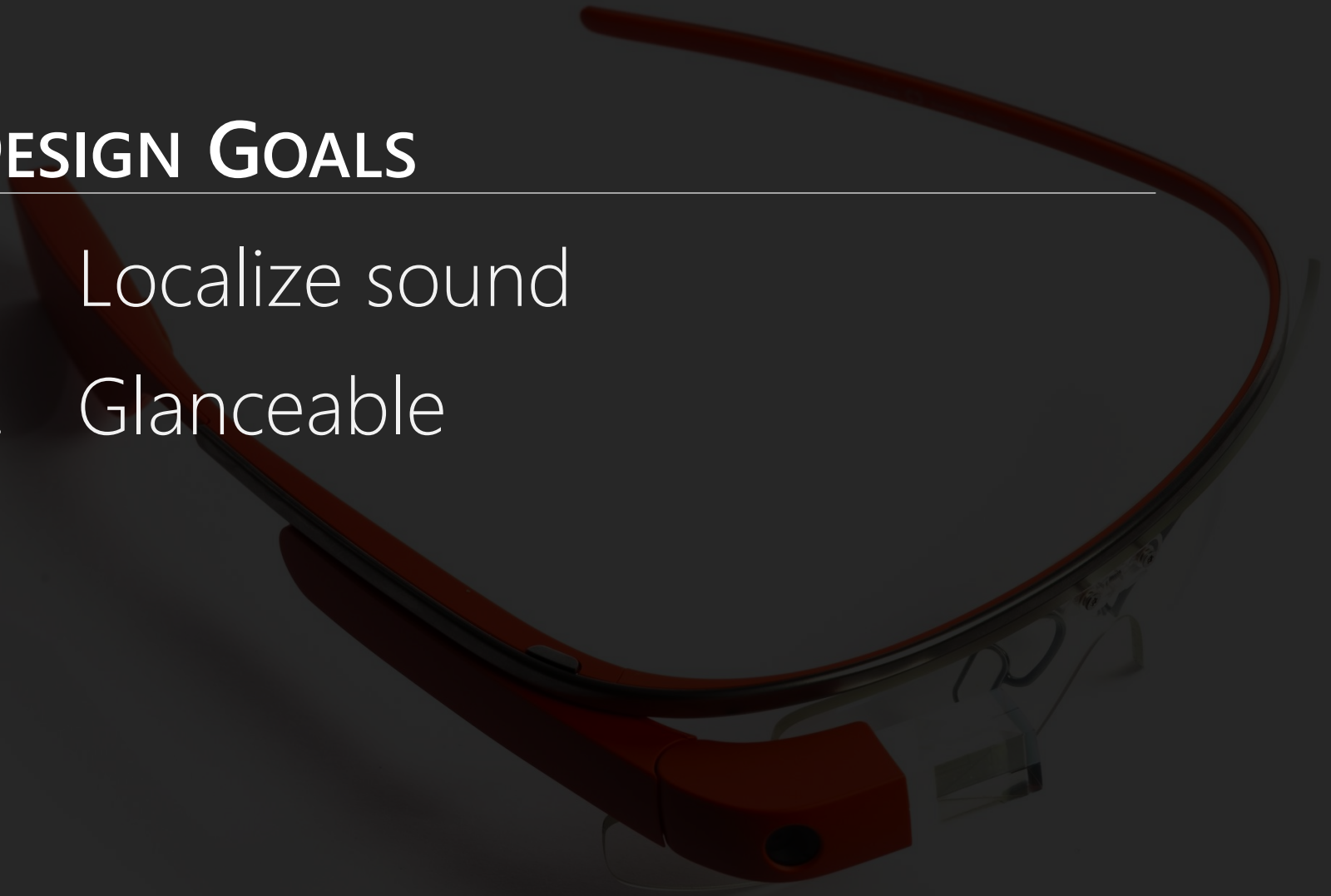


impact ->

# DESIGN GOALS

---

1. Localize sound
2. Glanceable

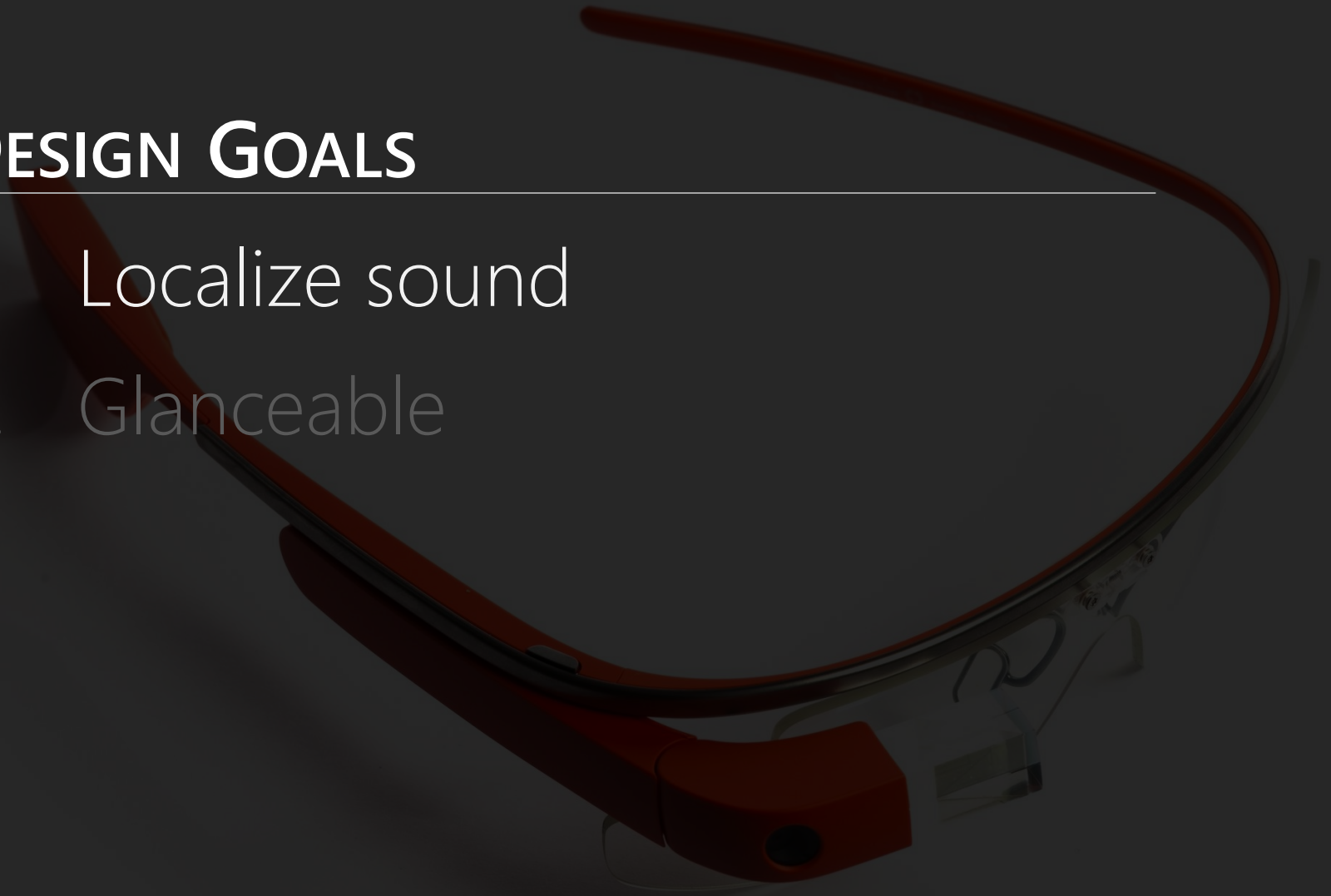




# DESIGN GOALS

---

1. Localize sound
2. Glanceable



# DESIGN GOALS

---

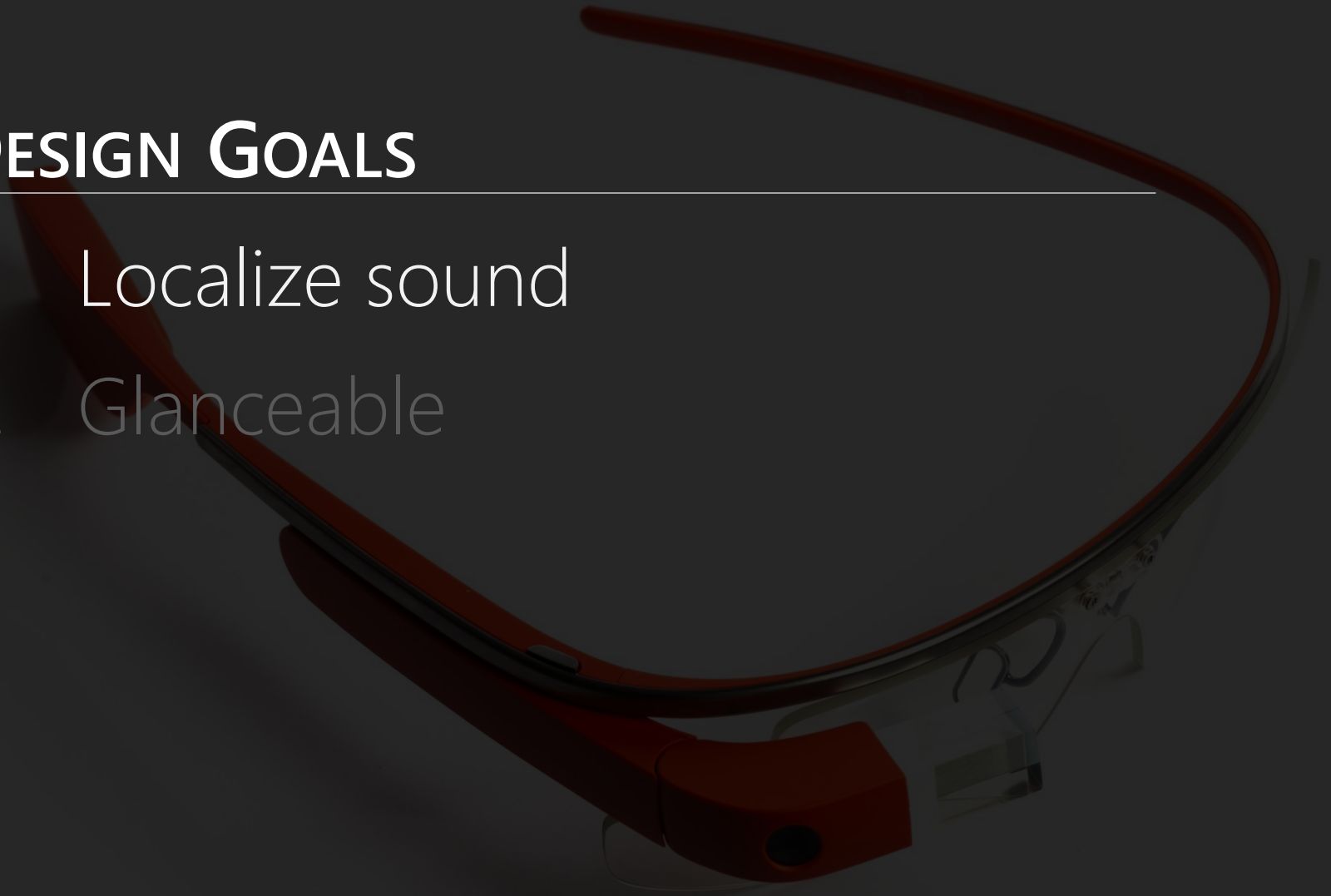
## 1. Localize sound:

The visualizations should provide unobtrusive and accurate indication of where the sound occurs

# DESIGN GOALS

---

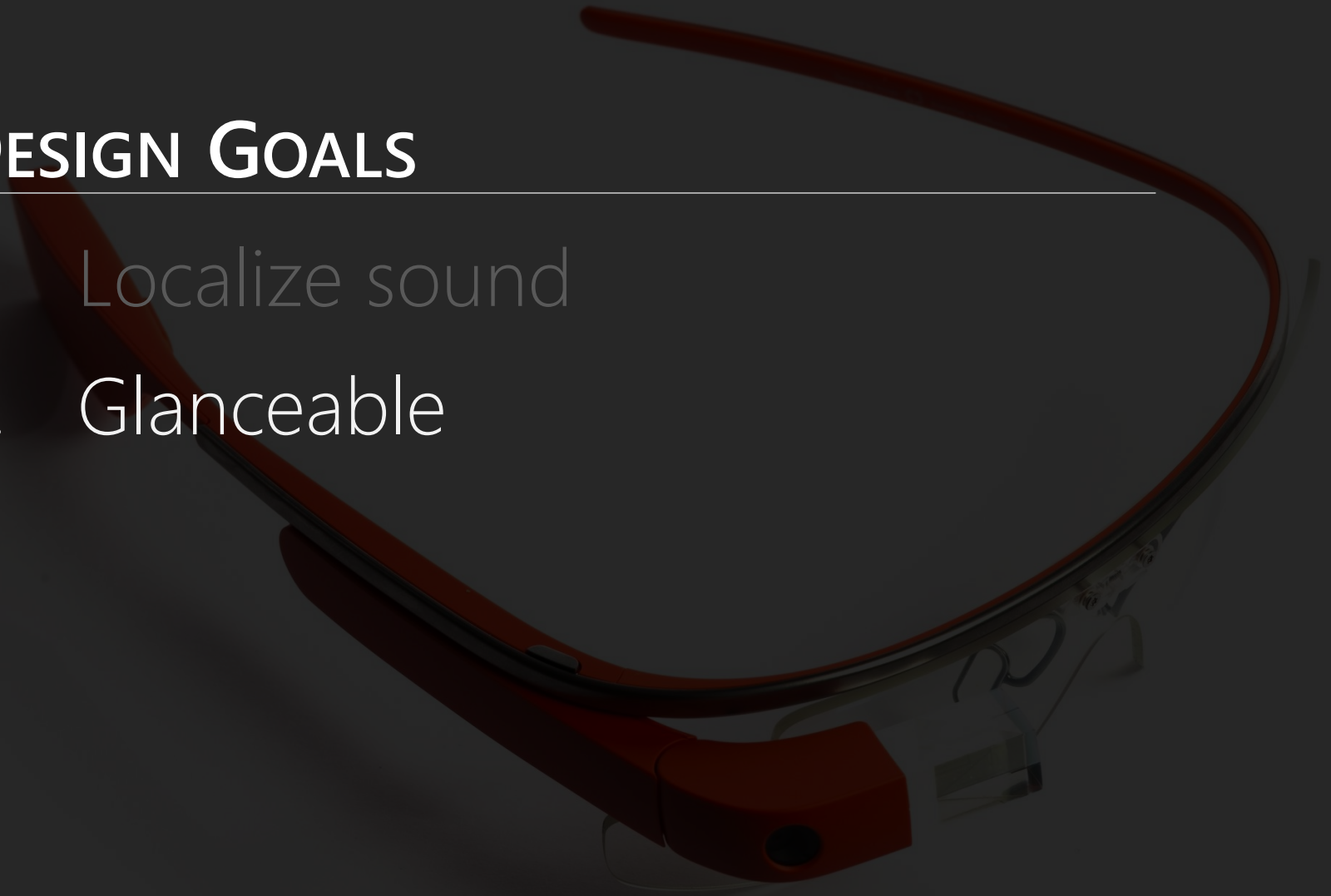
1. Localize sound
2. Glanceable



# DESIGN GOALS

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1. Localize sound
2. Glanceable



# DESIGN GOALS

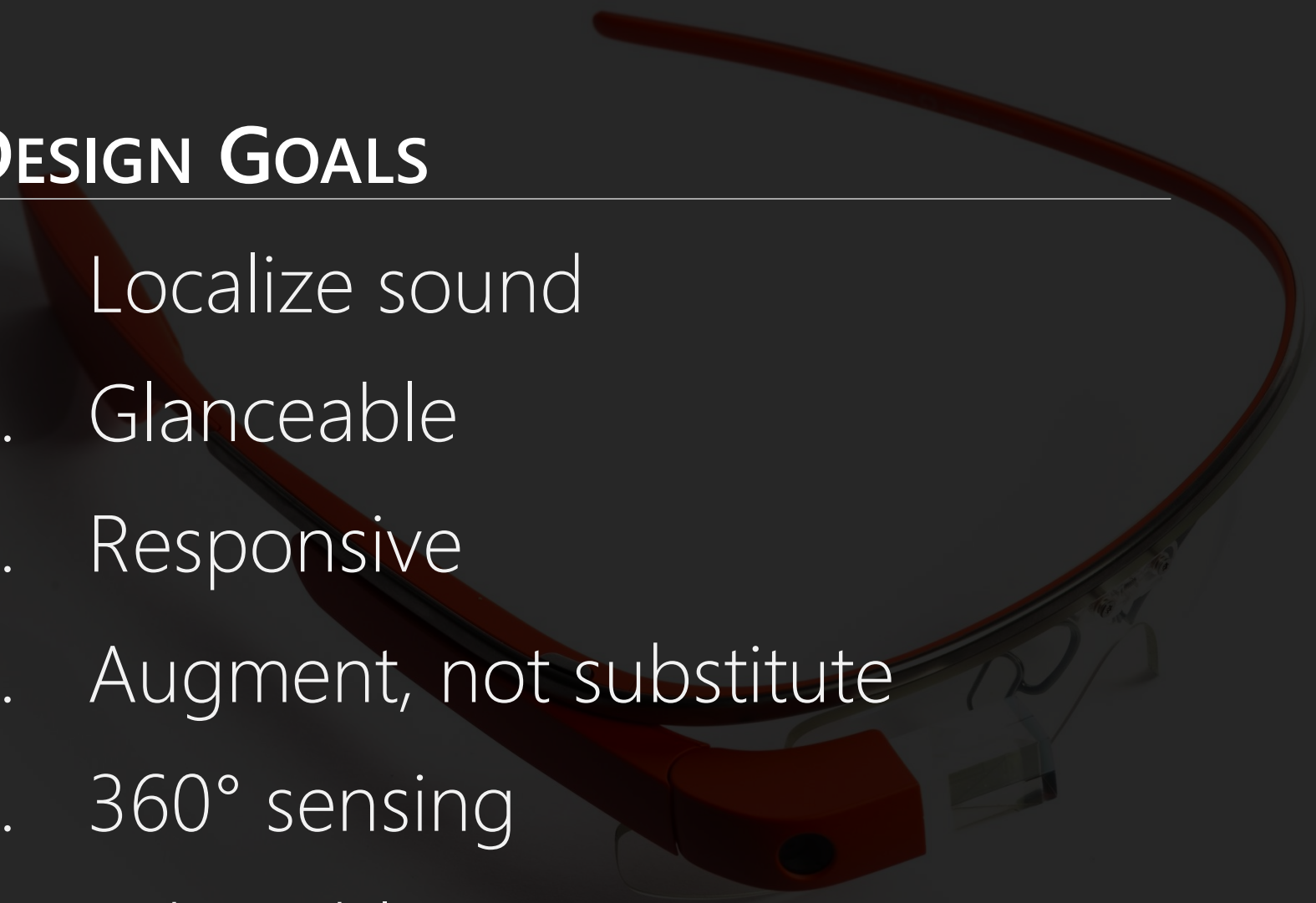
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## 2. Glanceable:

**The directional information should be easy-to-understand at a glance**

# DESIGN GOALS

---

1. Localize sound
  2. Glanceable
  3. Responsive
  4. Augment, not substitute
  5. 360° sensing
  6. Adaptable
- 

# Designing the Sound Visualizations

perspective



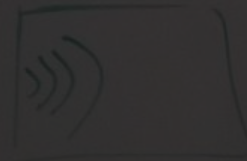
directional fidelity



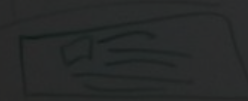
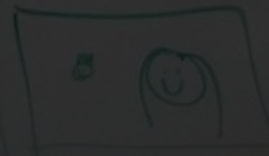
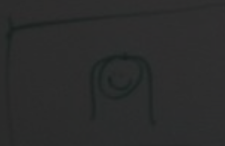
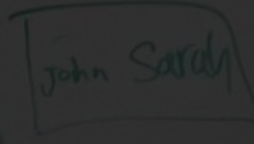
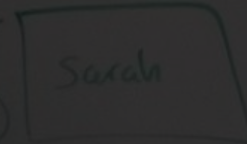
Animation or not



shape



Speaker etc



How does one go about the process of **designing interfaces**  
for **sound visualization** for **head-mounted display**?





# Design Inspirations

information systems

inputs (models, theories)

GENERAL THEORY

methodology

methodology

methodology

methodology

methodology





WINNING  
00:50

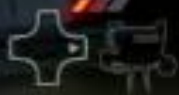
LVL 5 / 21 LVL 13 / 21

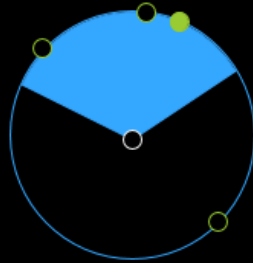
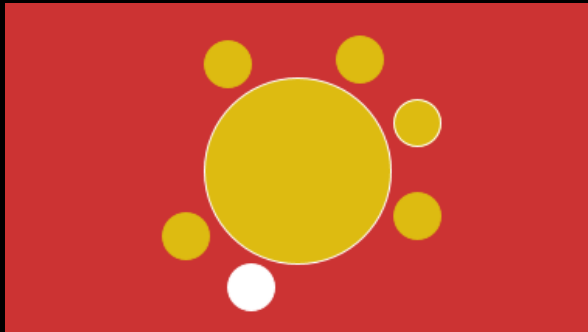
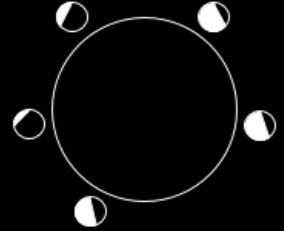
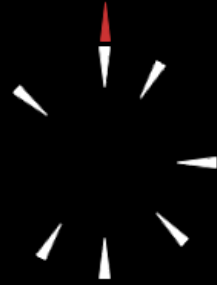


Spoktyk

LEVEL 3  
DAMAGE +5.0%

9/

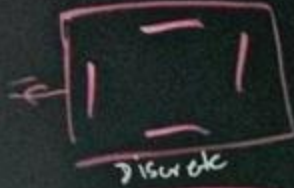




perspective



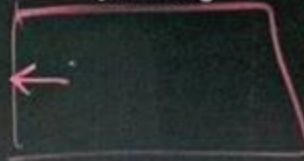
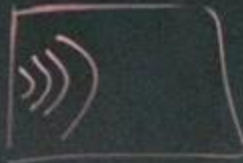
directional fidelity



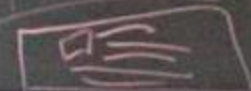
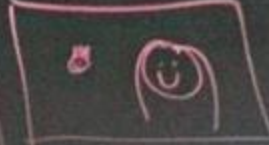
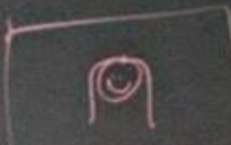
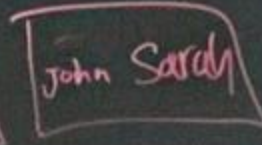
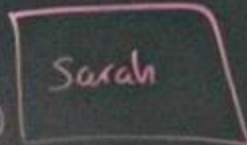
animation or not



shape

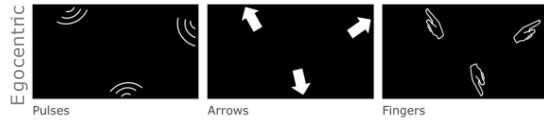


Speaker etc.



# 8 DESIGN DIMENSIONS

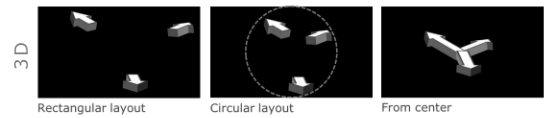
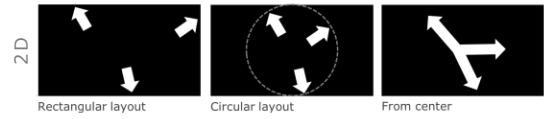
## WEARER'S PERSPECTIVE



## SCREEN LAYOUT



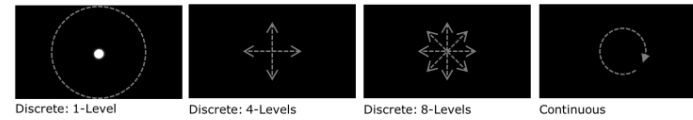
## 2D vs. 3D



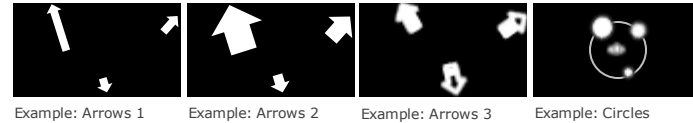
## CONVEYING SOUND SOURCE



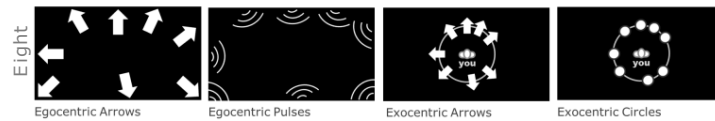
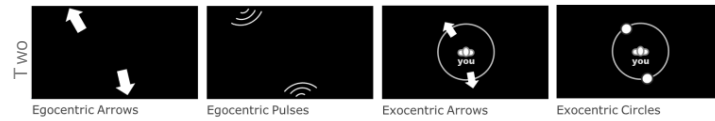
## DIRECTIONAL GRANULARITY



## LOUDNESS



## MAXIMUM SIMULTANEOUS ICONS

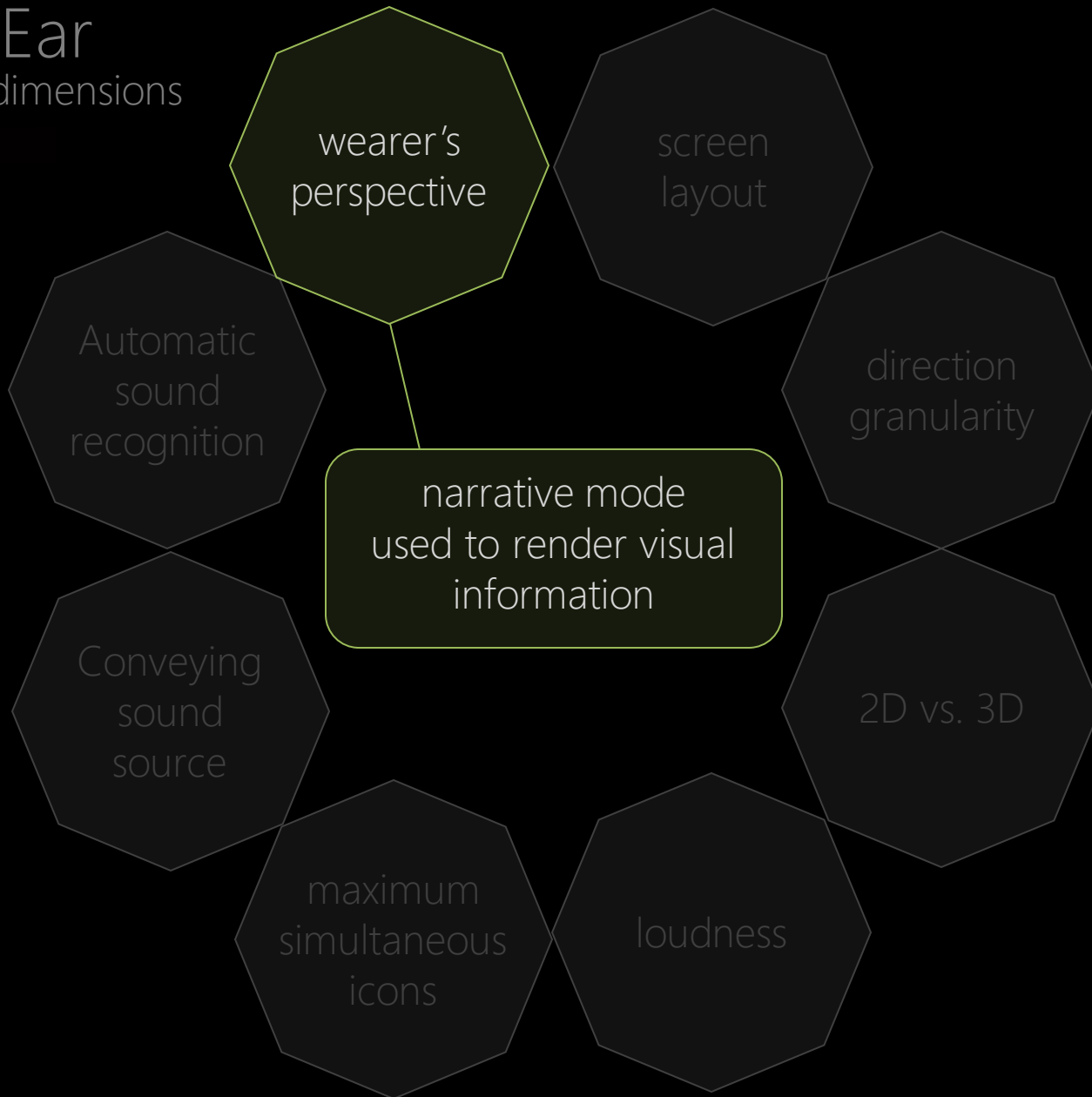


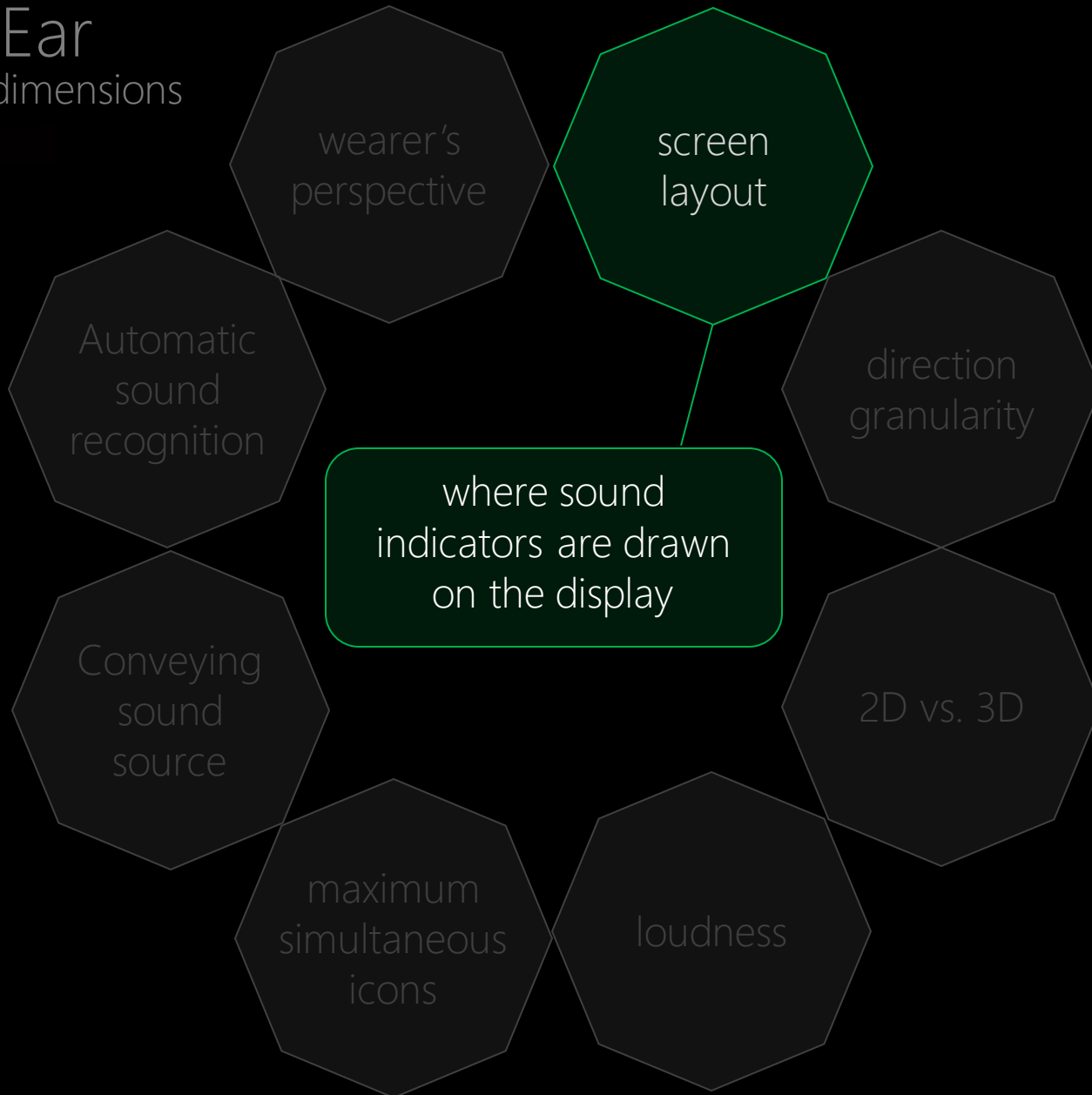
## AUTOMATIC SOUND RECOGNITION



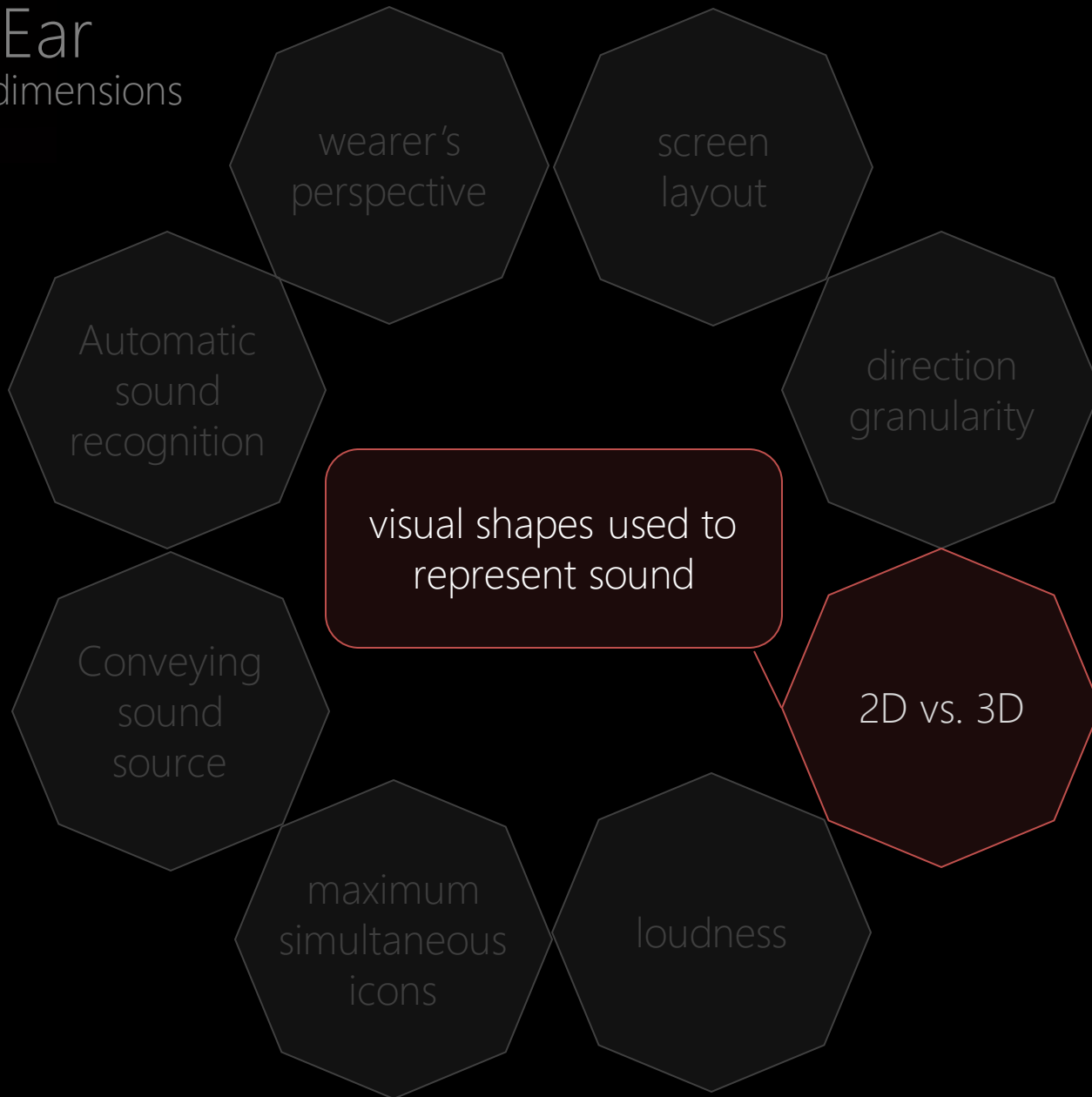


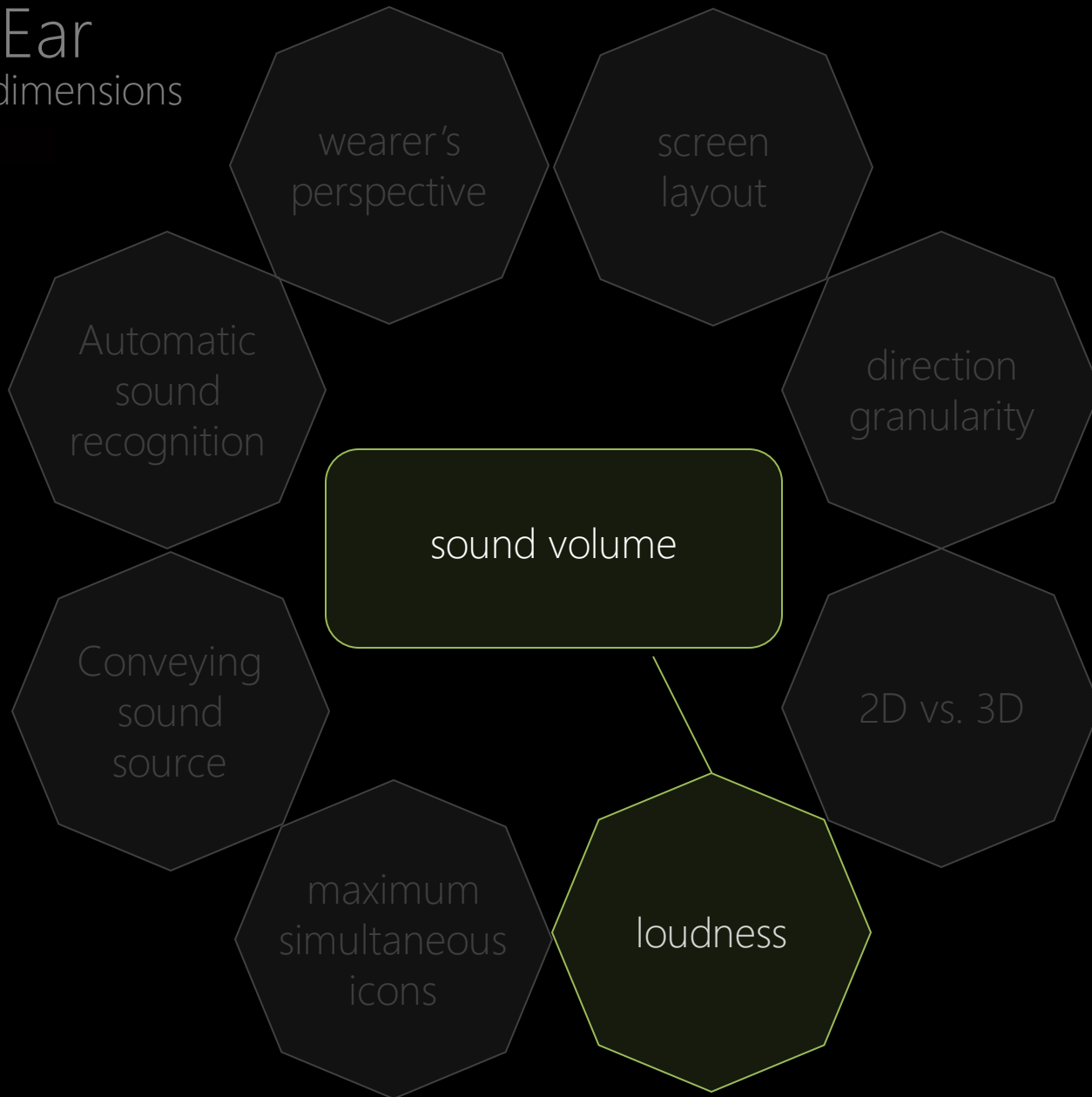


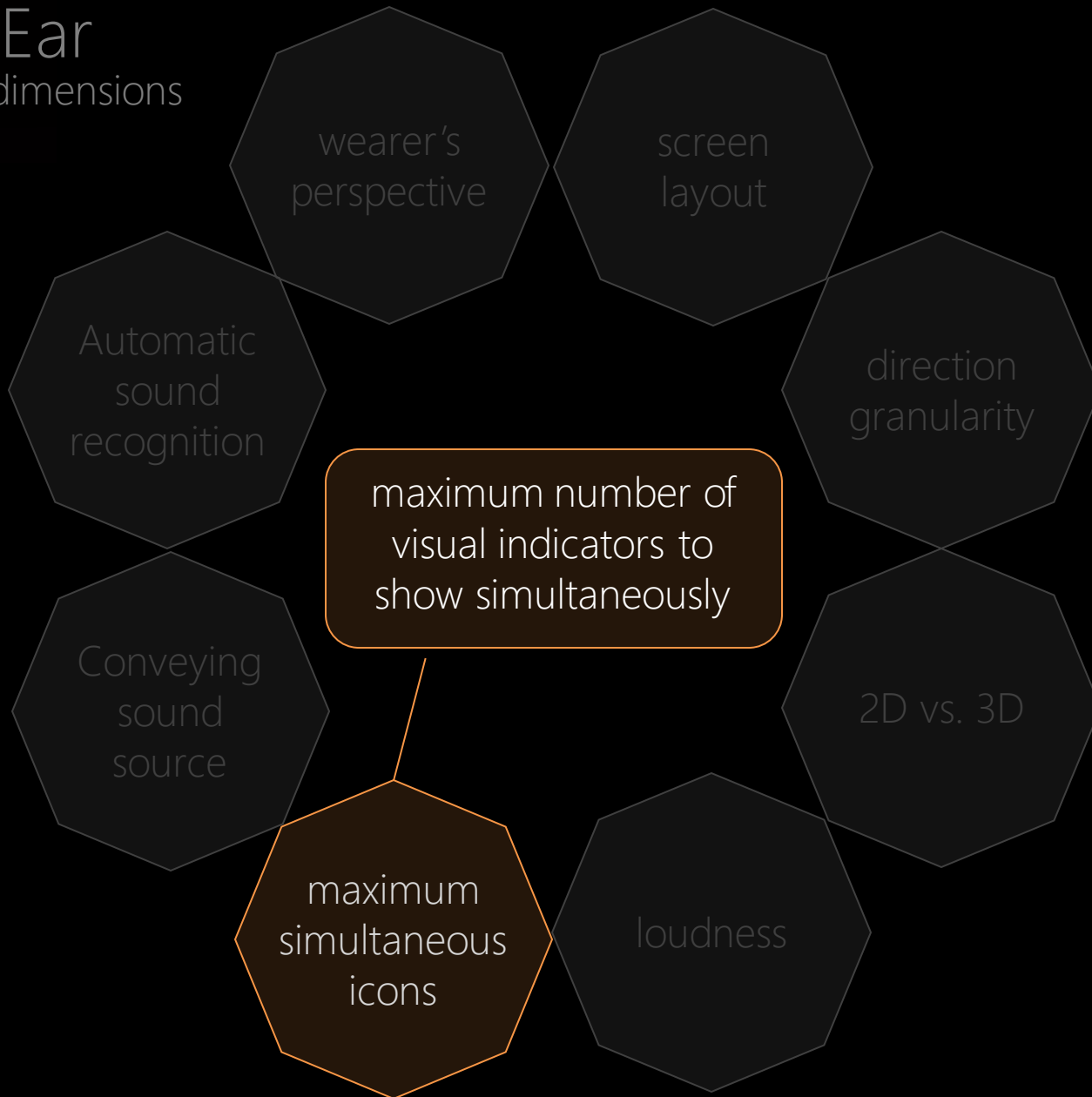


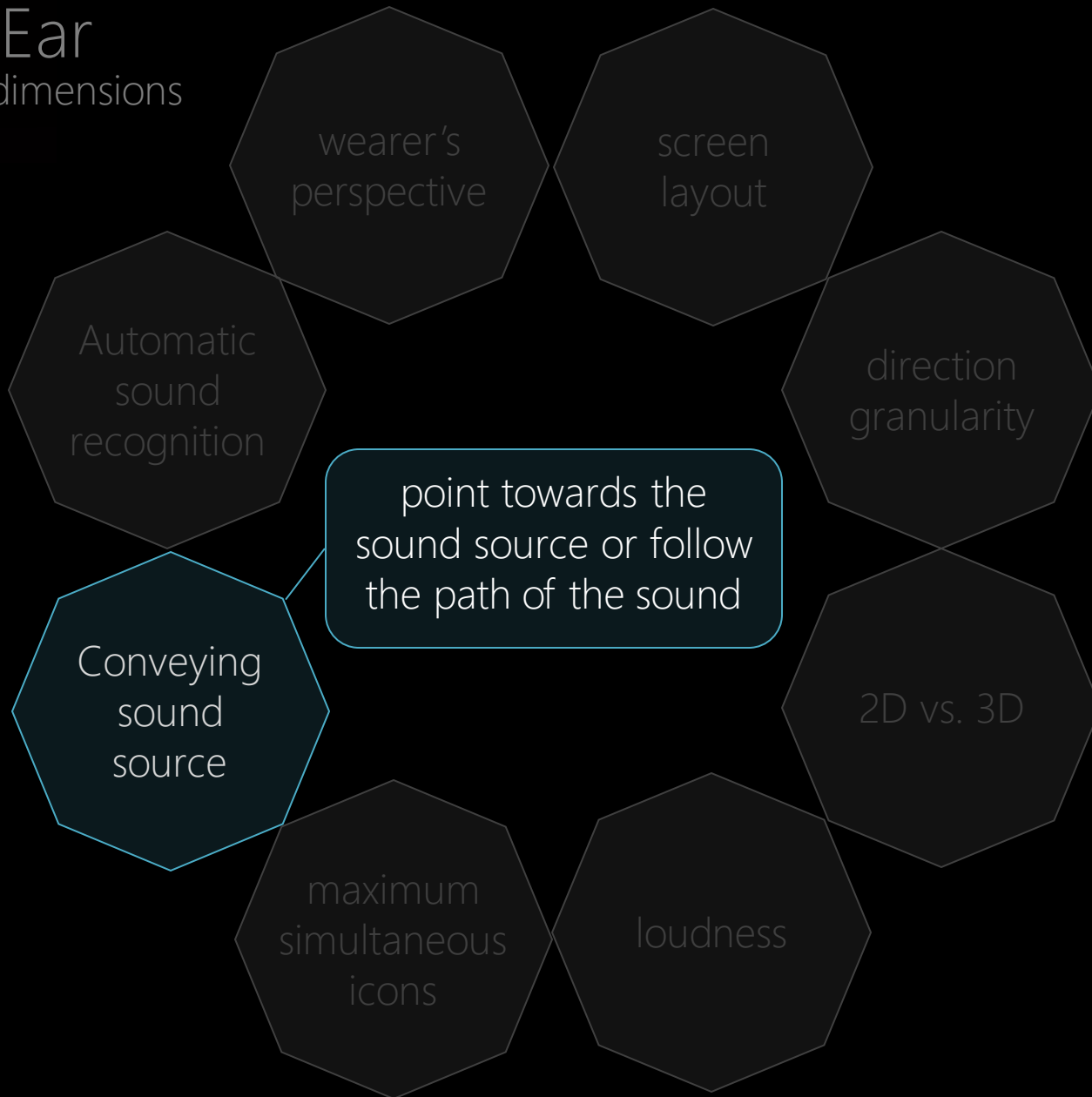


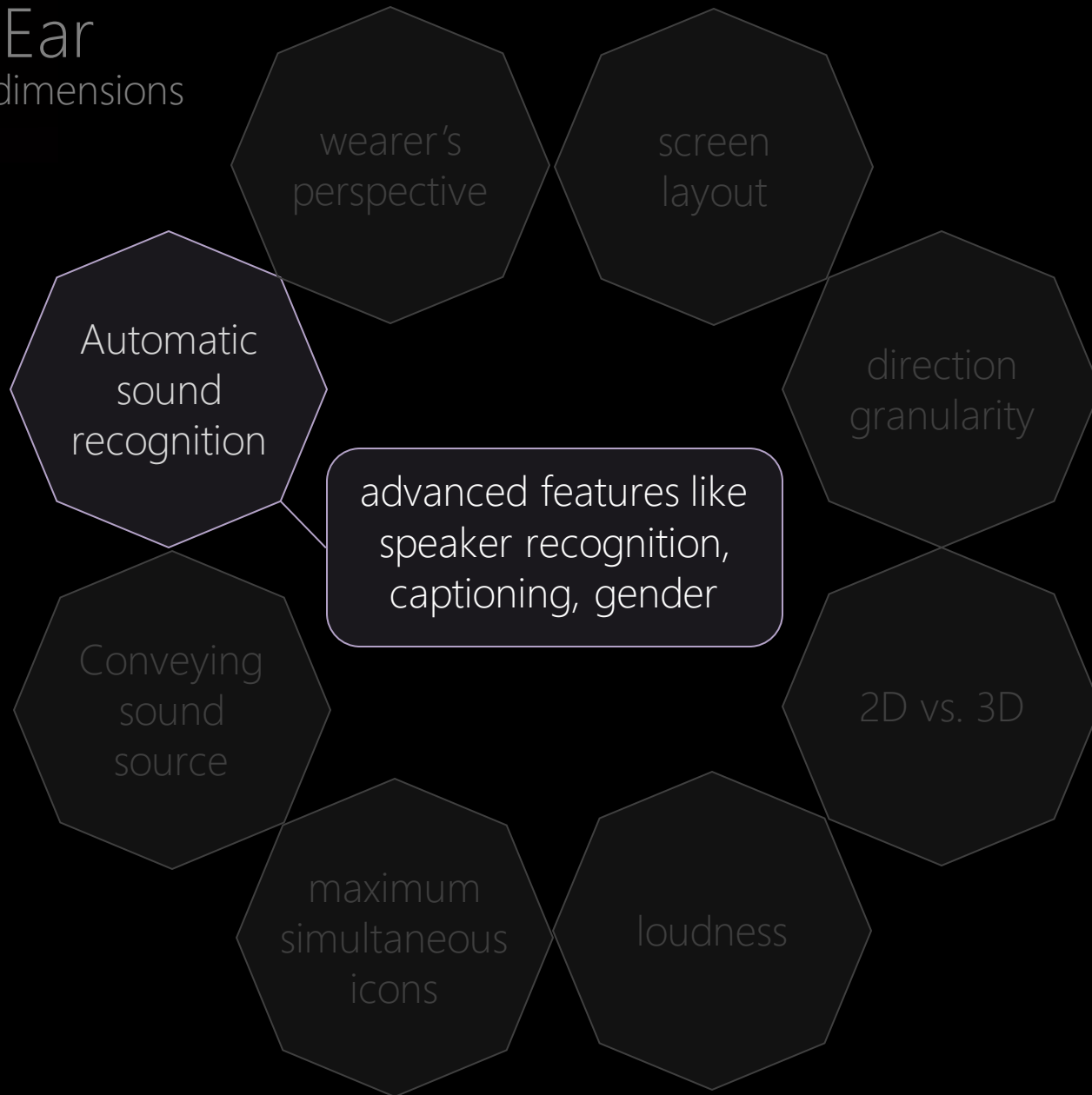














wearer's  
perspective

screen  
layout

Automatic  
sound  
recognition

direction  
granularity

the  
GLASS Ear  
design dimension

I would explain only two dimensions, given the short time

Conveying  
sound  
source

2D vs. 3D

maximum  
simultaneous  
icons

loudness

wearer's  
perspective

screen  
layout

Automatic  
sound  
recognition

direction  
granularity

the  
GL<sup>o</sup>SS Ear  
design dimensions

Conveying  
sound  
source

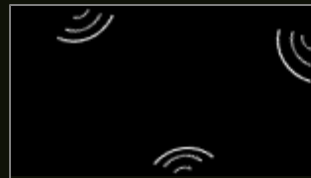
2D vs. 3D

maximum  
simultaneous  
icons

loudness

wearer's  
perspective

## EGOCENTRIC



Pulses

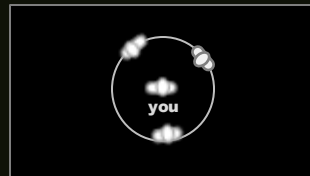


Arrows

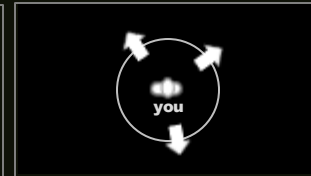


Fingers

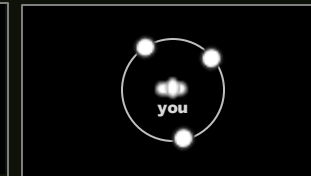
## EXOCENTRIC



People



Arrows



Circles

wearer's  
perspective

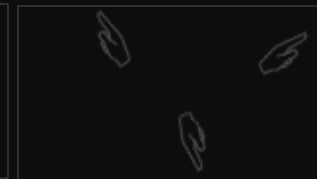
## EGOCENTRIC



Pulses

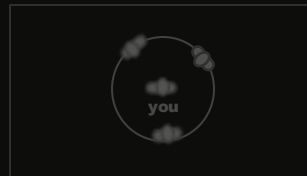


Arrows

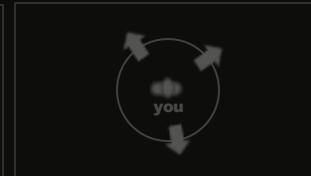


Fingers

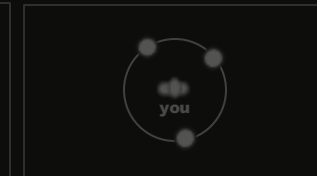
## EXOCENTRIC



People



Arrows



Circles

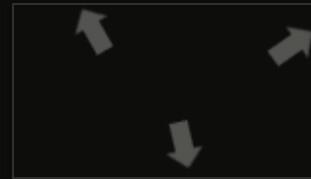


wearer's  
perspective

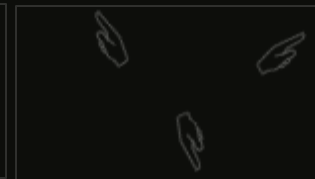
## EGOCENTRIC



Pulses

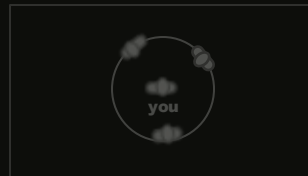


Arrows

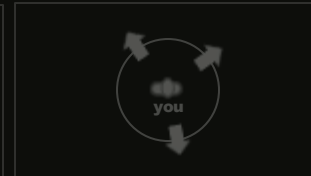


Fingers

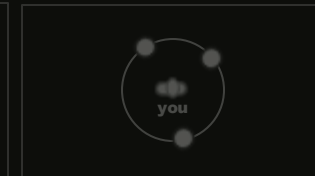
## EXOCENTRIC



People



Arrows



Circles

wearer's  
perspective >

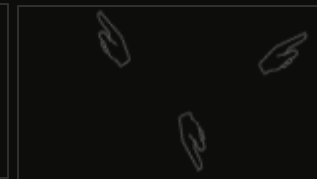
## EGOCENTRIC



Pulses



Arrows

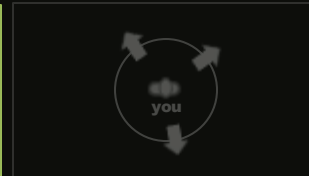


Fingers

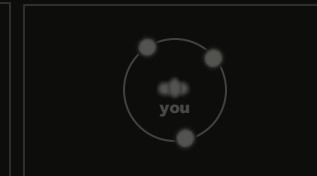
## EXOCENTRIC



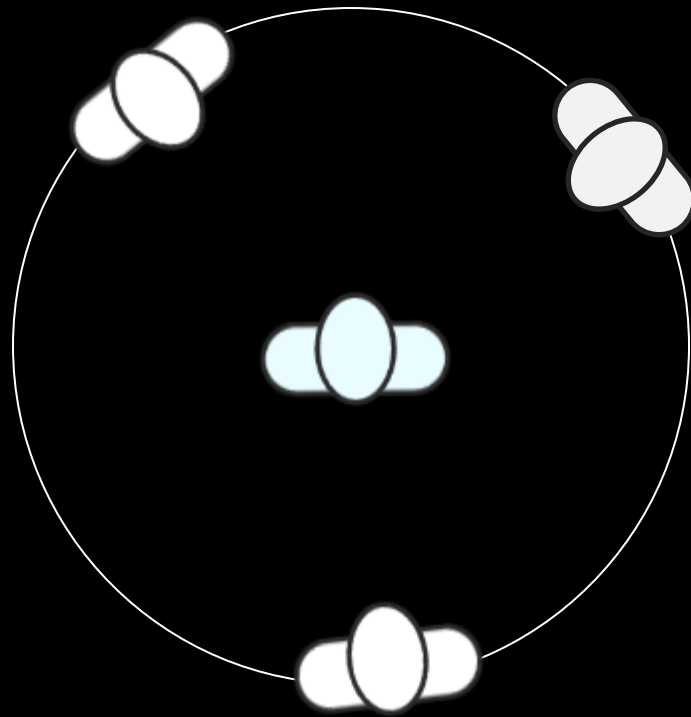
People



Arrows



Circles







wearer's  
perspective



direction  
granularity



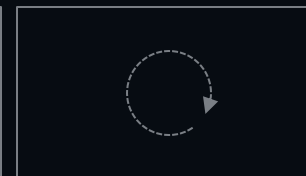
Discrete: 1-Level



Discrete: 4-Levels



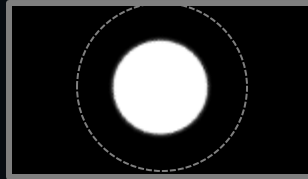
Discrete: 8-Levels



Continuous

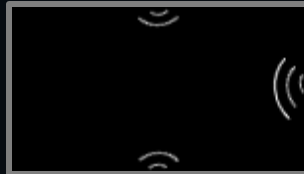
direction  
granularity

1-LEVEL

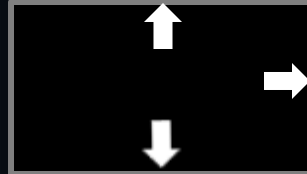


Circle

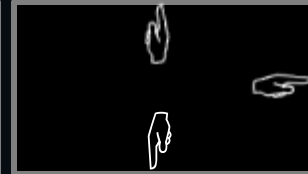
4-LEVELS



Pulses



Arrows

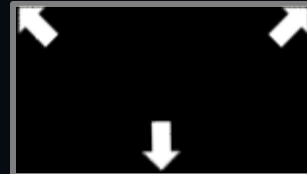


Fingers

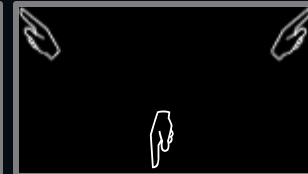
8-LEVELS



Pulses

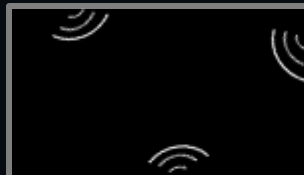


Arrows

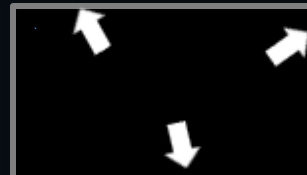


Fingers

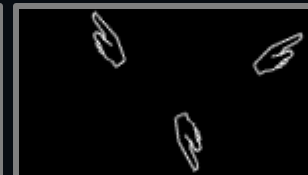
CONTINUOUS



Pulses



Arrows



Fingers

# DESIGN DIMENSIONS

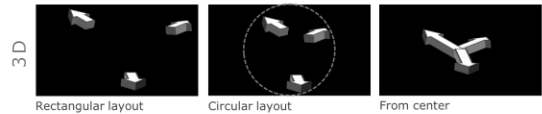
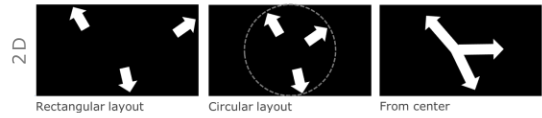
## WEARER'S PERSPECTIVE



## SCREEN LAYOUT



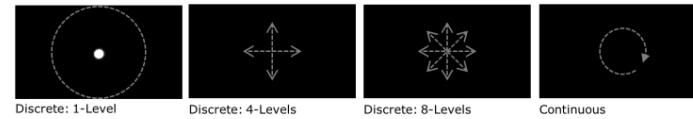
## 2D vs. 3D



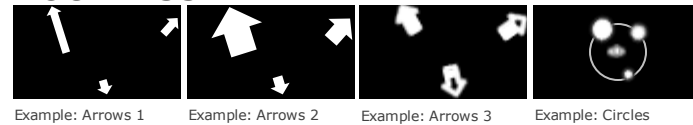
## CONVEYING SOUND SOURCE



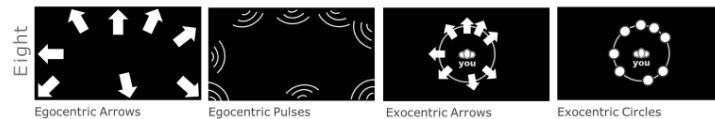
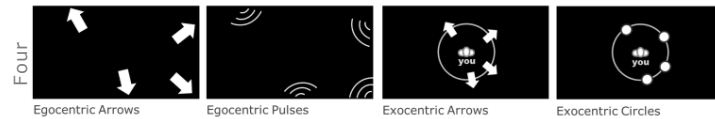
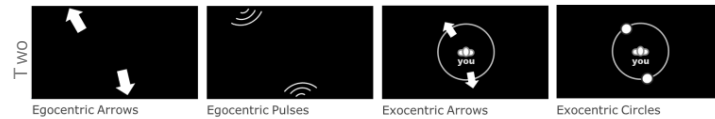
## DIRECTIONAL GRANULARITY



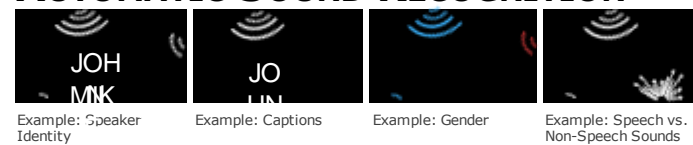
## LOUDNESS



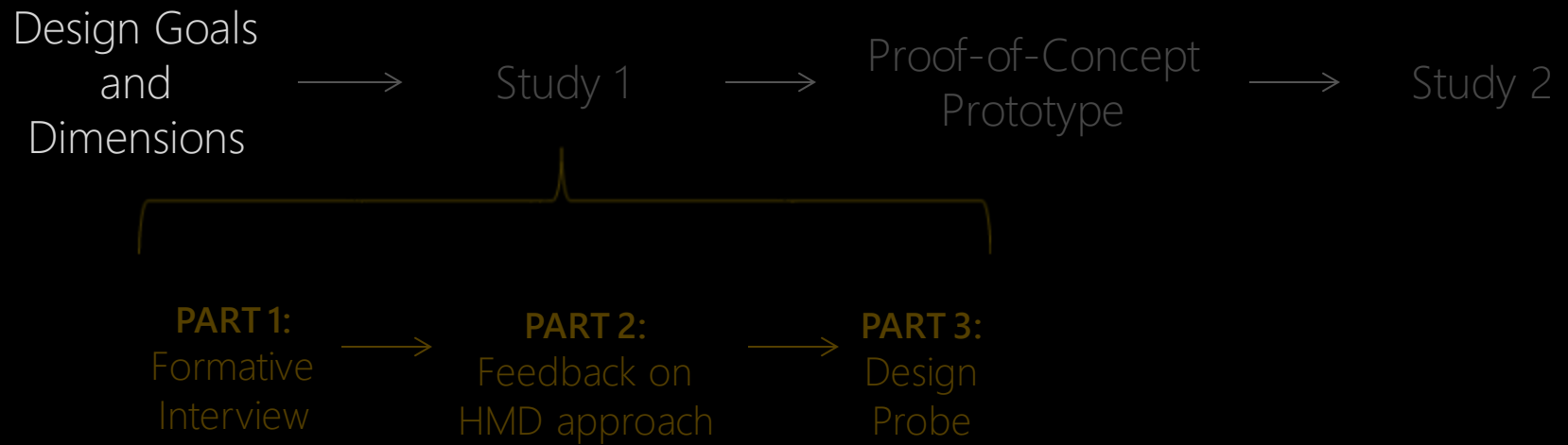
## MAXIMUM SIMULTANEOUS ICONS



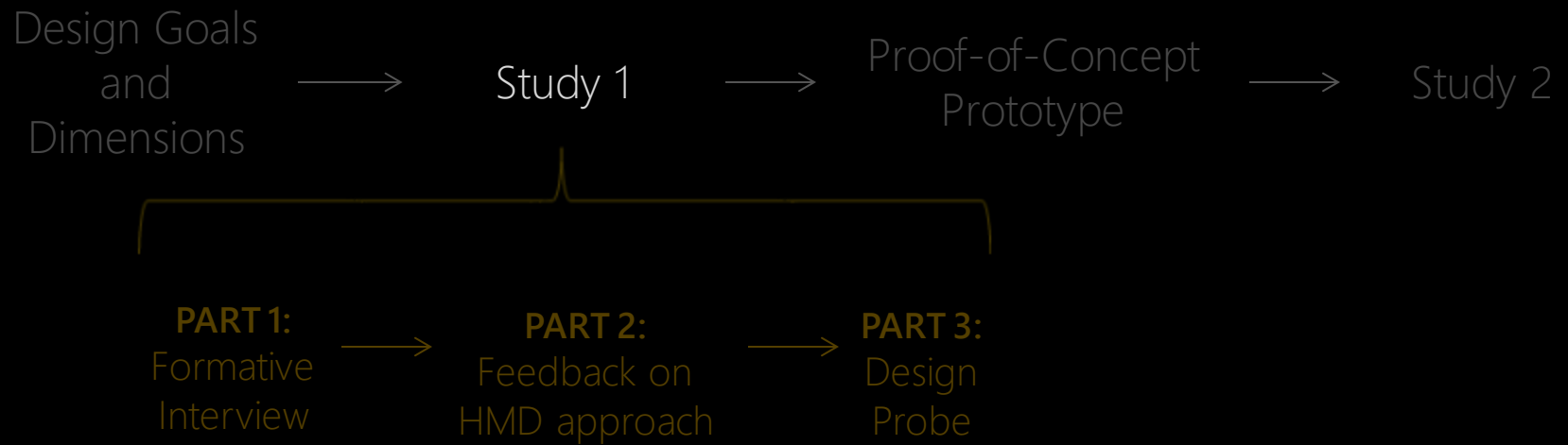
## AUTOMATIC SOUND RECOGNITION



# OUTLINE



# OUTLINE



# Study 1

People with hearing loss r x

→ ↻ [www.cs.umd.edu/~jonf/glassear.html](http://www.cs.umd.edu/~jonf/glassear.html) 🔍 ☆ 🕒

Apps Hearing Sparks SensoryPrimitives Travel Collab ATHack

## makeability lab

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### People with Hearing Loss Needed for Google Glass Study

**We received an overwhelming response and all spots are filled. If you are interested in participating in future similar studies (either online or in-person in the DC metro area), please fill out this [1 minute form](#).**

**Are you deaf or hard-of-hearing? Do you lip read? We need your help designing the next generation of accessible heads-up display technology like Google Glass!**

Our research team is studying how to make the next generation of mobile computing technology more accessible. Specifically, we are exploring the use of Google Glass to provide visual information about sound, such as where sound is coming from, who is speaking in a group conversation, and so on.

We are recruiting participants who are **deaf or hard of hearing and 18 years of age or older**. The study includes a hands-on activity with Google Glass where we will ask you for feedback on your experiences. We are also collecting basic demographic information and will briefly discuss your experiences with group conversations.

Study sessions will be conducted at our lab on the University of Maryland, College Park campus. In rare circumstances, we may be able to arrange in-person sessions at a location that is more convenient to you in the DC metropolitan area (DC, Maryland, Virginia). The study will take up to 75 minutes and you will be compensated \$20 for your time. Participants will also receive \$30 toward transportation costs if the study session is at a location you would not normally visit, making the total compensation \$50.

If you are interested in participating, please email Dhruv Jain ([djain1@umd.edu](mailto:djain1@umd.edu)) with the following information:

- Degree of hearing loss.
- Two or three possible days/times to meet between now and August 8. We are available any day of the week including Saturday and Sunday. If you are interested in participating but not available until after August 8th, we'd still like to hear from you.

Feel free to take a look at our lab's website to find out more about our research program: <http://www.cs.umd.edu/hcil/>. This research is part of a larger investigation into wearables and accessibility led by Professors [Leah Findlater, PhD](#) and [Jon Froehlich, PhD](#) at the University of Maryland.

Sincerely,

Dhruv Jain  
Department of Computer Science  
University of Maryland  
A.V. Williams Building, 4122  
College Park, MD 20742  
<http://dhruvian.info>

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## Recruitment

- Online postings and social media
- Received ~300 responses, recruited 24

## Study Method

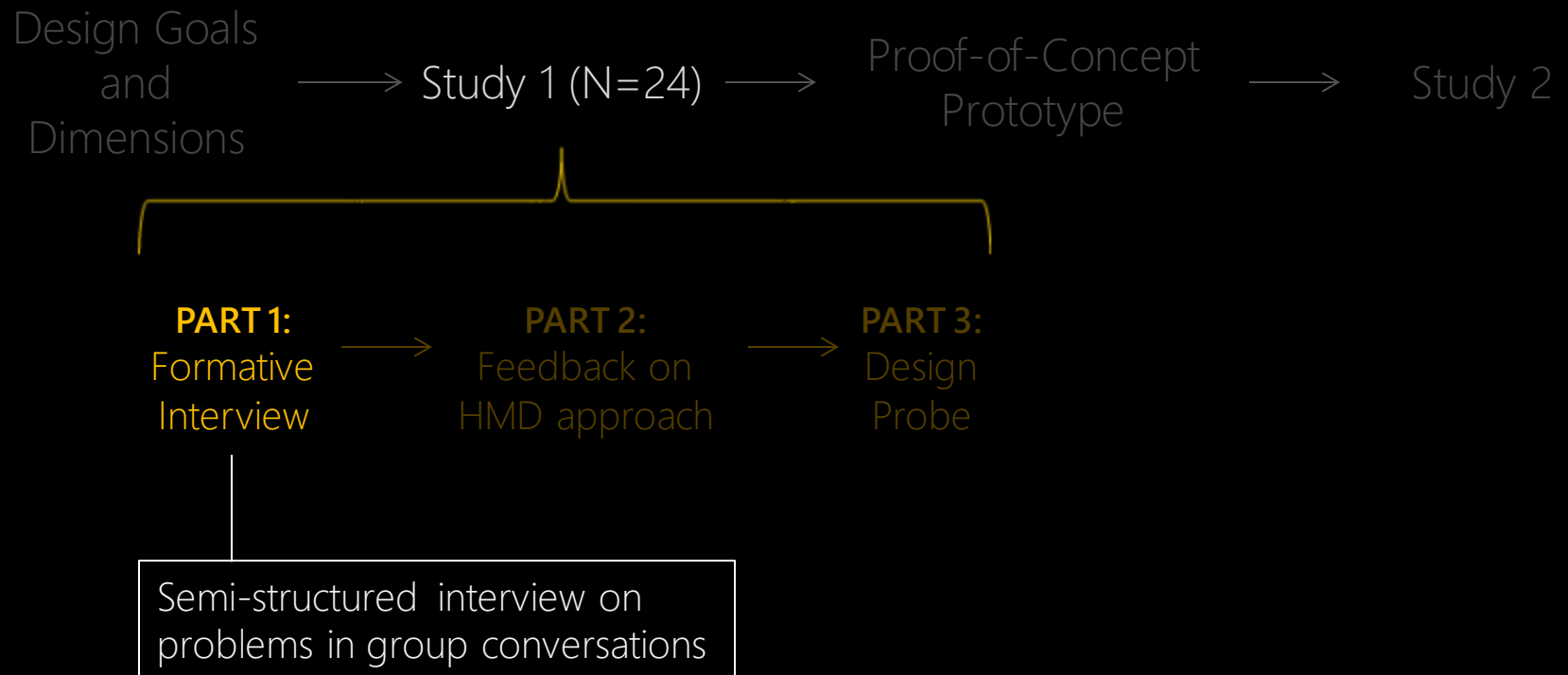
- Semi-structured interview, feedback on HMD approach and design probe
- Average 67 minutes
- Participated communicated verbally (N=9) or by typing (N=15), according to preference

## Participants

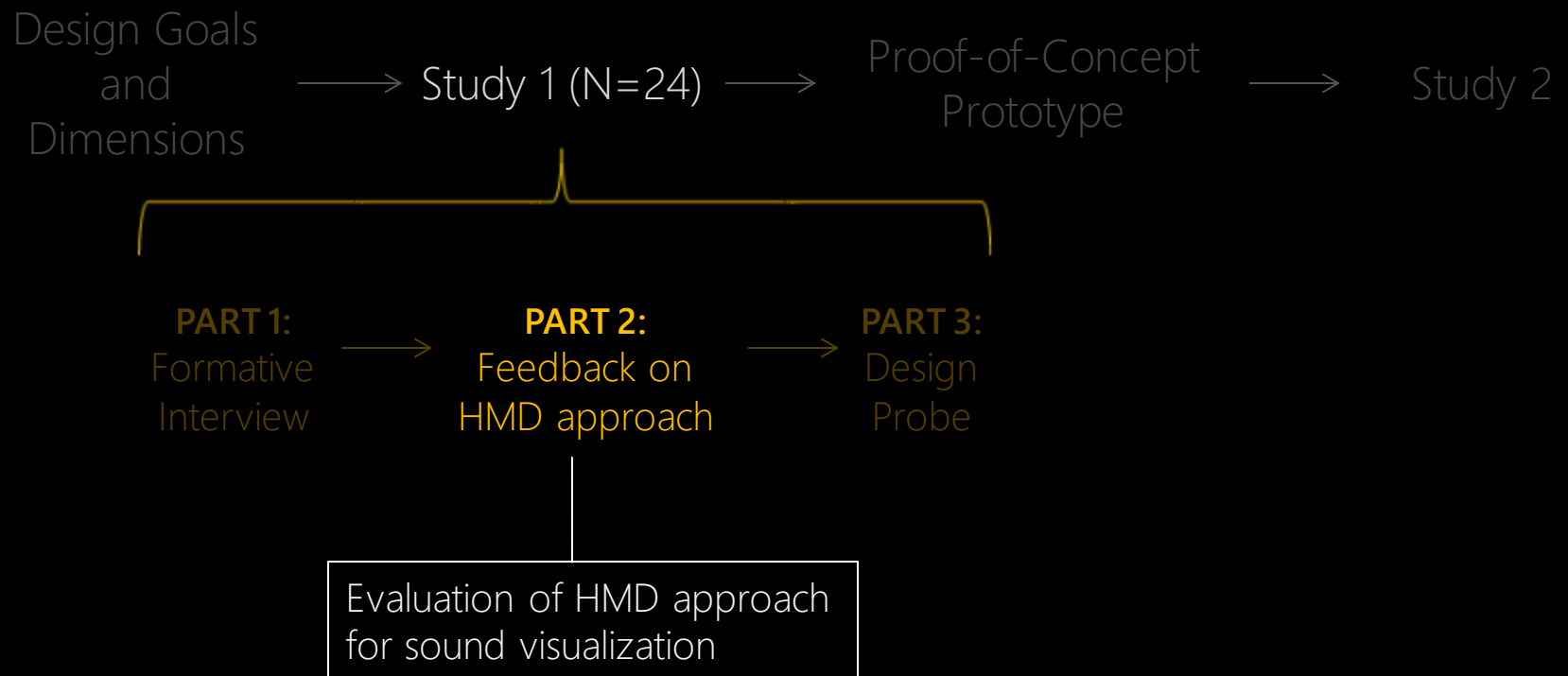
- 12 female/12 male
- 20 with profound, the remaining 4 had at least moderate hearing loss
- 19 employed lip-reading during conversations



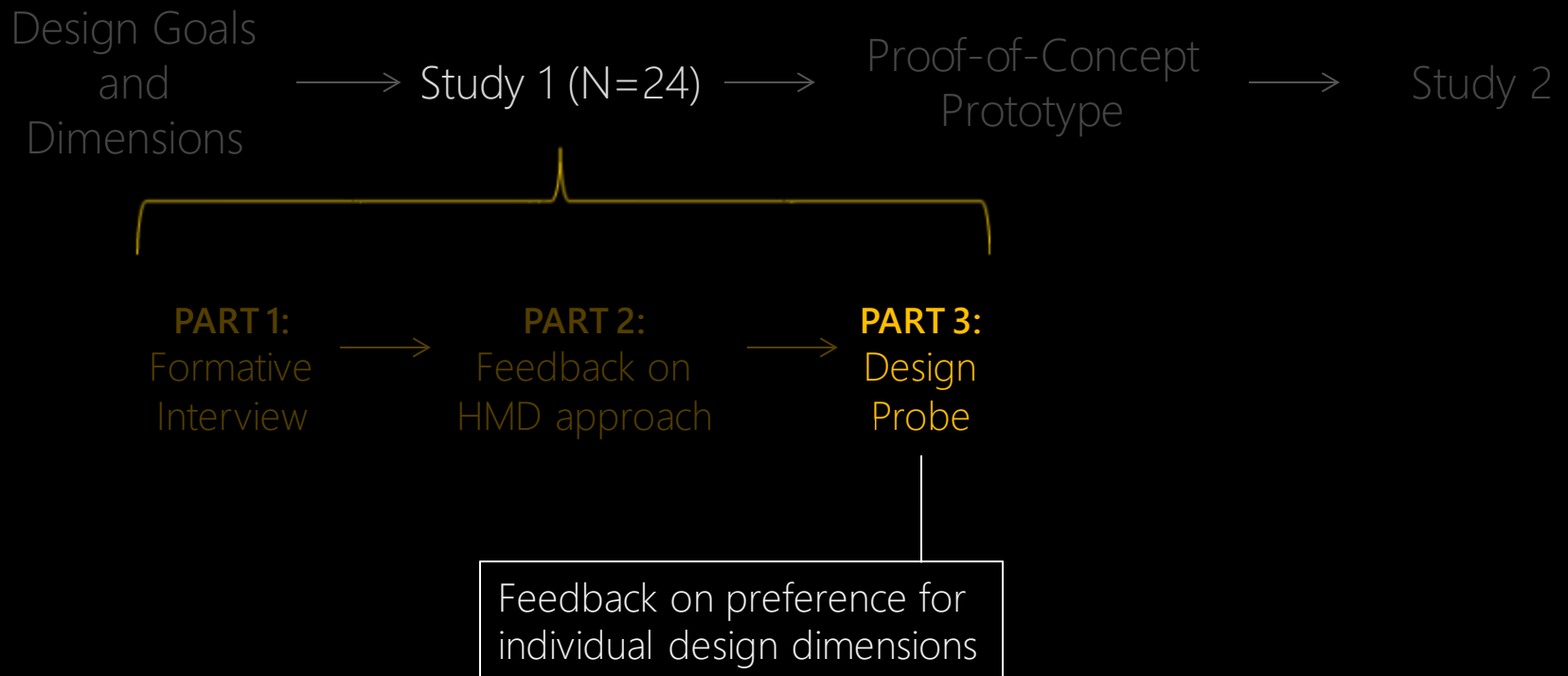
# OUTLINE



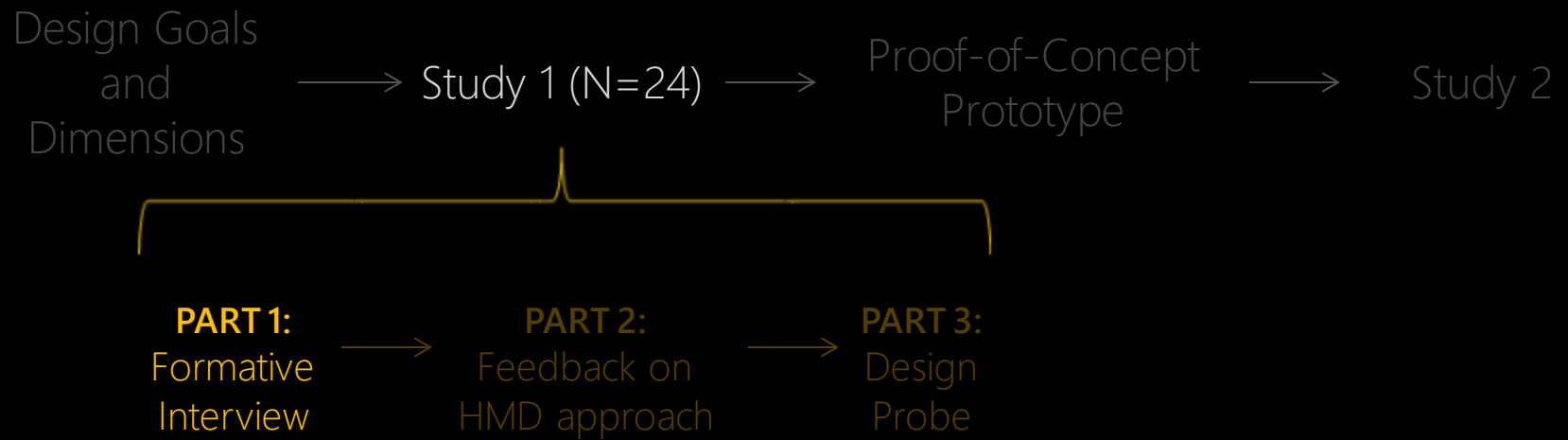
# OUTLINE



# OUTLINE



# OUTLINE

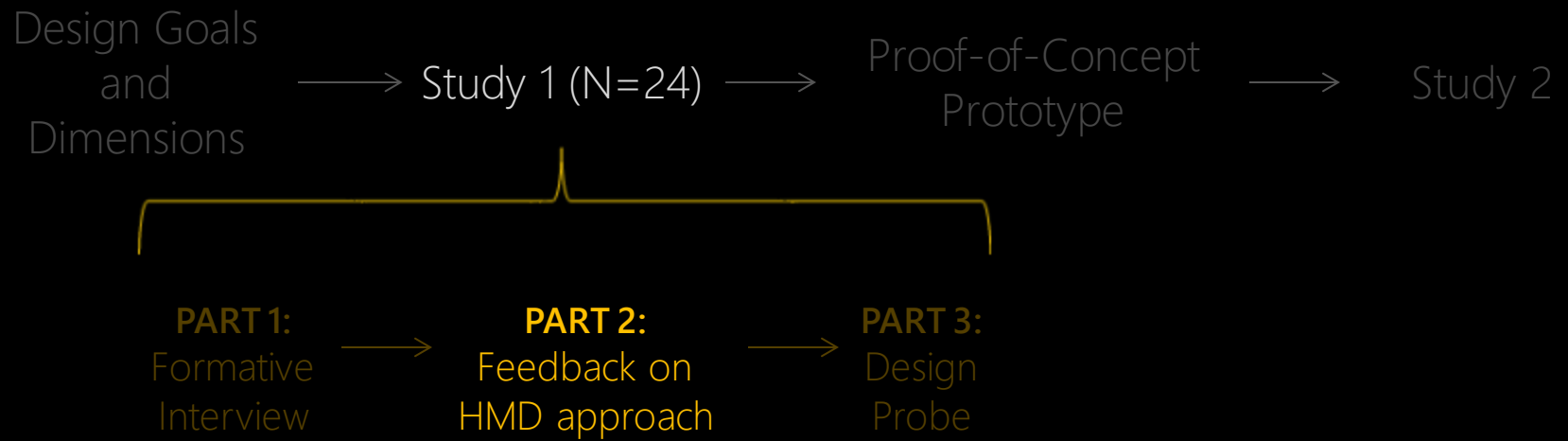


## STUDY 1 PART 1: FORMATIVE INTERVIEW

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- **Problems encountered** in group conversations
- How the participant **accommodated** those problems
- Prior experience with **computing or mobile devices** to support group conversation
- **Ideas for future** technology

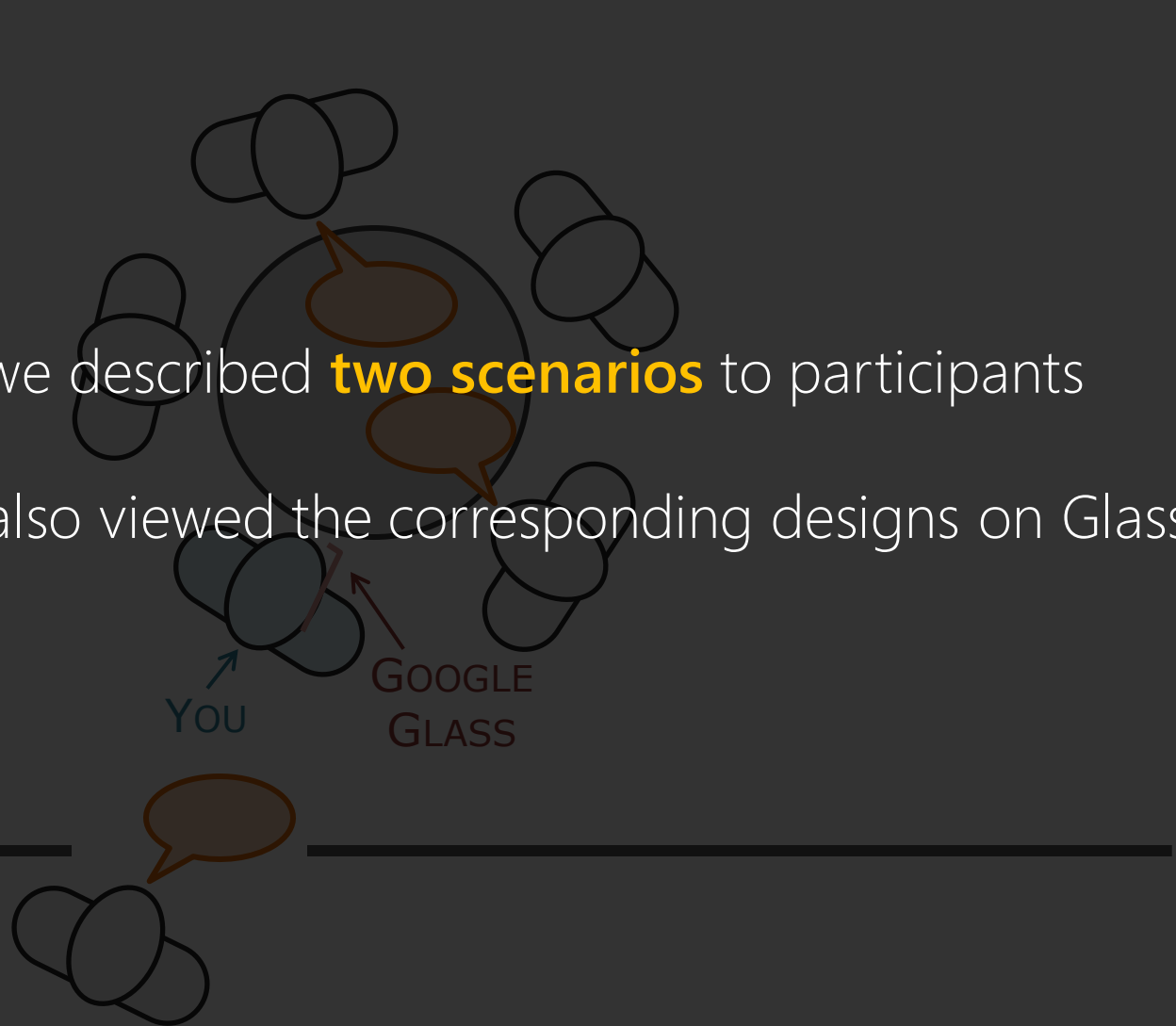
# OUTLINE



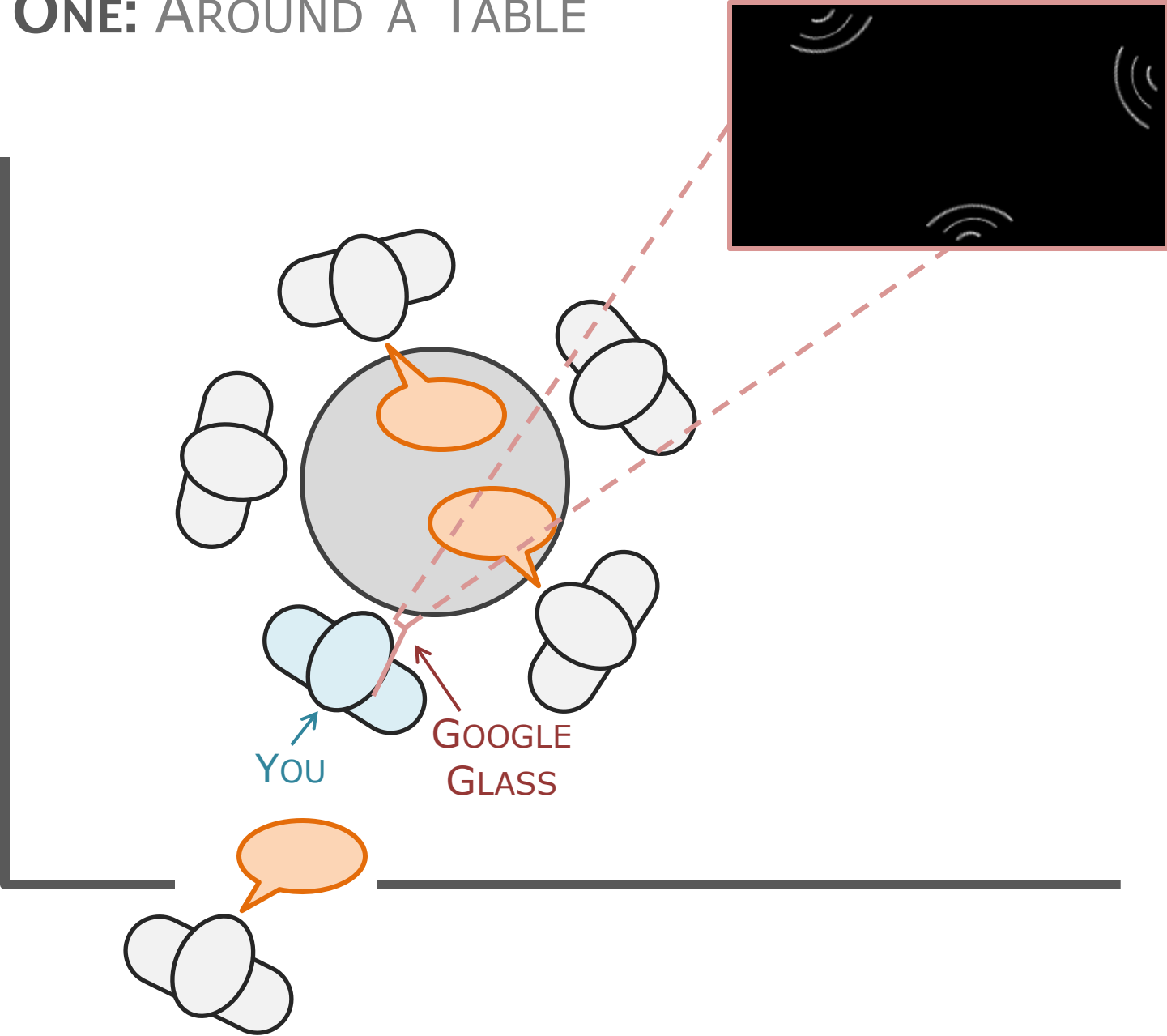
# SCENARIO ONE: AROUND A TABLE

Initially, we described **two scenarios** to participants

Participants also viewed the corresponding designs on Glass

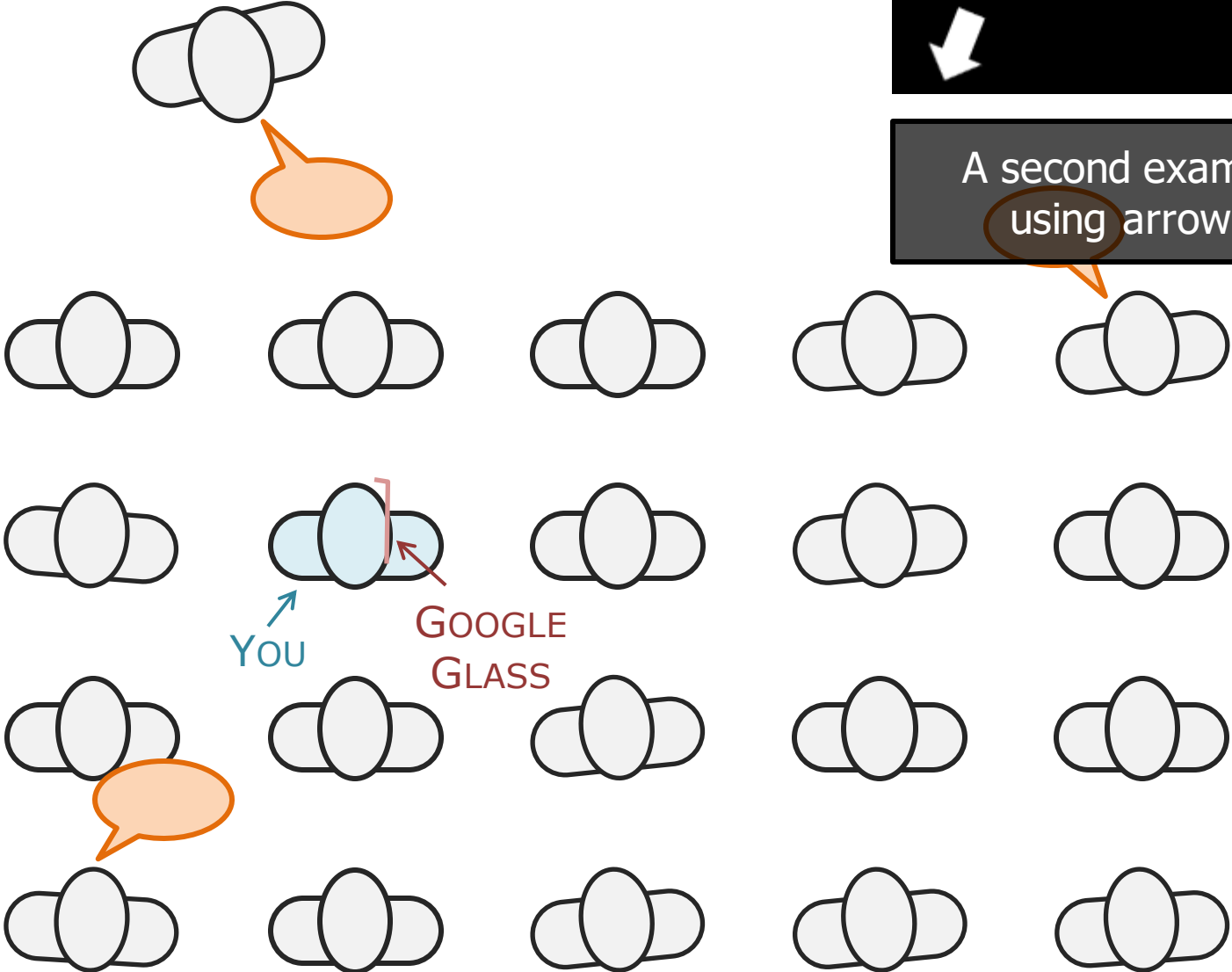


# SCENARIO ONE: AROUND A TABLE





# SCENARIO TWO: IN A CLASSROOM



A second example using arrows



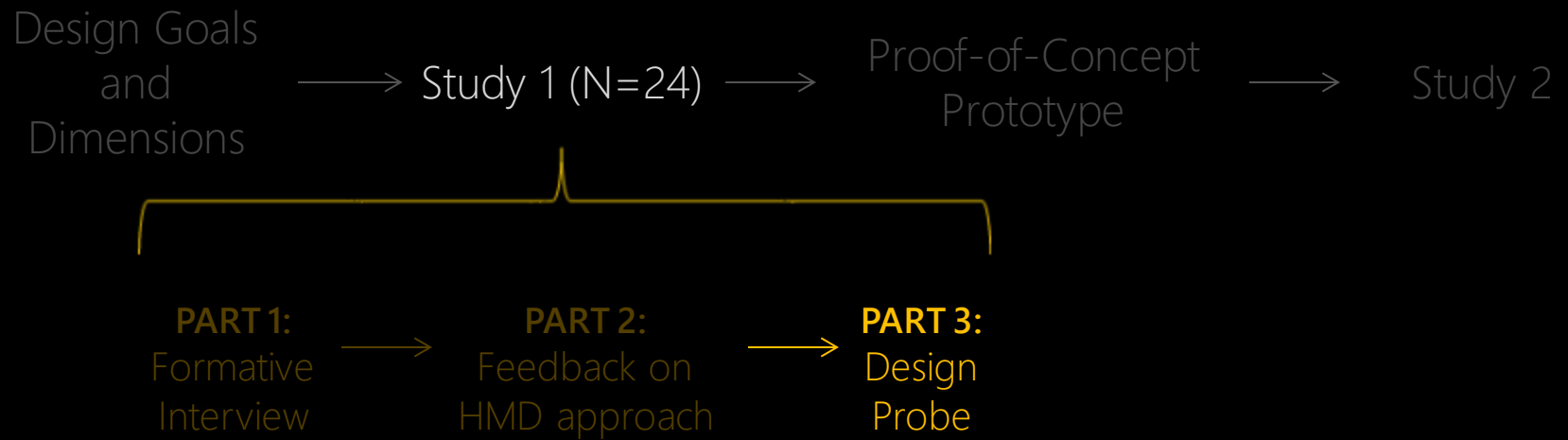
An example video shows a participant viewing the scenarios

Participant: P13  
Moderate hearing loss

(Please download the powerpoint version to view the video)



# OUTLINE



# Design **Probe**

# Design Probe



IPAD



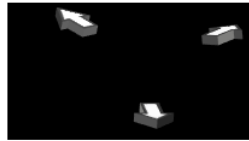
GLASS

**TWO VISUAL MEDIUMS**

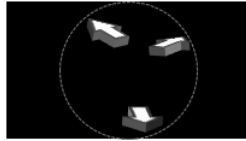
# Design Probe

Which one do you prefer: 3D or 2D? Why?

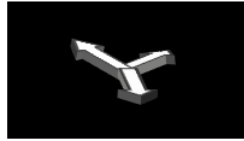
3D



Rectangular layout



Circular layout

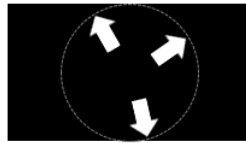


From center

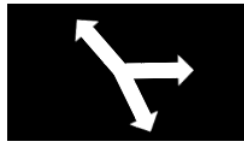
2D



Rectangular layout

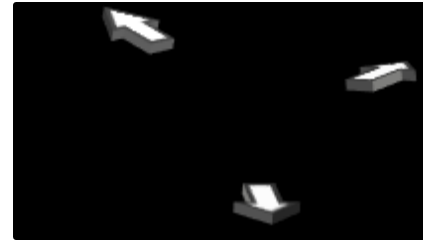


Circular layout

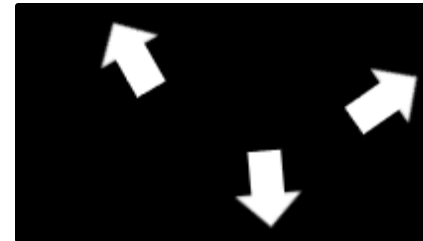


From center

3D



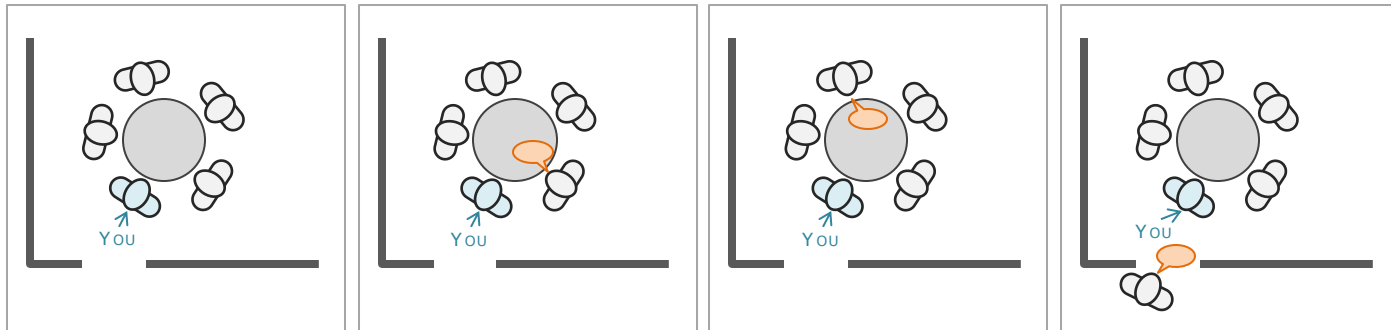
2D



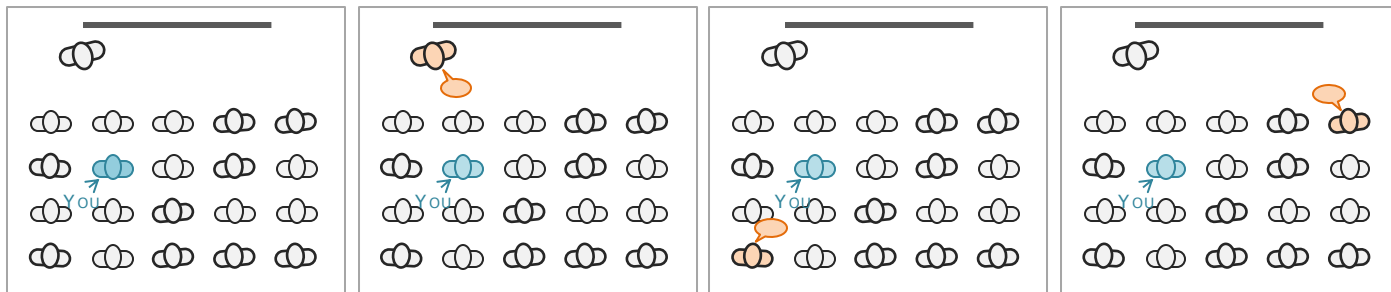
IPAD

GLASS

# Design Probe



SCENARIO 1: AROUND A TABLE



SCENARIO 2: IN A CLASSROOM



We **evaluated** the **design dimensions** by showing examples

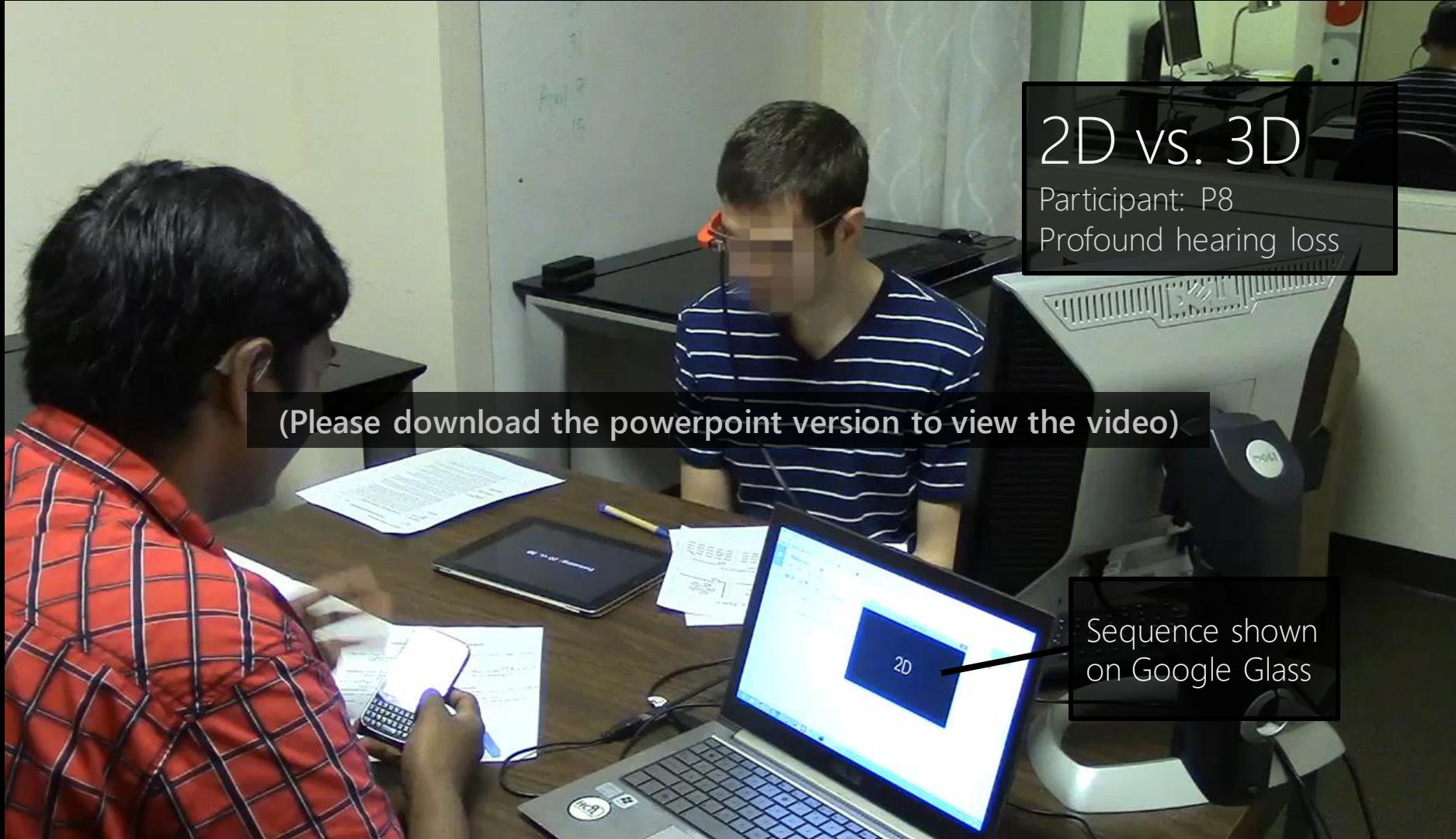
We asked for **open ended feedback** and  
**specific preference** with **rationale**

Two example videos demonstrate this

2D vs. 3D  
Participant: P8  
Profound hearing loss

(Please download the powerpoint version to view the video)

Sequence shown  
on Google Glass



# Sequence shown on iPad

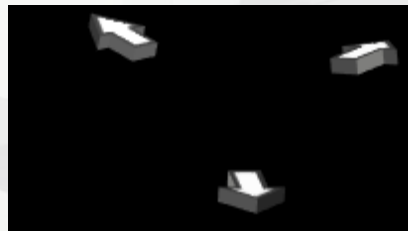
Which one do you prefer: 3D or 2D? Why?

2D vs. 3D

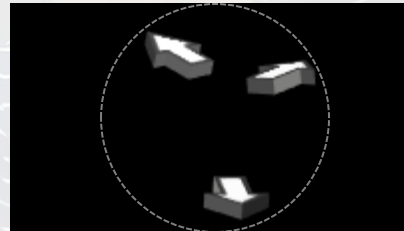
Participant: P8

Profound hearing loss

3D



Rectangular layout

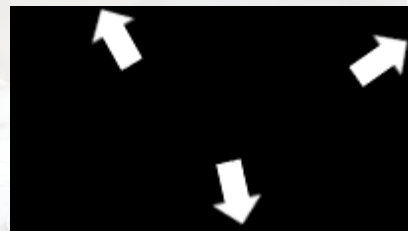


Circular layout

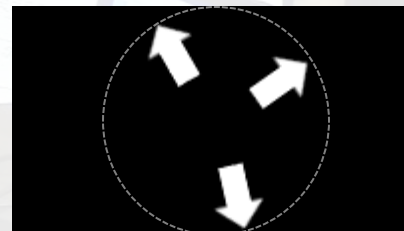


From center

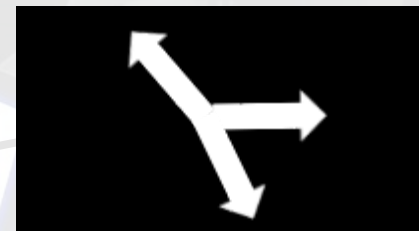
2D



Rectangular layout

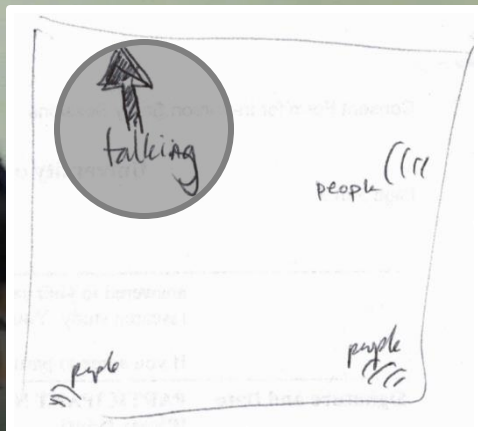


Circular layout



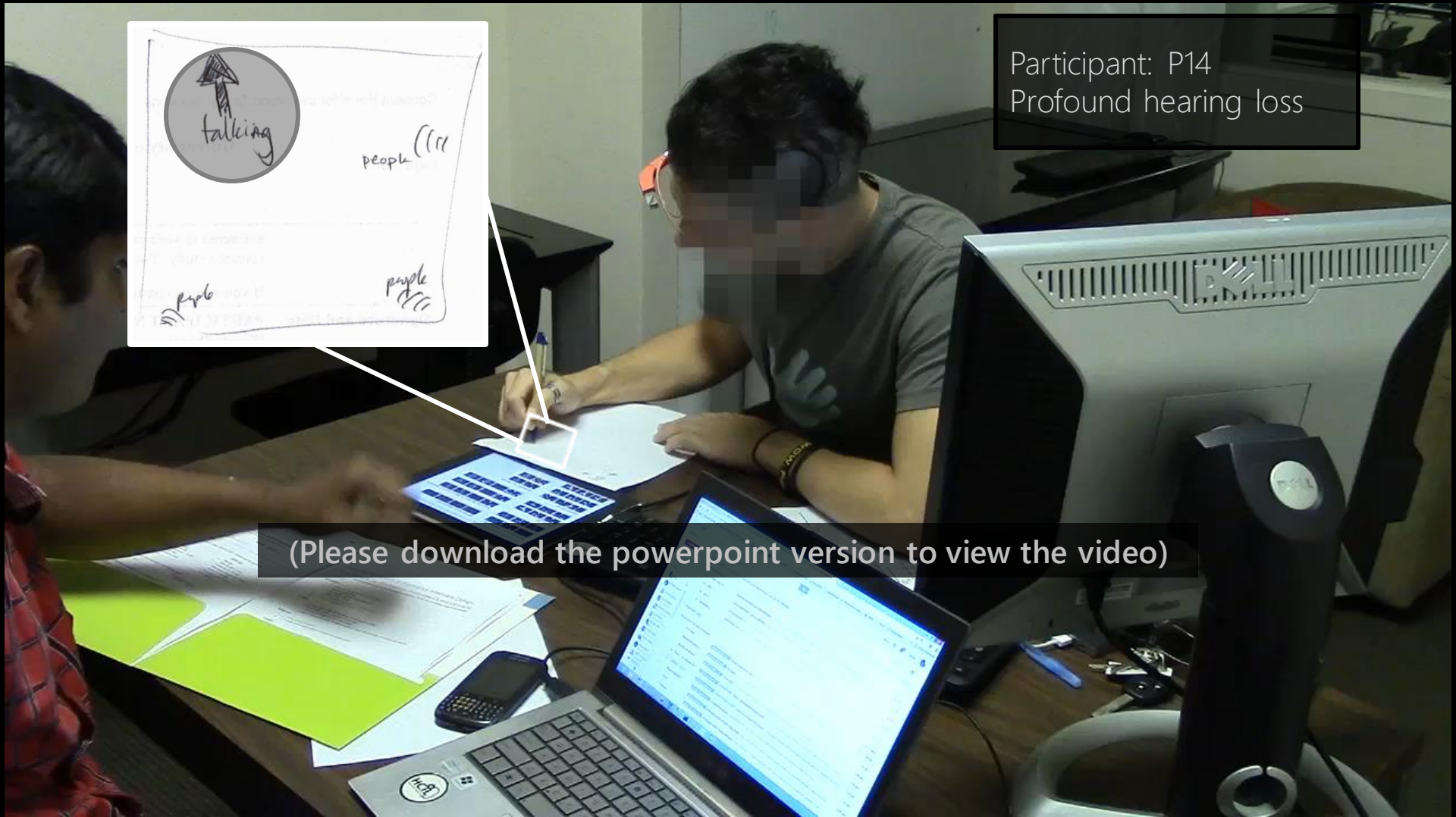
From center

# When asked to sketch their own designs...



Participant: P14  
Profound hearing loss

(Please download the powerpoint version to view the video)

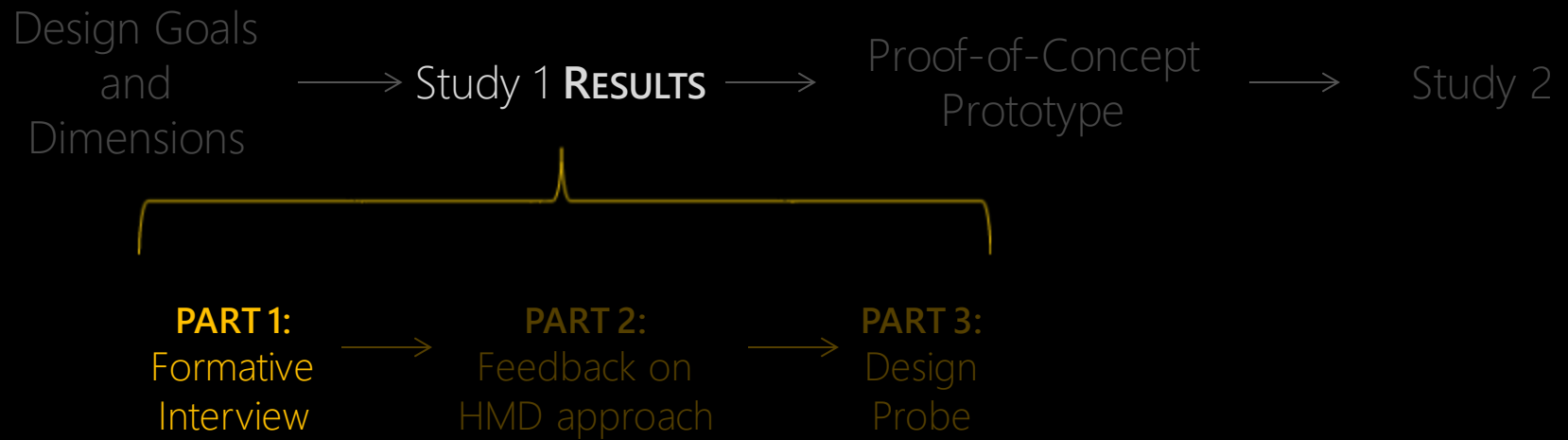


# Results


Study 1: Evaluating Design Dimensions



# OUTLINE




Two researchers iteratively coded the formative interview



All 24 participants agreed that communicating in a group with hearing persons can be challenging





“If one person finishes talking, I do not know who to look at next—that is my problem because hearing people can hear who the next person is, and what they are saying.”

-P20, profound hearing loss

# ADAPTIVE STRATEGIES FOR GROUP COMMUNICATION

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## Traditional techniques

Interpreters/Captioners

Participants mentioned various strategies for group communication



## Low-fidelity adaptation

Pen/Paper

(7 Participants)




## Use of technology

iPhone/Computer

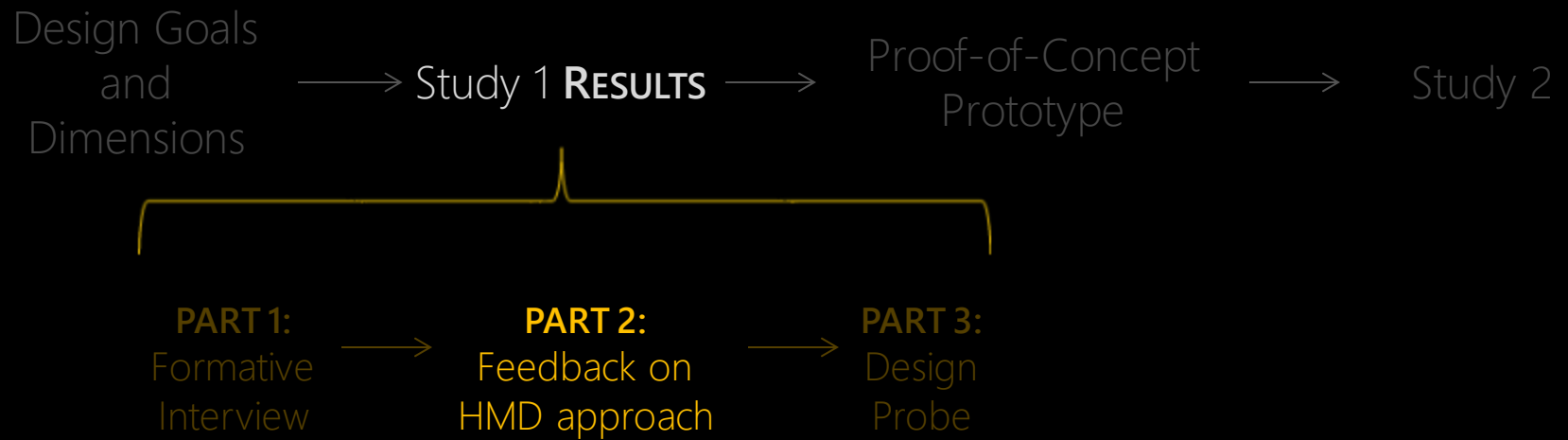
(16 Participants)

RESULTS OF STUDY 1: PART 1 (FORMATIVE INTERVIEW)

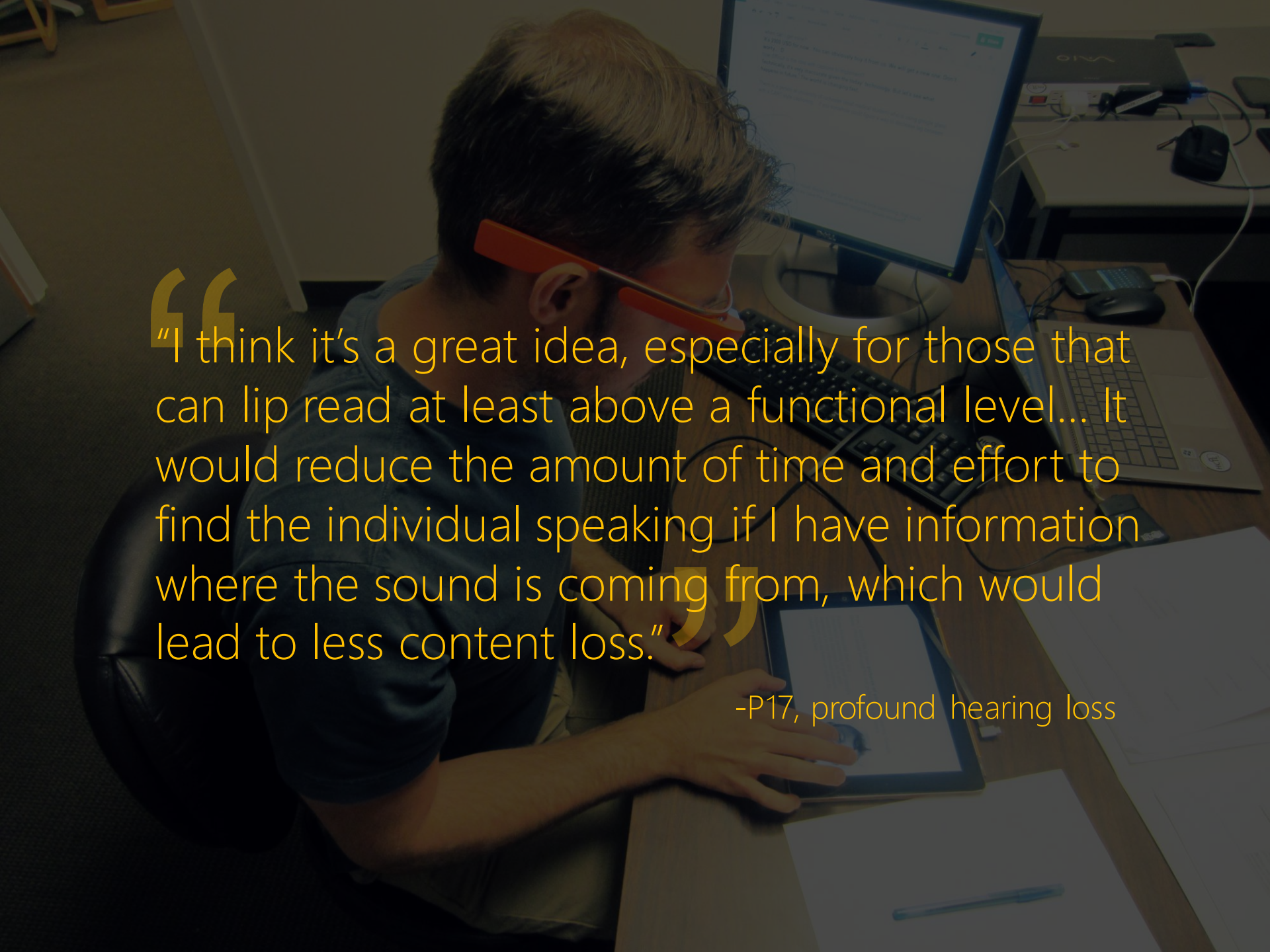


7 participants mentioned maladaptive strategies,  
i.e. distract or prevent communication

# OUTLINE



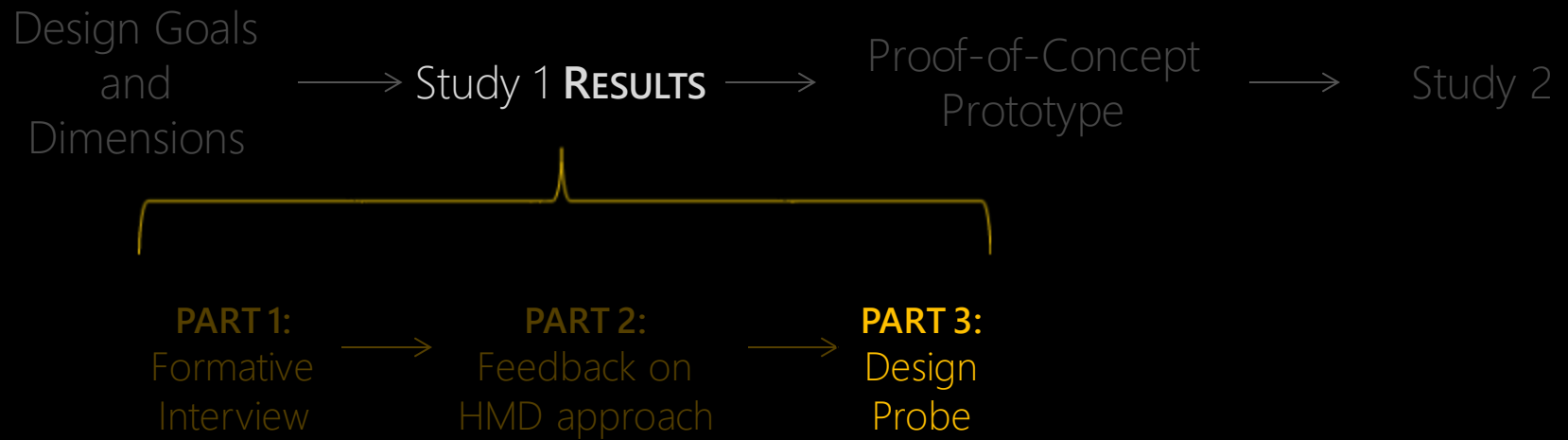
All 24 participants thought the idea of head-mounted visualizations for sound awareness was useful

A person with a hearing aid is sitting at a desk, looking at a laptop and a tablet. The person is wearing a blue t-shirt and a black chair. The desk has a laptop, a tablet, a keyboard, and a mouse. The background shows a computer monitor and some papers.

“I think it’s a great idea, especially for those that can lip read at least above a functional level... It would reduce the amount of time and effort to find the individual speaking if I have information where the sound is coming from, which would lead to less content loss.”

-P17, profound hearing loss

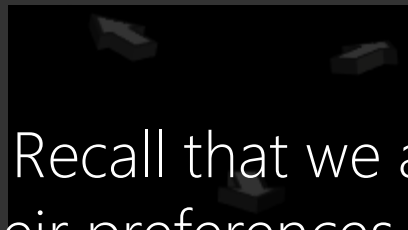
# OUTLINE



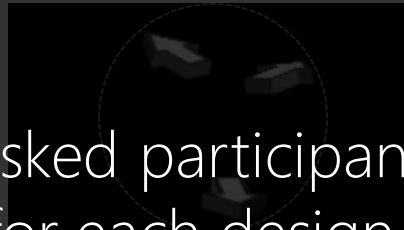
# PREFERENCES FOR DESIGN DIMENSIONS

Which one do you prefer: 3D or 2D? Why?

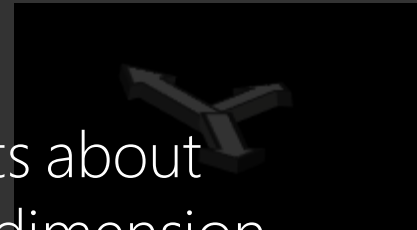
3D



Rectangular layout



Circular layout



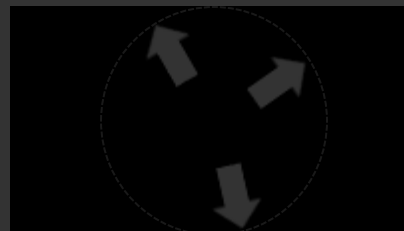
From center

Recall that we asked participants about their preferences for each design dimension

2D



Rectangular layout



Circular layout

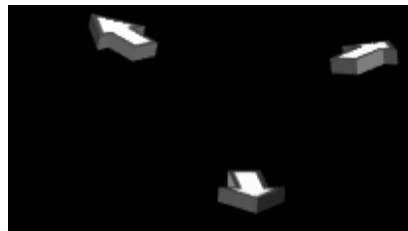


From center

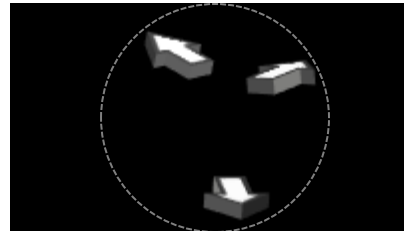


# Which one do you prefer: 3D or 2D? Why?

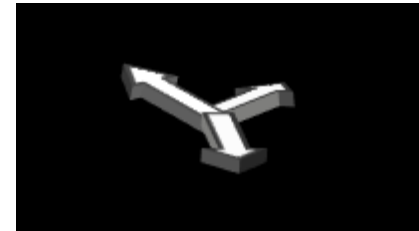
3D



Rectangular layout

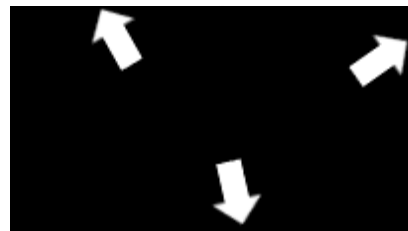


Circular layout

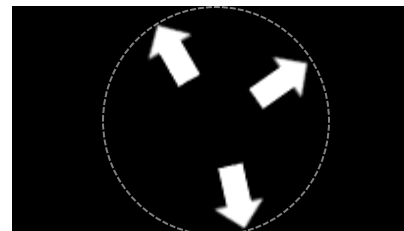


From center

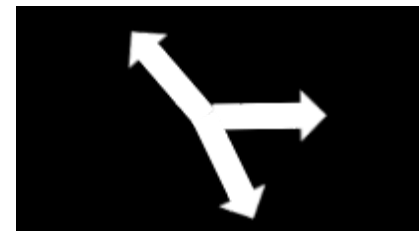
2D



Rectangular layout



Circular layout



From center

## Chi-Square Test on Distribution of Preference

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One vote for "Yes"

Zero vote for "No"

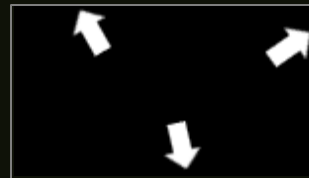
0.5 vote each for "Maybe", "I like both"

wearer's  
perspective

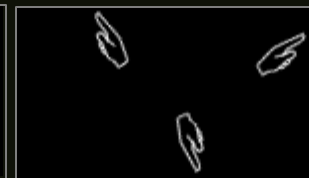
EGOCENTRIC  
(11 VOTES)



Pulses

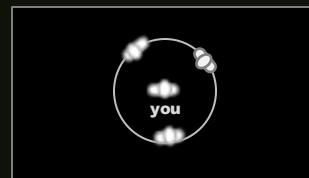


Arrows

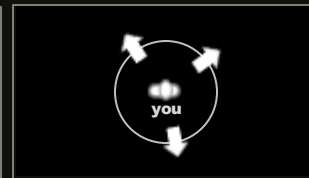


Fingers

EXOCENTRIC  
(13 VOTES)



People



Arrows

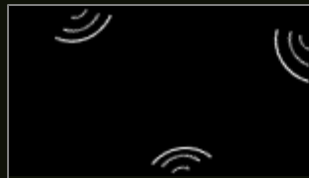


Circles

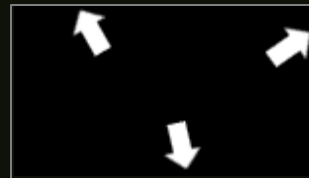
$$\chi^2_{(1, N=24)} = 0.04, p = ns$$

wearer's  
perspective

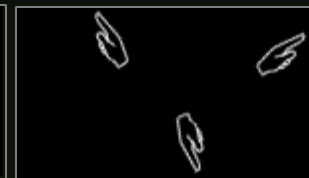
EGOCENTRIC  
(11 VOTES)



Pulses

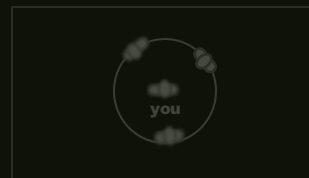


Arrows

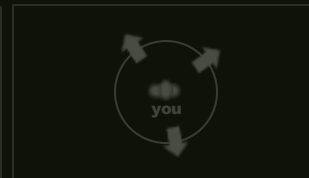


Fingers

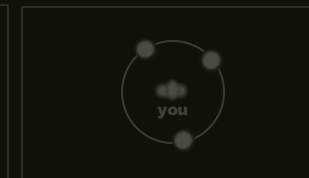
EXOCENTRIC  
(13 VOTES)



People



Arrows



Circles

$$\chi^2_{(1, N=24)} = 0.04, p = ns$$

# EGOCENTRIC PERSPECTIVE (11 VOTES)



Easier to interpret  
(4 Participants)

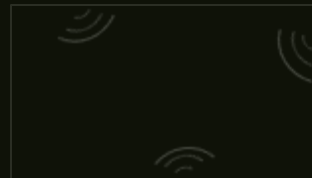


Less cluttered  
(3 Participants)

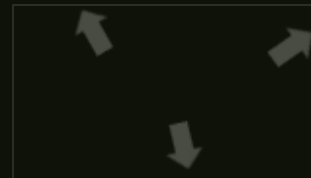


wearer's  
perspective

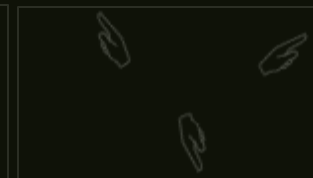
EGOCENTRIC  
(11 VOTES)



Pulses

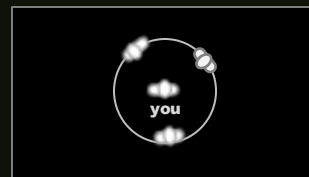


Arrows



Fingers

EXOCENTRIC  
(13 VOTES)



People



Arrows



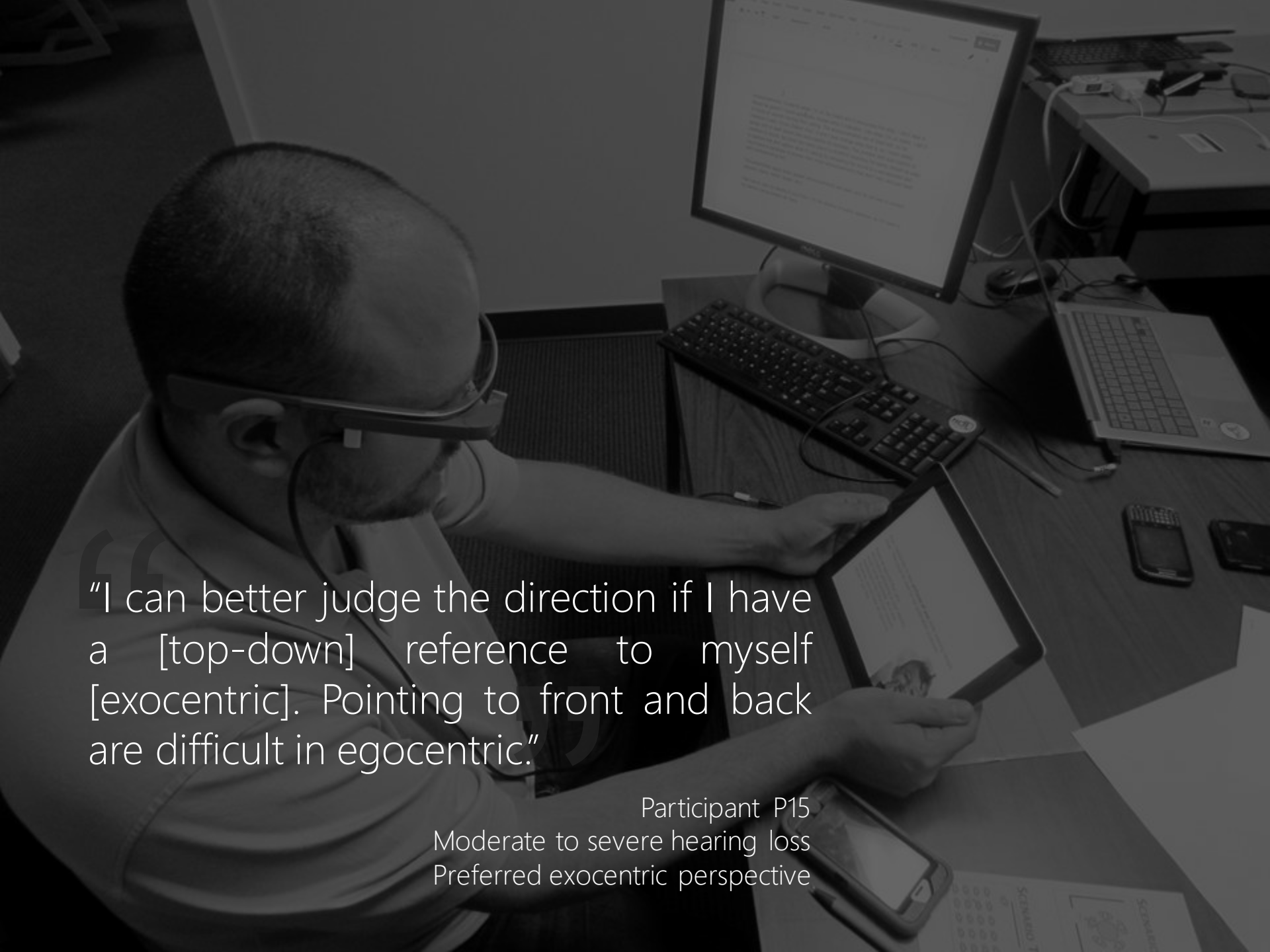
Circles

$$\chi^2_{(1, N=24)} = 0.04, p = ns$$

# EXOCENTRIC PERSPECTIVE (13 VOTES)

Shows the location of the wearer  
(12 Participants)





“I can better judge the direction if I have a [top-down] reference to myself [exocentric]. Pointing to front and back are difficult in egocentric.”

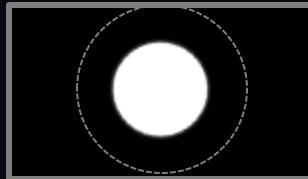
Participant P15  
Moderate to severe hearing loss  
Preferred exocentric perspective



Both egocentric and exocentric were well received, so **either could be used**

direction  
granularity

1-LEVEL  
(1 VOTE)



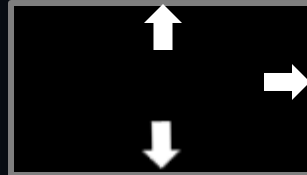
Circle

$$\chi^2_{(3, N=24)} = 17.75, p < .001$$

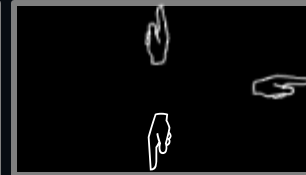
4-LEVELS  
(3 VOTES)



Pulses



Arrows



Fingers

8-LEVELS  
(5.5 VOTES)



Pulses

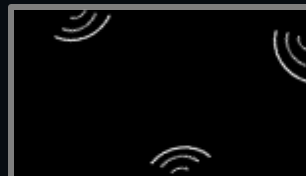


Arrows

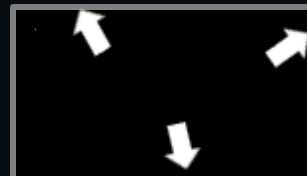


Fingers

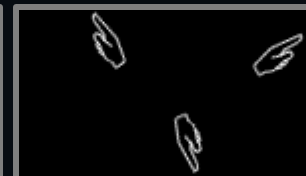
CONTINUOUS  
(14.5 VOTES)



Pulses



Arrows



Fingers

direction  
granularity

1-LEVEL  
(1 VOTE)

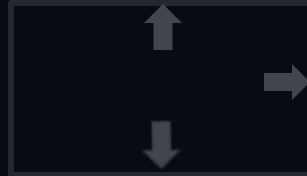


Circle

4-LEVELS  
(3 VOTES)



Pulses

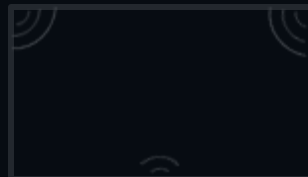


Arrows

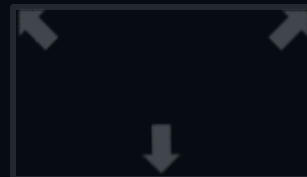


Fingers

8-LEVELS  
(5.5 VOTES)



Pulses

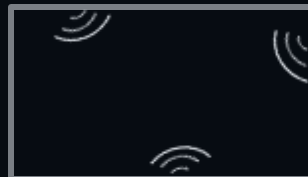


Arrows



Fingers

CONTINUOUS  
(14.5 VOTES)



Pulses



Arrows



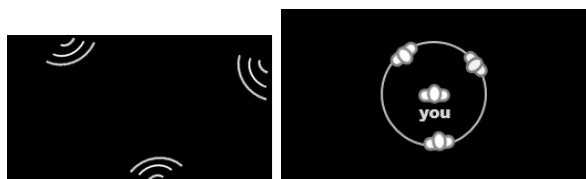
Fingers

$$\chi^2_{(3, N=24)} = 17.75, p < .001$$

Precision is valued,  
use **high** directional **granularity**

# PREFERENCES FOR SOME DESIGN DIMENSIONS

## WEARER'S PERSPECTIVE



EGOCENTRIC  
11 VOTES

EXO-CENTRIC  
13 VOTES

## DIRECTIONAL GRANULARITY



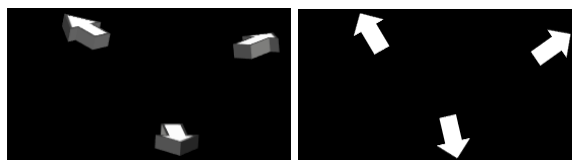
CONTINUOUS  
14.5 VOTES

8-LEVEL  
5.5 VOTES

4-LEVEL  
3 VOTES

1-LEVEL  
1 VOTE

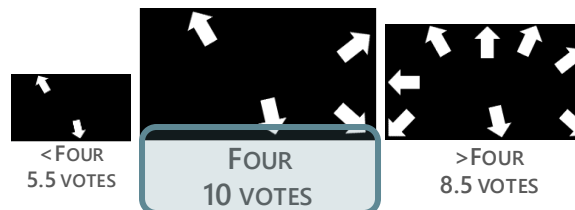
## 2D vs. 3D



3D  
12 VOTES

2D  
12 VOTES

## MAXIMUM SIMULTANEOUS ICONS

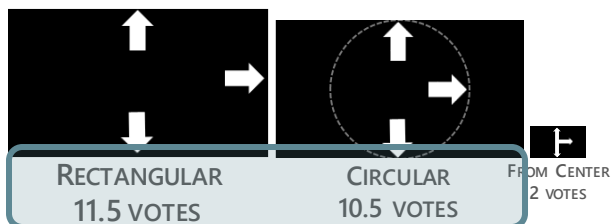


<FOUR  
5.5 VOTES

FOUR  
10 VOTES

>FOUR  
8.5 VOTES

## SCREEN LAYOUT

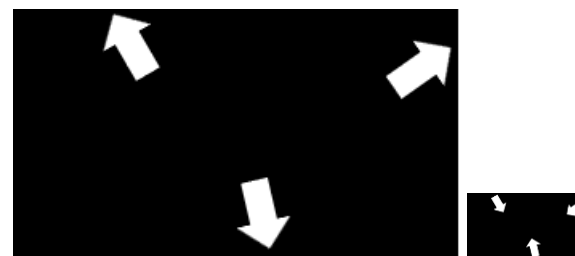


RECTANGULAR  
11.5 VOTES

CIRCULAR  
10.5 VOTES

FROM CENTER  
2 VOTES

## CONVEYING SOUND SOURCE

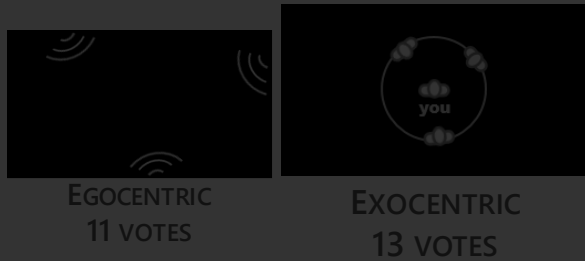


OUTWARD  
19 VOTES

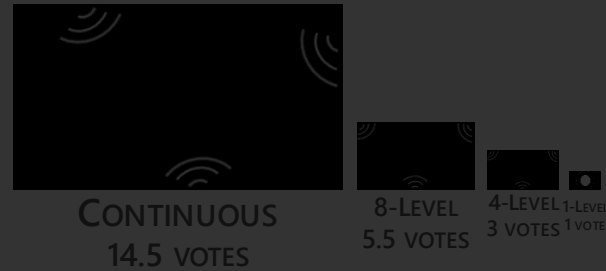
INWARD  
5 VOTES

# PREFERENCES FOR SOME DESIGN DIMENSIONS

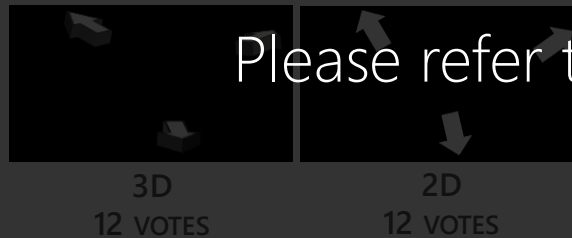
## WEARER'S PERSPECTIVE



## DIRECTIONAL GRANULARITY



## 2D vs. 3D

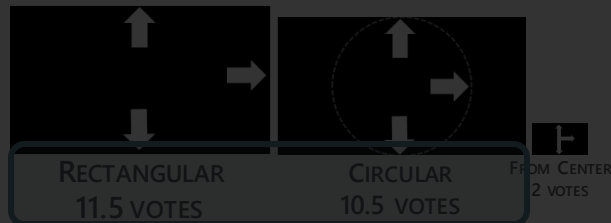


Please refer to the paper for more design results

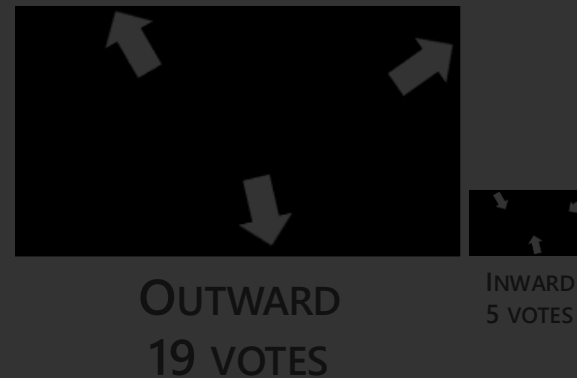
## MAXIMUM SIMULTANEOUS ICONS



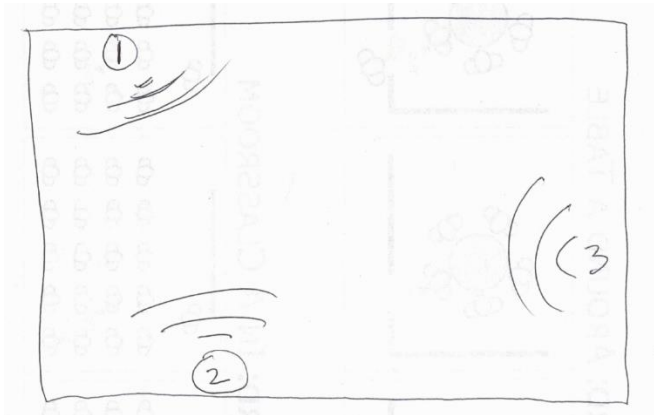
## SCREEN LAYOUT



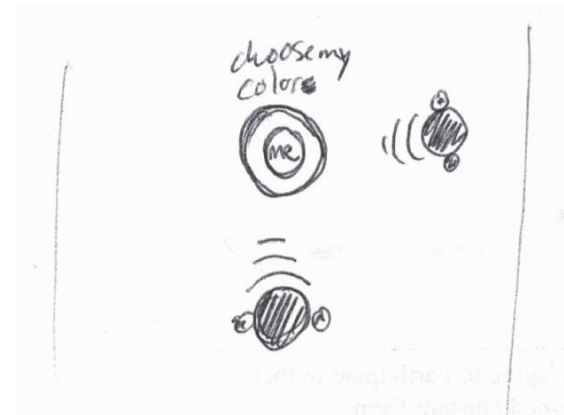
## CONVEYING SOUND SOURCE



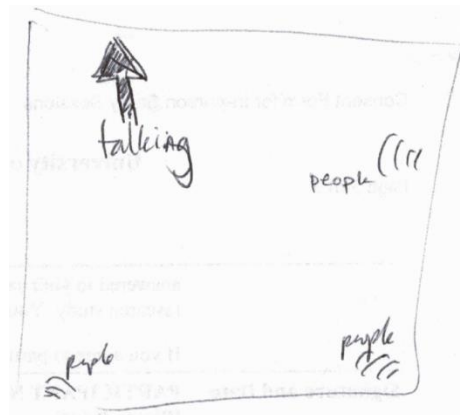
# DESIGNS SKETCHED BY PARTICIPANTS



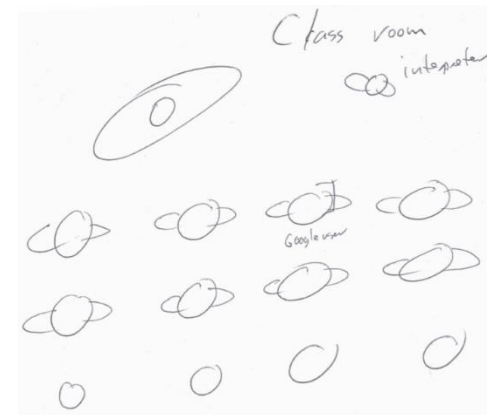
**P19: Extended Egocentric Pulses**  
To show recent speaking order



**P14: Different Exocentric Design**  
Visualize all potential speakers

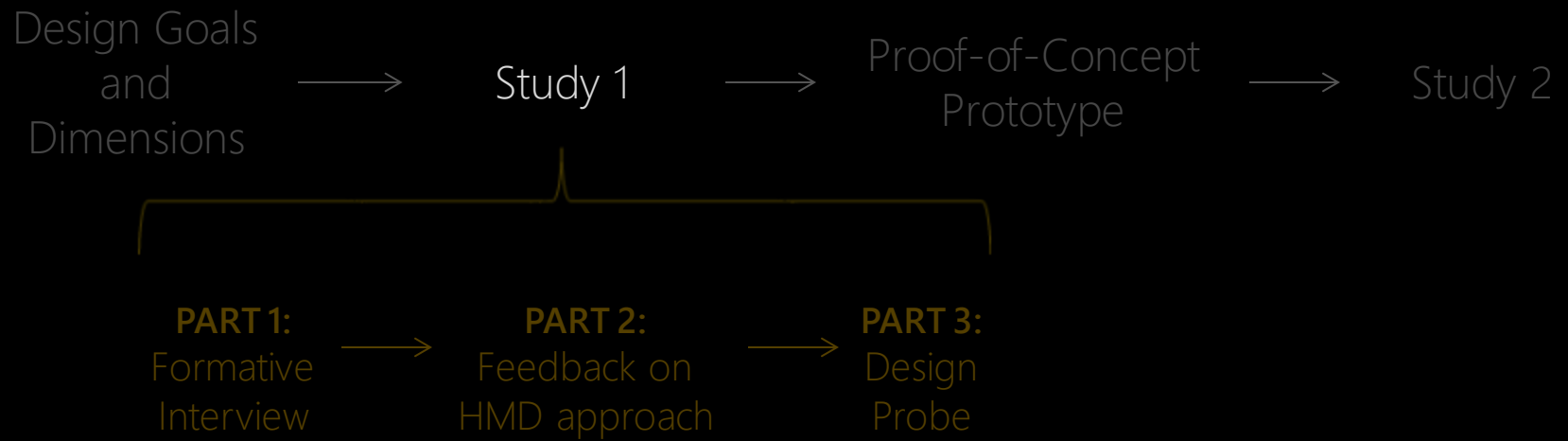


**P14: Extended Egocentric Design**  
Pulses represent recent speakers, 3D arrow shows current speaker



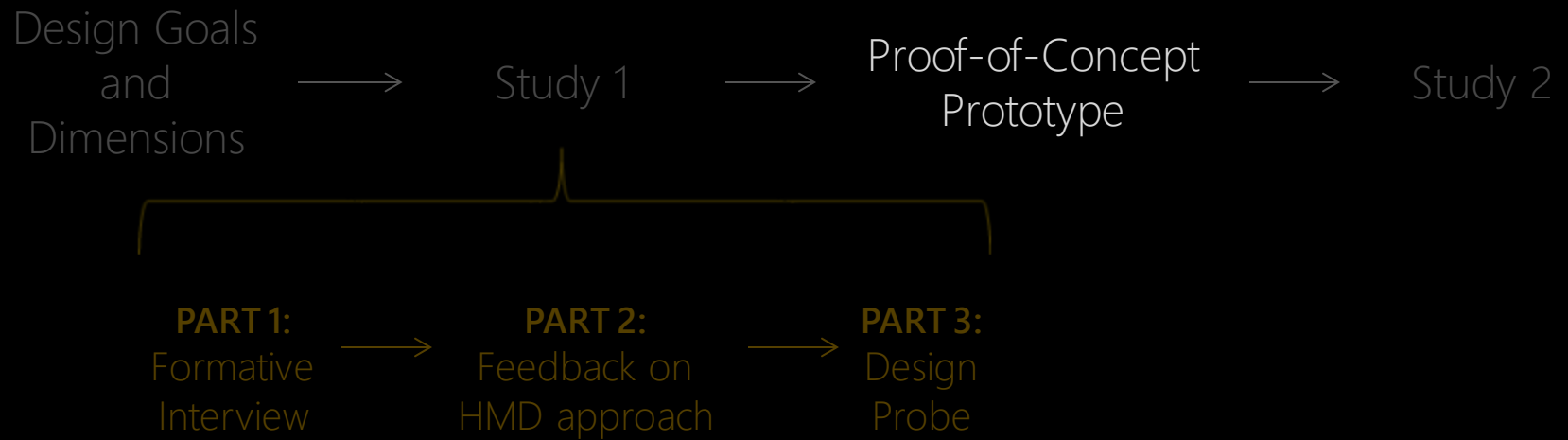
**P7: Different Exocentric Design**  
Room layout and people locations

# OUTLINE





# OUTLINE





Microphone array

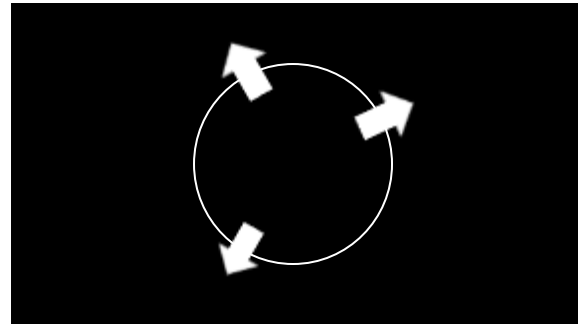
Visualization that is shown on Google Glass

Laptop for interfacing

We implemented live versions of two popular designs:

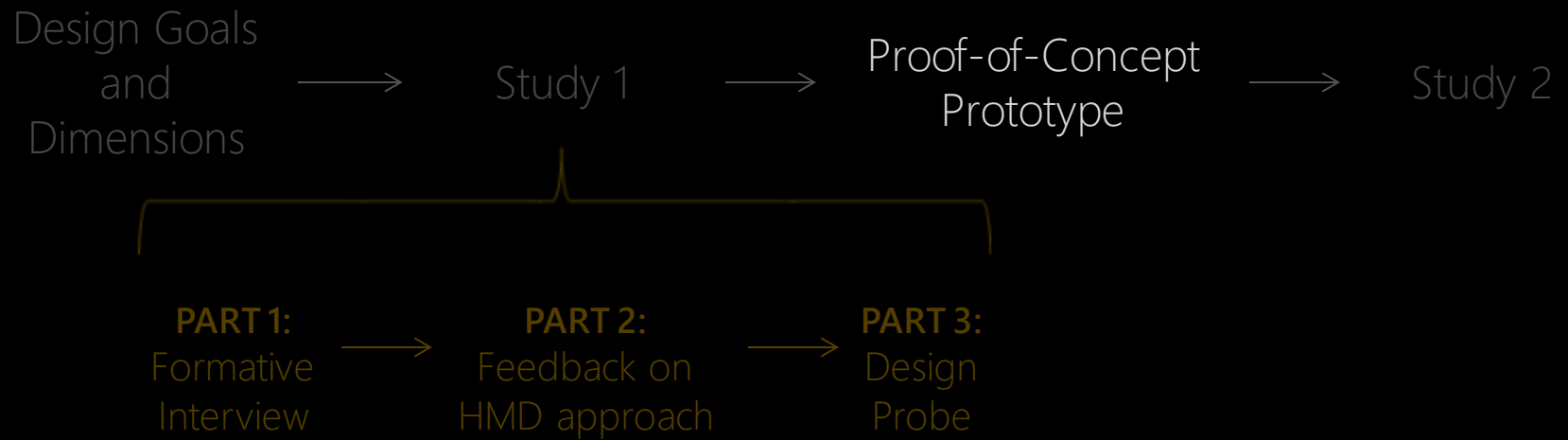


Egocentric Pulses

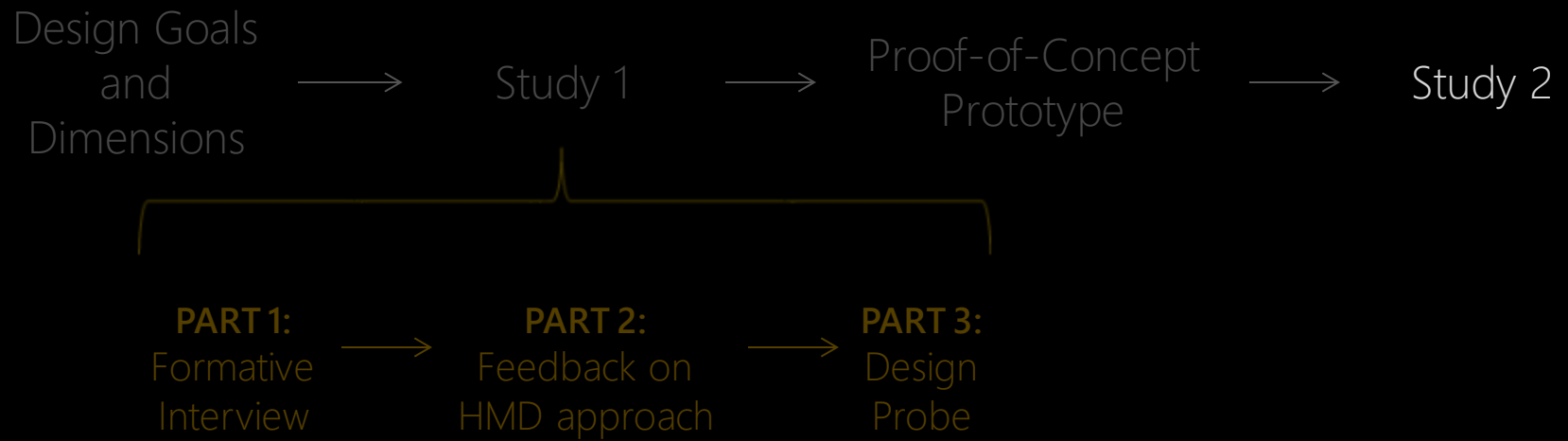


Exocentric Arrows

# OUTLINE



# OUTLINE



We implemented live versions of two popular designs:

## STUDY 2

---

**4 new participants**

**Two scripted conversations** for each design

**One open ended conversation** for each design

**Qualitative interview** after each design

Egocentric Pulses

Exocentric Arrows

# SCRIPTED CONVERSATION

SCRIPT: GHOSTBUSTERS


(Please download the powerpoint version to view the video)

# Preliminary Feedback

Study 2: Evaluating Proof-of-Concept Prototype







"This approach would be helpful because my sound processor is not able to point where the sound was from"

-R2, severe hearing loss

“I might not need it because they (hearing friends) would want me to understand better by real conversation rather than expecting to read from Google Glass.”

Participant R4  
Profound hearing loss

Please refer to the paper for more details on  
real-time implementation and evaluation

"I might not need it because they  
(hearing friends) would want me to  
understand better by real conversation  
rather than expecting to read from  
Google Glass."

Participant R4  
Profound hearing loss

# CLOSING THOUGHT FOR STUDY 2

PARTICIPANT'S OVERALL EXPERIENCE WITH PROTOTYPE



(Please download the powerpoint version to view the video)

# Primary Contributions

- 1** **First work** to design and evaluate sound visualizations on HMDs for the deaf and hard of hearing
- 2** Explored a broad range of **novel designs**
- 3** Implemented a preliminary **working prototype**

A person is shown from a side profile, wearing Google Glass. They are seated at a desk with a computer monitor, keyboard, and mouse. The scene is dimly lit, and the overall image has a dark, semi-transparent overlay. The word "Reflections" is written in white text across the bottom of the image.

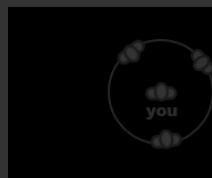
# Reflections

# PREFERENCES FOR SOME DESIGN DIMENSIONS

## WEARER'S PERSPECTIVE



EGOCENTRIC  
11 VOTES



EXOCENTRIC  
13 VOTES

# Need for Customizability

While strong preference existed for certain features, others were mixed

CONTINUOUS  
14.5 VOTES

8-LEVEL  
5.5 VOTES

4-LEVEL  
3 VOTES

1-LEVEL  
1 VOTE

## 2D vs. 3D



3D  
12 VOTES



2D  
12 VOTES

## MAXIMUM SIMULTANEOUS ICONS



<FOUR  
5.5 VOTES



FOUR  
10 VOTES



>FOUR  
8.5 VOTES

## SCREEN LAYOUT



RECTANGULAR  
11.5 VOTES



CIRCULAR  
10.5 VOTES



FROM CENTER  
2 VOTES

## CONVEYING SOUND SOURCE



OUTWARD  
19 VOTES



INWARD  
5 VOTES



Interference



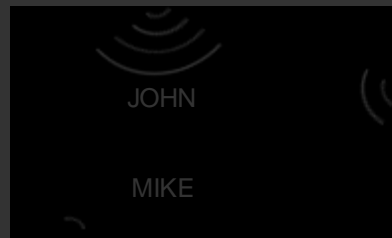
A person is shown from the side, wearing a VR headset. They are sitting at a desk with a computer monitor, keyboard, and mouse. The scene is dimly lit, with the primary light source coming from the computer screen. The person's hand is visible on the mouse. The overall atmosphere is focused and immersive.

# Ideal HMD for Sound Visualizations

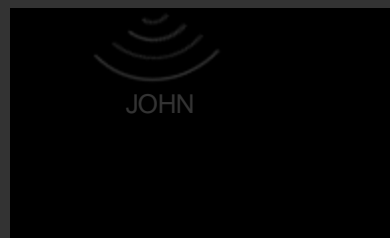
accommodates existing hearing devices, is lightweight, comfortable, and accurate, and contain a large transparent display superimposed over the eye

*Interference*

## MORE SOPHISTICATED SOUND PROCESSING



Example: Speaker Identity



Example: Captions



Example: Gender



Example: Speech vs. Non-Speech Sounds

# More Sophisticated Sound Processing

Automatic sound recognition, real-time captioning, gender identification

**HMDs** as **glanceable displays**  
offer an interesting opportunity

to

**transform** the **auditory sense**  
to the **visual sense**

leading to

**new solutions** for accessibility

# HEAD-MOUNTED DISPLAY VISUALIZATIONS TO SUPPORT SOUND AWARENESS FOR THE DEAF AND HARD OF HEARING

Dhruv Jain<sup>1,2,5</sup>, Leah Findlater<sup>1,5</sup>, Jamie Gilkeson<sup>4</sup>, Benjamin Holland<sup>4</sup>,  
Ramani Duraiswami<sup>5</sup>, Dmitry Zotkin<sup>5</sup>, Christian Vogler<sup>3</sup>, Jon Froehlich<sup>1,5</sup>



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Ramani Duraiswami<sup>5</sup>, Dmitry Zotkin<sup>5</sup>, **Christian Vogler**<sup>3</sup>, Jon Froehlich<sup>1,5</sup>



# Questions?

@higherdefender