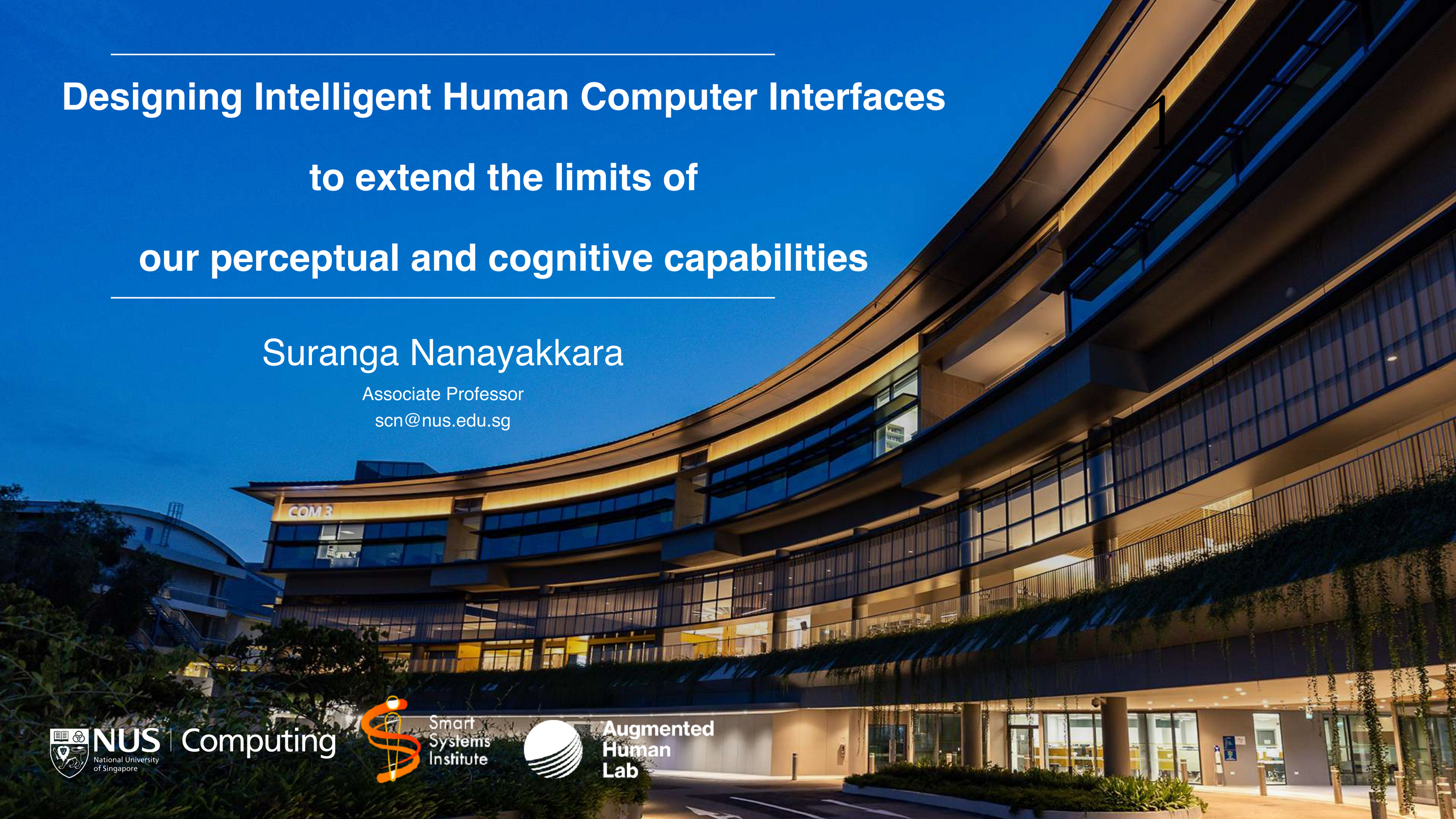
# Designing Intelligent Human Computer Interfaces to extend the limits of our perceptual and cognitive capabilities

Suranga Nanayakkara
Associate Professor
scn@nus.edu.sg




NUS National University of Singapore | Computing
Smart Systems Institute
Augmented Human Lab

# Overview

Motivation

Assistive Augmentation

Several examples

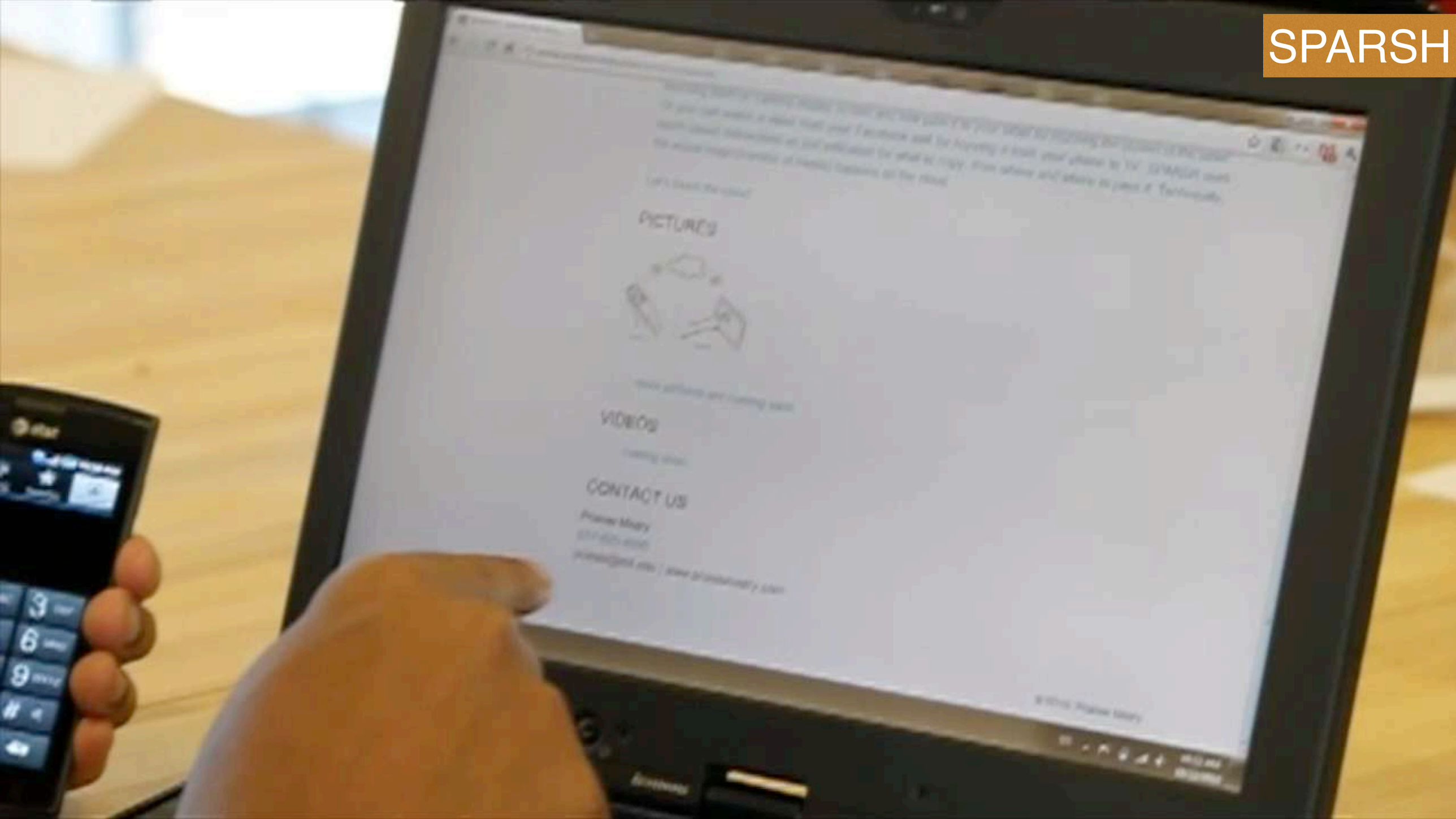
Future

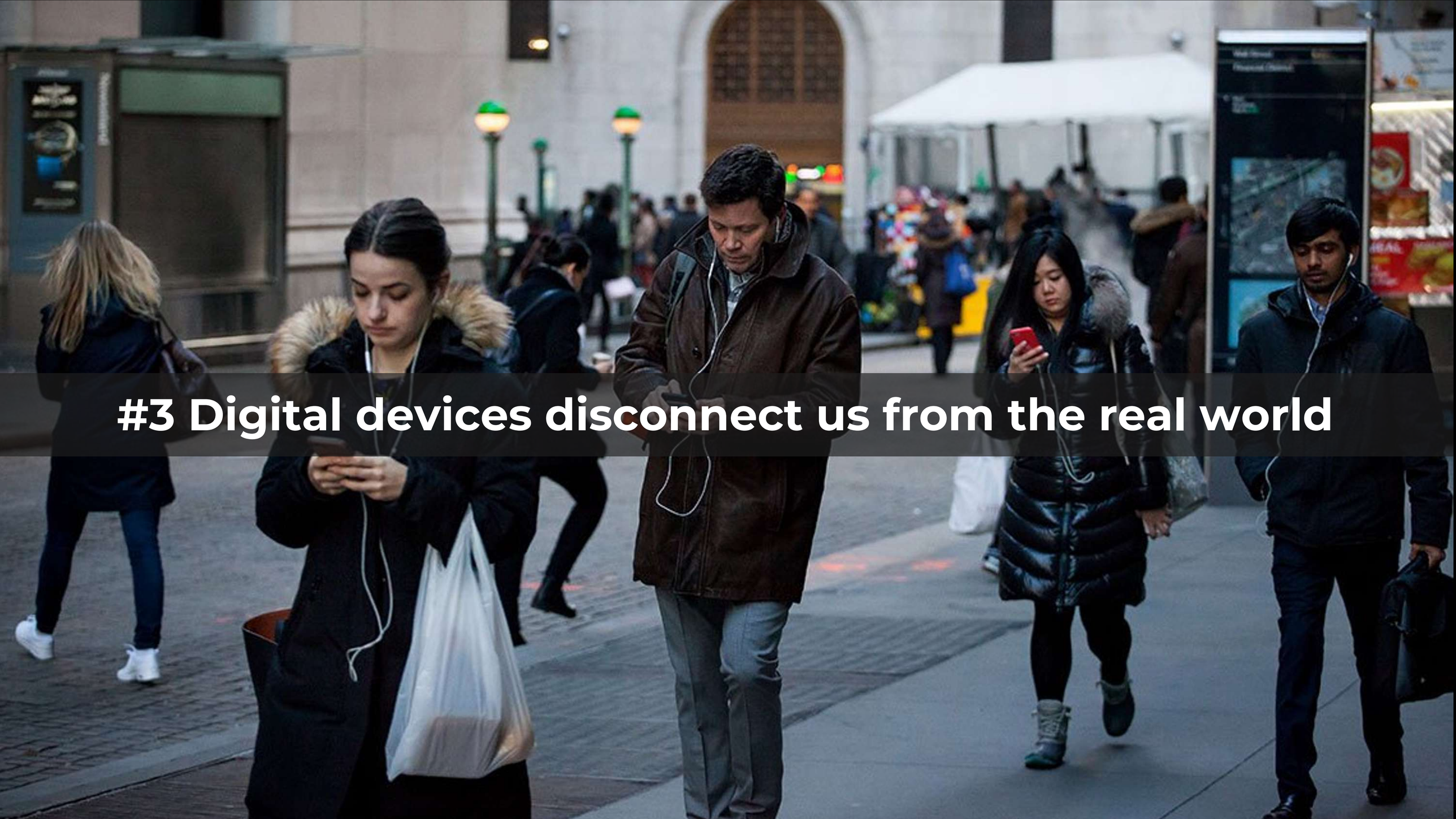
# Motivation

**All of us are disabled one way or the other**

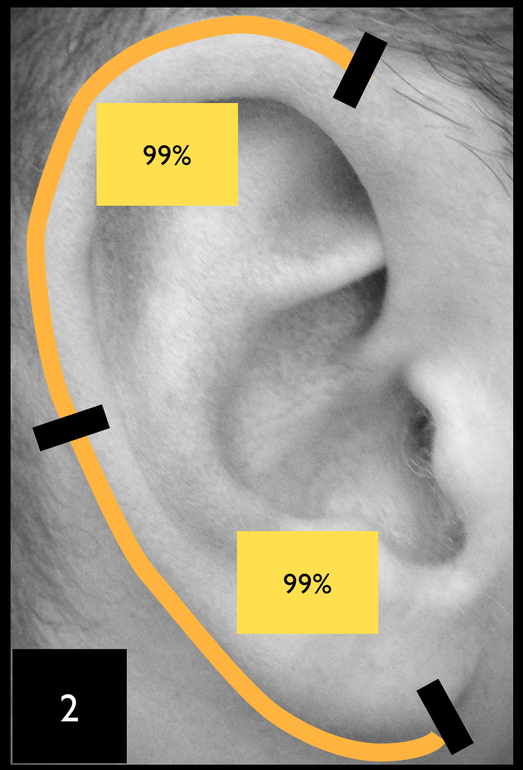
Supporting Rhythm Activities of Deaf Children… (CHI'18)

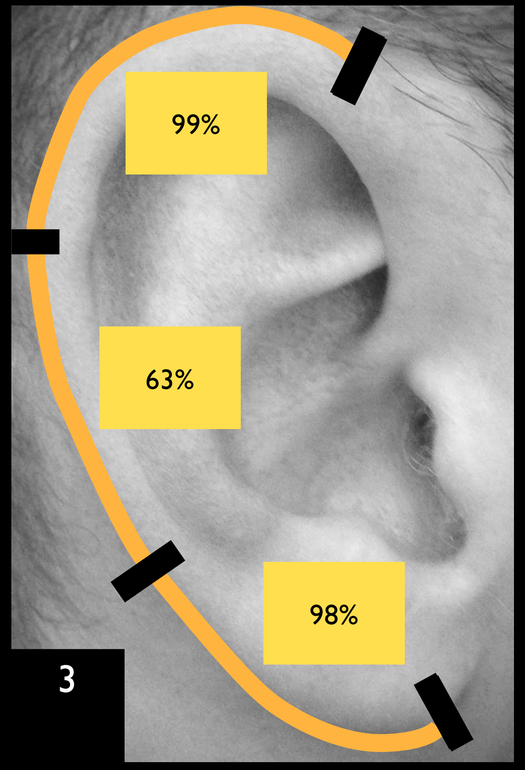
## #2 Digital interactions do not match our natural behaviour

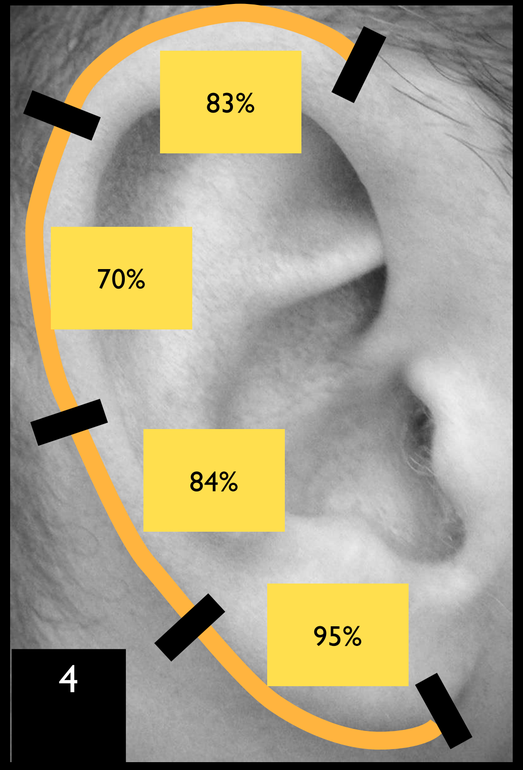

SPARSH
PICTURES
VIDEOS
CONTACT US

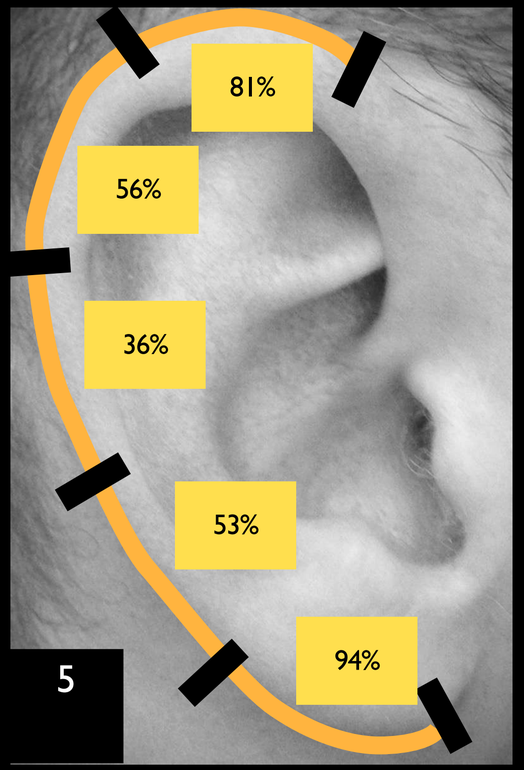


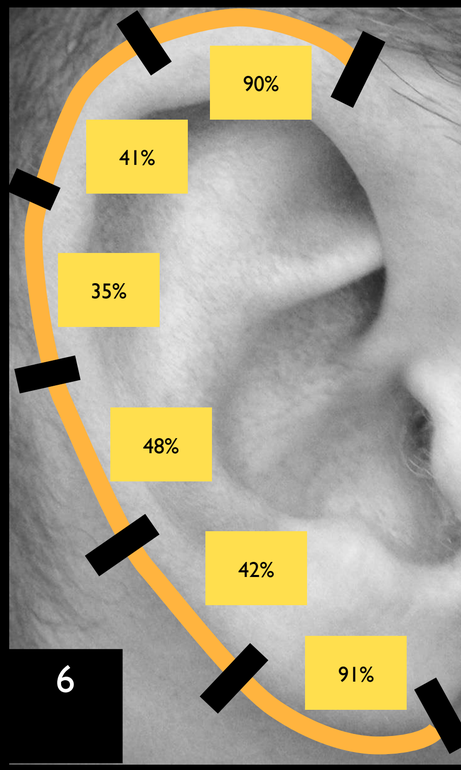
# #3 Digital devices disconnect us from the real world

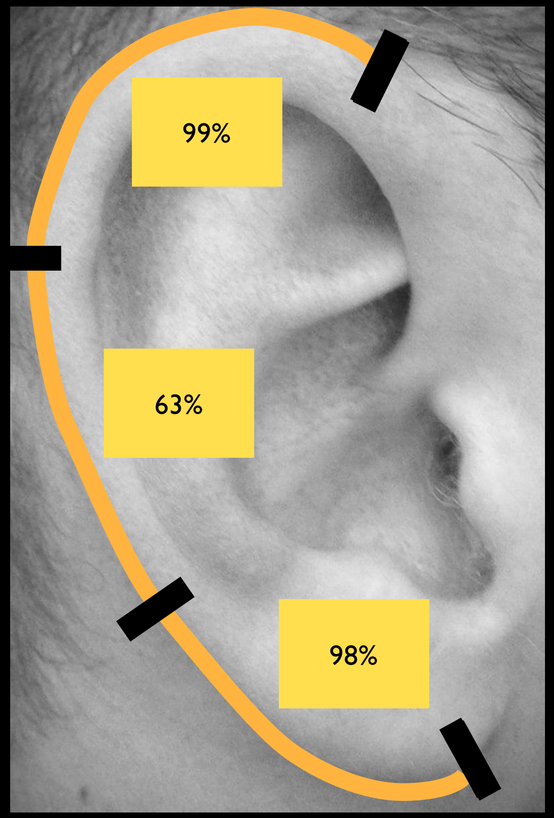

99%
99%
2


99%
63%
98%
3


83%
70%
84%
95%
4


81%
56%
36%
53%
94%
5


90%
41%
35%
48%
42%
91%
6

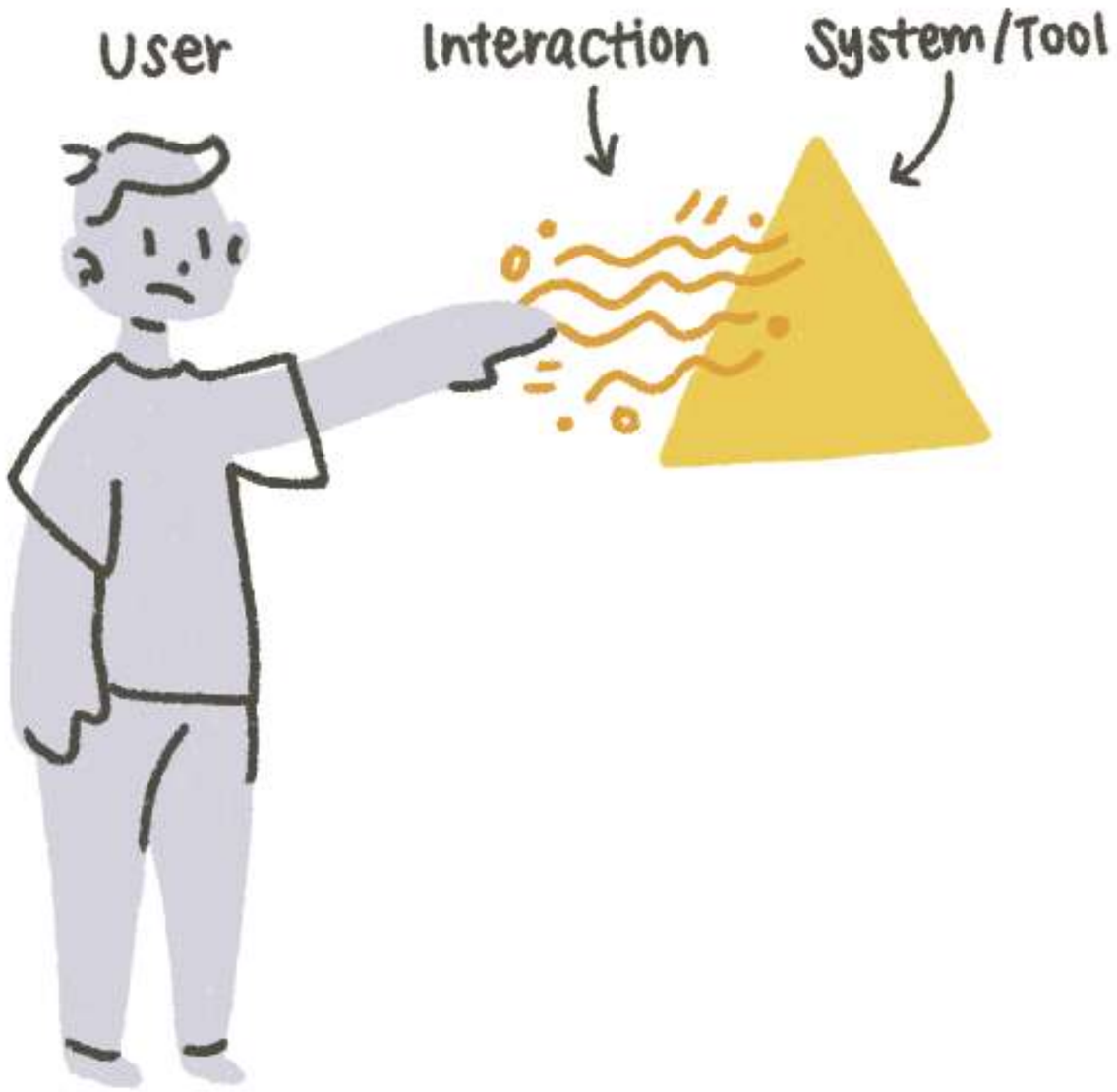

99%
63%
98%

EARPUT
FOSSIL

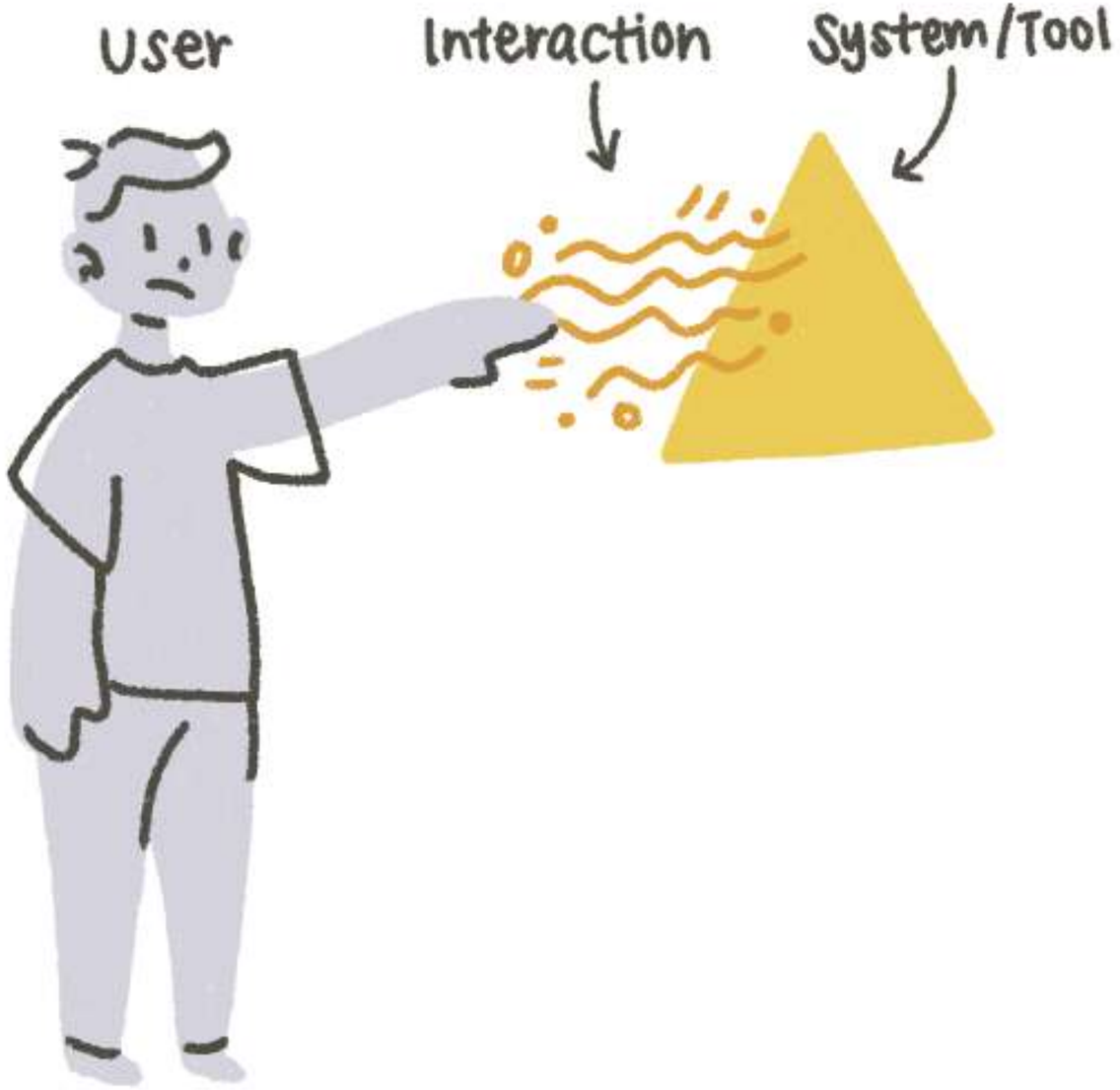
# Assistive Augmentation

**Subtle yet significant shift, moving from viewing technology as a separate tool to considering it as an integrated extension of the human body, mind, and identity.**

## User-System Compatibility Perspective



## User-System Compatibility Perspective




## Assistive Augmentation Perspective

# Ability

| Augmentation Method | Ability Dimensions | Examples |
|---|---|---|
| Amplify | Perceptual | Hearing aids for improved sound clarity |
| | Physical | Exoskeleton for increased strength and endurance |
| | Cognitive | Improving memory via automated targeted memory reactivation during sleep |
| Subtitute | Perceptual | Text-to-speech for a person with visual impairments (PVI) |
| | Physical | Bionic limb for replacing a lost limb |
| | Cognitive | Reconstructing silent speech from facial neuromuscular signals |
| Extend | Perceptual | Electrosmog translated into a visual blur via AR, creating a new sensory experience of electromagnetic radiation in the environment |
| | Physical | Adding an extra anthropomorphic limbs for new manipulation capabilities |
| | Cognitive | Modulating new emotional & cognitive states with aesthetic chills/thermal feedback |

# Integration

**Hugh Herr's** bionic limb, *"Through technological innovation, I returned to my sport, stronger and better. Technology had eliminated my disability, and allowed me a new climbing prowess."*

**Neil Harbisson's** antenna implant, *"I don't feel like I'm using technology, or wearing technology. I feel like I am technology. I don't think of my antenna as a device – it's a body part."*

**Aimee Mullins'** aesthetic and customizable prosthetic limbs, *"The conversation with society has changed profoundly in this last decade. It is no longer a conversation about overcoming deficiency. It's a conversation about augmentation."*

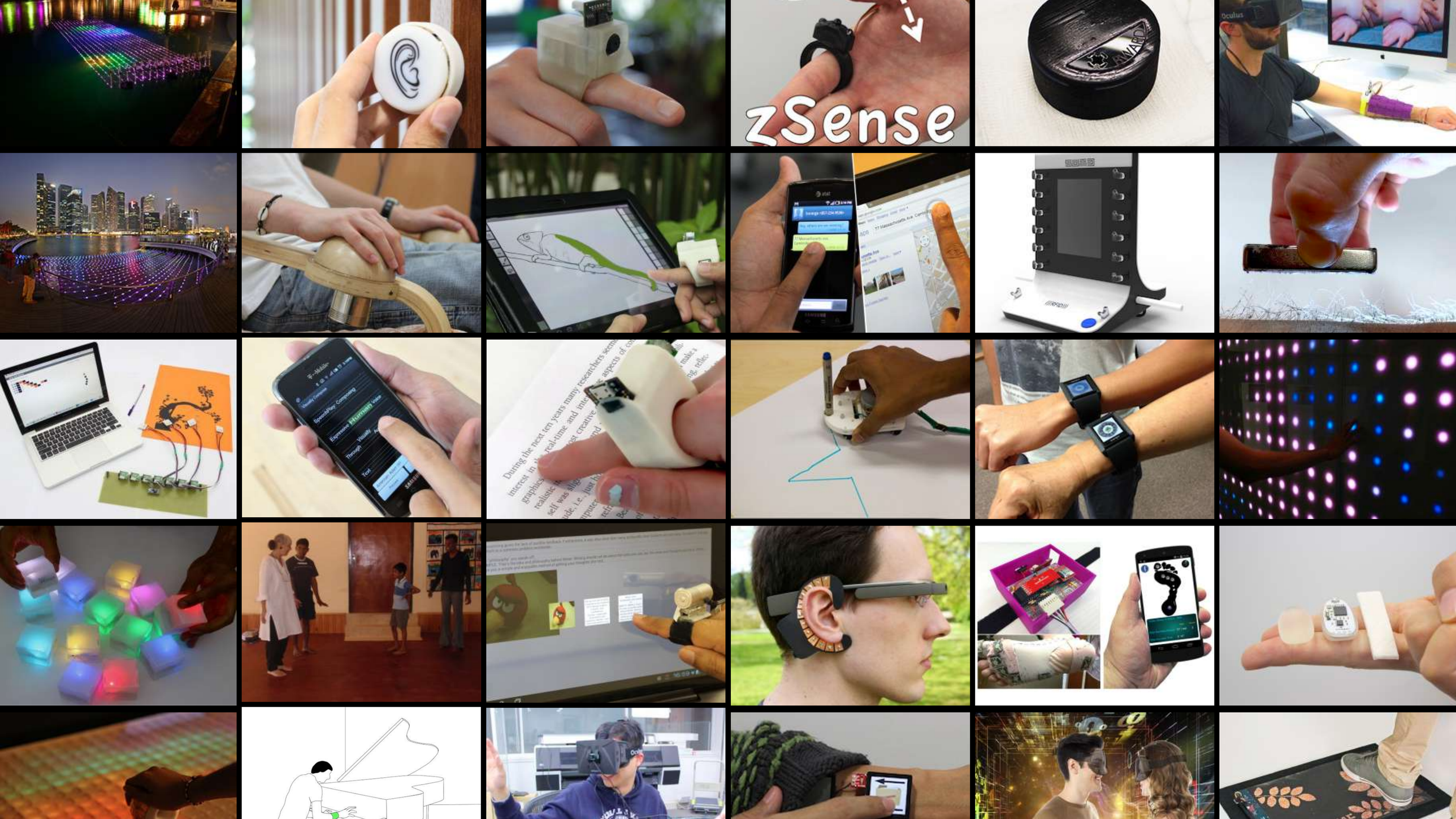
**Legend**

Body Integration

Identity Integration

Temporal Integration

Socio-Cultural Integration

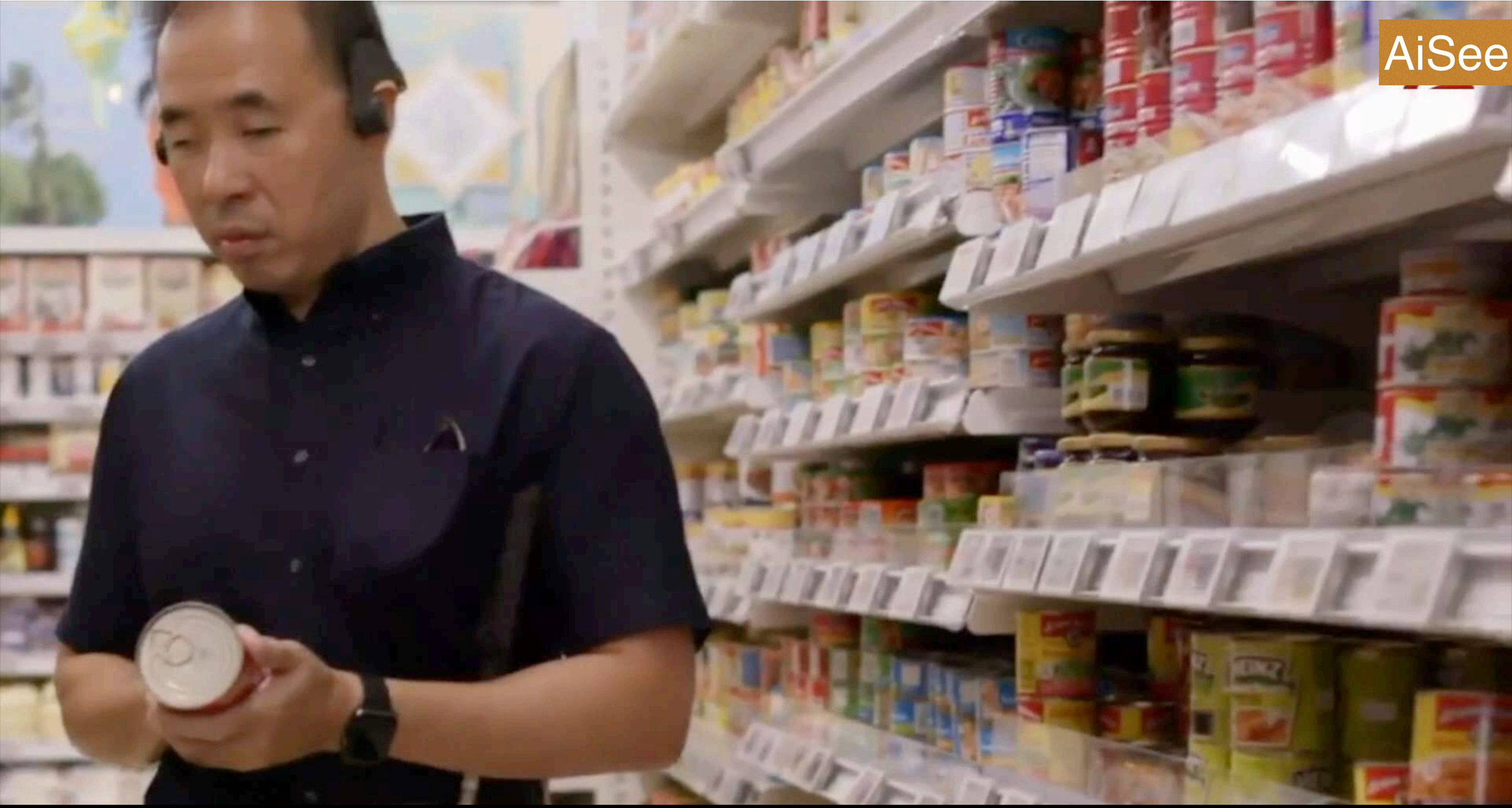

zSense

# Assistive

# AiSee

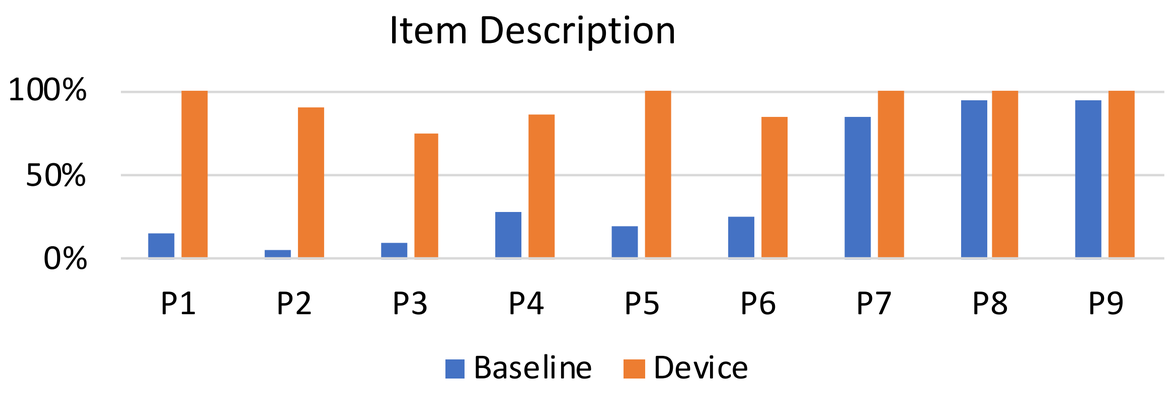
An intelligent companion co-designed with people with visual impairment to help them access information on the go

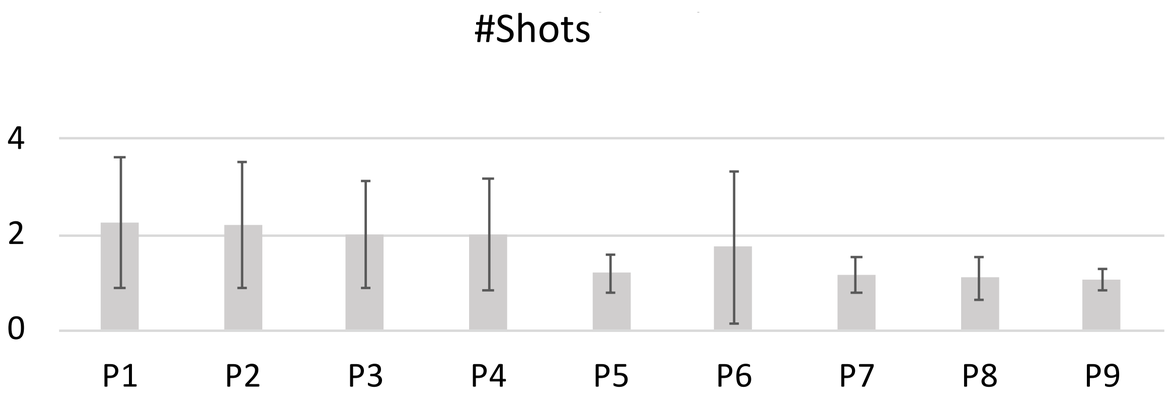
EyeRing (AH'12), FingerReader (CHI'19, IMWUT'18) AiSee… (IMWUT'20)




EyeRing (AH'12), FingerReader (CHI'19, IMWUT'18) AiSee… (IMWUT'20)

AiSee




| Case | Age | Gender | WHO *Score* | SUS |
|---|---|---|---|---|
| P1 | 63 | Male | Blindness (cat=6) | 62.5 |
| P2 | 64 | Female | Blindness (cat=6) | 70 |
| P3 | 37 | Male | Blindness (cat=5) | 65 |
| P4 | 72 | Male | Blindness (cat=5) | 57.5 |
| P5 | 32 | Male | Blindness (cat=4) | 82.5 |
| P6 | 68 | Male | Blindness (cat=4) | 72.5 |
| P7 | 61 | Male | Severe (cat=3) | 75 |
| P8 | 63 | Male | Severe (cat=3) | 75 |
| P9 | 31 | Female | Moderate (cat=2) | 77.5 |

# Wearable conversational companion that **help blind people** to **access information on the go**

AiSee

**Capture and extract visual information**

**Seamless voice-based question and answer interaction**

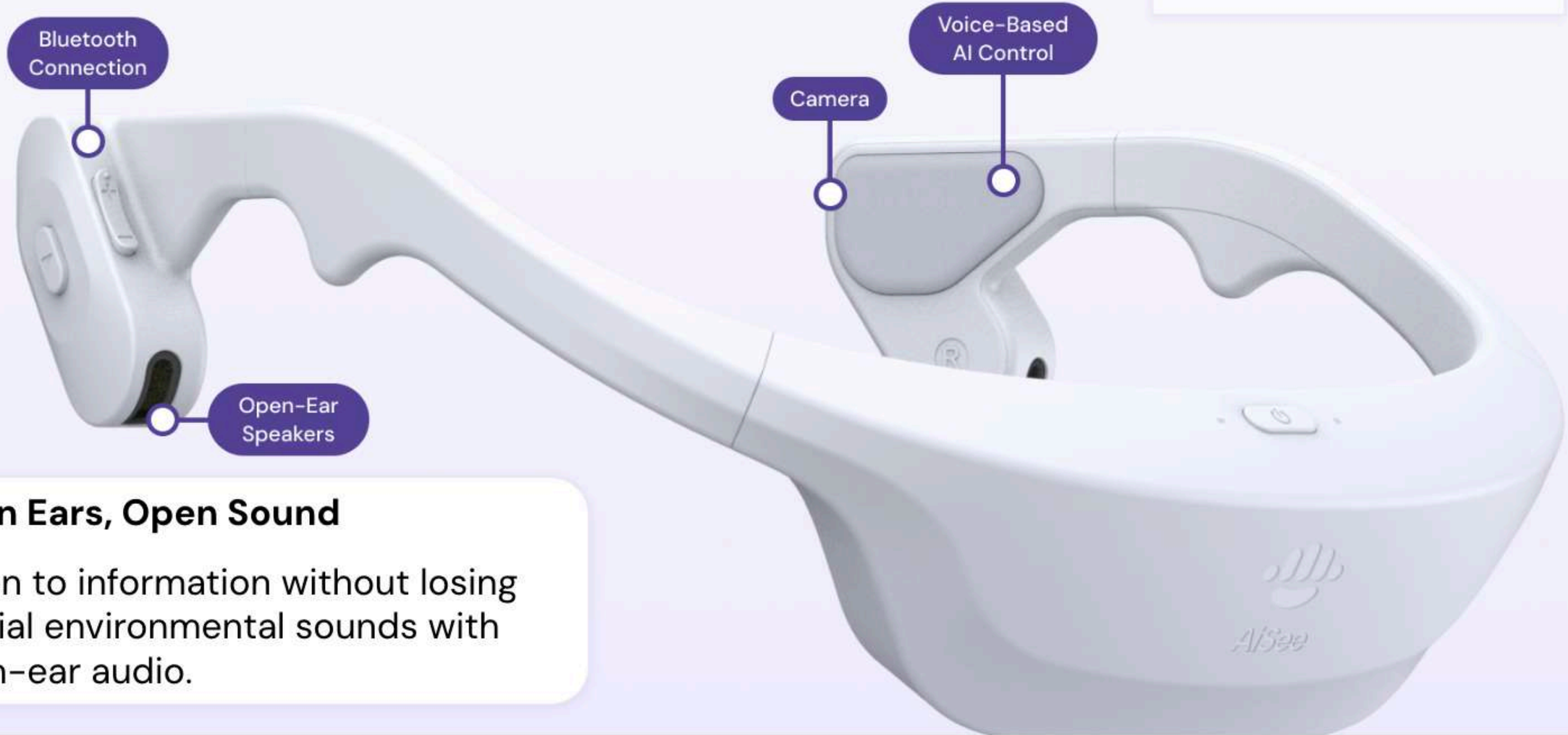
**Common, affordable headphone accessory**

# AiSee Hardware

## Always Ready to Help

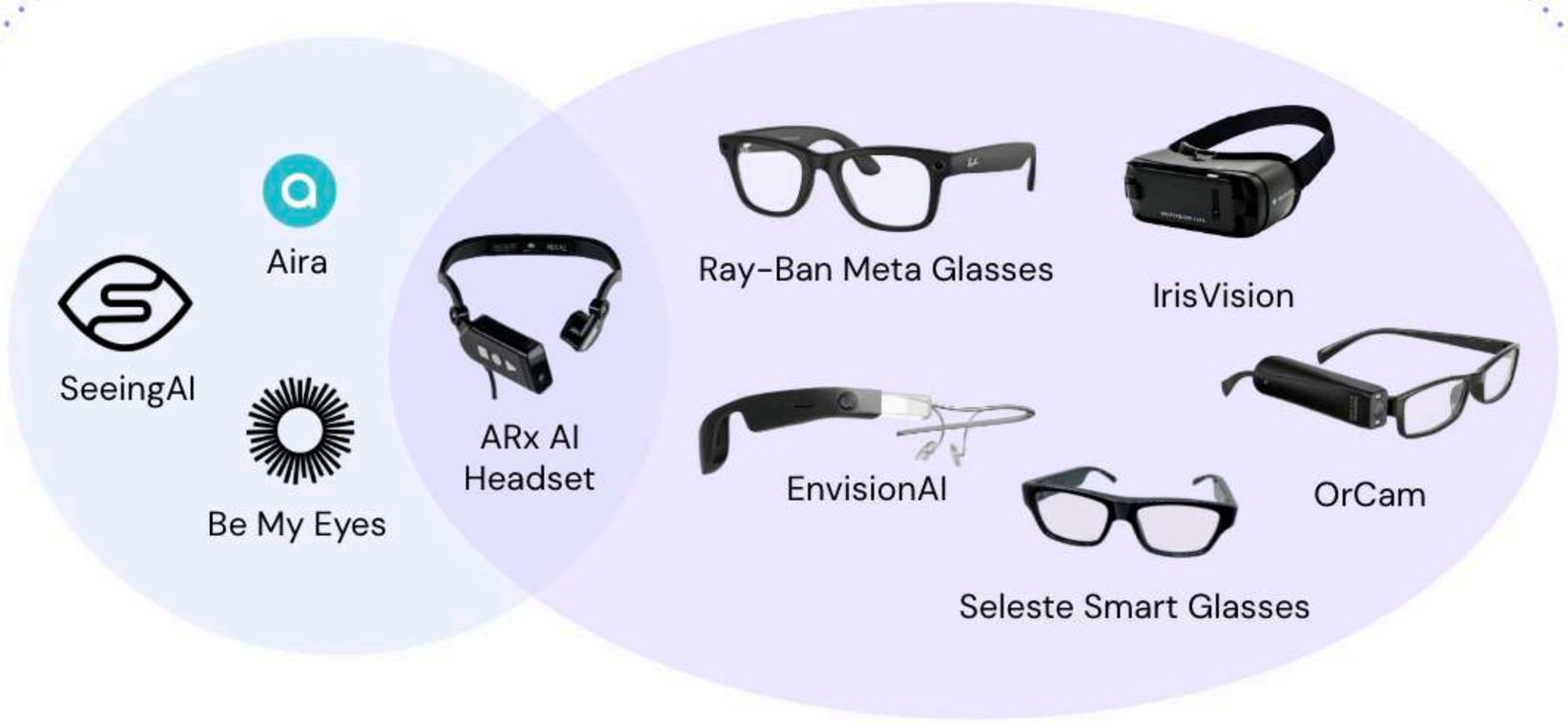
AiSee is simply a button press or voice command away.

**Specs:**
**CPU:** 1.2 GHz Quad-core Qualcomm Snapdragon 410 64-bit SoM
**Camera:** 13MP 1080p CMOS Image Sensor
**Wireless:** Wi-Fi (802.11n), Bluetooth 4.1
**Connectivity:** USB-C for charging and data transfer (up to 480Mb/s)




## Open Ears, Open Sound

Listen to information without losing crucial environmental sounds with open-ear audio.




**Smartphone Apps**
Cumbersome to use

**Smart Glasses**
'Another new device' for blind users

AiSee

Replacing the traditional headphones with a smart headphone.

**Smart Headphone**
Most blind people already use a headphone

# Powerful Platform

## Hardware-Agnostic AiSee Agentic Framework

**Memory:** Short- and long-term recall.

**Tool Calling:** Recognise objects and faces, read text and currencies, translate languages, search the web

**Planning & Reasoning:** Human-centred, LLM-based cognitive architecture

## AiSee Hardware

**CPU:** 1.2 GHz Quad-core Qualcomm Snapdragon 410 64-bit SoM
**Camera:** 13MP 1080p CMOS Image Sensor
**Wireless:** Wi-Fi (802.11n), Bluetooth 4.1
**Connectivity:** USB-C for charging and data transfer (up to 480Mb/s)

## Other Hardware

Meta Aria Gen 2

Even Realities G1

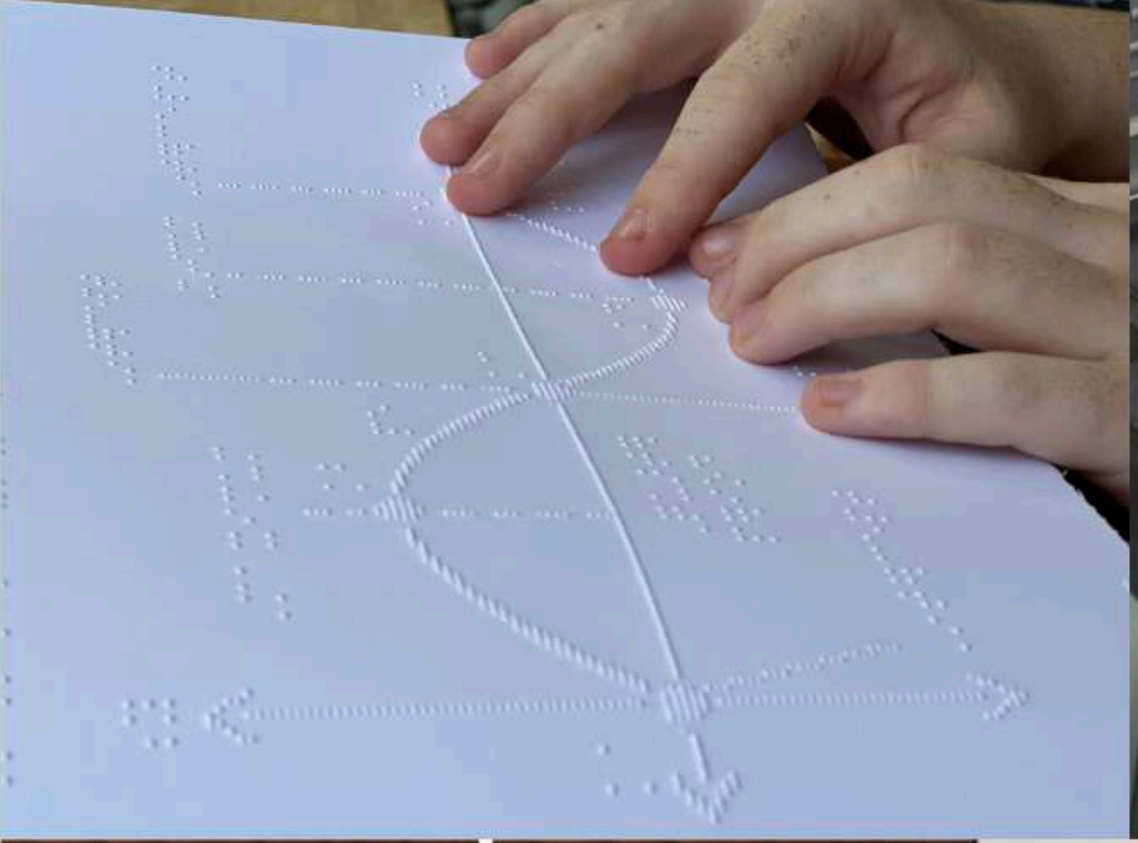
Ray-Ban Meta Glasses

Vuzix Z100

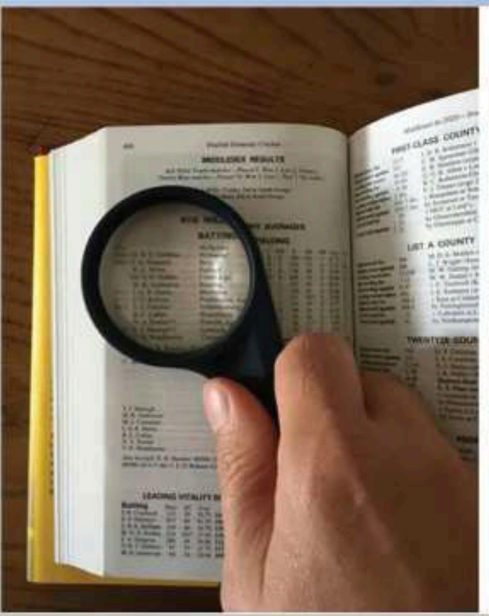
AiSee

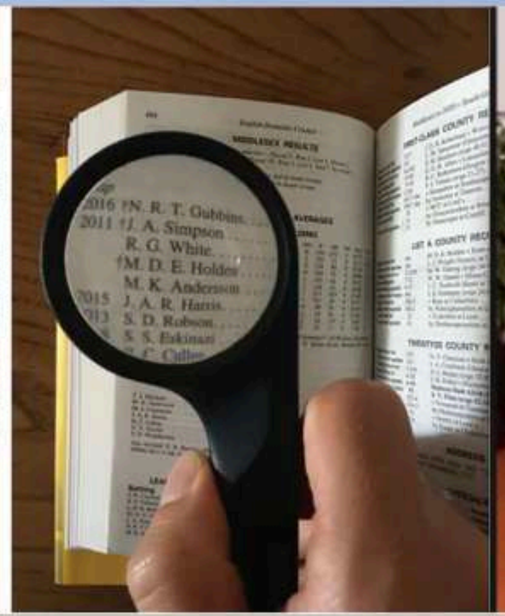
# Can we empower these students to achieve their full potential?

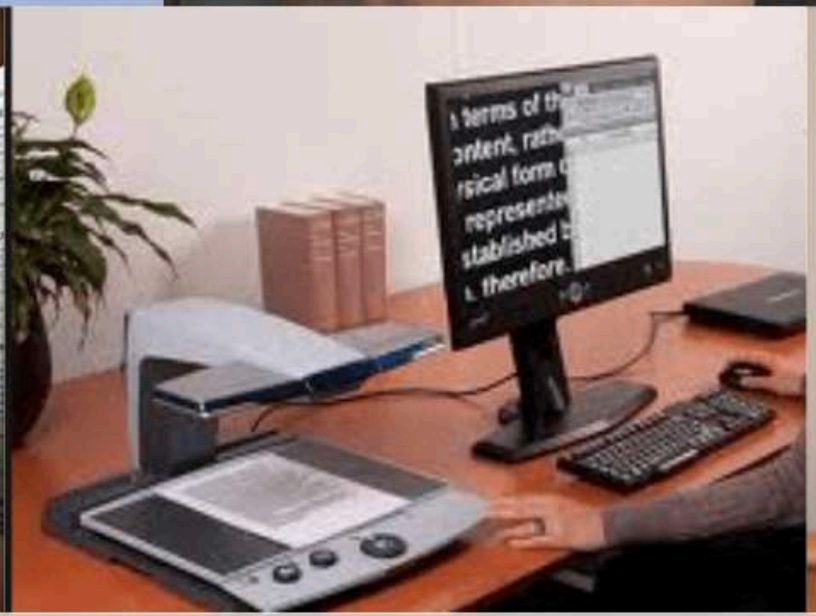
AiSee
SENSE



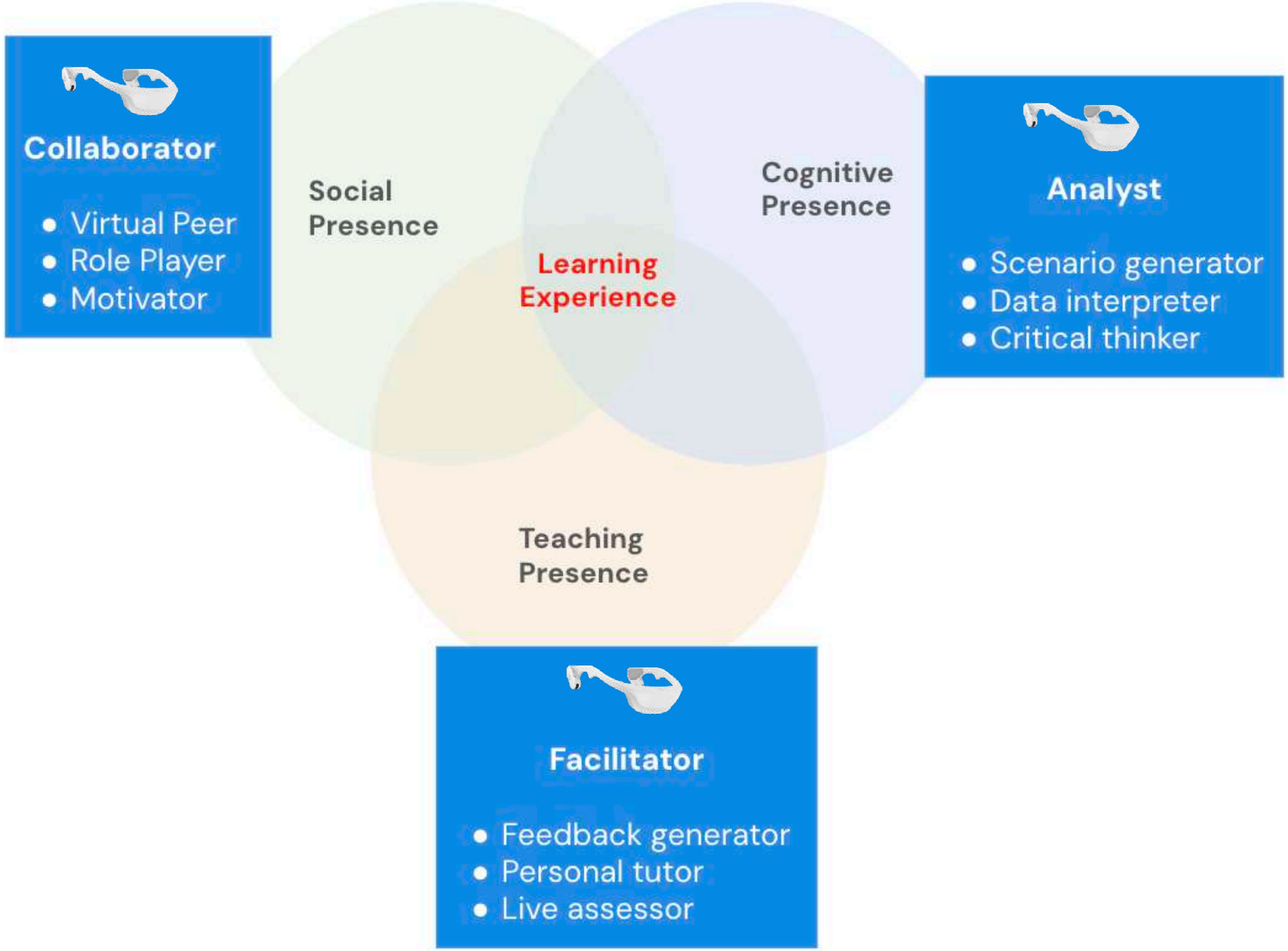
SENSE







# Effective Learning Experience




*Adopted from The Community of Inquiry Framework (Garrison, Anderson & Archer, 2000)*

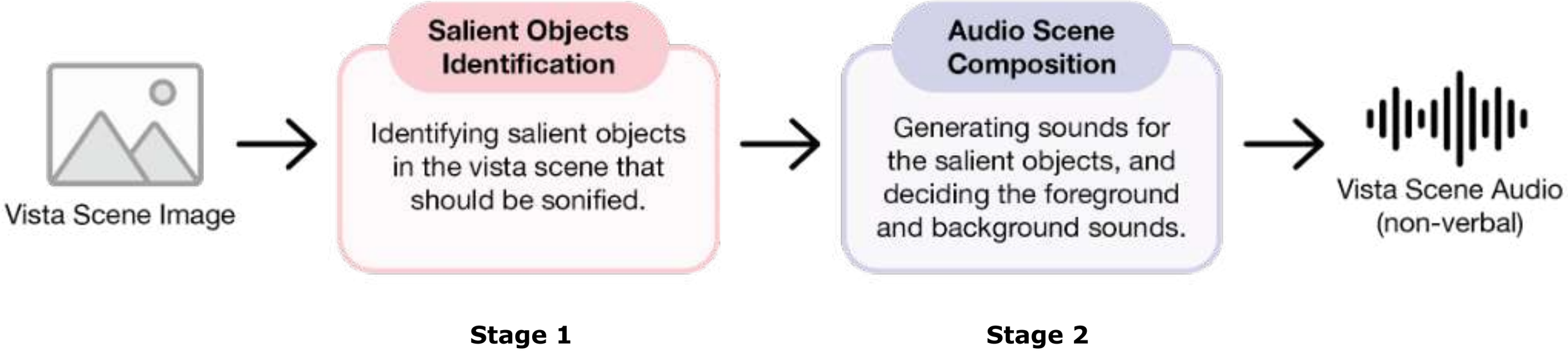
SonicVista

# Creating Awareness of Distant Scenes through Sonification

SonicVista (IMWUT'24) | TOCHI (Under Preparation)

SonicVista

SonicVista (IMWUT'24) | TOCHI (Under Preparation)


Vista Scene Image
Salient Objects Identification
Identifying salient objects in the vista scene that should be sonified.
Audio Scene Composition
Generating sounds for the salient objects, and deciding the foreground and background sounds.
Vista Scene Audio (non-verbal)
Stage 1
Stage 2

SonicVista

## Stage 1

### Salient Objects Identification

Vista Scene Image

*Im2Text PROMPT*

- "Describe this image with respect to the sound making objects in the scene.
- Only provide a noun+verb like phrase such that the noun is the sound making object and the verb is the possible action on or by the object that could create a sound.
- At the end of each noun+verb phrase, attach a label "discrete" or "continuous", depending on whether the sound producted by the object is genereally discrete or continuous."

*Text2Audio*

| PROMPT | EVENT TYPE |
|---|---|
| ["Cows mooing", | discrete] |
| ["Leaves rustling", | continuous] |
| ["Church bell ringing", | discrete] |

## Stage 2

### Audio Scene Composition

*Text2Audio*

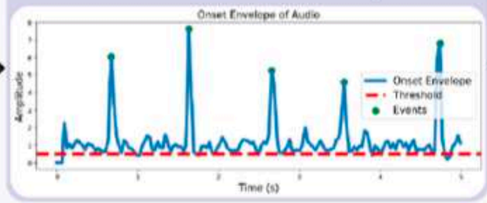
| PROMPT | EVENT TYPE |
|---|---|
| ["Cows mooing", | discrete] |
| ["Leaves rustling", | continuous] |
| ["Church bell ringing", | discrete] |

Discrete ?

Yes → PROMPT → Text-to-Audio

No → Text-to-Audio ← PROMPT

Discrete Event Counter, n




Select with minimum n

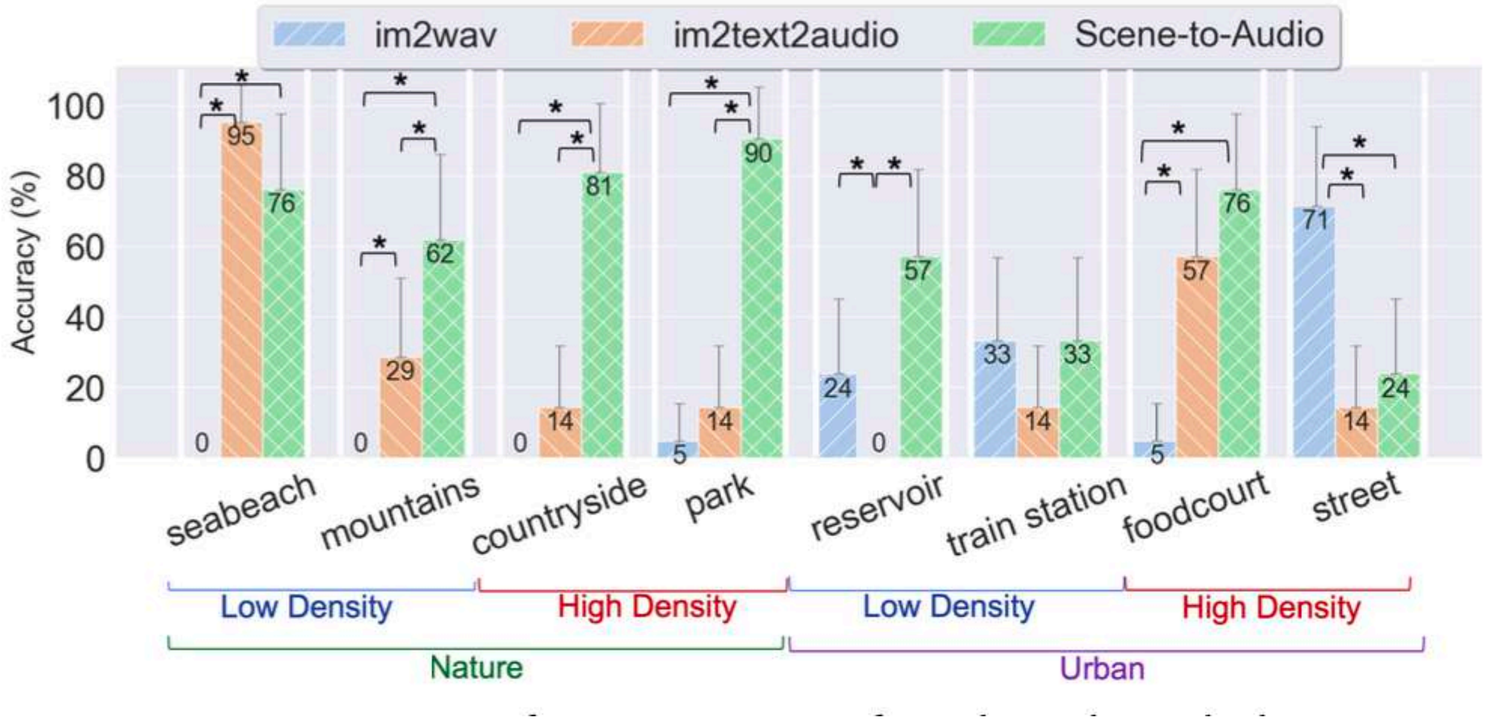
Foreground (0.8)

Background (0.2)

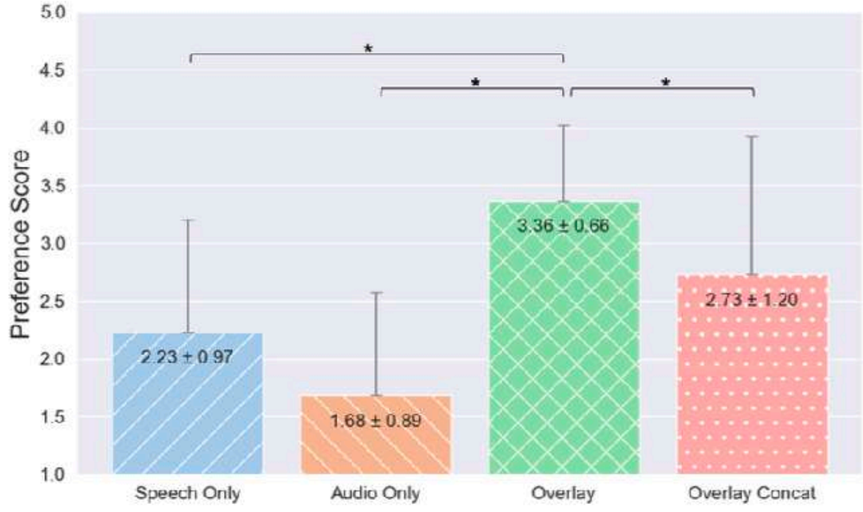
Combine

Vista Scene Audio (non-verbal)

Accuracy



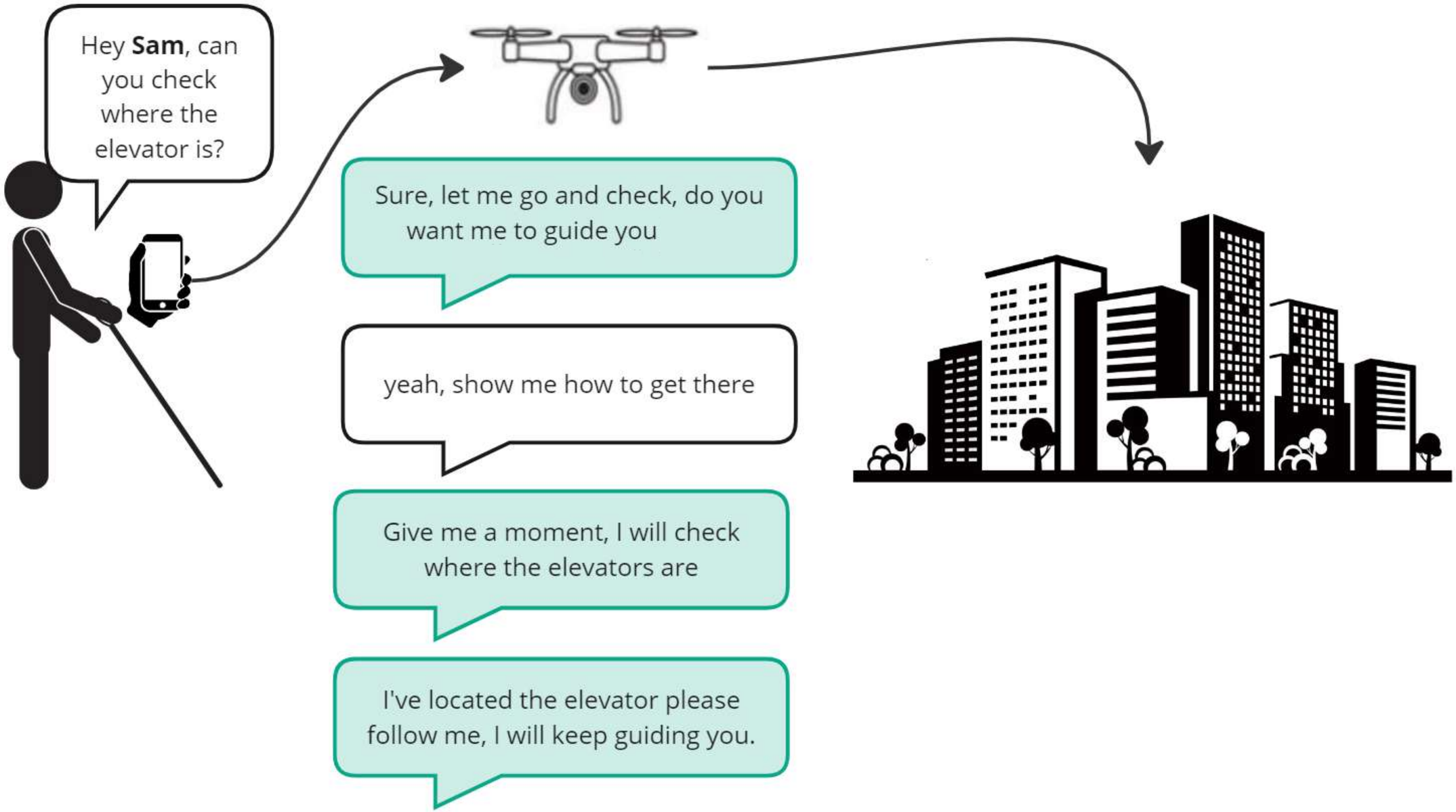

Rank-order preference



# DroneBuddy

Drone as a Companion for People with Visual Impairments

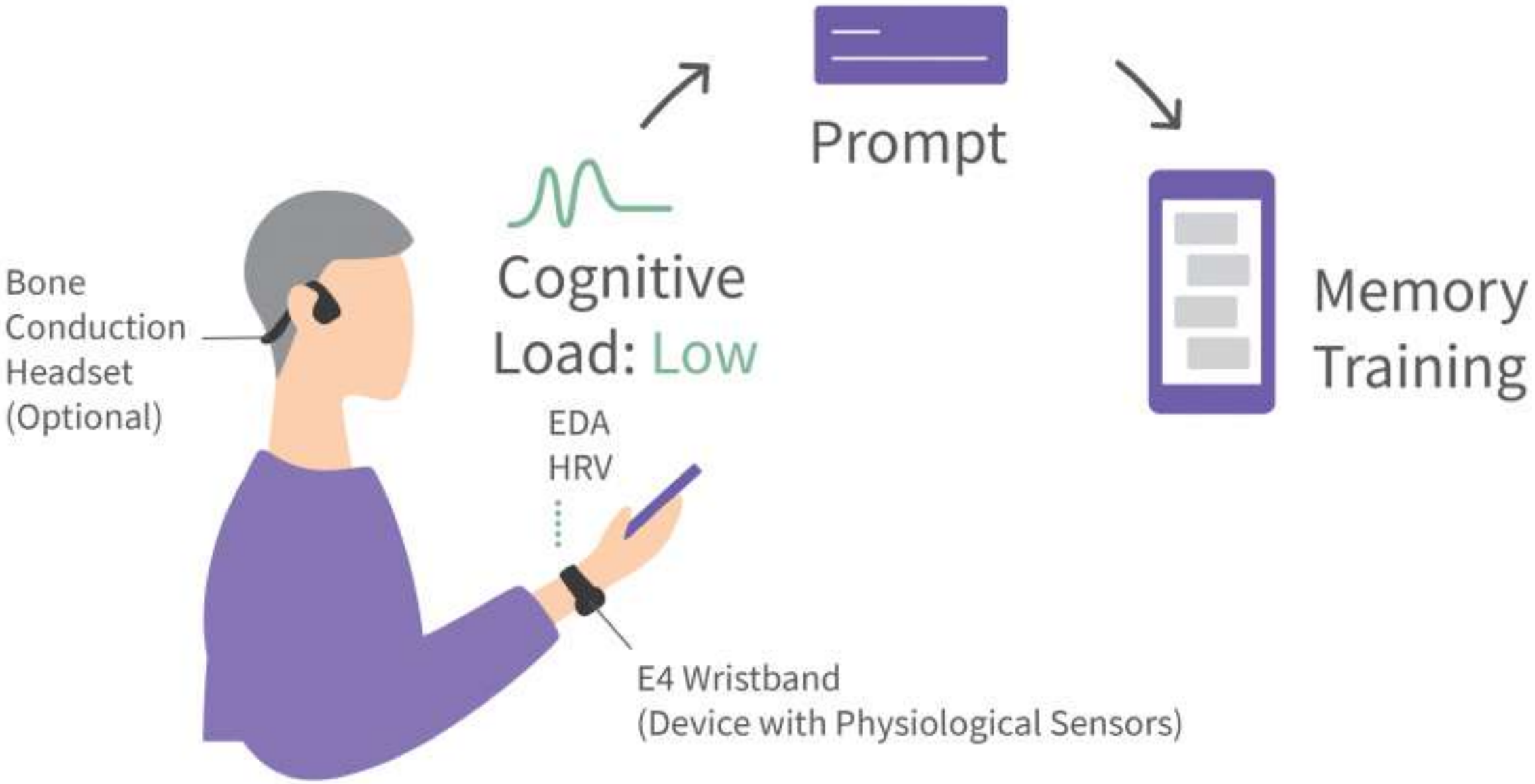
# DroneBuddy


Hey **Sam**, can you check where the elevator is?
Sure, let me go and check, do you want me to guide you
yeah, show me how to get there
Give me a moment, I will check where the elevators are
I've located the elevator please follow me, I will keep guiding you.

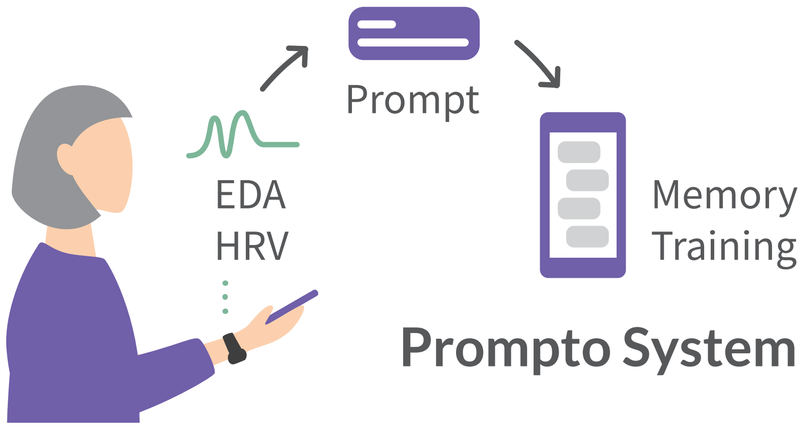
# Wellbeing

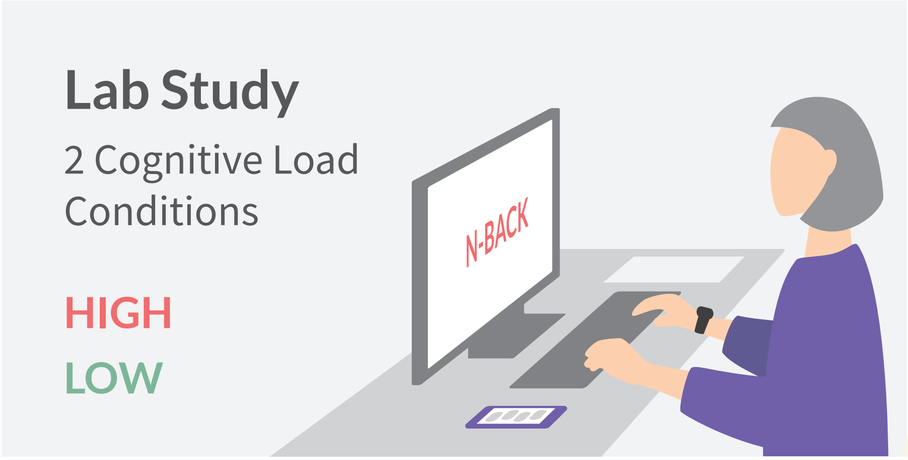
Prompto(AH'19, IMWUT'20)

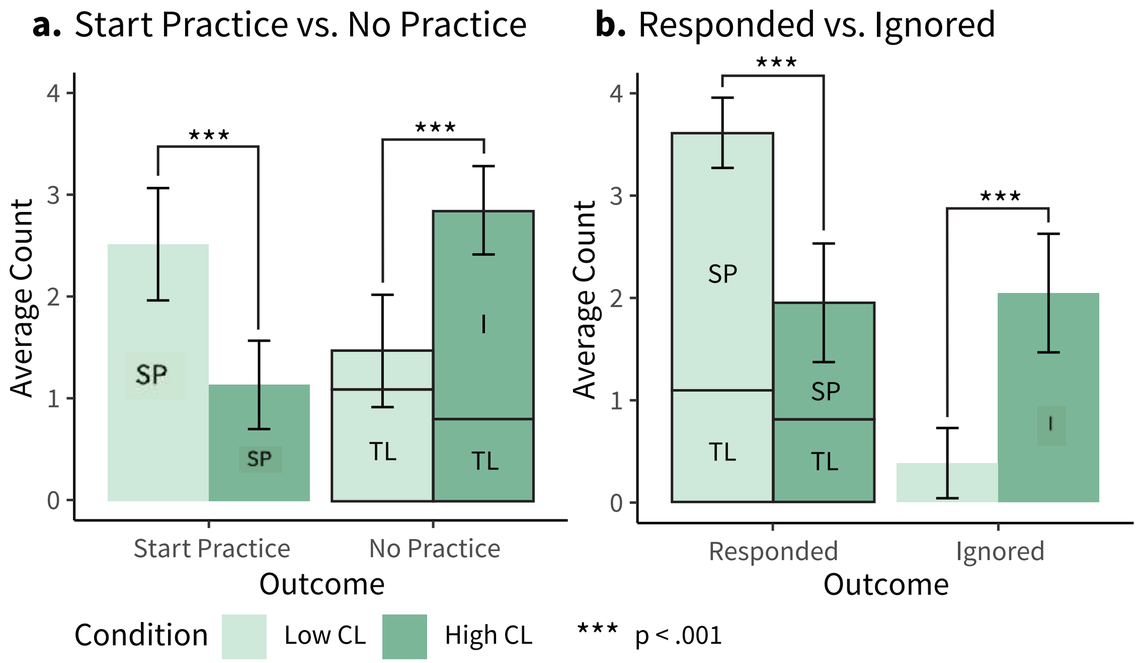
Prompto




Prompto(AH'19, IMWUT'20)






SP = Start Practice

TL= Try Later

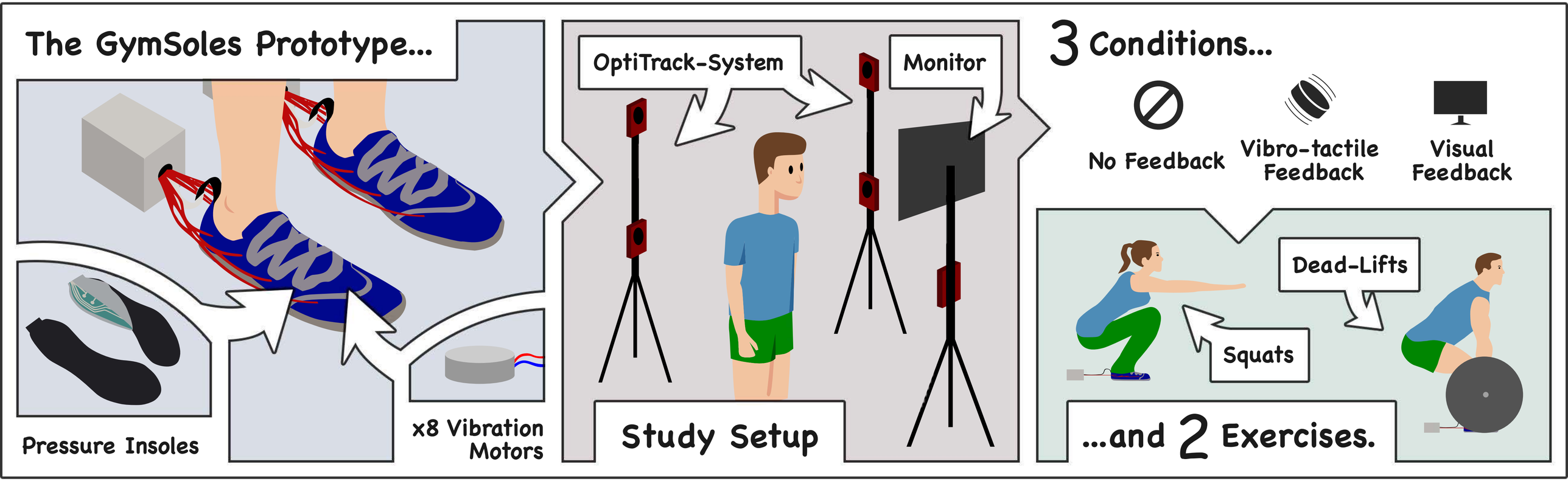
I = Ignore

Prompto(AH'19, IMWUT'20)

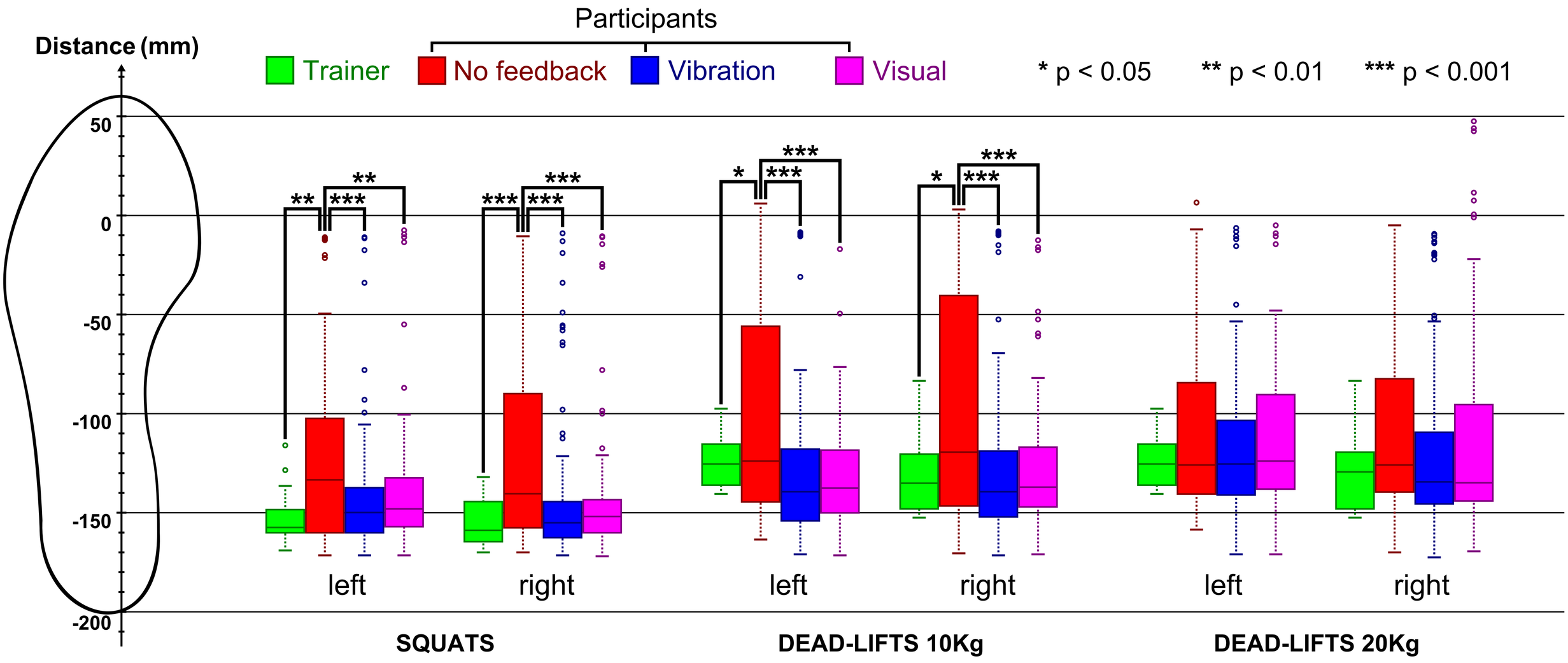
GymSole (CHI'19), GymSoles++ (AHs'10, PETRA'21)

GymSole (CHI'19), GymSoles++ (AHs'10, PETRA'21)

# GymSoles




GymSole (CHI'19), GymSoles++ (AHs'10, PETRA'21)

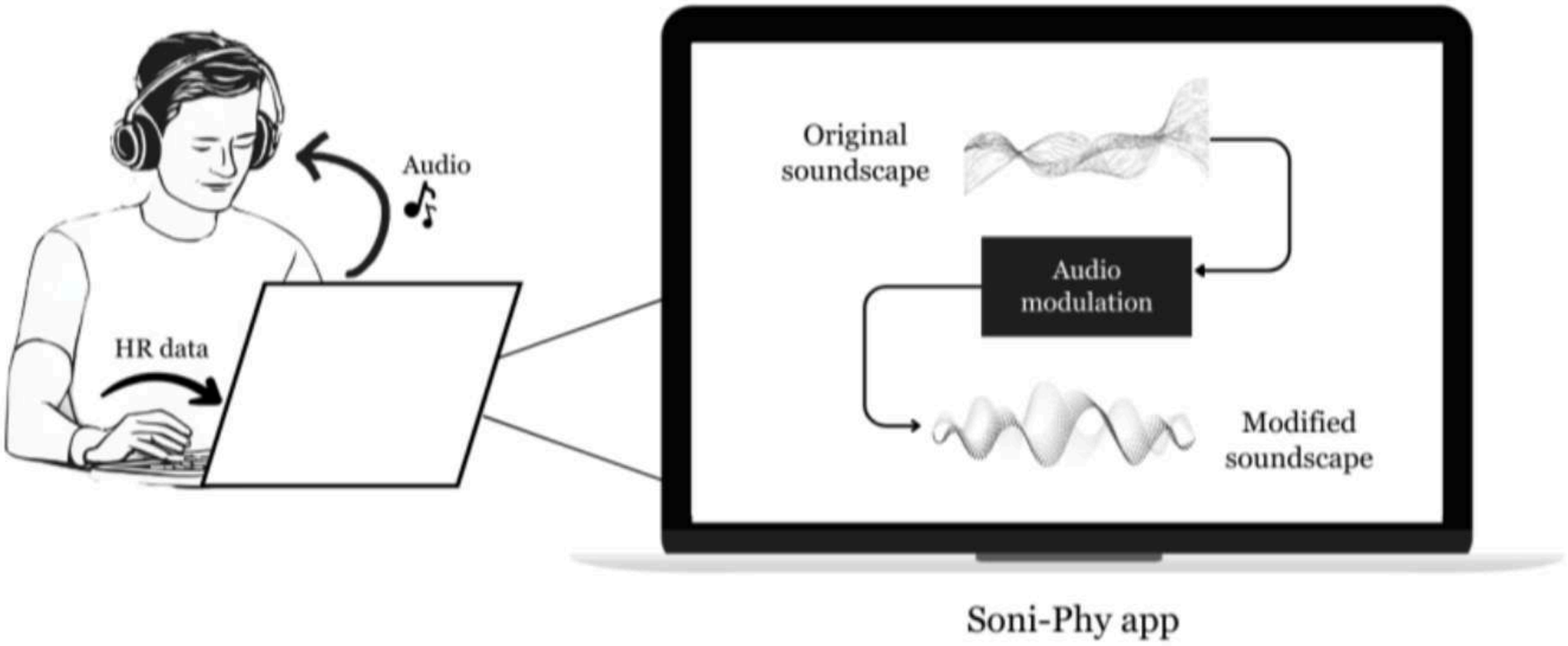



GymSole (CHI'19), GymSoles++ (AHs'10, PETRA'21)

SonyPhy

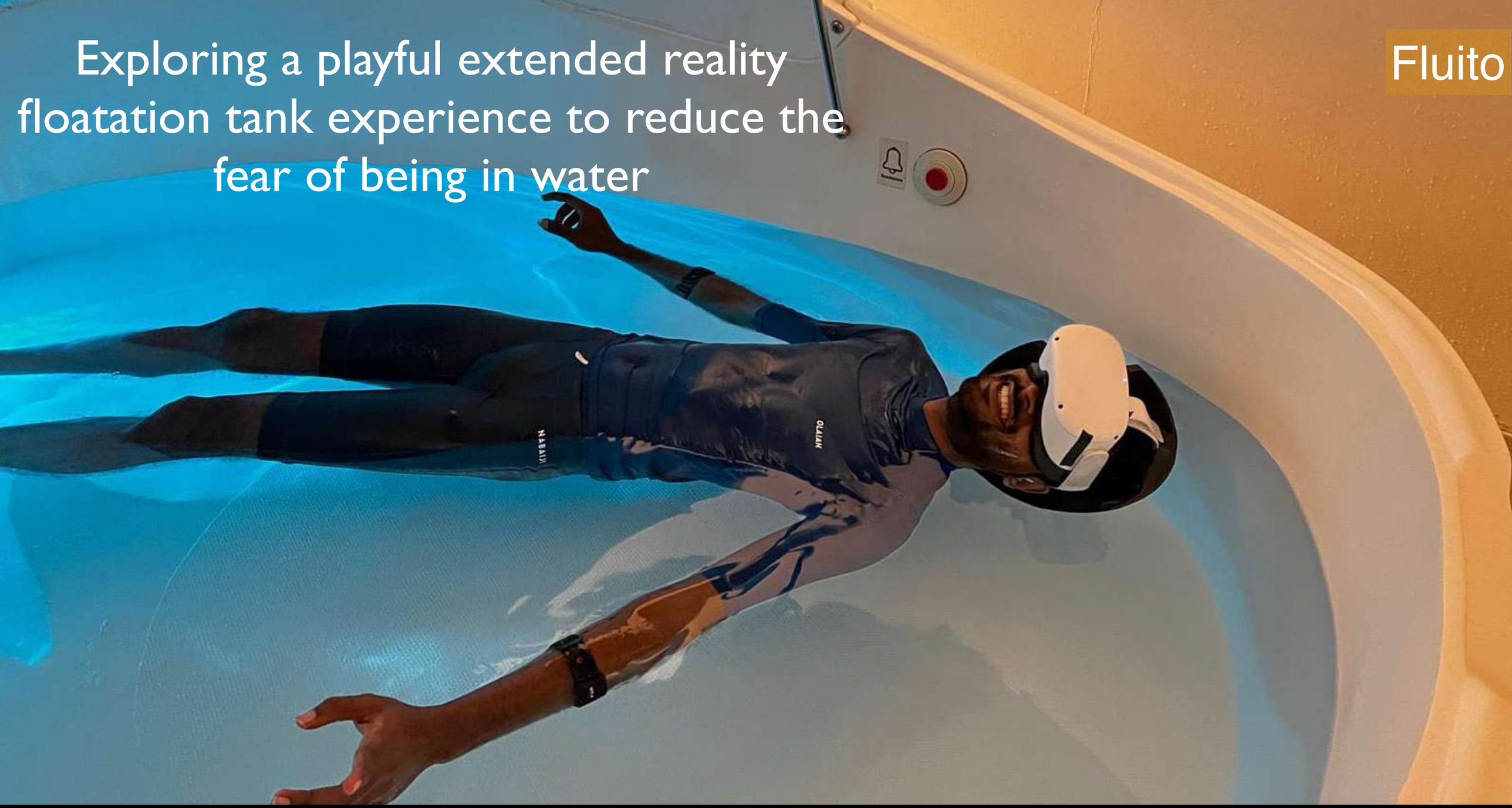
Investigate whether, and how, ambient biofeedback can be used to amplify our perception of internal bodily sensations and support emotion regulation

SonyPhy


Audio
HR data
Original soundscape
Audio modulation
Modified soundscape
Soni-Phy app

# Exploring a playful extended reality floatation tank experience to reduce the fear of being in water

Fluito



CHI’24

# Gut IO

# Learning

Kiwrious
How do we keep Kiwi Kids Kiwrious?

Kiwrious

# The Kiwrious Science Experience

The Kiwrious sensors

Inquiry Editor Platform

Resources for teachers

The first integrated science learning tool to be designed in New Zealand

Aligned with the level 4 and 5 of the national curriculum.

A solution allowing

**Interactive, Collaborative and Inquiry-Based**

science learning

Kiwrious

# 4200

Kiwrious sensors deployed

# 40

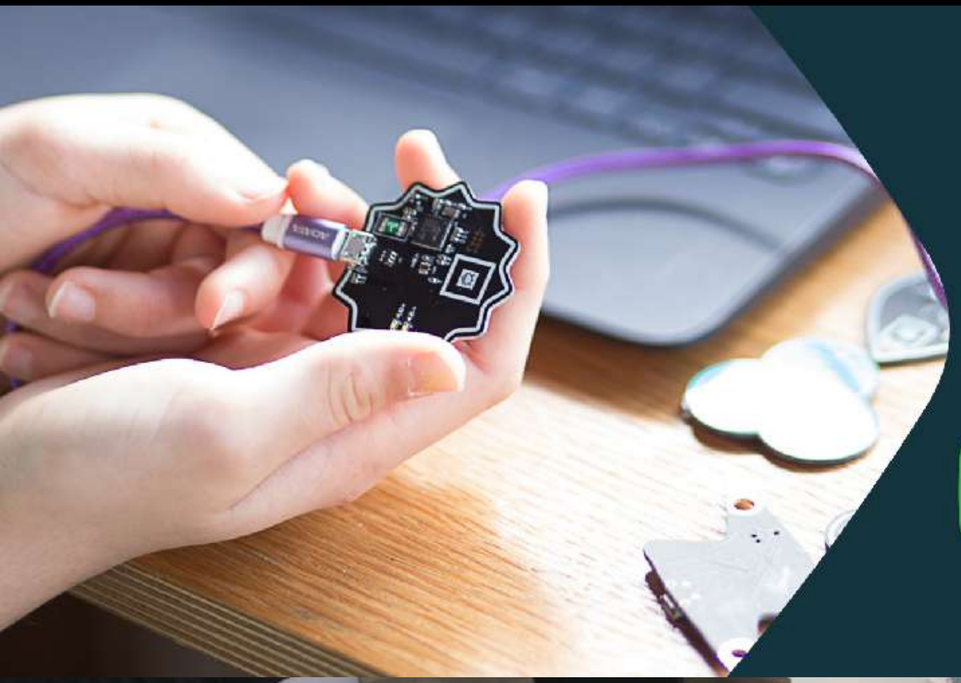
schools using Kiwrious
across a range of deciles

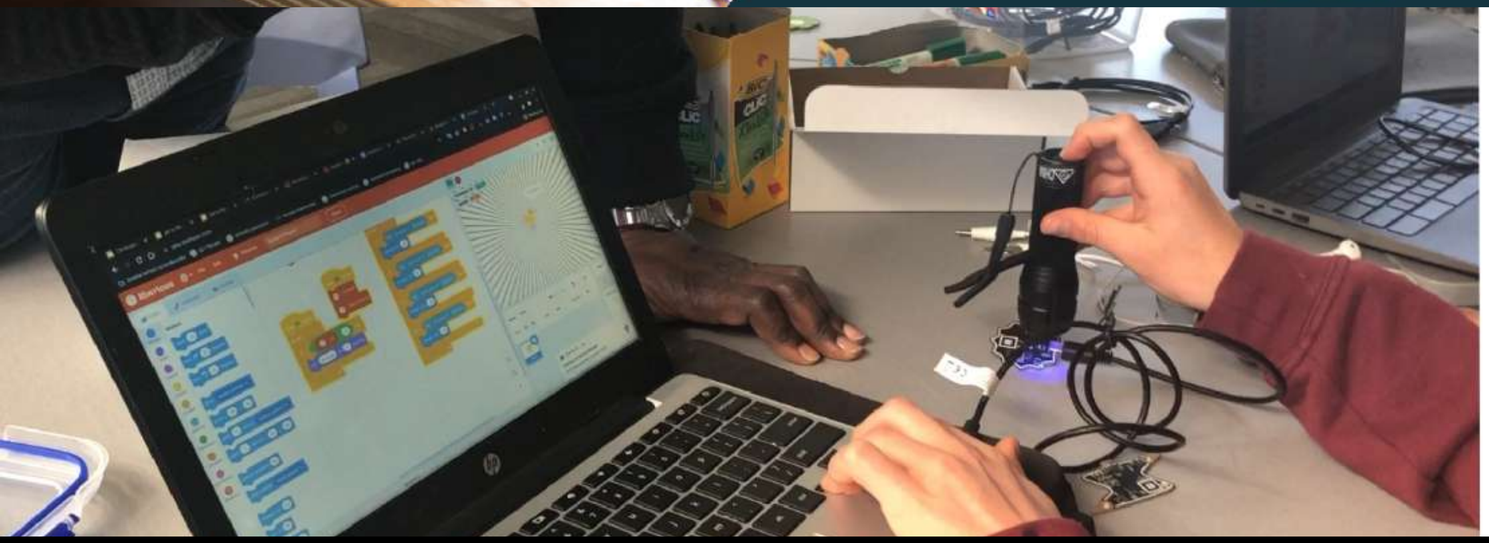
# 1575+

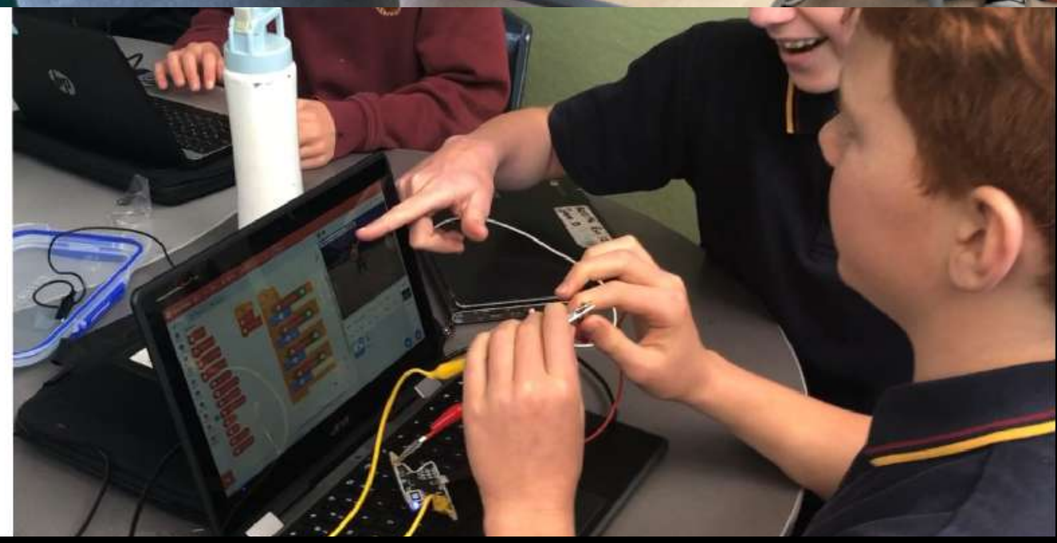
inquiries saved or
published by students
and growing daily

# Using Real-Time Sensor Data to Motivate Students Learning Scratch

Kiwrious



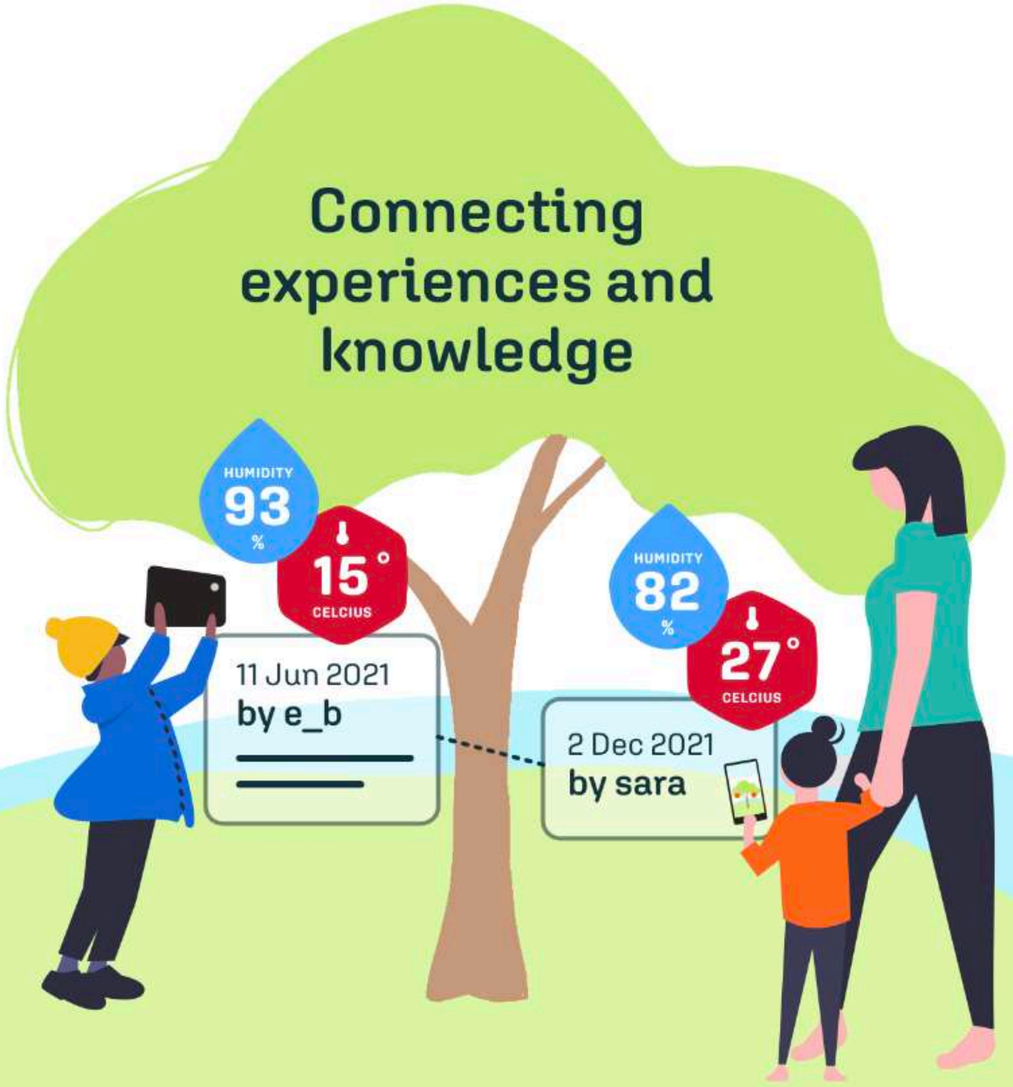




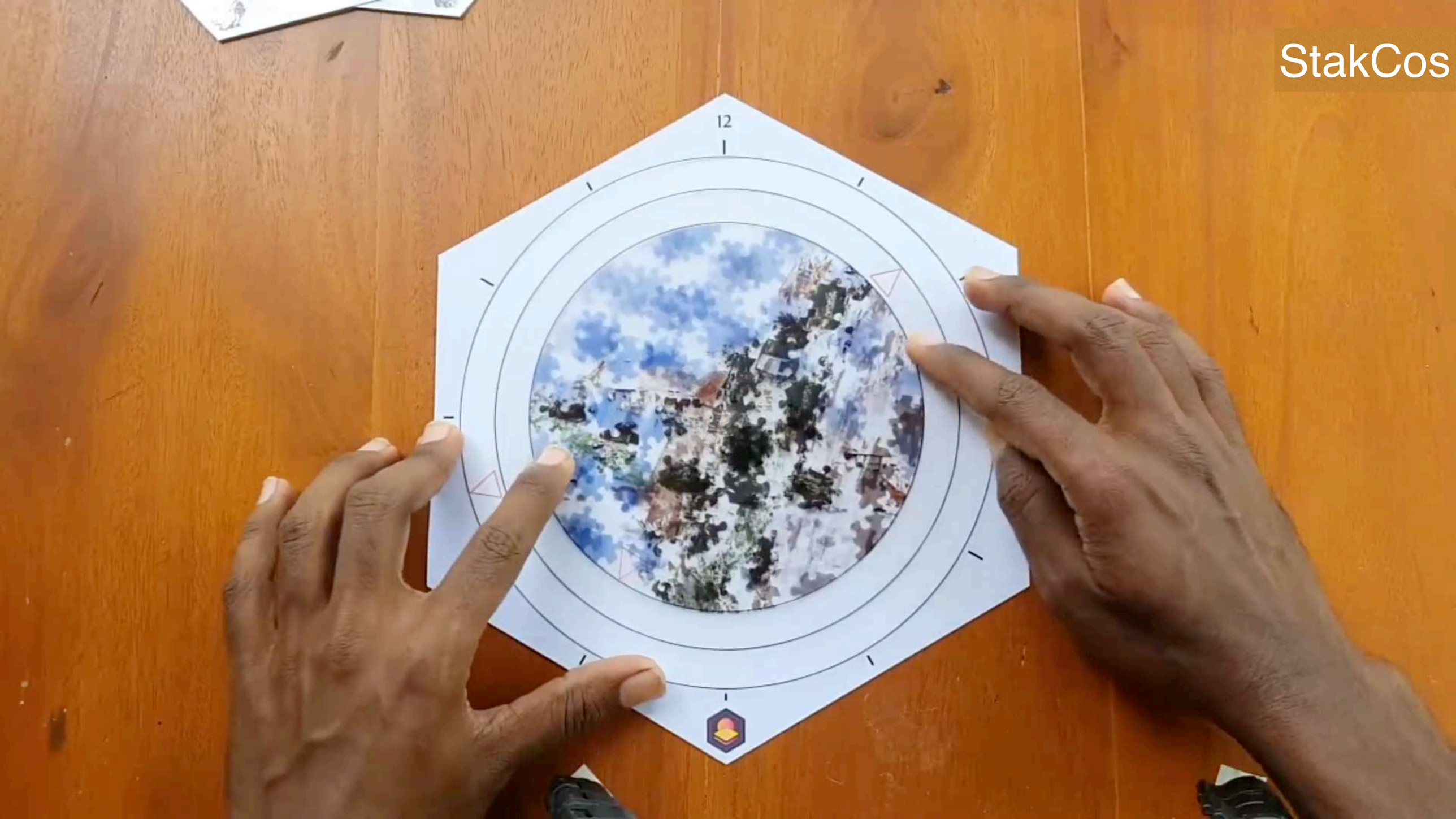
IDC'20, SIGCSE'22, ACE'22, ITiCSE'23

## Using sensors accessible to all

## Connecting experiences and knowledge

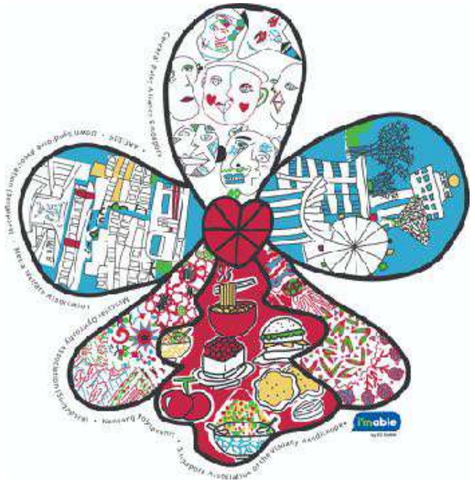


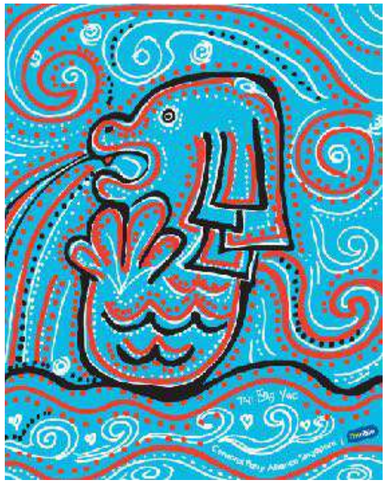

## Motivating learning in unique ways

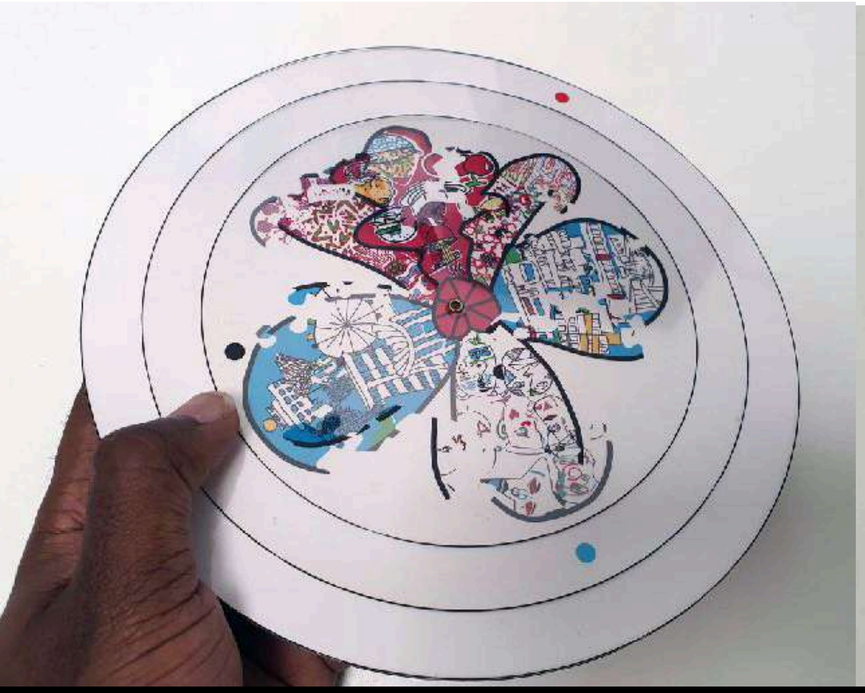

StakCos
12

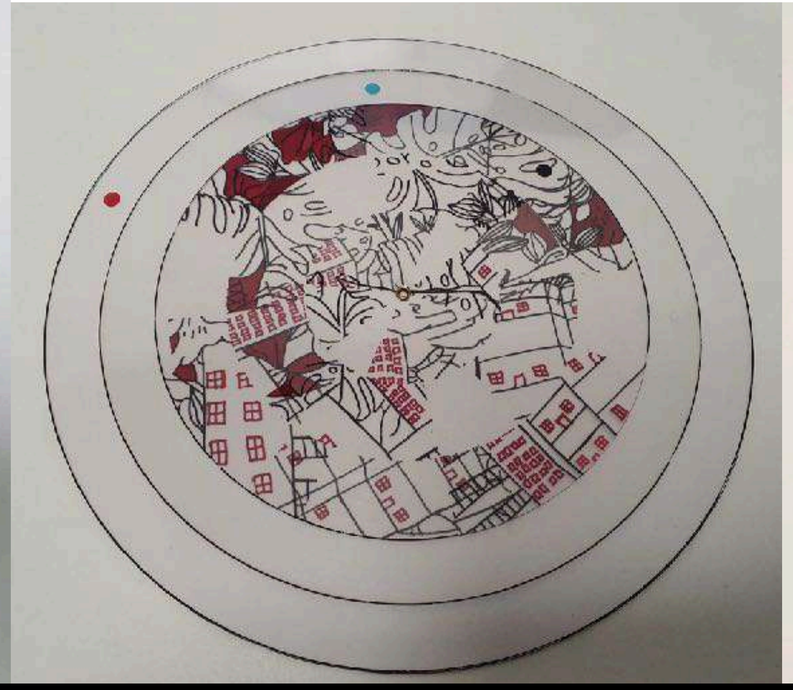
StakCos

i'mable COLLECT!VE







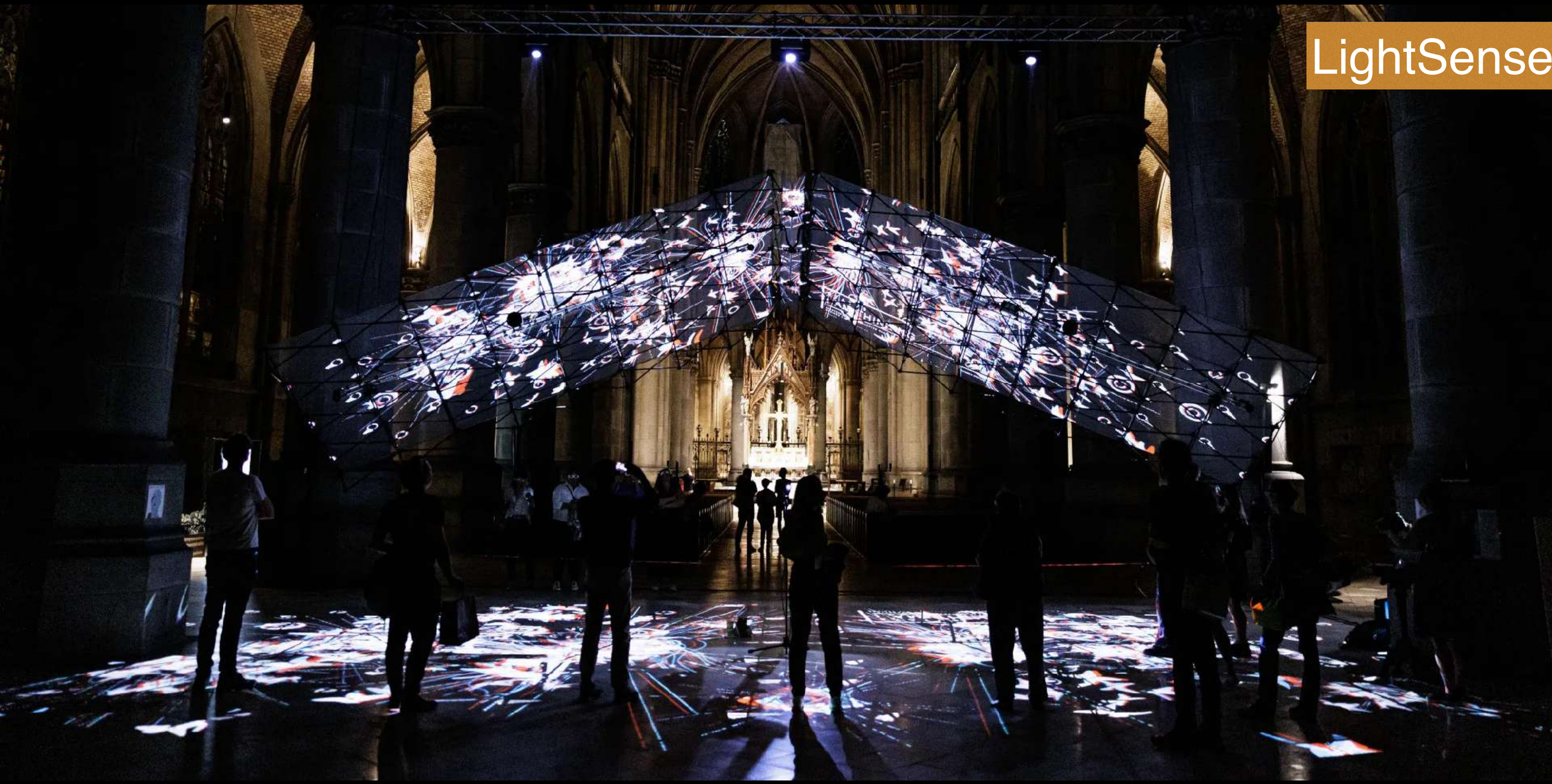


Installation in progress at AWWA School, Singapore

Stakco
v 3.1.11

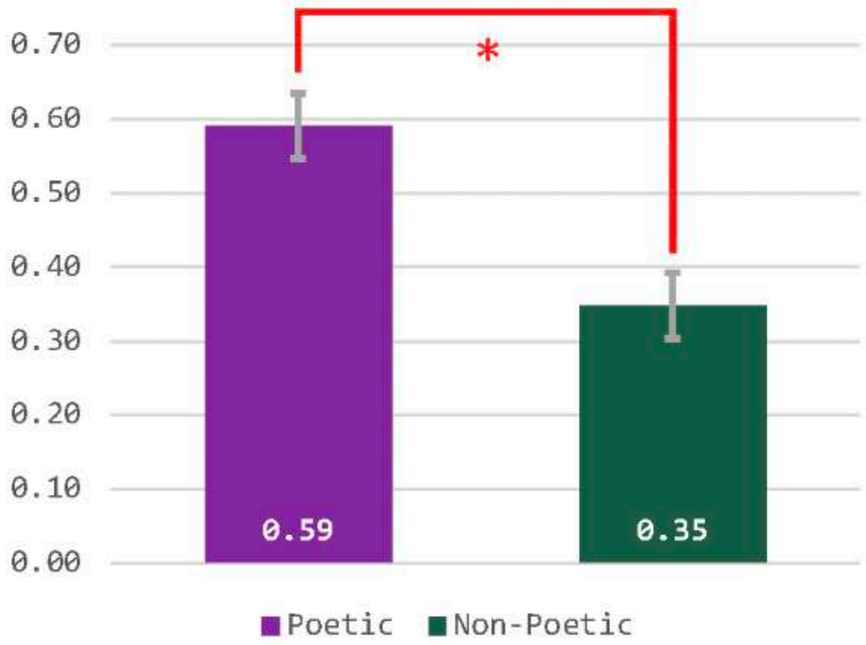
00:08

play.stakcos.com




Ars Electronica’21

22:32
Kavy
Hold and Speak
Moon is relaxing and it helps us feel more relaxed.
Kavy
The mighty moon is over the sea, and the mighty stars are over the sky, and all the wonder of the world is in the air... today is interesting. Tell me more, what are your thougts?

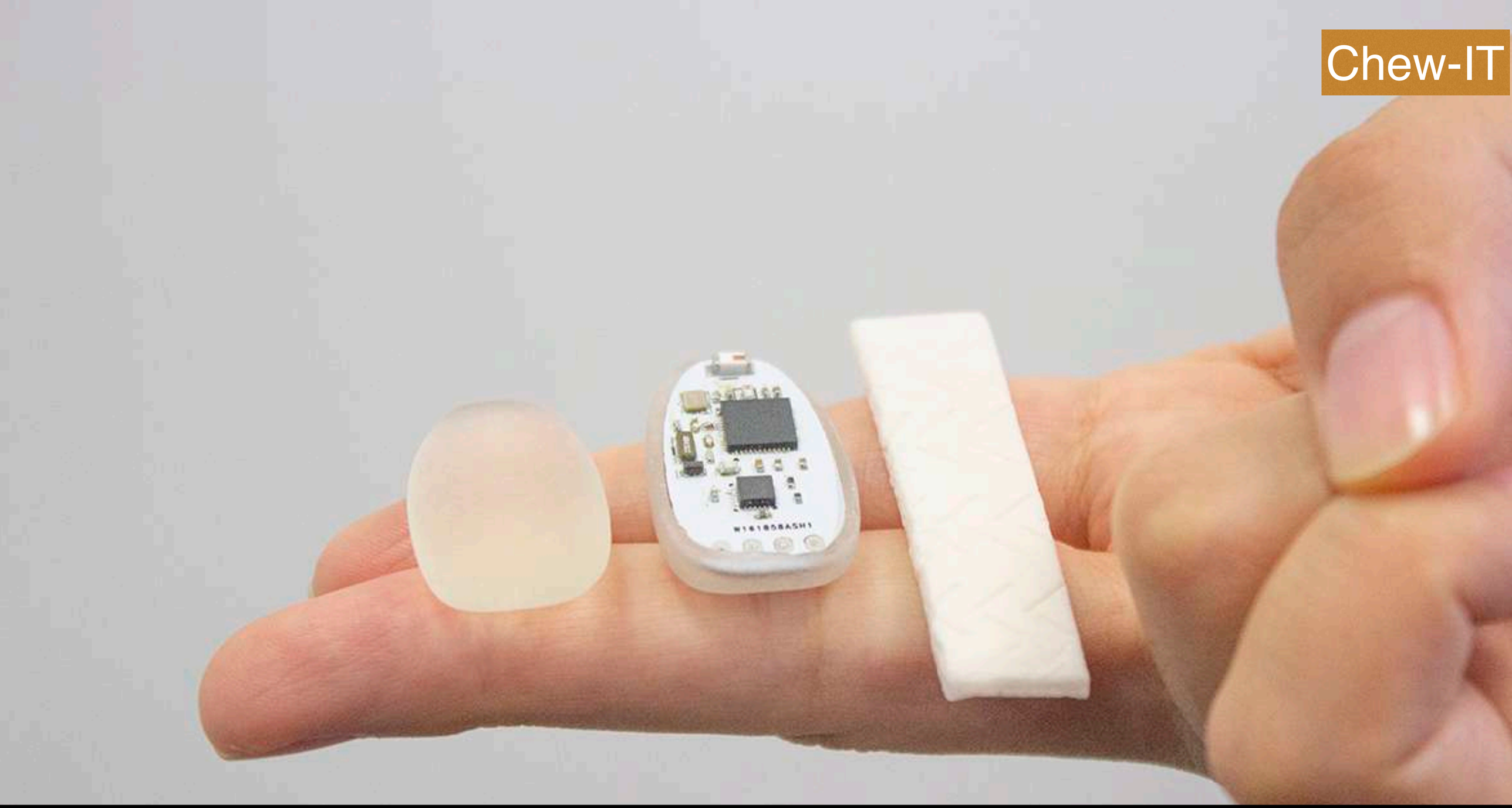



## More new words

T(12) = 7.17 showed a significant difference ($p<0.05$)

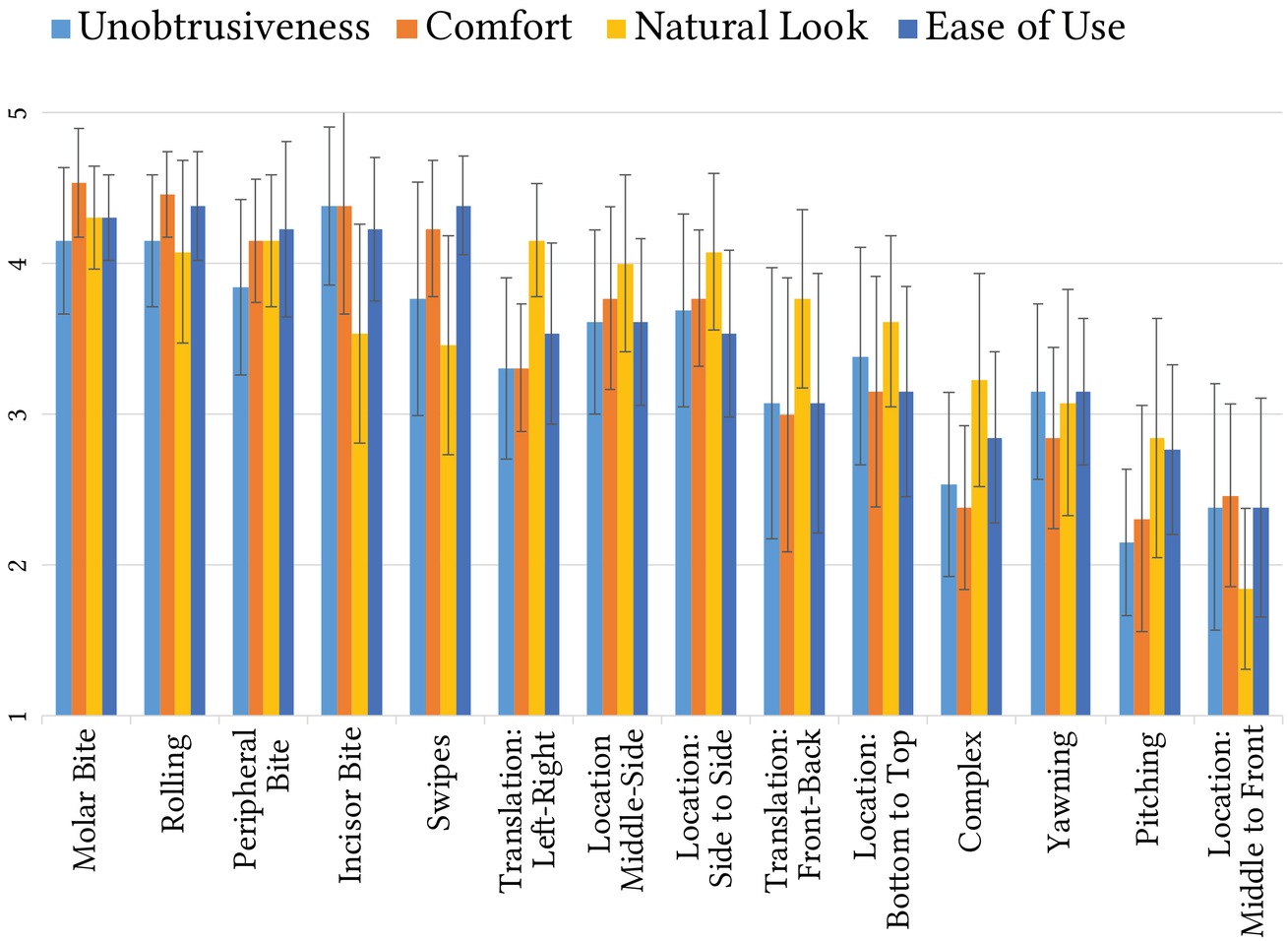
# (F)actually

Wearable, Live, fact-checker



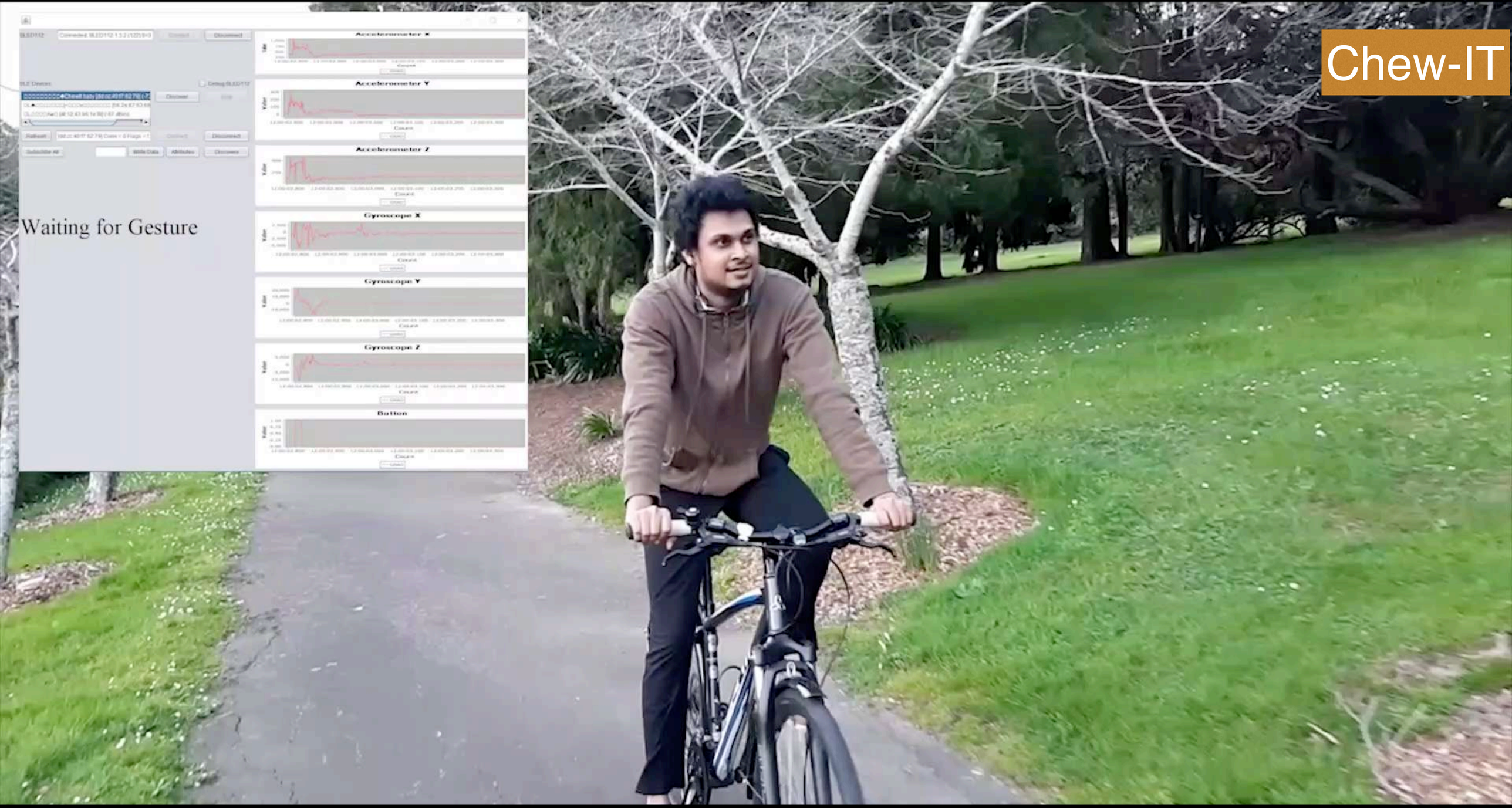

ChewIT (CHI'19)

## User Rating for all possible Gestures




## Confusion matrix for 9 gestures

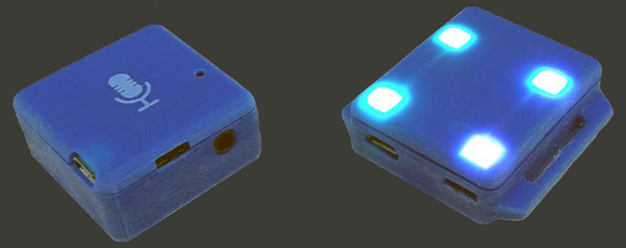
| Classified as > | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| A. Location: Bottom to Top | 96.8 | 0 | 0 | 0 | 0 | 3.2 | 0 | 0 | 0 | 0 |
| B. No Gesture | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C. Translation: Front-Back | 0 | 6.5 | 83.9 | 0 | 0 | 6.5 | 0 | 0 | 0 | 3.1 |
| D. Incisor Bite | 0 | 0 | 0 | 83.9 | 0 | 0 | 16.1 | 0 | 0 | 0 |
| E. Translation: Left-Right | 0 | 0 | 3.2 | 0 | 93.6 | 0 | 0 | 0 | 0 | 3.2 |
| F. Location: Middle-Side | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| G. Molar Bite | 0 | 0 | 0 | 22.6 | 0 | 0 | 71 | 6.4 | 0 | 0 |
| H. Peripheral Bite | 0 | 0 | 0 | 0 | 0 | 0 | 58.1 | 41.9 | 0 | 0 |
| I. Rolling | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.2 | 96.8 | 0 |
| J. Location: Side to Side | 0 | 0 | 3.2 | 0 | 0 | 3.2 | 0 | 0 | 0 | 93.6 |




ChewIT (CHI'19) Honorable Mention

**Technology can be empowering when the interaction between the technology and human is well designed**

# MUSS-BITS



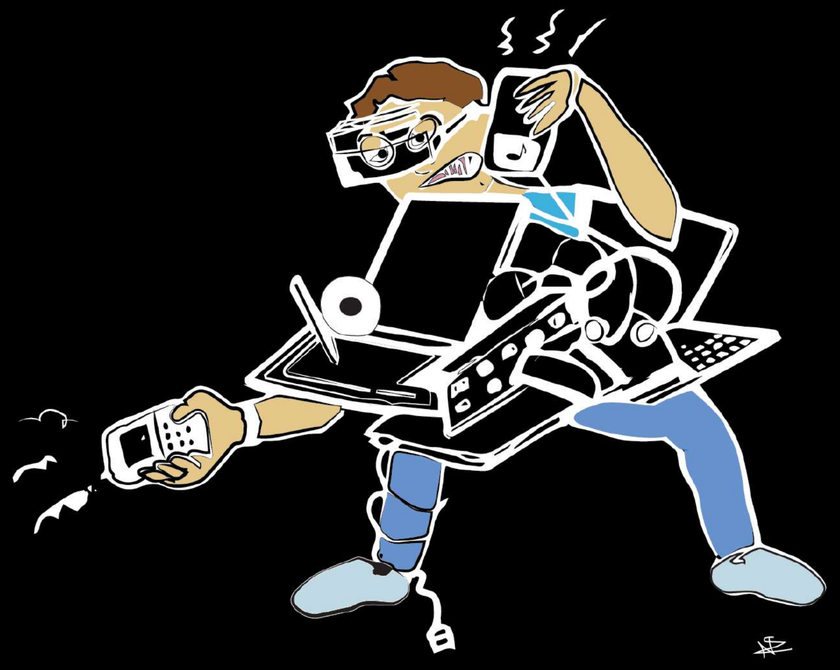
26 March

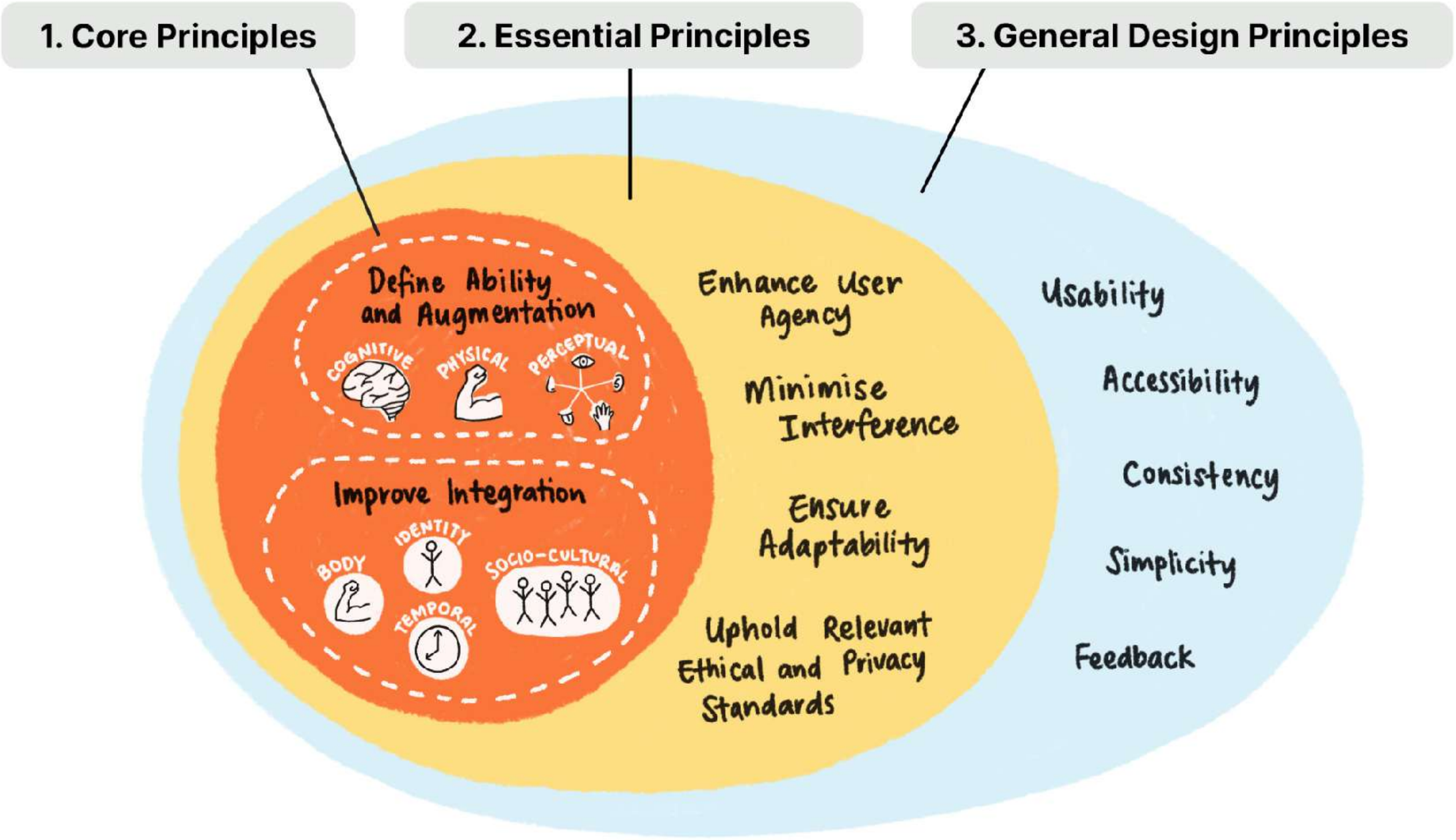
I wore it driving today It made driving So much more enjoyable

Should ve Seen me, I was really dancing in the car-probably out of beat Lot but i did'nt care

# Worth Thinking about…

- **User Agency**
  - User opts in
  - User decides rules & behaviours
- **Ethics and Privacy**
  - Privacy preserving storage & learning
  - Mindful of impact on others
- **Trust & Transparency**
  - Reporting & explanations
  - Carefully consider if we should automate, assist or teach

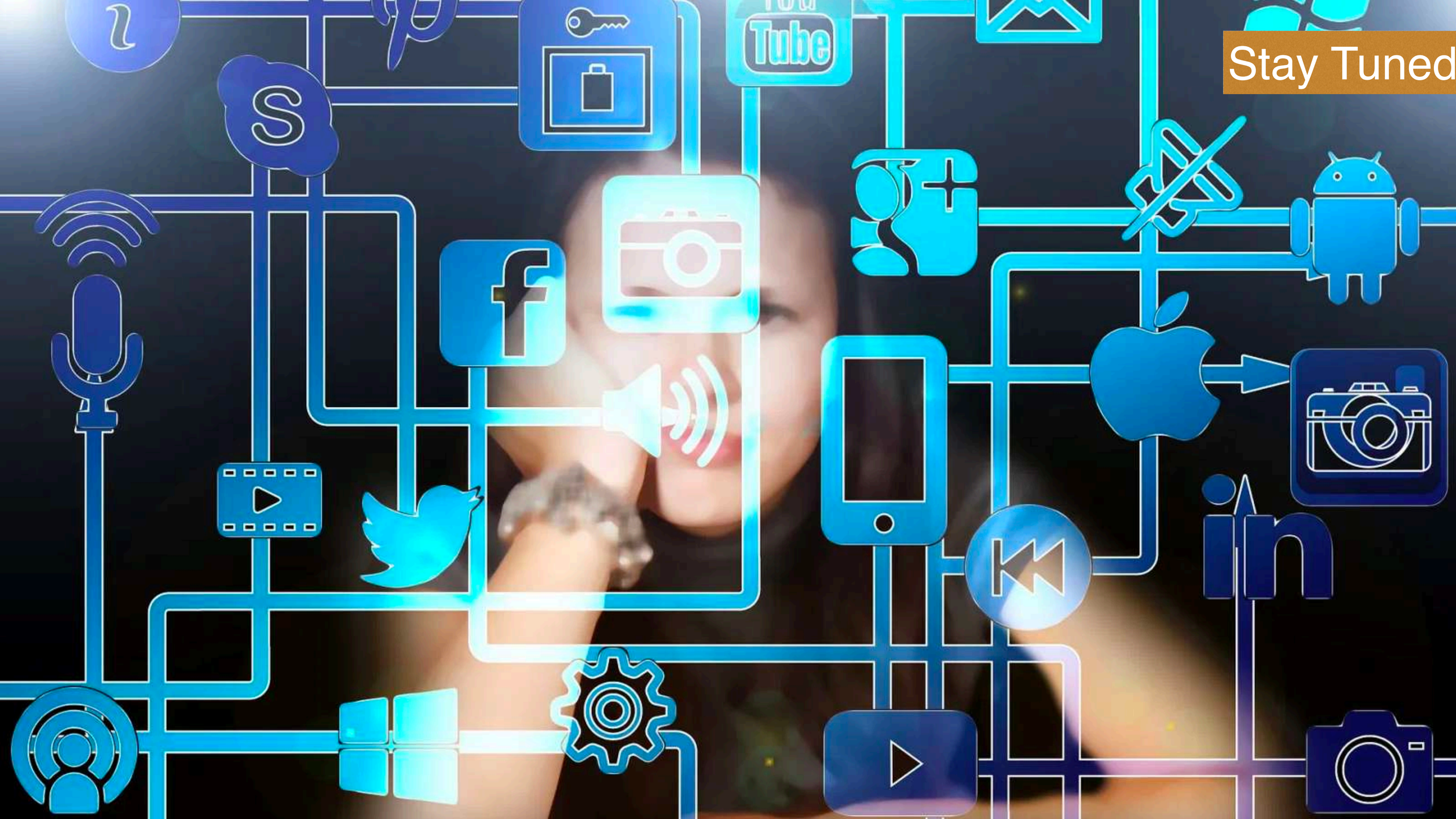



1. Core Principles
2. Essential Principles
3. General Design Principles
Define Ability and Augmentation
COGNITIVE
PHYSICAL
PERCEPTUAL
Improve Integration
IDENTITY
BODY
SOCIO-CULTURAL
TEMPORAL
Enhance User Agency
Minimise Interference
Ensure Adaptability
Uphold Relevant Ethical and Privacy Standards
Usability
Accessibility
Consistency
Simplicity
Feedback

# Combine AI+AR+Robotics

# Future

[صوت الهواء]
0:44
4:45

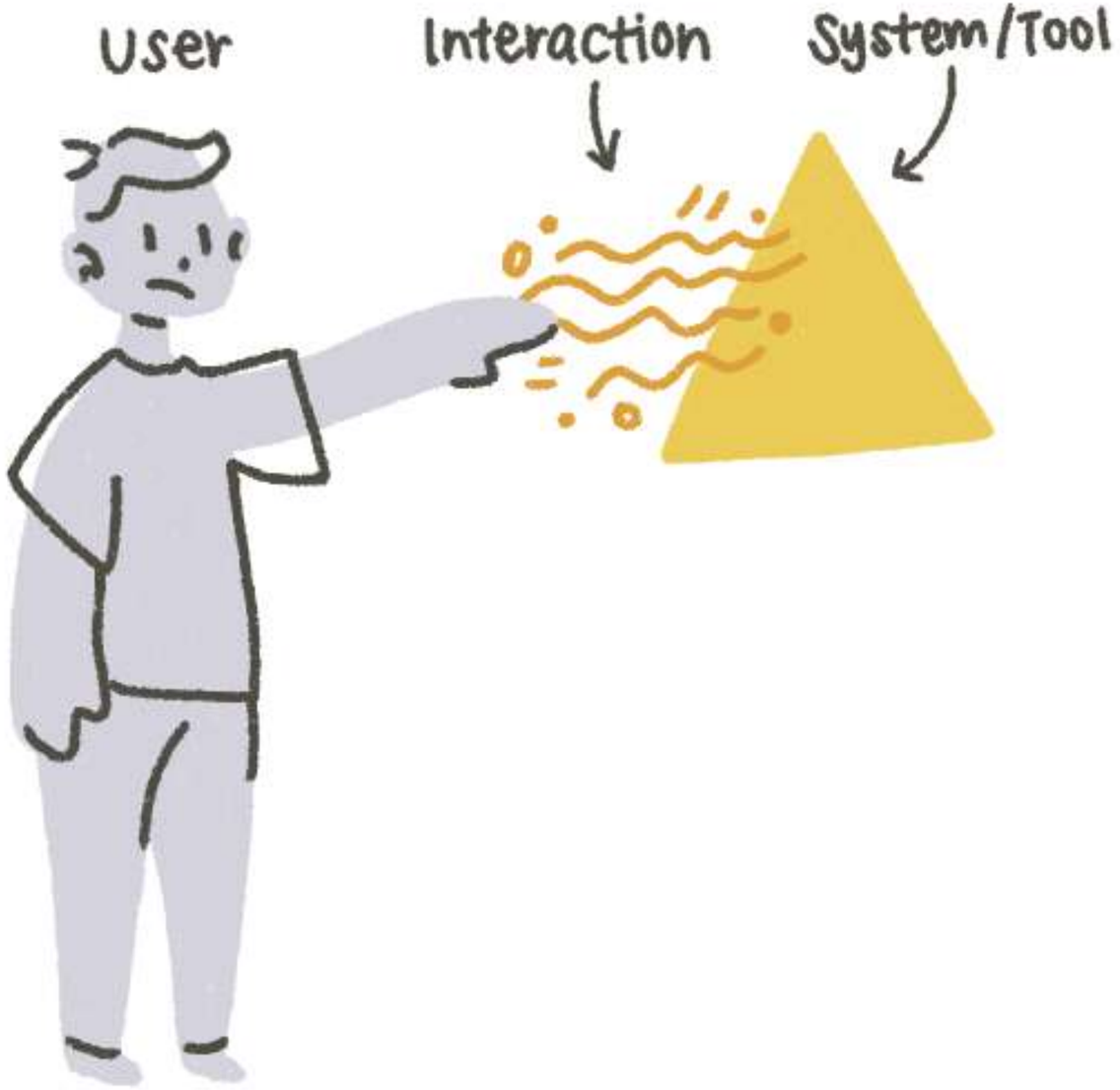

Stay Tuned

Stay Connected

Stay Focused

New Experiences

## User-System Compatibility Perspective




## Assistive Augmentation Perspective

INTERACTIONS JANUARY–FEBRUARY 2025 VOLUME XXXII.1

Association for Computing Machinery

# Assistive Augmentation: Fundamentally Transforming Human Ability

Exploring Neural Interface Education

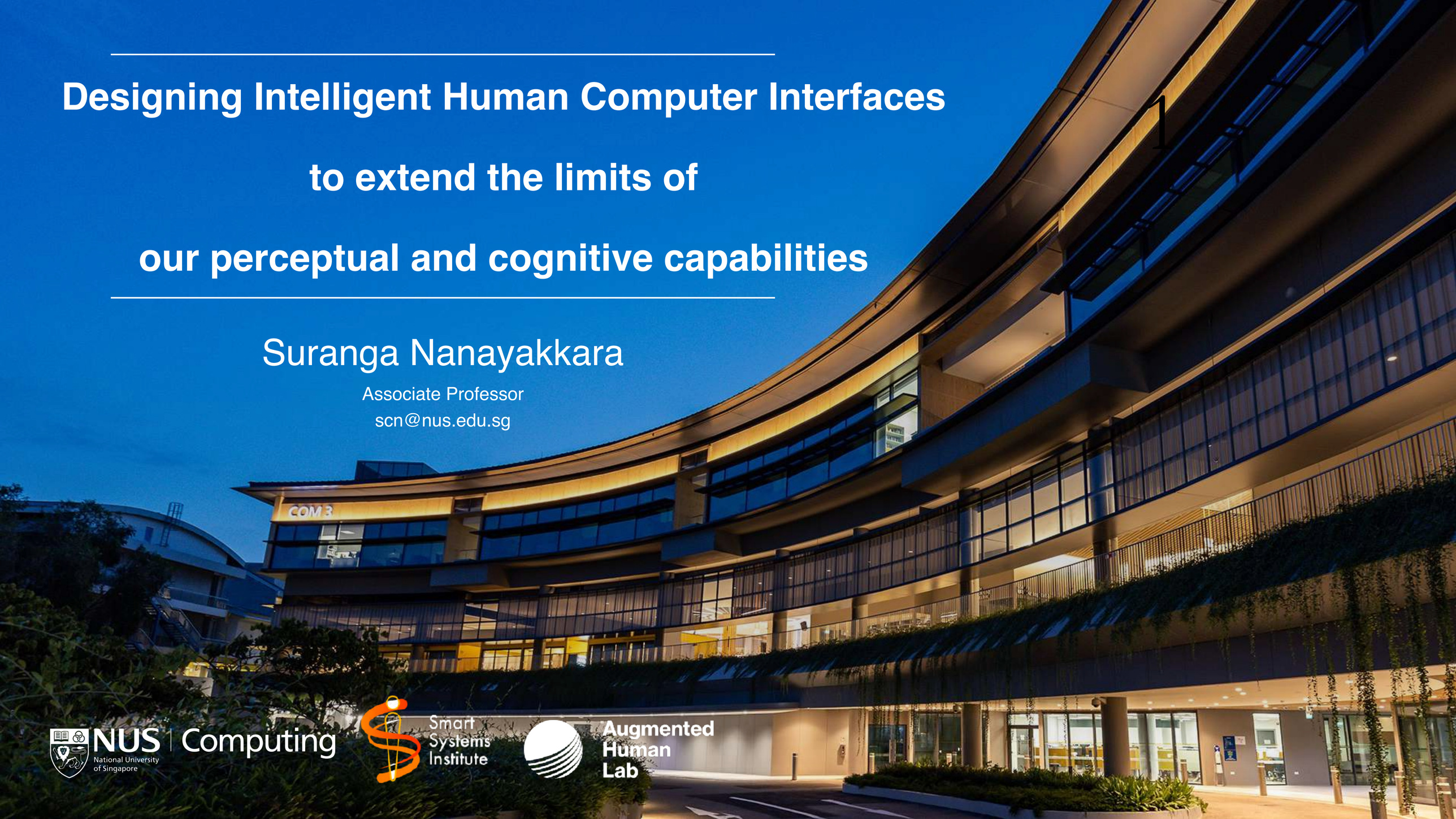
CHI's Greatest Hits

What If We Don't Accept the Cookies?

Human-Data Interaction: Thinking Beyond Individual Datasets

# Designing Intelligent Human Computer Interfaces to extend the limits of our perceptual and cognitive capabilities

Suranga Nanayakkara
Associate Professor
scn@nus.edu.sg




NUS National University of Singapore | Computing
Smart Systems Institute
Augmented Human Lab