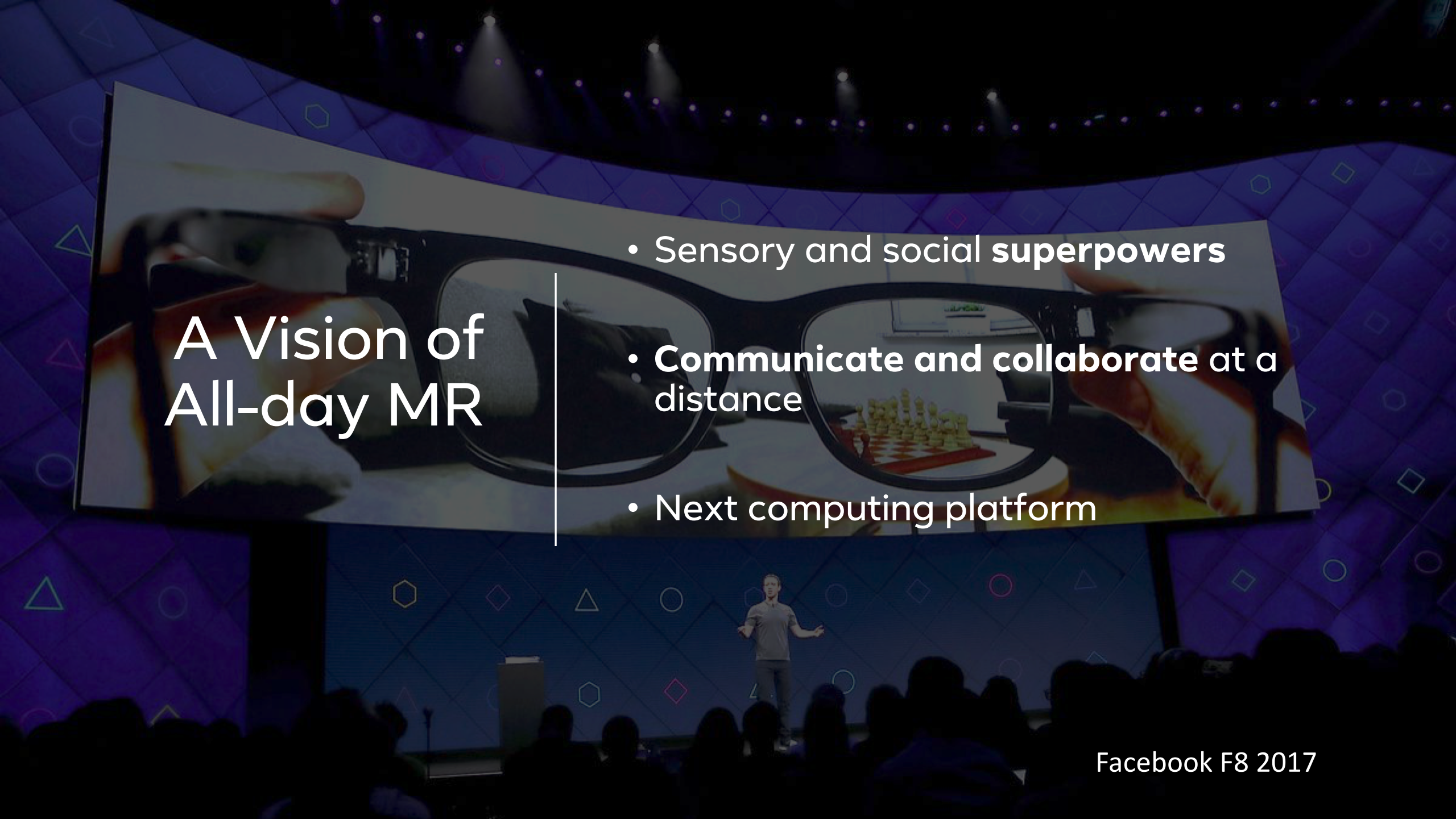
The Future of Mixed Reality Interactions

Hrvoje Benko

IEEE AIVR 2019

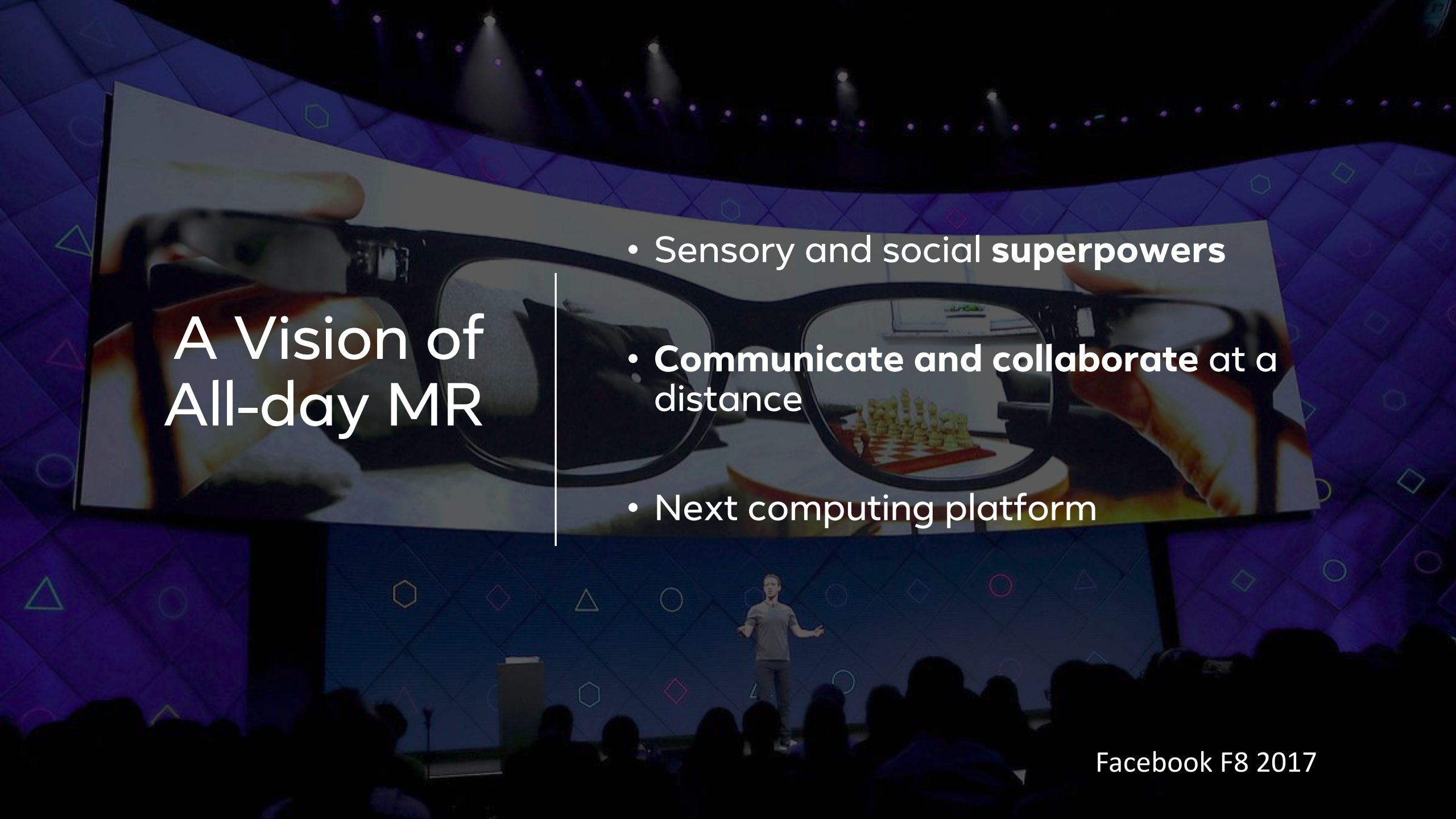

Facebook F8 2017



A Vision of All-day MR

- Sensory and social **superpowers**
- **Communicate and collaborate** at a distance
- Next computing platform

Facebook F8 2017



A Vision of All-day MR

- Sensory and social **superpowers**
- **Communicate and collaborate** at a distance
- Next computing platform

Facebook F8 2017

Hollerer, T., Bell, B., Feiner, S., et al.
Mobile Augmented Reality System, ISAR 2001

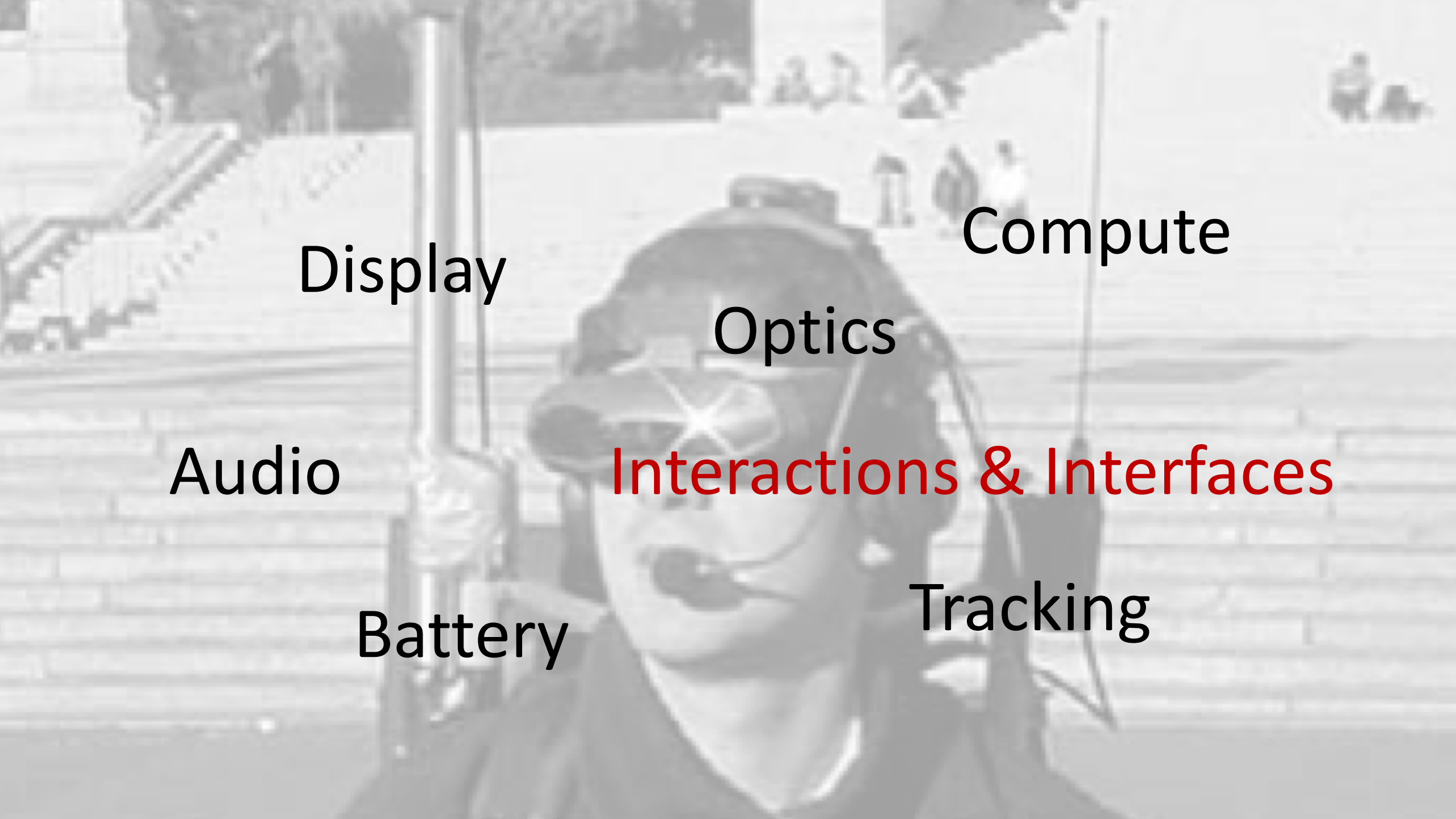
Hollerer, T., Bell, B., Feiner, S., et al.
Mobile Augmented Reality System, ISAR 2001

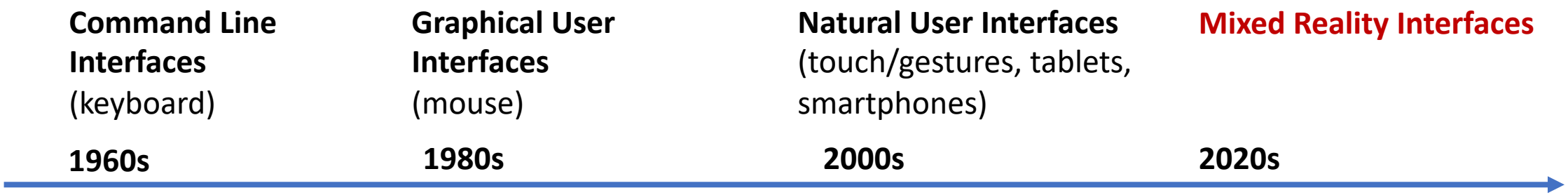

TOM'S RESTAURANT
Tom's Restaurant


TOM'S RESTAURANT

What is taking so long?


Compute
Display
Optics
Audio
Tracking
Battery


Compute
Display
Optics
Audio
Interactions & Interfaces
Tracking
Battery



New Computing Era =

New Display Form Factor

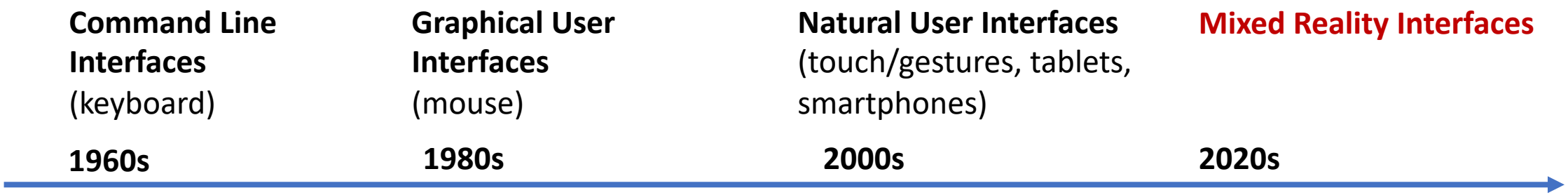
+ New Input Method

+ New Interactions

Not convinced?


Excel Mobile
F5
Product X
EMEA
US
Americas
APAC
Units
15.00
17.00
22.00
20.00
11.25
12.75
16.5
15
2.00
4.00
2.00
1.00
2.00
4.00
2.00
1.00
Ready
Shipments
Sum=2.00
View
Menu
15:28
ok
TOSHIBA


Mic
Holo
BREFLEKT
Vulkan



New Computing Era =

New Display Form Factor

+ New Input Method

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Command Line Interfaces (keyboard)

1960s

Graphical User Interfaces (mouse)

1980s

Natural User Interfaces (touch/gestures, tablets, smartphones)

2000s

Mixed Reality Interfaces

2020s

1968
Engelbart & English
MOAD

1983
Microsoft Mouse / Apple Mouse

Command Line Interfaces (keyboard)

1960s

Graphical User Interfaces (mouse)

1980s

Natural User Interfaces (touch/gestures, tablets, smartphones)

2000s

Mixed Reality Interfaces

2020s

1985
MultiTouch Tablet

2007
Apple iPhone

S.K. Lee, W. Buxton, and K. C. Smith.
A multi-touch three dimensional touch-sensitive tablet.
In Proc. of the ACM CHI '85.

Command Line Interfaces (keyboard)

1960s

Graphical User Interfaces (mouse)

1980s

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2000s

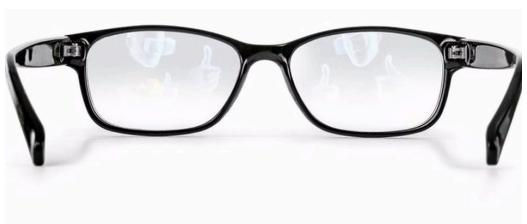
Mixed Reality Interfaces

2020s

"The future is already here – it's just not evenly distributed yet."

William Gibson

What makes for compelling Mixed Reality interfaces?




oculus


Optoma

What makes for compelling Mixed Reality interfaces?

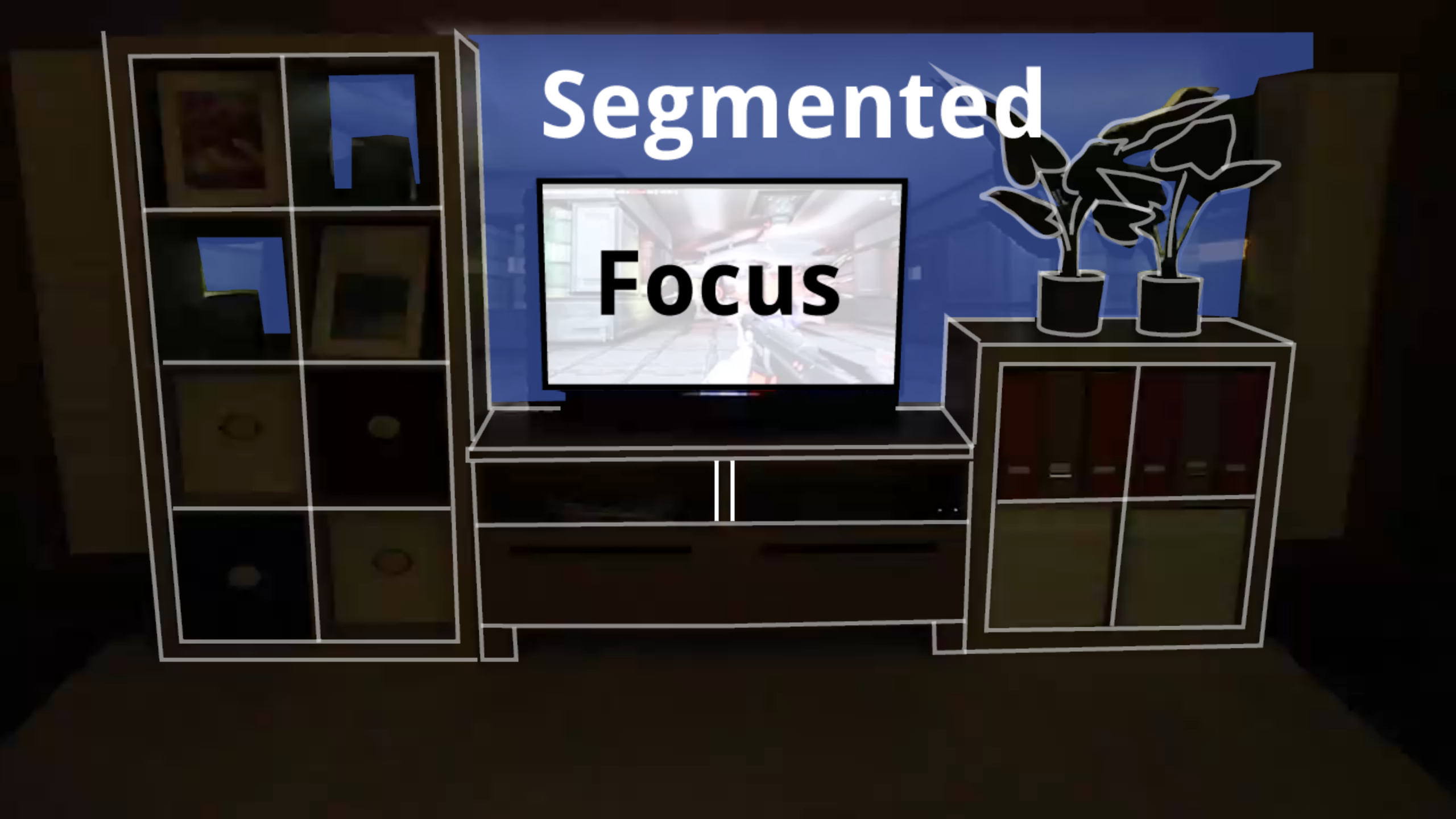
Compelling MR interfaces are *adaptive*

IllumiRoom: Peripheral Projected Illusions for Interactive Experiences.
Jones, B., Benko, H., Ofek, E., and Wilson, A. D. In *Proc. of ACM CHI 2013*.

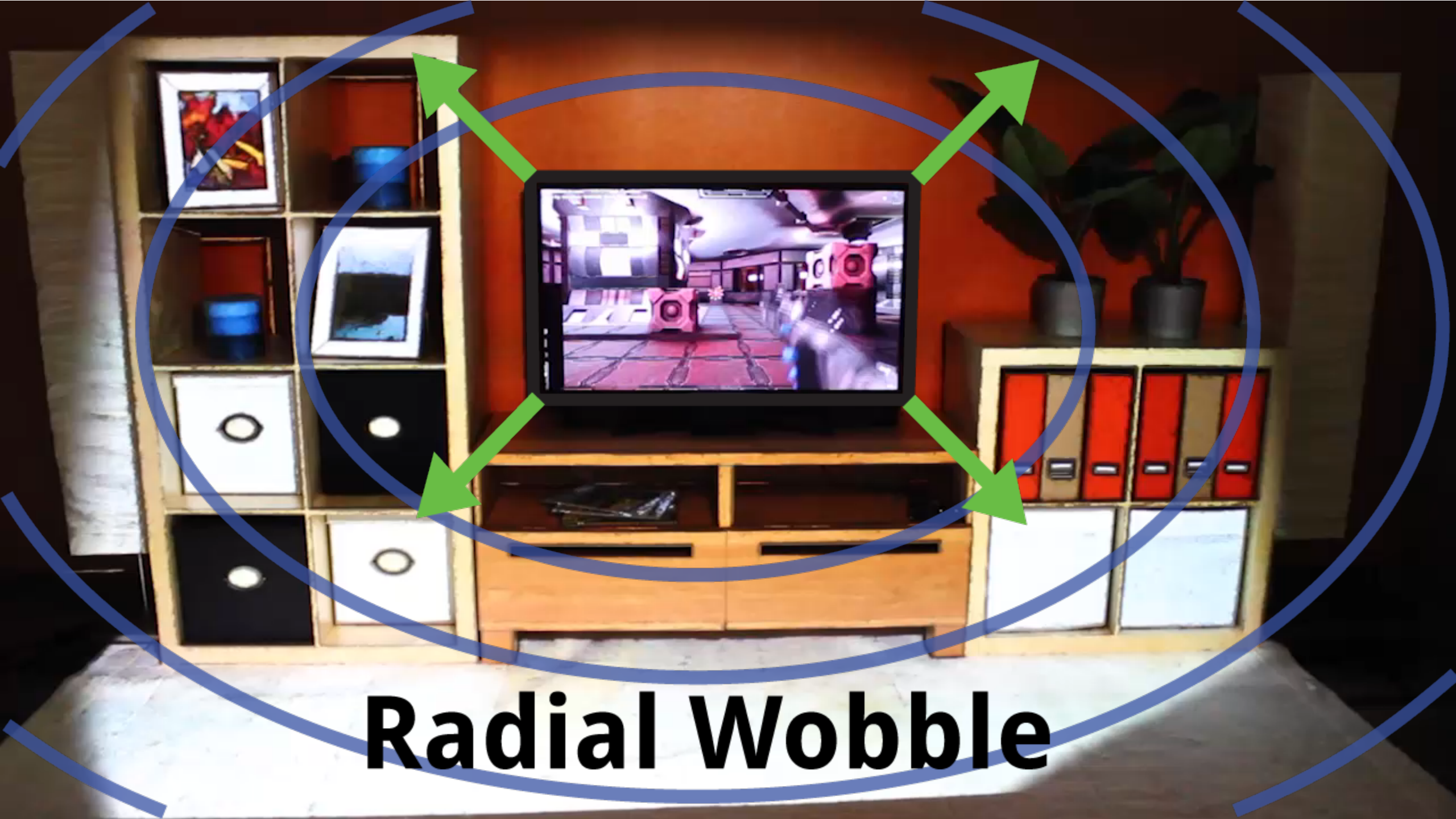
IllumiRoom

Jones, Benko, Ofek and Wilson, CES Las Vegas and ACM SIGCHI 2013


Focus
Context Full


Segmented
Focus


Appearance


Radial Wobble

Lighting

Magic of MR interactions happens when they are tightly coupled to the user's ~~environment~~.

context

Context

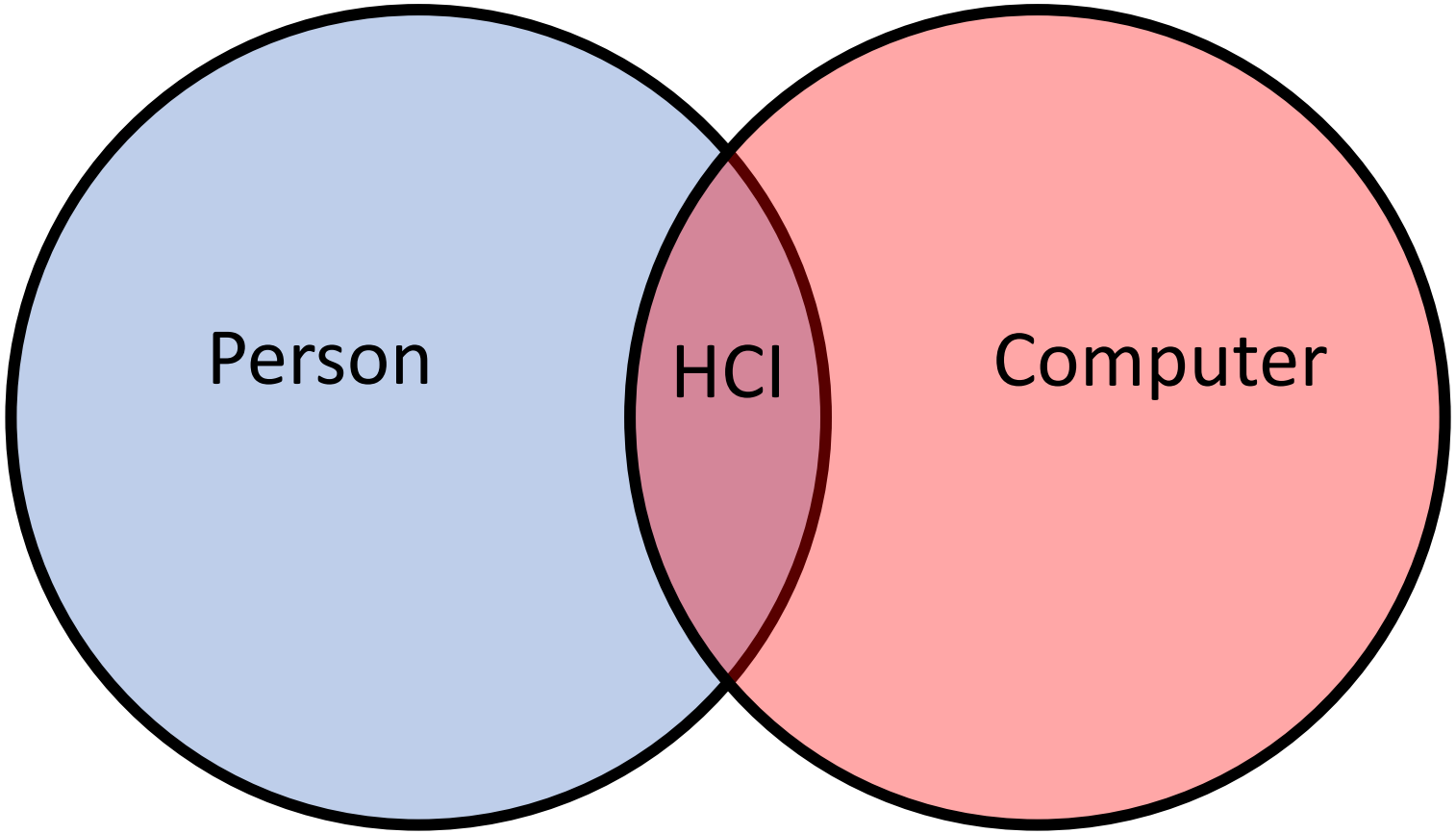
environment
(space geometry, object semantics, people around,…)

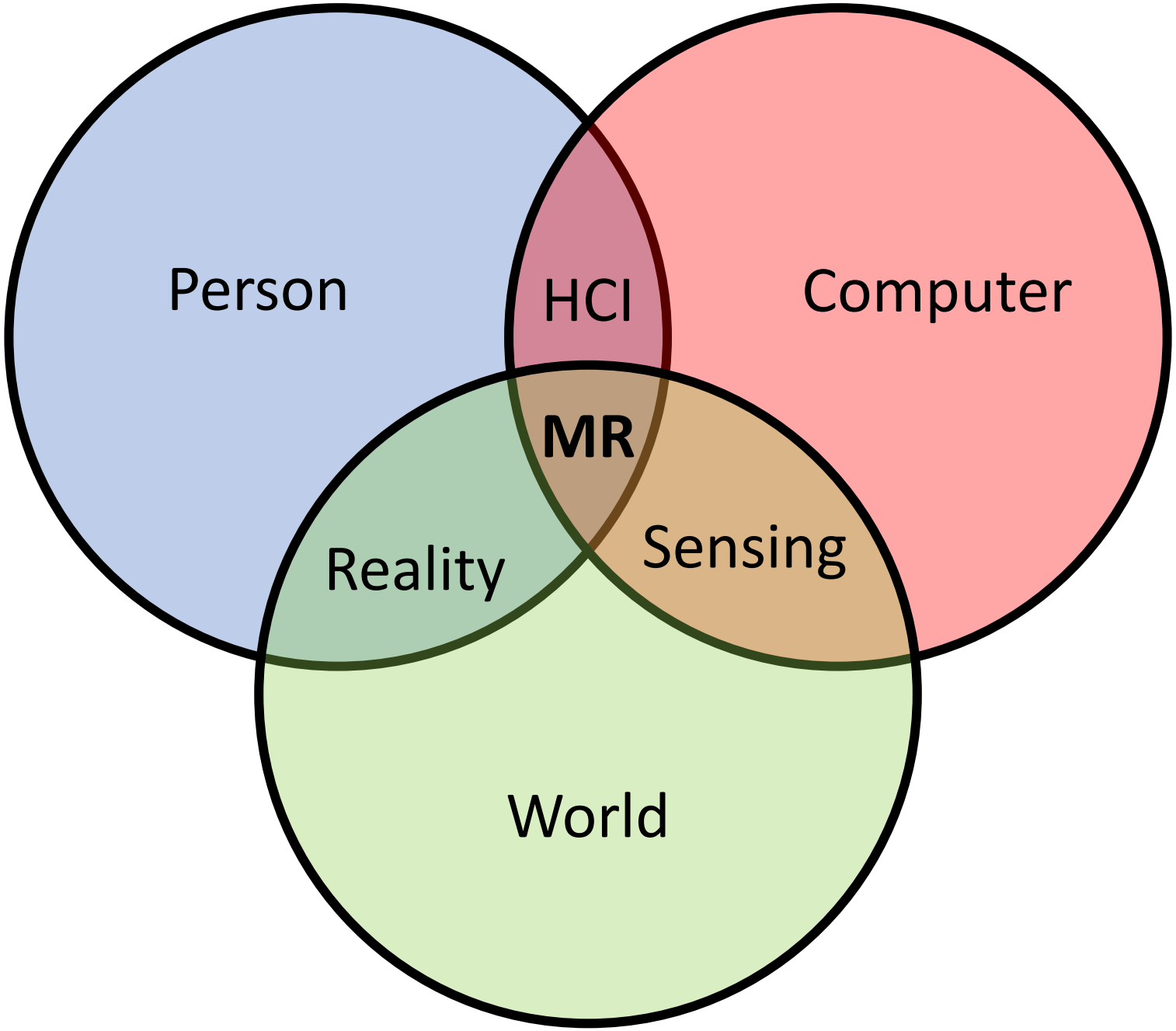
task
(communication, navigation, calendar,…)

user actions
(gestures, body pose, bio-signals,…)

user’s mental state
(emotional, mental load, cognitive focus,…)

Context not known at design time.


Person
HCI
Computer


Person
HCI
Computer
MR
Reality
Sensing
World

Compelling MR interfaces are *adaptive*

Compelling MR interfaces are *adaptive, believable*

In MR, we are obsessed with creating a rich sense of reality!

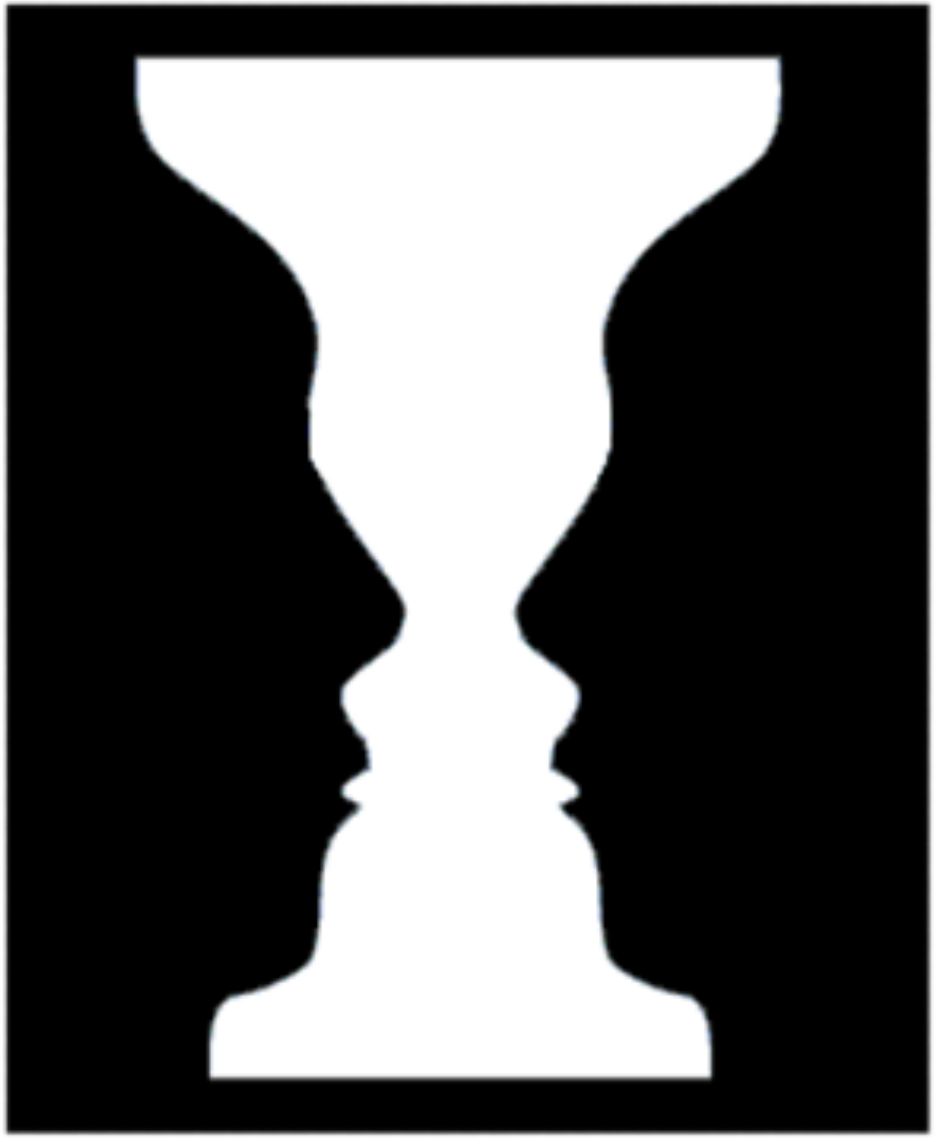
GENERATIONS / VANCOUVER 12-16 AUGUST
SIGGRAPH2018

Deep Appearance Models for Facial Rendering

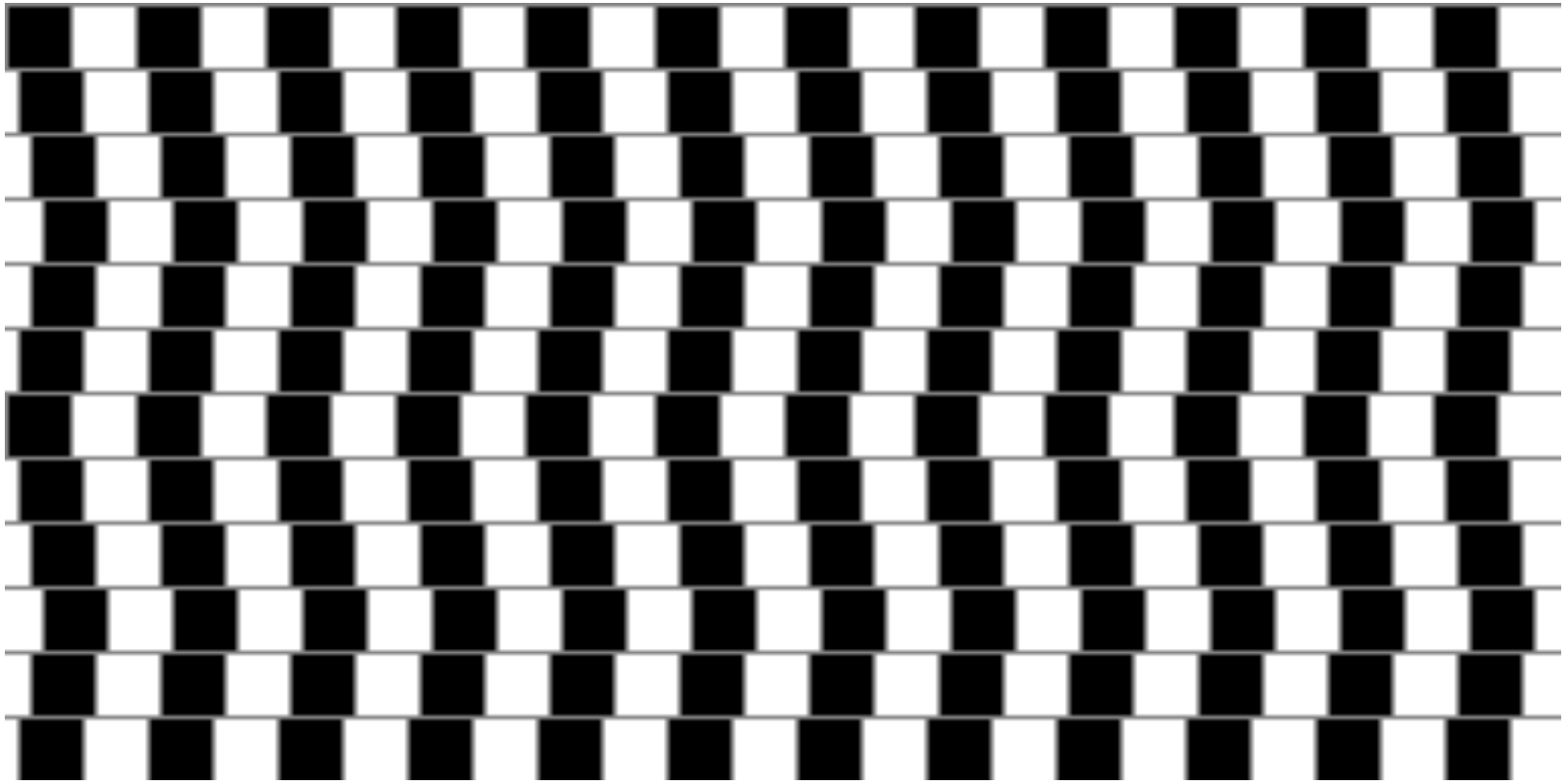
STEPHEN LOMBARDI, JASON SARAGIH, TOMAS SIMON, YASER SHEIKH
Facebook Reality Labs

For interactions,
realistic is not always better

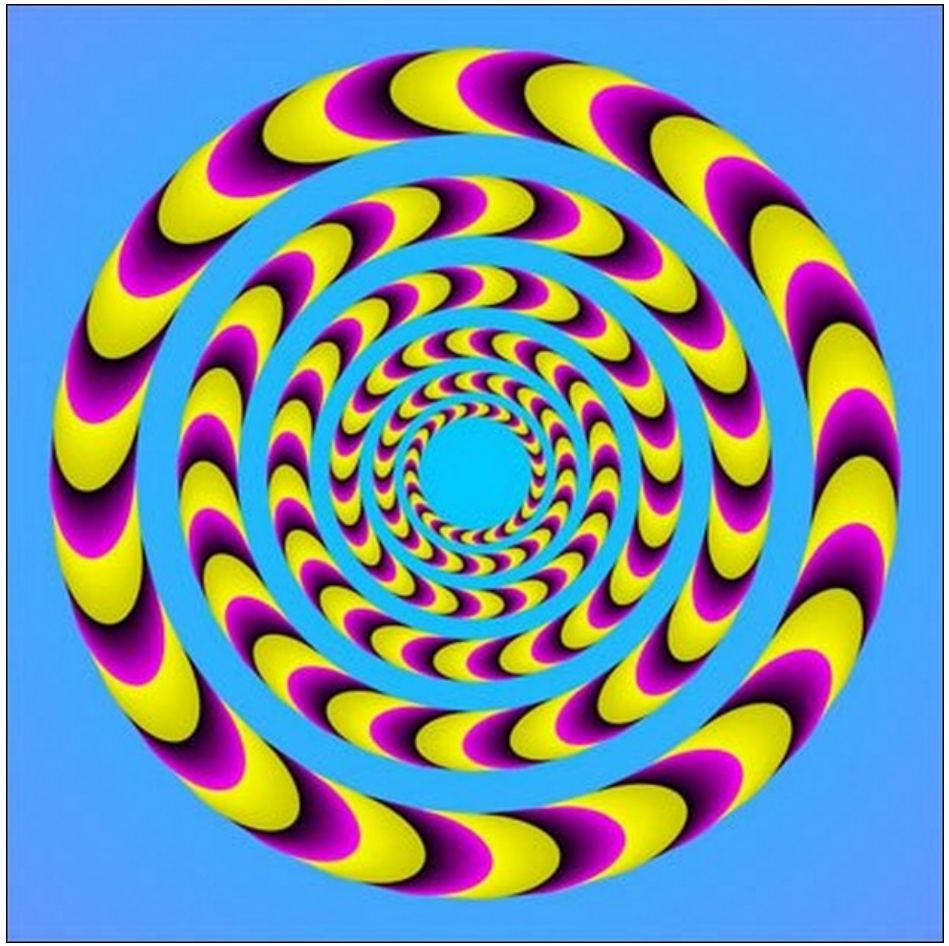
Faces or vase?



Straight or crooked?



Moving or static?



Think about MR interfaces as perceptual illusions that give the user a believable experience!

Believable ≠ Realistic

Example…

But, passive haptics don’t scale!

Haptic Retargeting
Dynamic Repurposing of Passive Haptics for Enhanced Virtual Reality Experiences

Mahdi Azmandian, Mark Hancock
Hrvoje Benko, Eyal Ofek, Andy Wilson
Microsoft Research

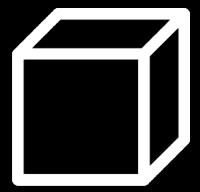
SIGCHI 2016

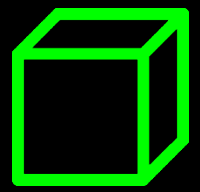
Haptic Retargeting: Dynamic Repurposing of Passive Haptics for Enhanced Virtual Reality Experiences.
Azmandian, M., Hancock, M., Benko, H., Ofek, E., and Wilson, A. *In Proc. of* ACM CHI 2016.

Leverage the dominance of vision to retarget people's hand motions.

Body Warping

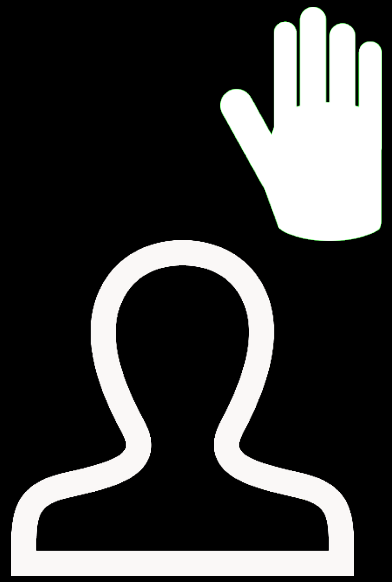
physical cube



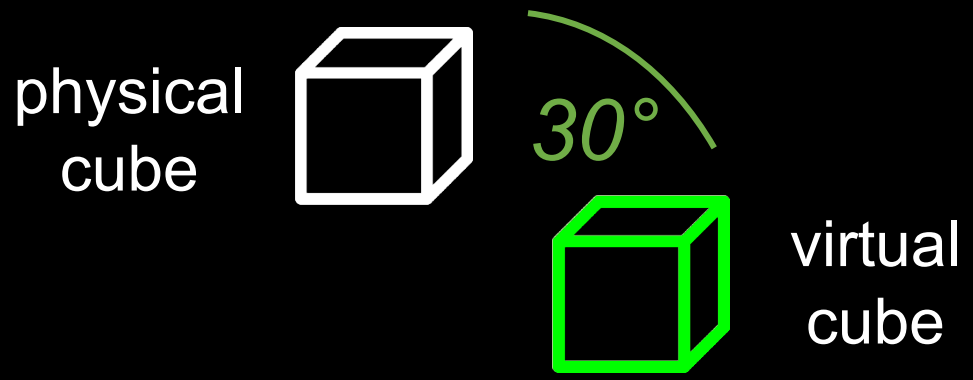


virtual cube

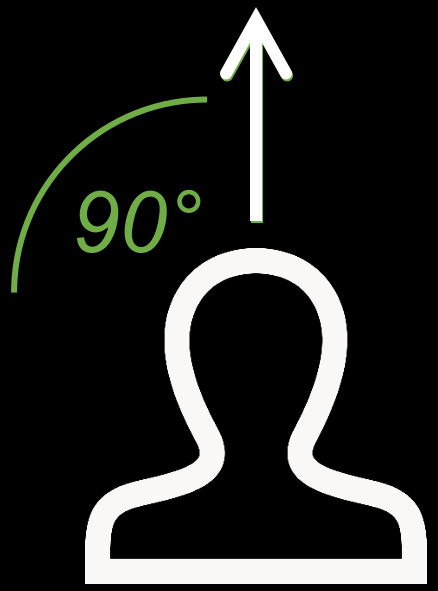
The Rendered Body Shifts to The Right



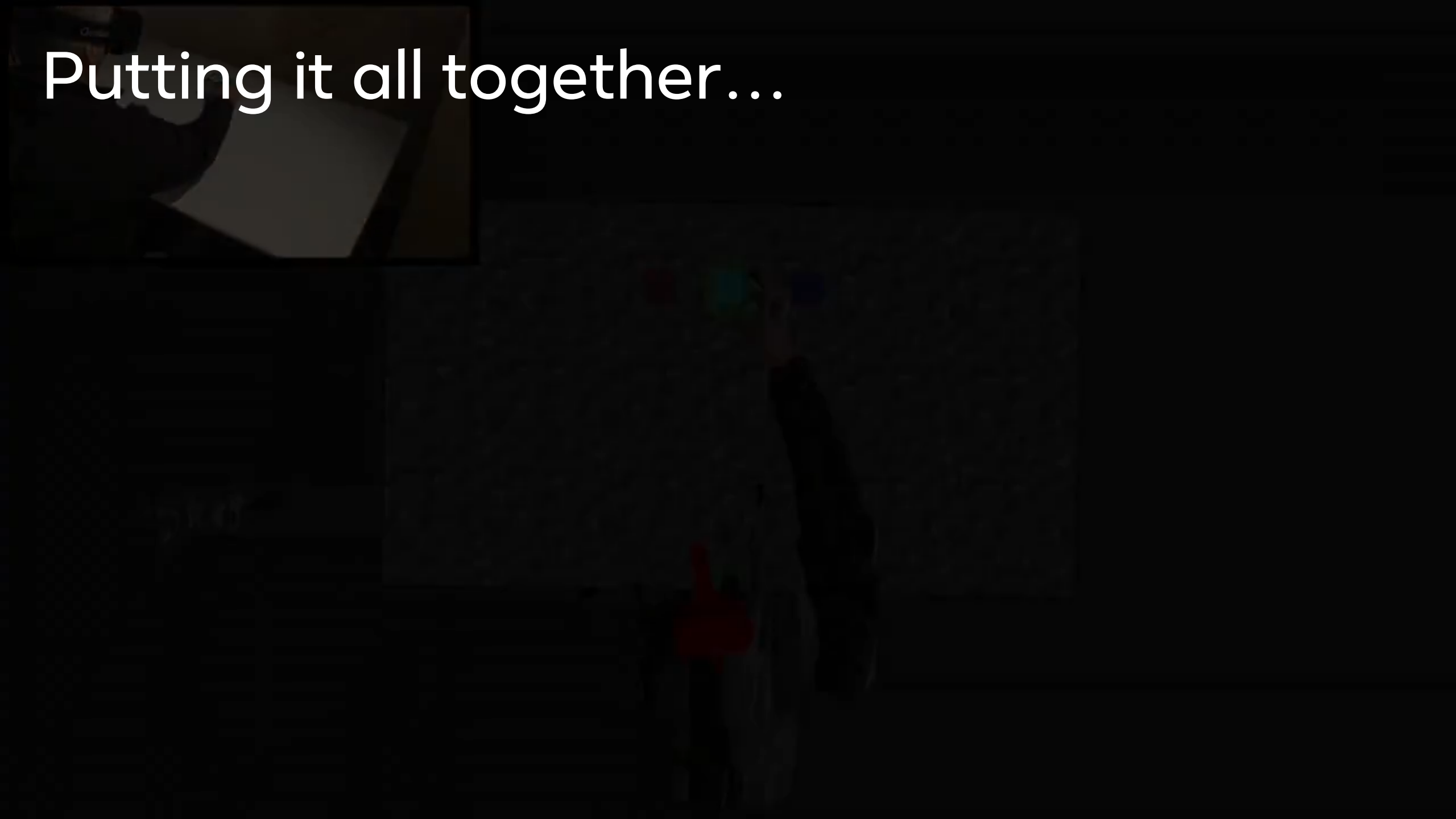
World Warping



The World Also Rotates
(At Different Rate)



Putting it all together…



We can even estimate the mass effect!

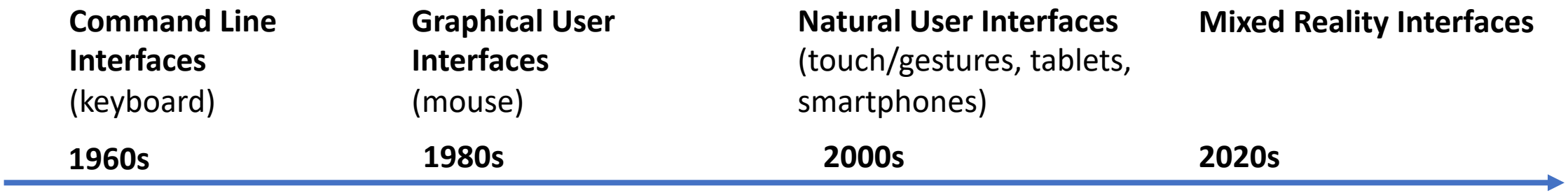
$$m_{per} = \frac{0.08\text{kg}}{0.82 + 0.18\lambda}$$

Samad, M., Gatti, E., Hermes, A., Benko, H., and Parise, C. (2019). **Pseudo-Haptic Weight: Changing the Perceived Weight of Virtual Objects By Manipulating Control-Display Ratio.** *In Proc. of ACM CHI 2019.*

Focusing on “as real as possible” designs can lead to sub-optimal MR experience.

Design for BELIEVABILITY, not REALISM.

Compelling MR interfaces are *adaptive, believable*


Command Line Interfaces (keyboard)
1960s
Graphical User Interfaces (mouse)
1980s
Natural User Interfaces (touch/gestures, tablets, smartphones)
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2020s

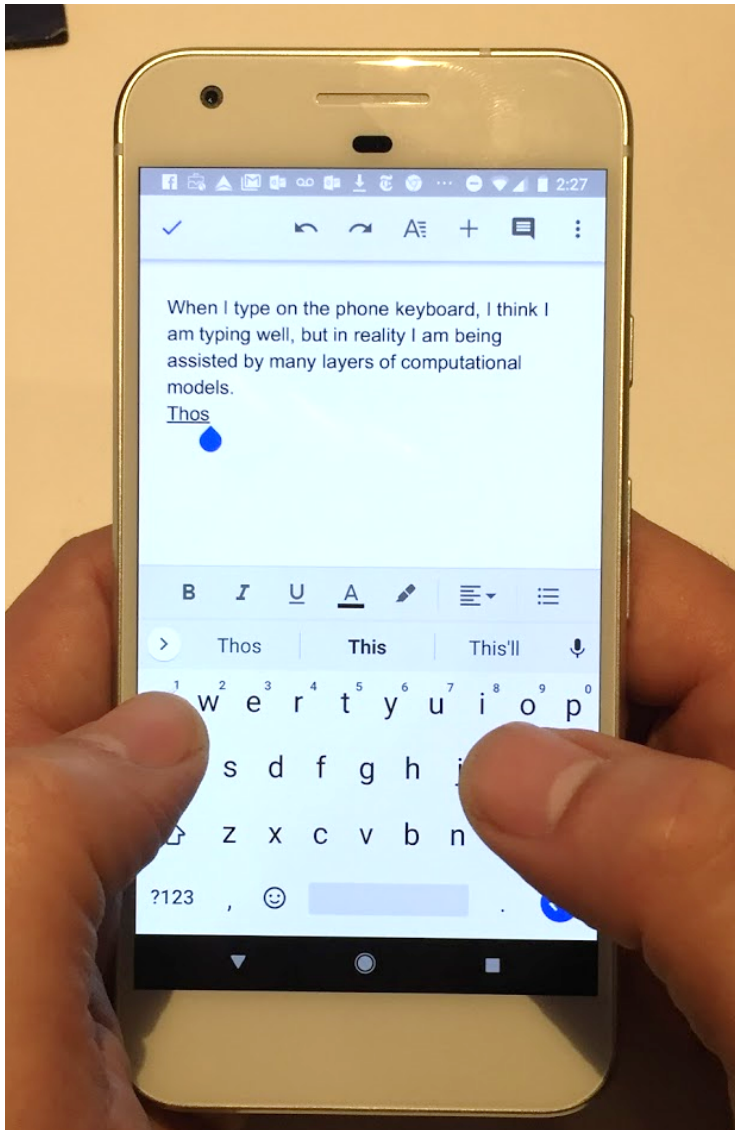

Location fixed
Mobile
Precise and accurate inputs
Imprecise and noisy inputs
Sensing poor
Sensing rich
Explicit (command driven)
Implicit (context assisted)

How to deal with imprecise, noisy, but sensing-rich inputs?

Compelling MR interfaces are *adaptive, believable,* and *computational*.

Can you type on a phone keyboard?

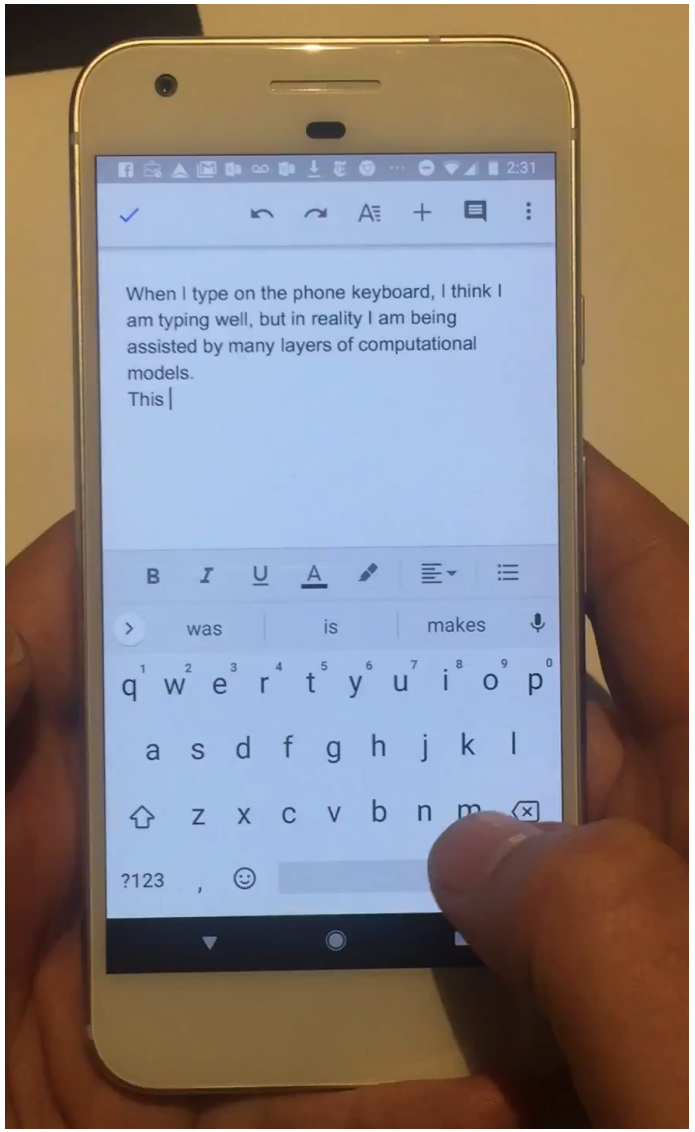
Probabilistic Phone Touch Keyboard



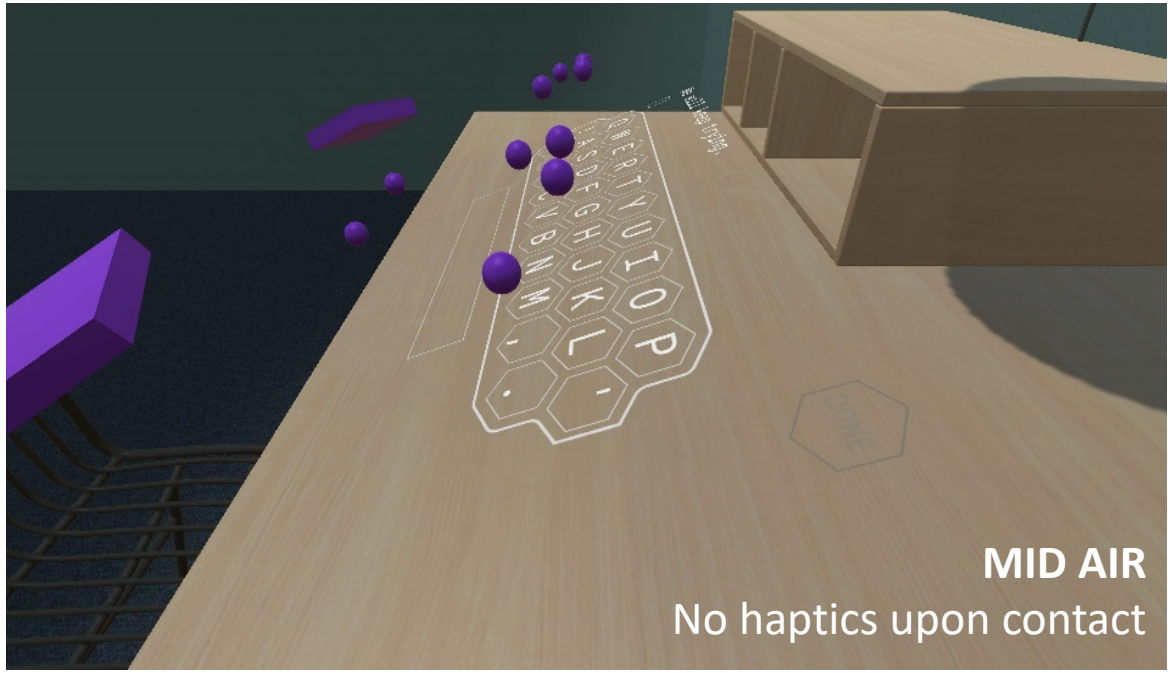
Keyboard geometry model
+ Touch precision model
+ Dictionary model
+ Language model

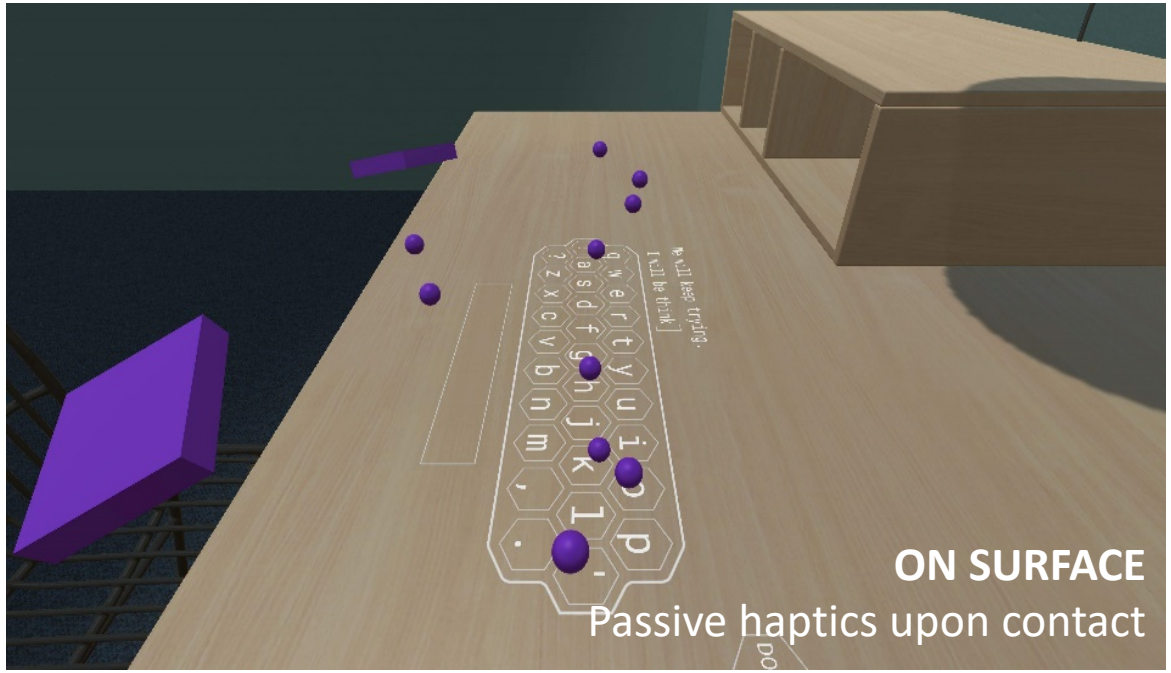
+ N-best list UI for error correction

+ Gesture model



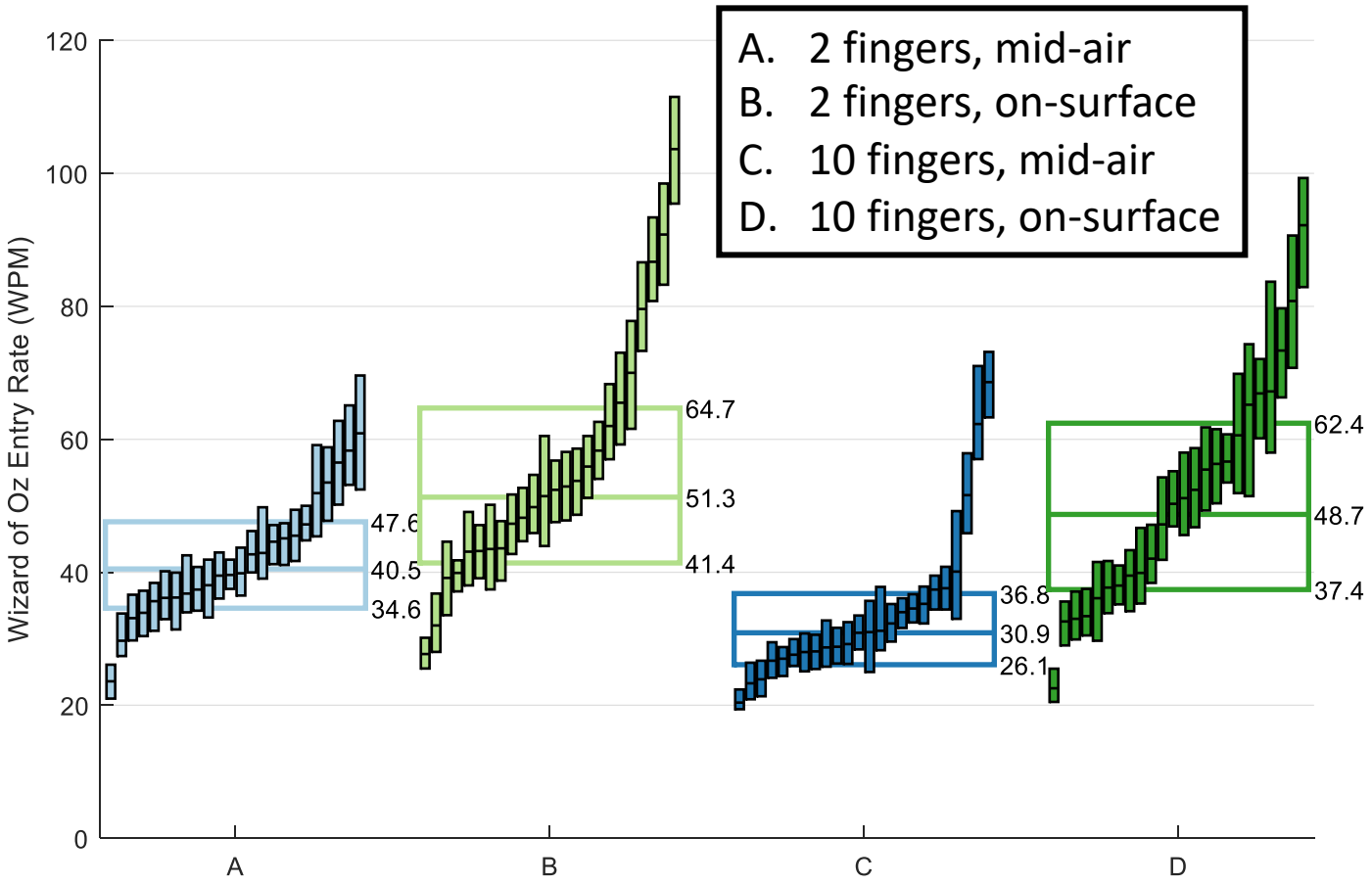
Smart virtual keyboard can be better than a physical keyboard





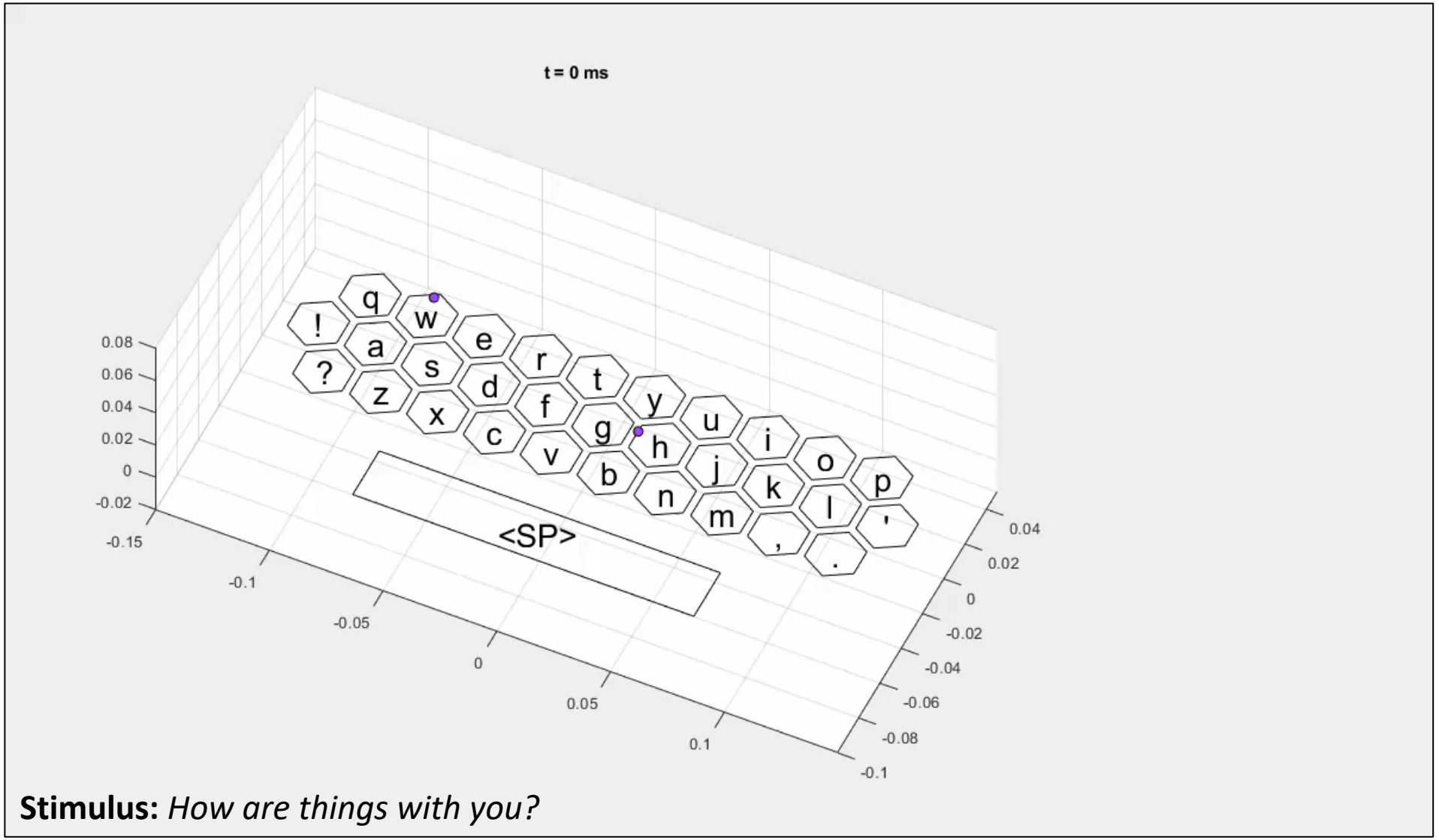
Dudley, J., Benko, H., Wigdor, D., and Kristensson, P.O. (2019). **Performance Envelopes of Virtual Keyboard Text Input Strategies in Virtual Reality.** *In Proc. of IEEE ISMAR 2019.*

Entry Rate Results



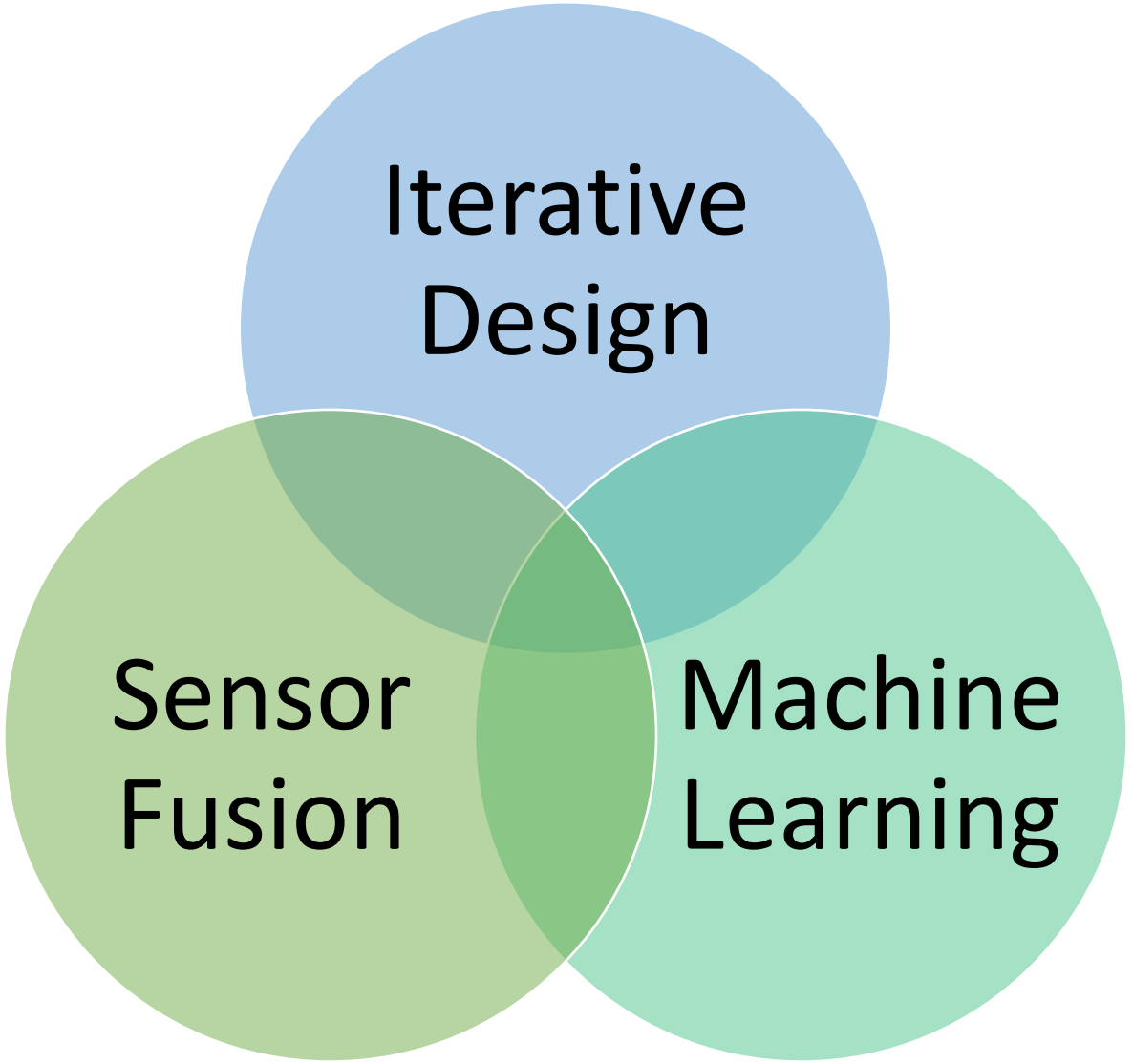
Plot shows participant q_1, median and q_3 (sorted by median) entry rates as well as lumped condition q_1, median and q_3 entry rates. Only entries where error rate < 10%.

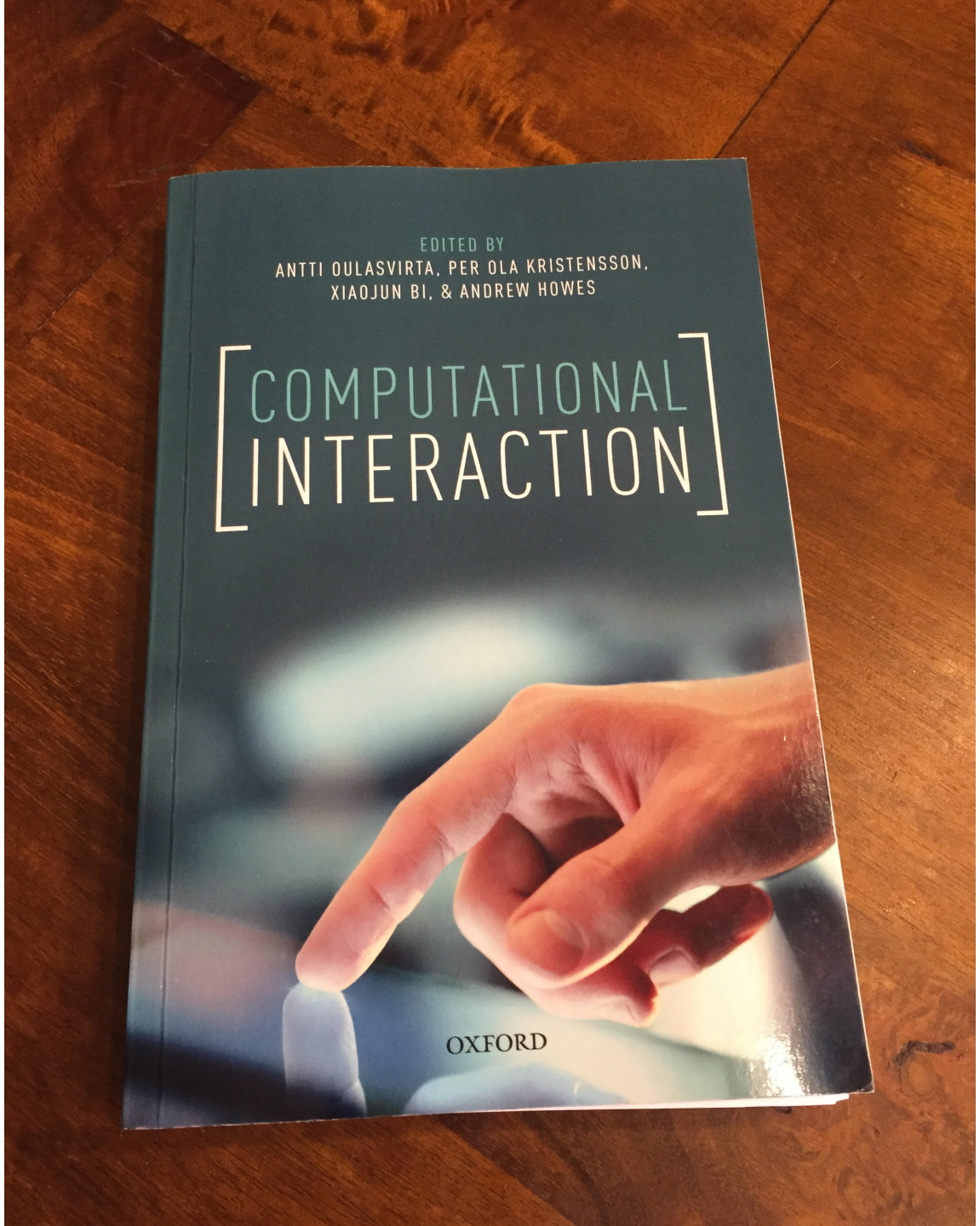
2 Finger VR Typing at >100 WPM



Stimulus: *How are things with you?*

The role of MR Interaction Designer

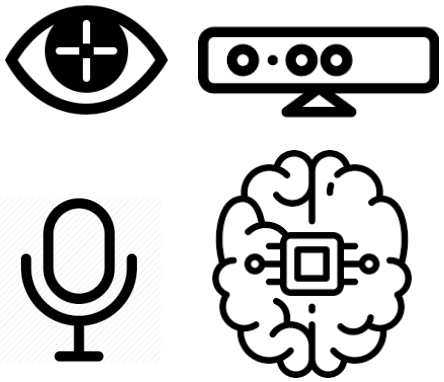




Antii Oulasvirta, Per Ola Kristenson,
Xiaojun Bi and Otmar Hilliges

MR Interaction Pipeline

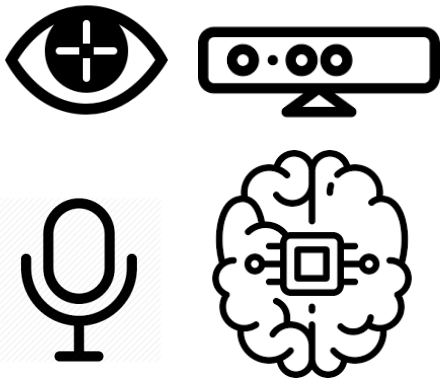
Understand Context

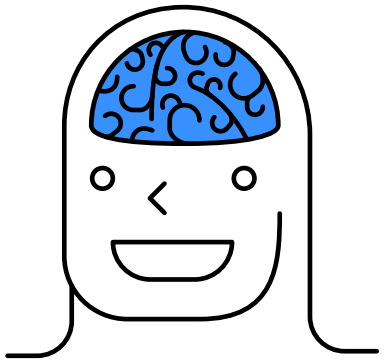


MR Interaction Pipeline

Understand Context

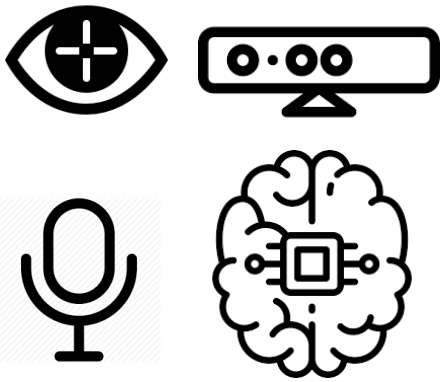
Infer Goals

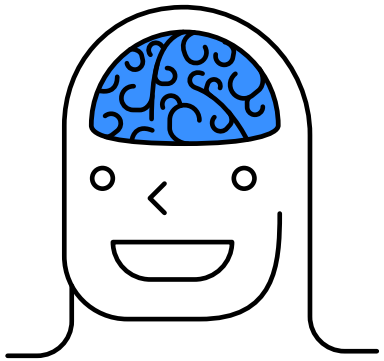


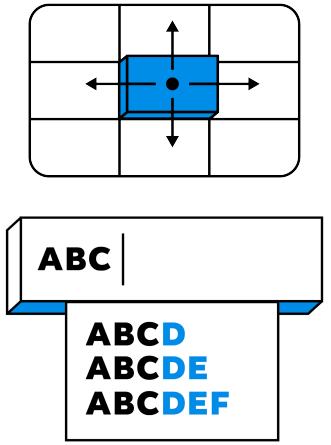


MR Interaction Pipeline

Understand Context → Infer Goals → Adapt Interaction







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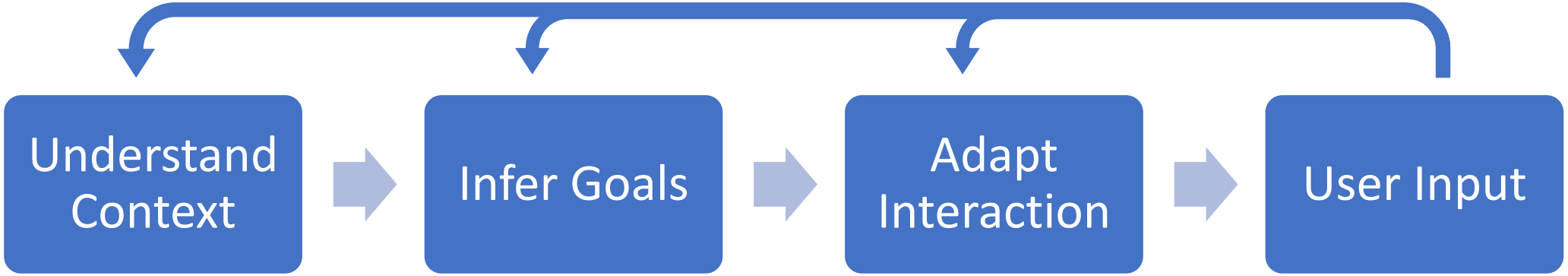
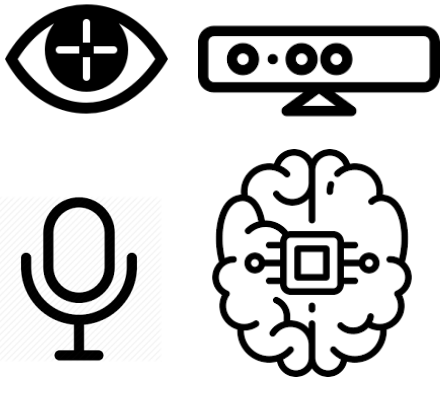
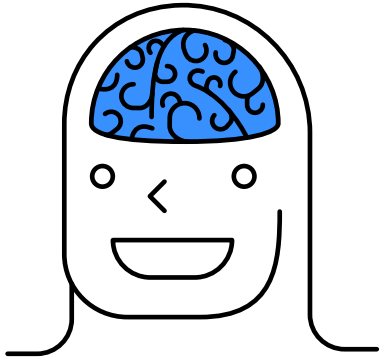
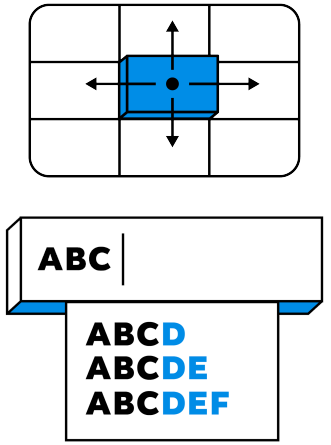
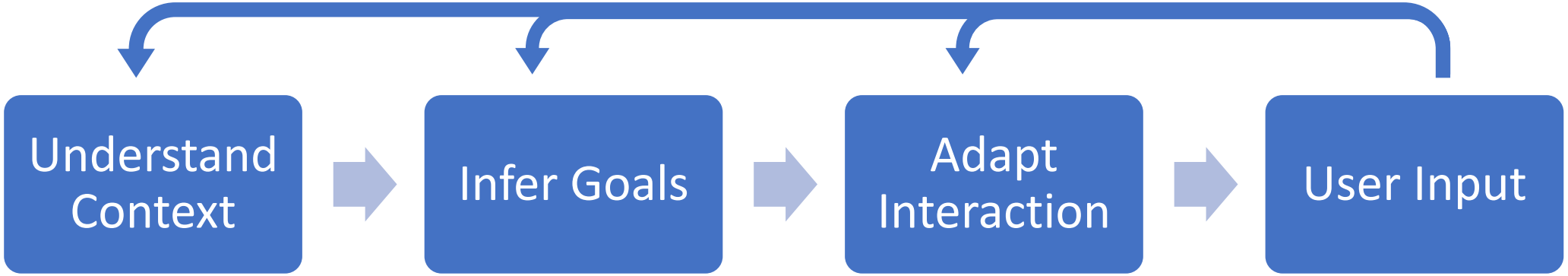


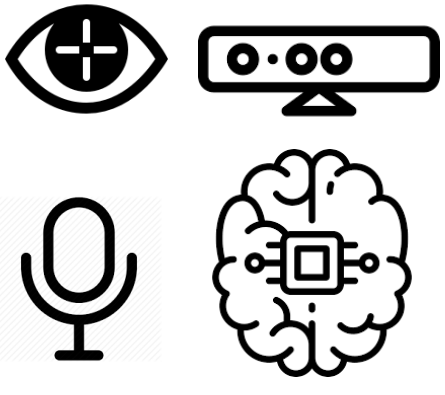


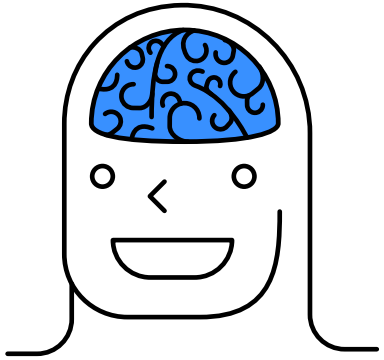


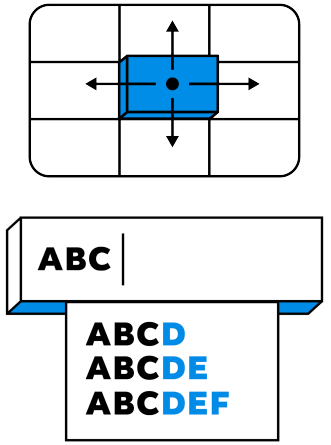


MR Interaction Pipeline



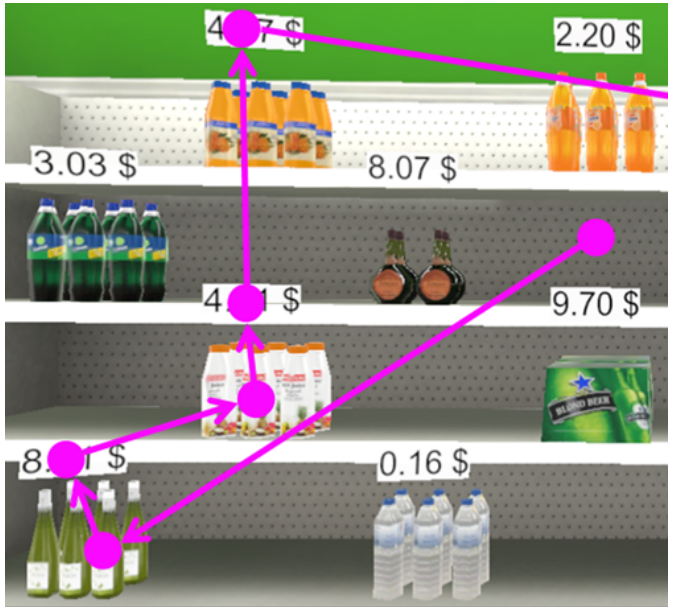


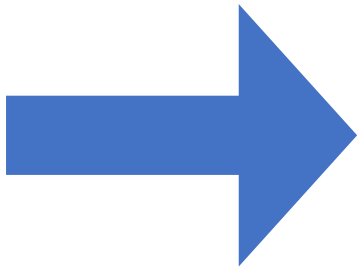




Learning MR UI Policies from Gaze Data

Trained RL agents to predict when an MR label is meaningful to the user.





Context: User's gaze behavior + task + environment

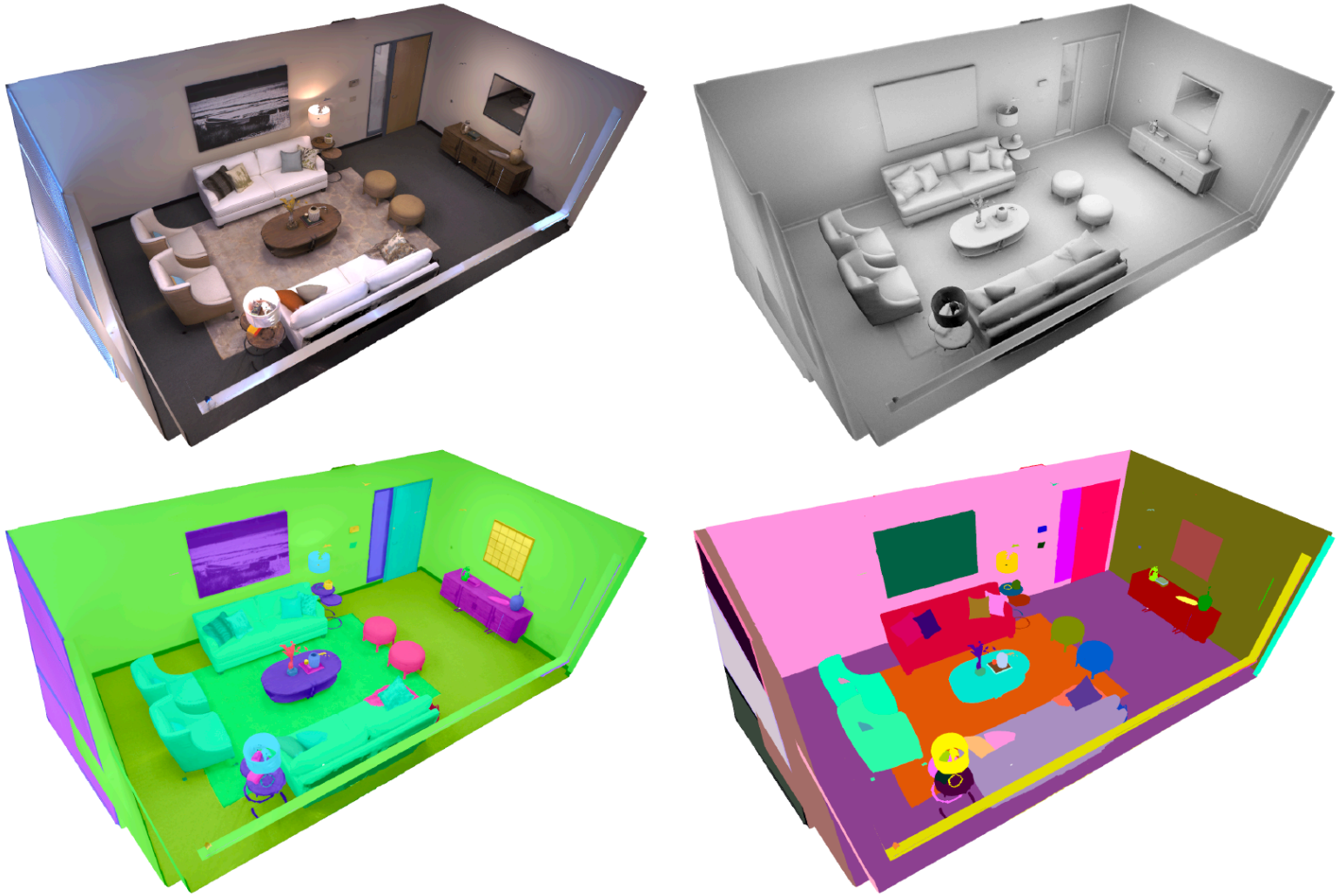
Output: Inferring task-specific goals + reduced clutter of MR labels

https://ait.ethz.ch/label-agent/

Gebhardt et al. **"Learning Cooperative Personalized Policies from Gaze Data"** ACM UIST 2019

Key Challenge = Missing Data

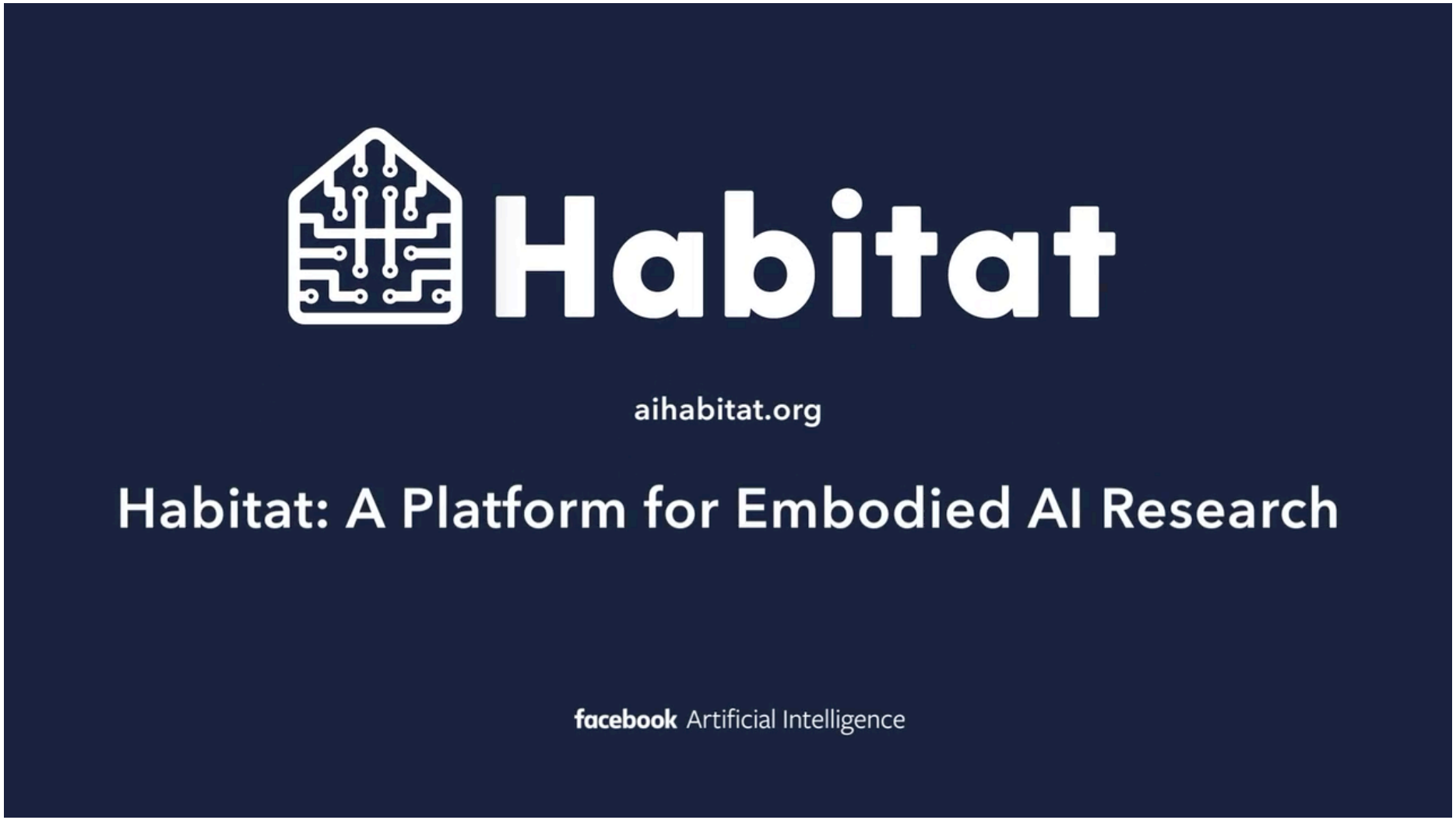
Replica: 3D Spaces and Object Semantics



https://github.com/facebookresearch/Replica-Dataset

Straub et al. “Replica Dataset: A digital replica of indoor spaces” arXiv 2019

AI Habitat



https://www.aihabitat.org/

EPIC-Kitchens Dataset

Damen et al. Scaling Egocentric Vision: The EPIC-KITCHENS DATASET. ECCV2018

https://epic-kitchens.github.io/2019

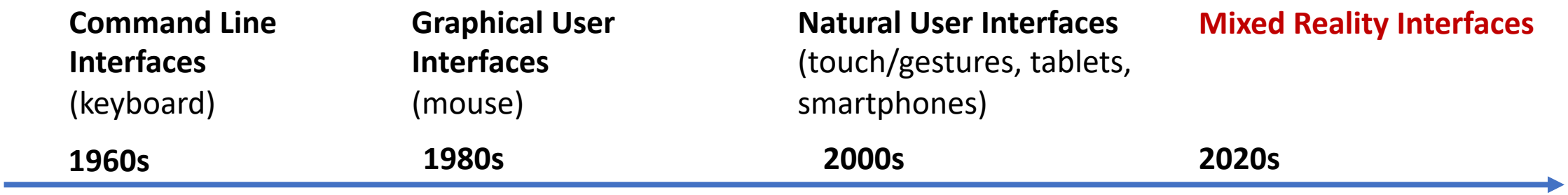
Call to action!

Collect and release datasets of MR interactions with different:

- Environments
- Objects (both real and virtual)
- Tasks
- People

Including eye-tracking, bio-signals, hand interactions, body movements, etc.

Summary



New Computing Era =

New Display Form Factor

+ New Input Method

+ New Interactions

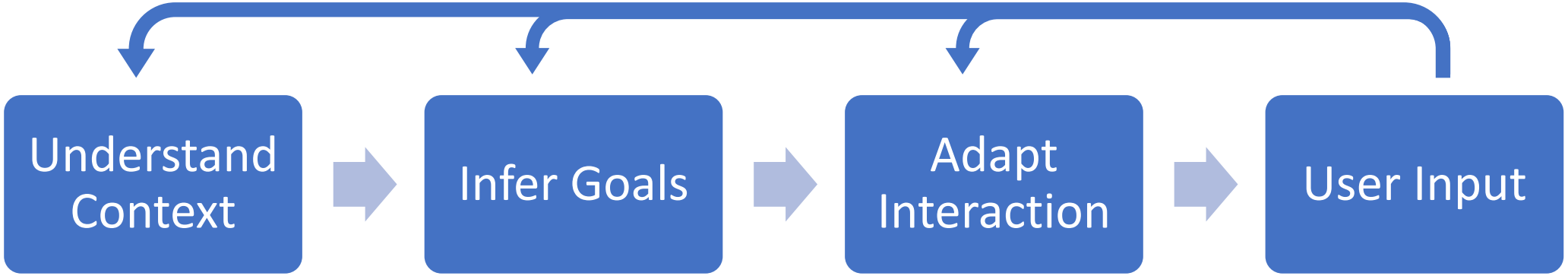
Compelling MR interactions are *adaptive, believable,* and *computational*.

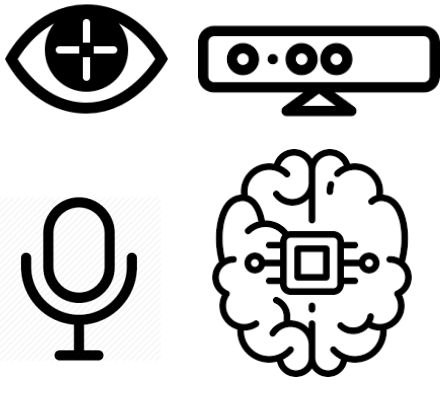
Design interactions that adapt to the user’s actions, the world around them, and the context of use.

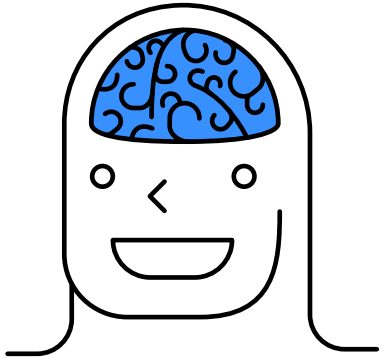
Focus on interaction believability.
Reality is overrated!

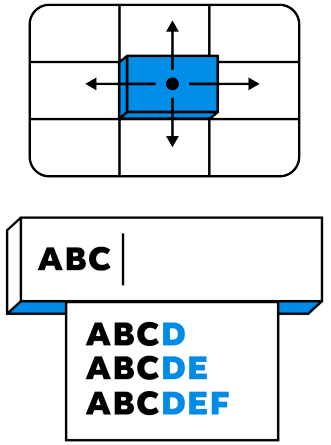
Harness the computational methods to overcome uncertainty, scale, noise, and enable personalization.

MR Interaction Pipeline









Thanks to all my collaborators!

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Facebook Reality Labs

We are hiring!