FaceWidgets:
Exploring Tangible Interaction on Face with Head-Mounted Displays

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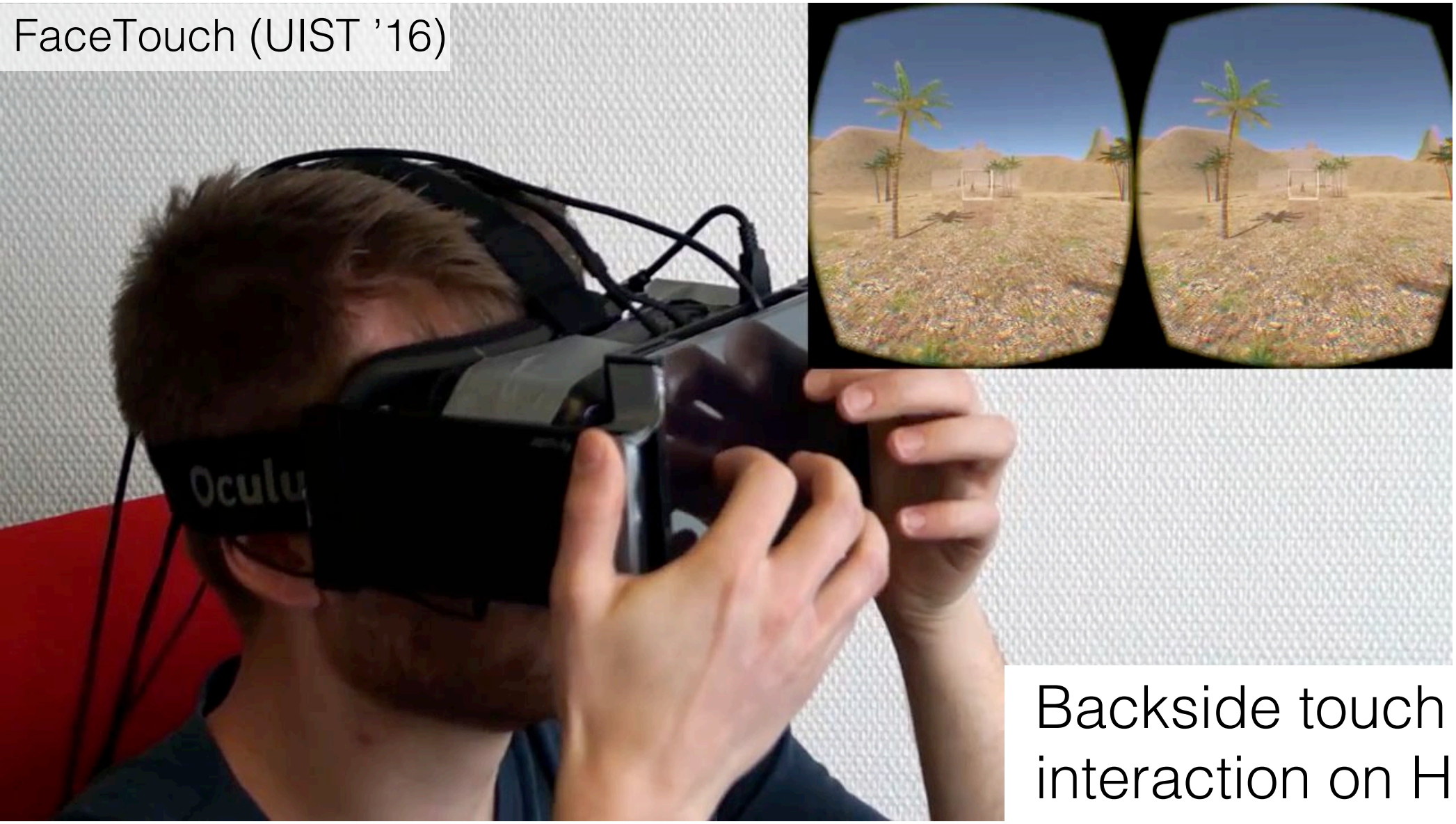
FaceWidgets allows
direct manipulation
on the HMD backside.

Motivation

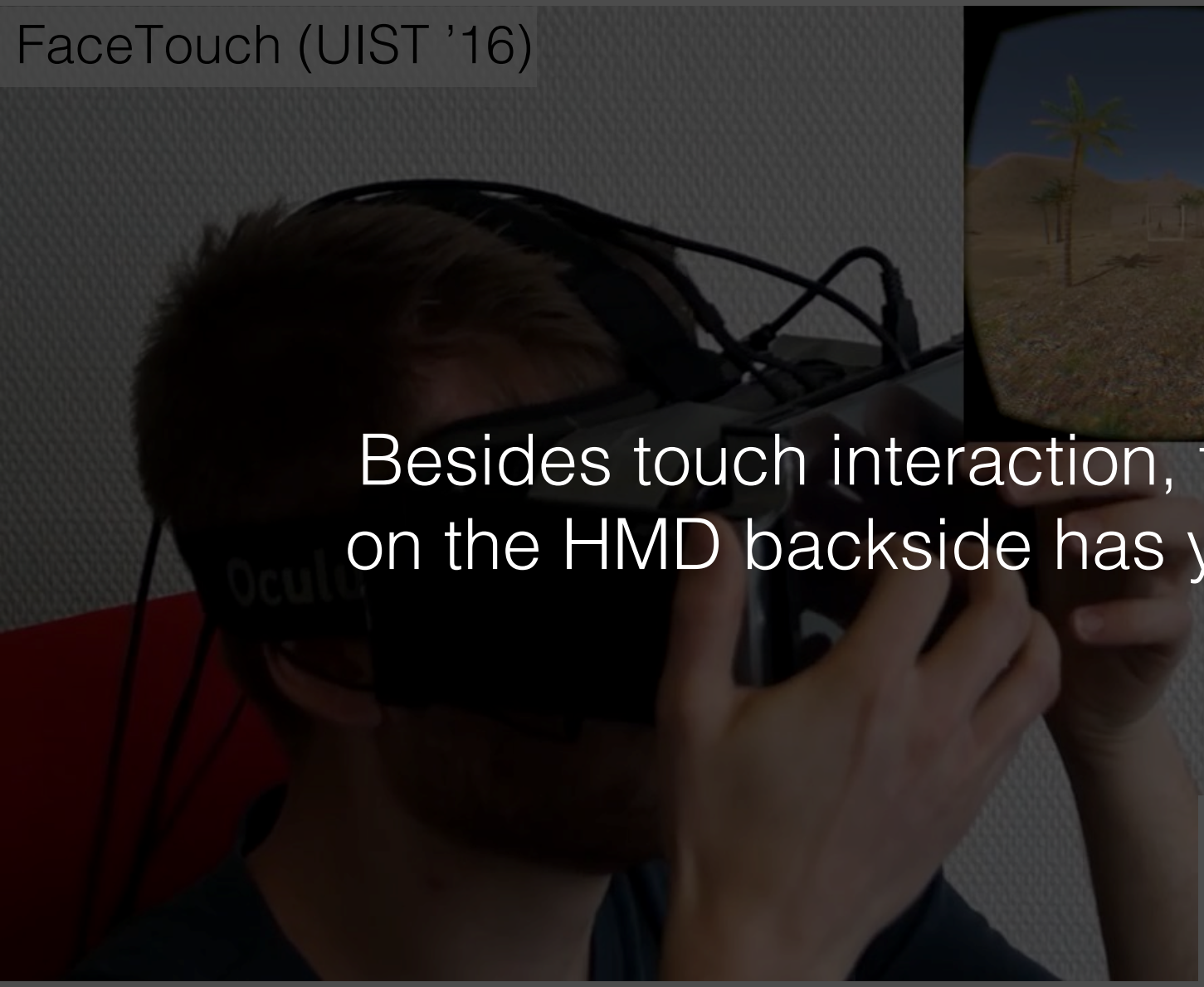
Recent research has explored
free hand input (e.g., mid-air finger input).

FaceTouch (UIST ’16)



Backside touch interaction on HMD

FaceTouch (UIST ’16)

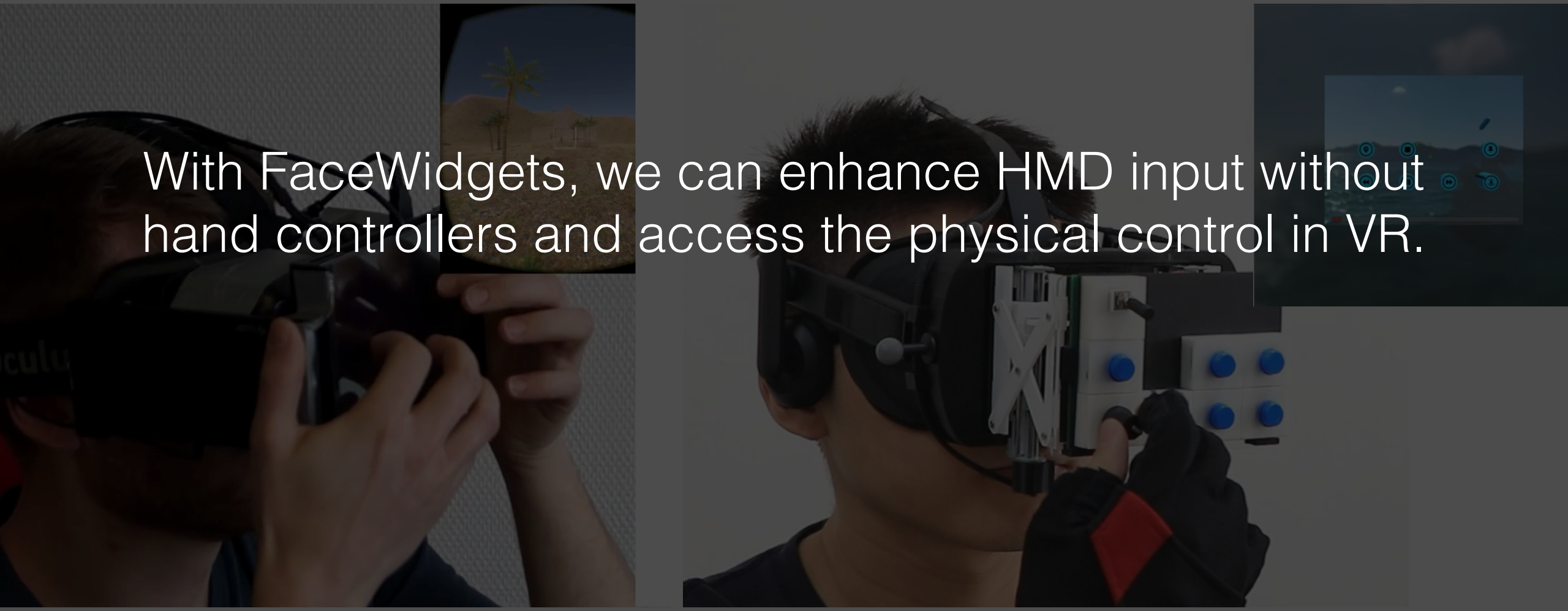


Besides touch interaction, the design space on the HMD backside has yet been explored.

Backside touch interaction on HMD

FaceWidgets enables tangible interactions
using **physical controls on the HMD backside**

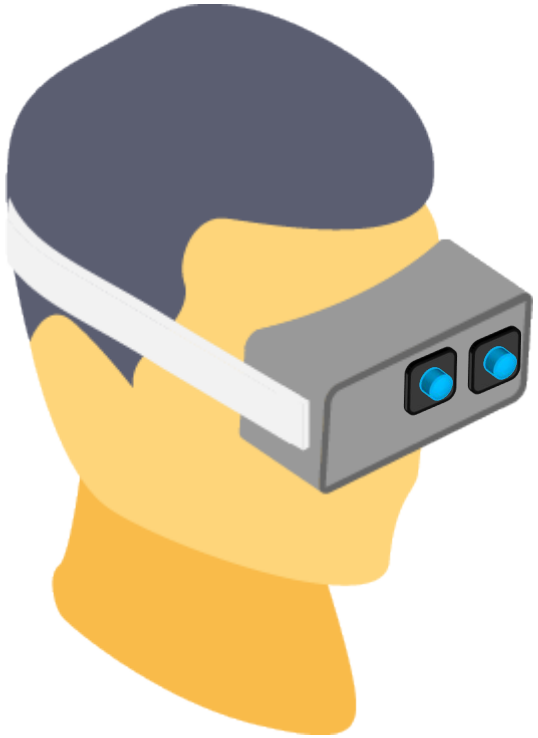
FaceWidgets enables tangible interactions using **physical controls on the HMD backside**

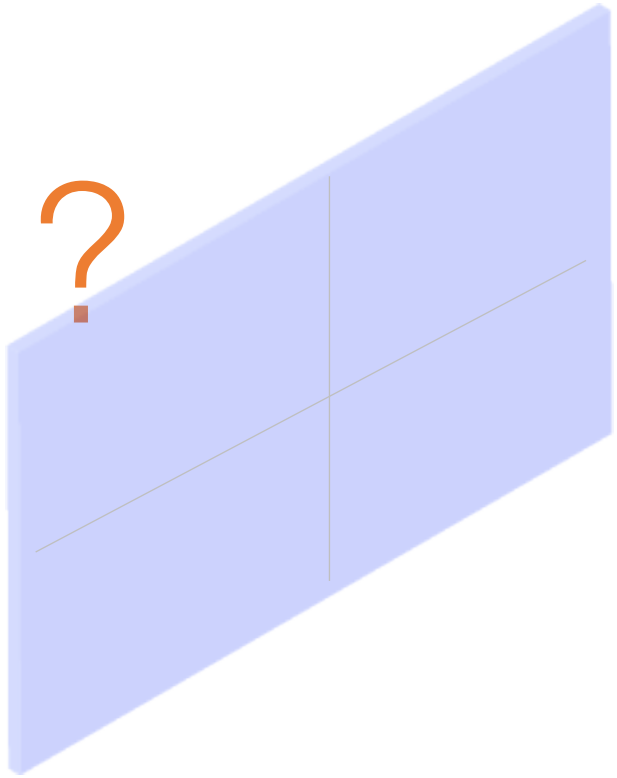


With FaceWidgets, we can enhance HMD input without hand controllers and access the physical control in VR.

Direct Manipulation

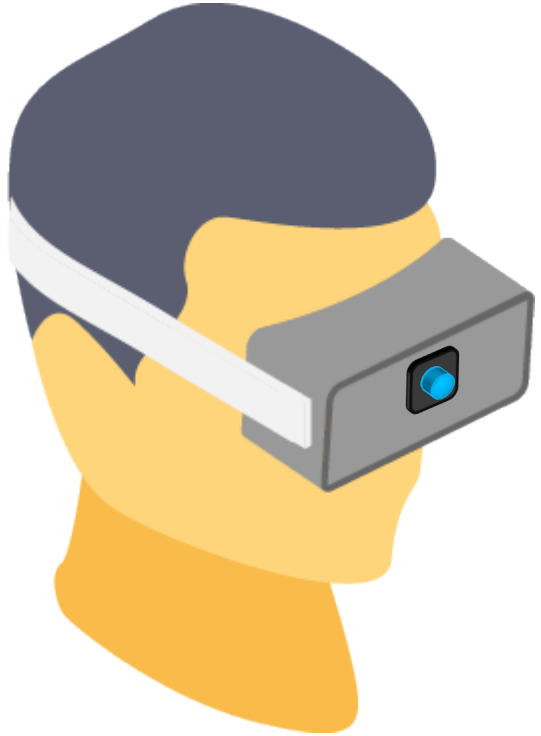
What you see is what you can touch



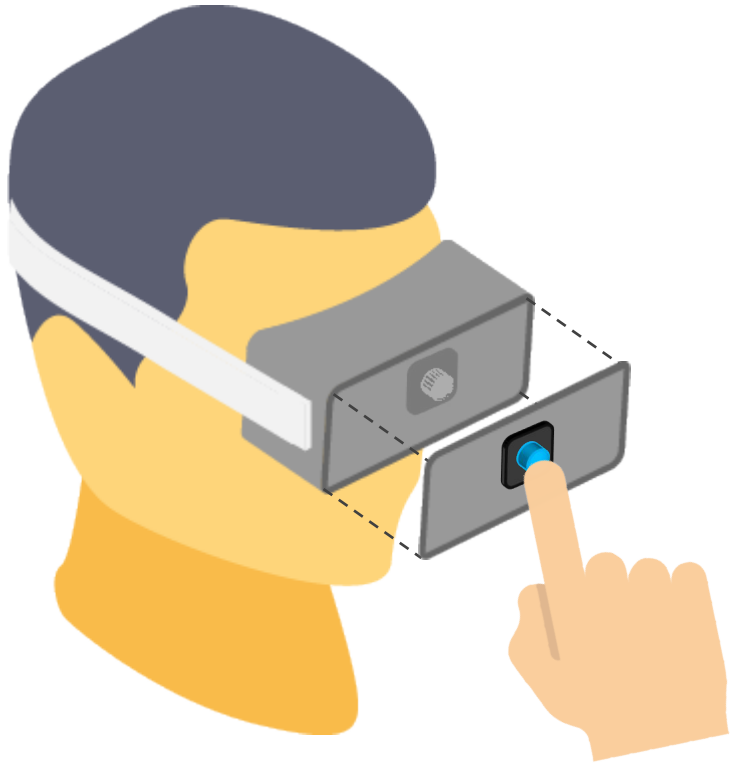


This work introduced how we learn to enable direct manipulation with FaceWidgets.

FaceWidgets allows
direct manipulation
on the HMD backside.



- **Direct manipulation**
  - Co-locate the virtual button with its physical counterpart
  - Difficult for eye convergence



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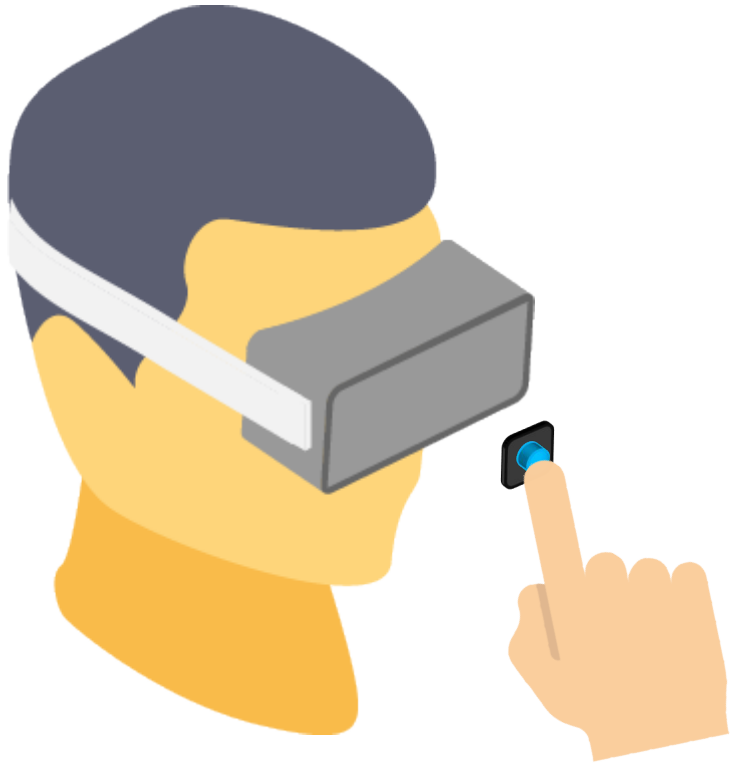

- **Direct manipulation**
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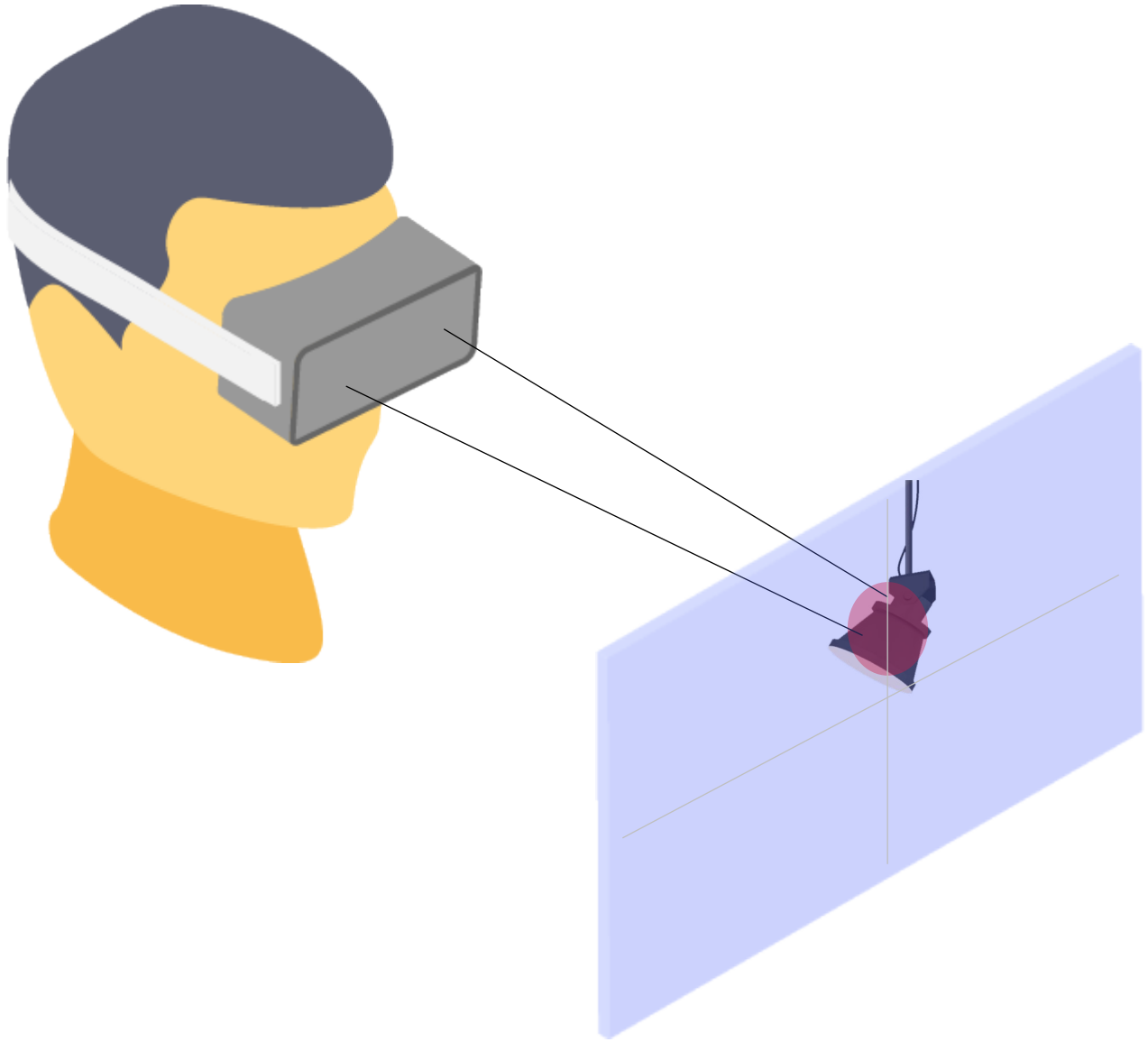
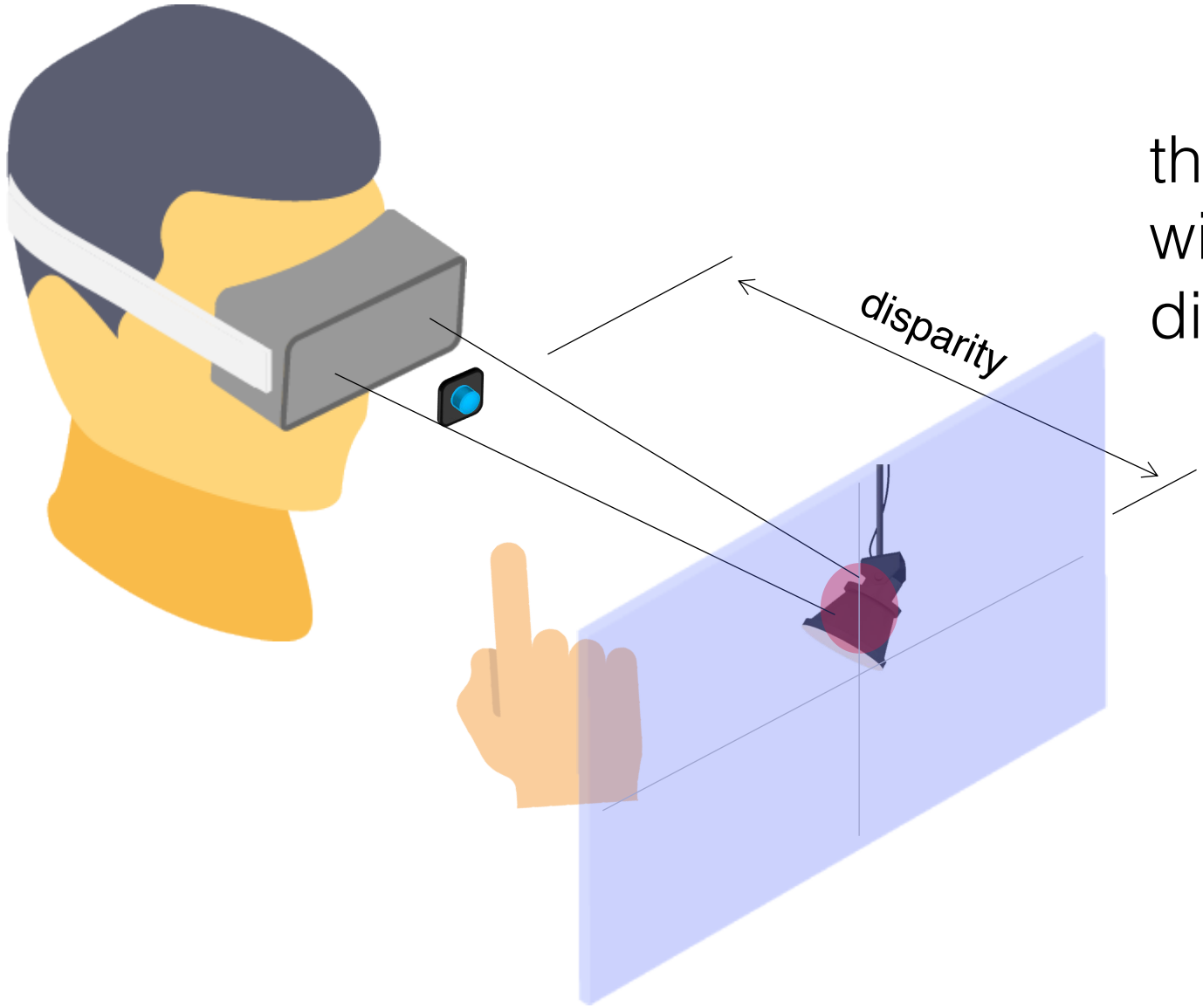
Use **Lift** to extend controls from the HMD backside.

Task: turning on the light in virtual environment



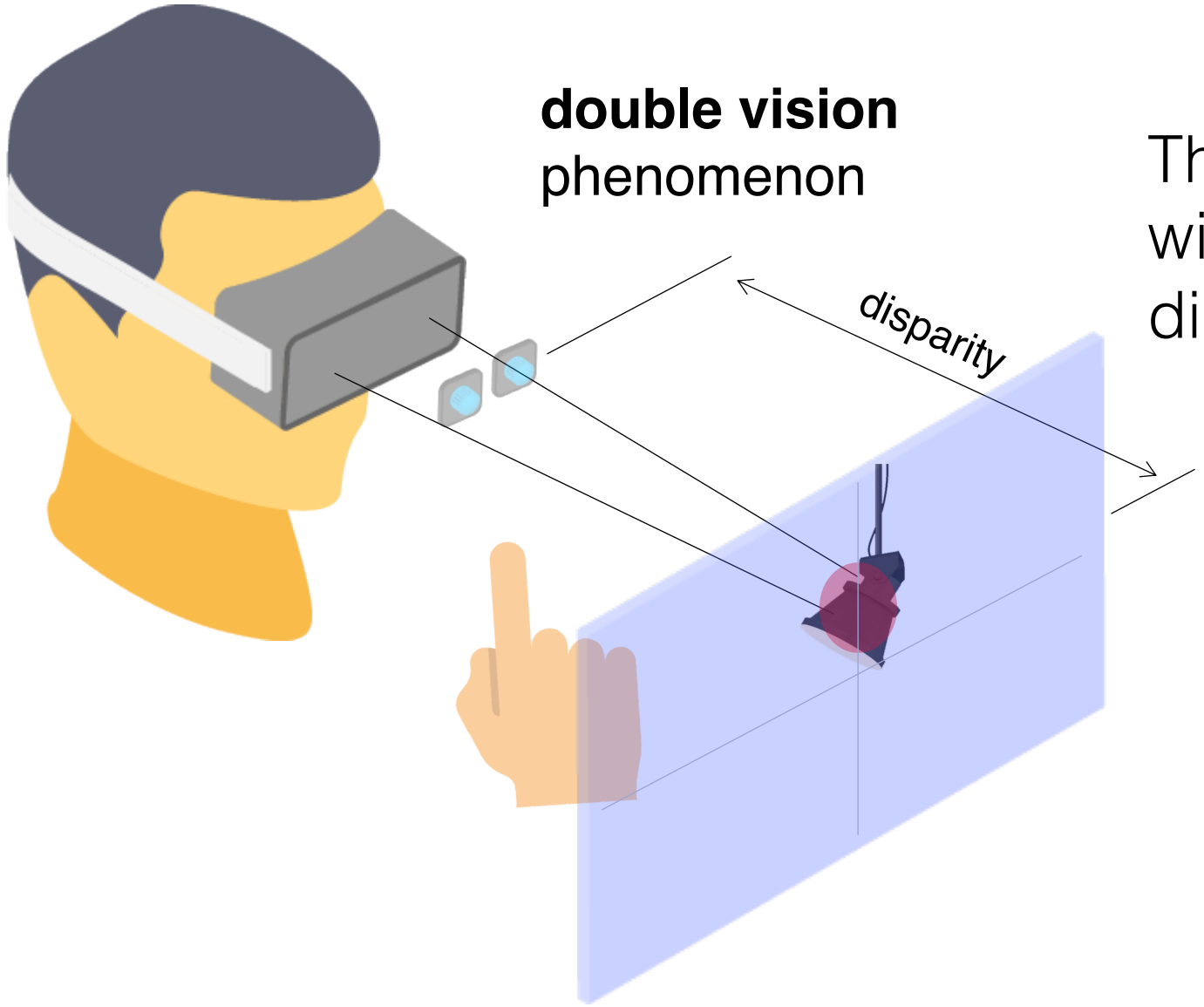
When fixating at the virtual object/scene at a far distance,

Task: turning on the light in virtual environment



the button out of fixation point will be seen as double at near distance, called **double vision**.

Task: turning on the light in virtual environment



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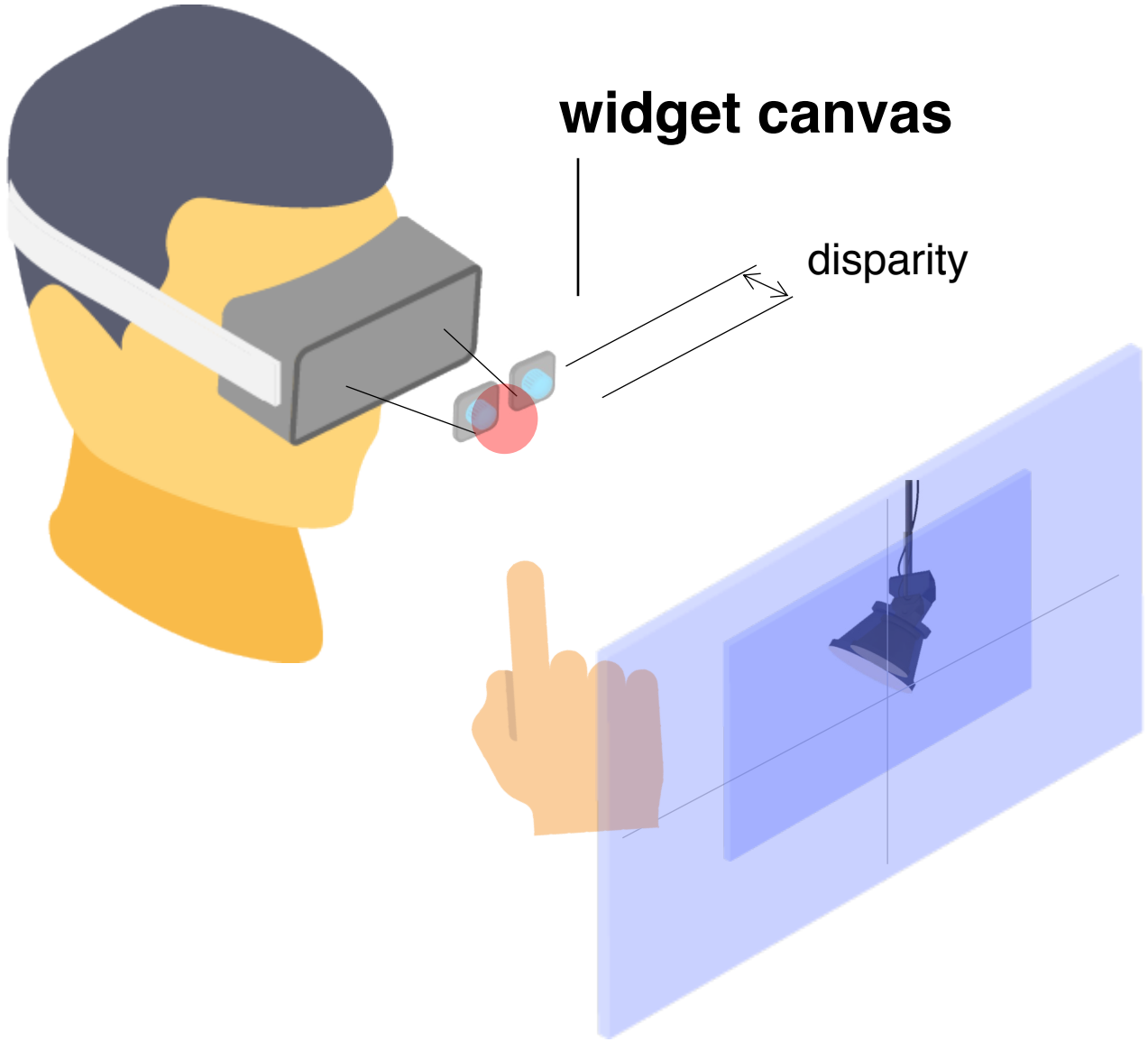
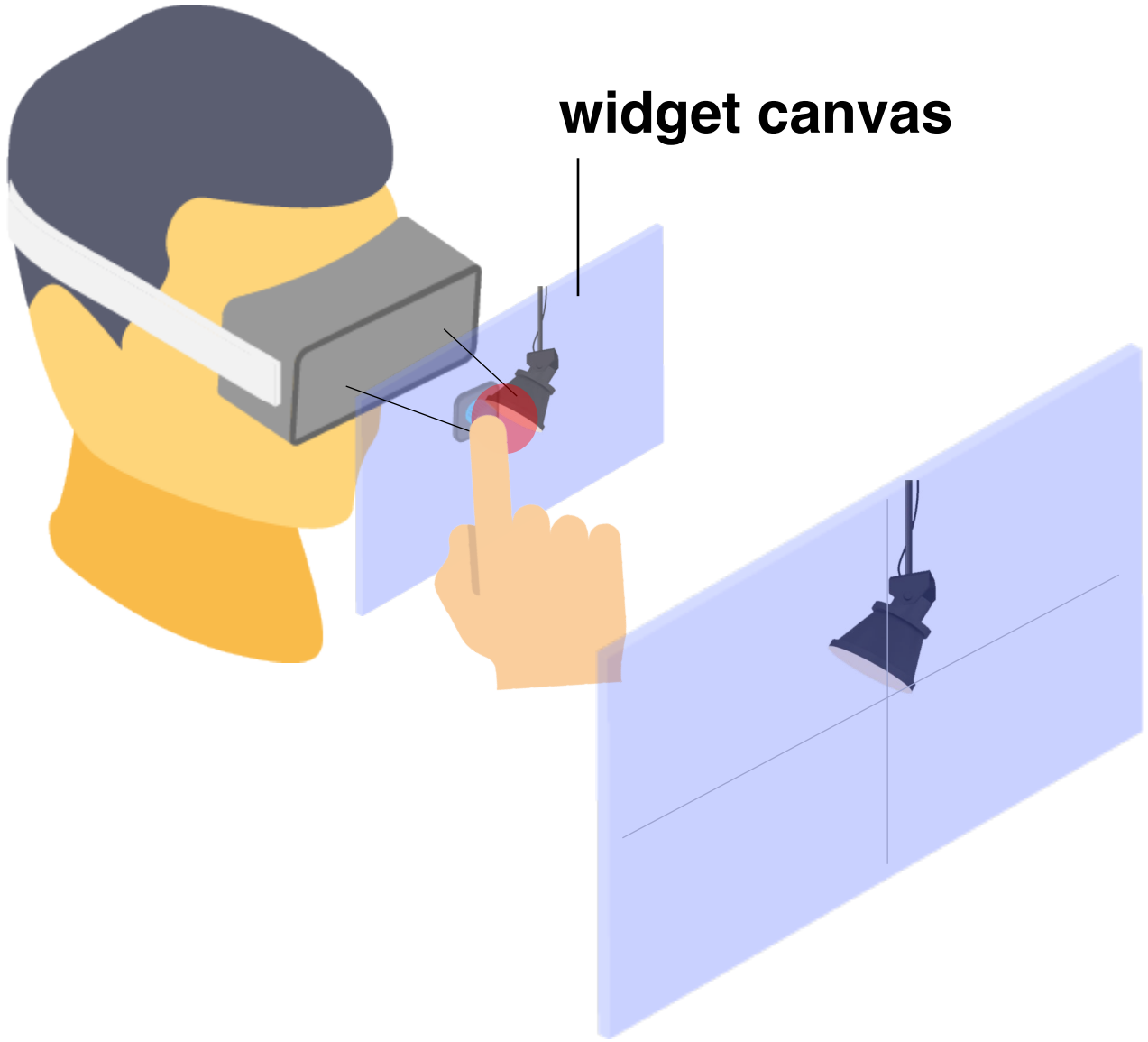


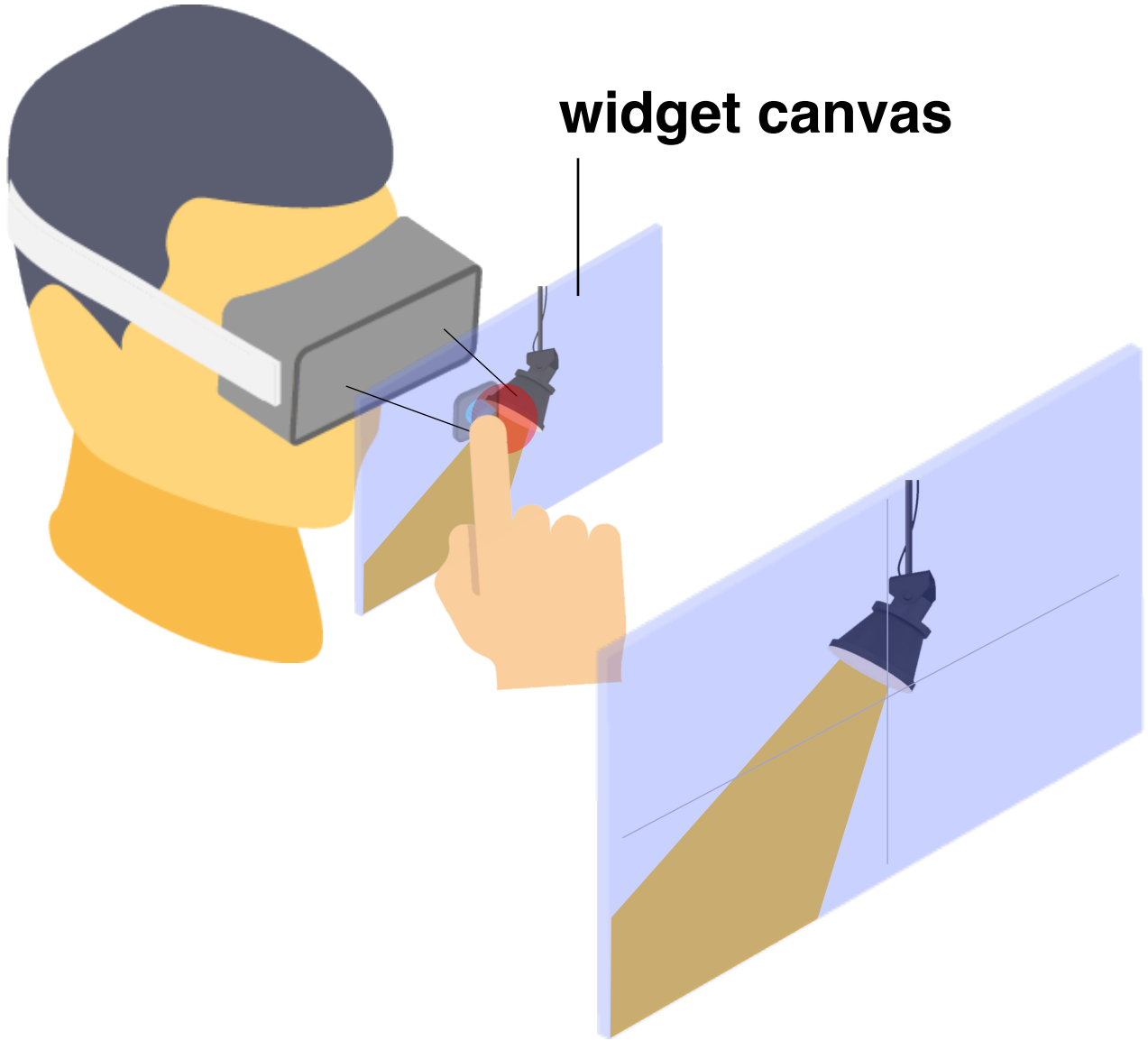
We reduce this disparity by placing a snapshot of the scene at the same depth with controls.

Task: turning on the light in virtual environment



The widget canvas can avoid double vision during interactions.

Task: turning on the light in virtual environment



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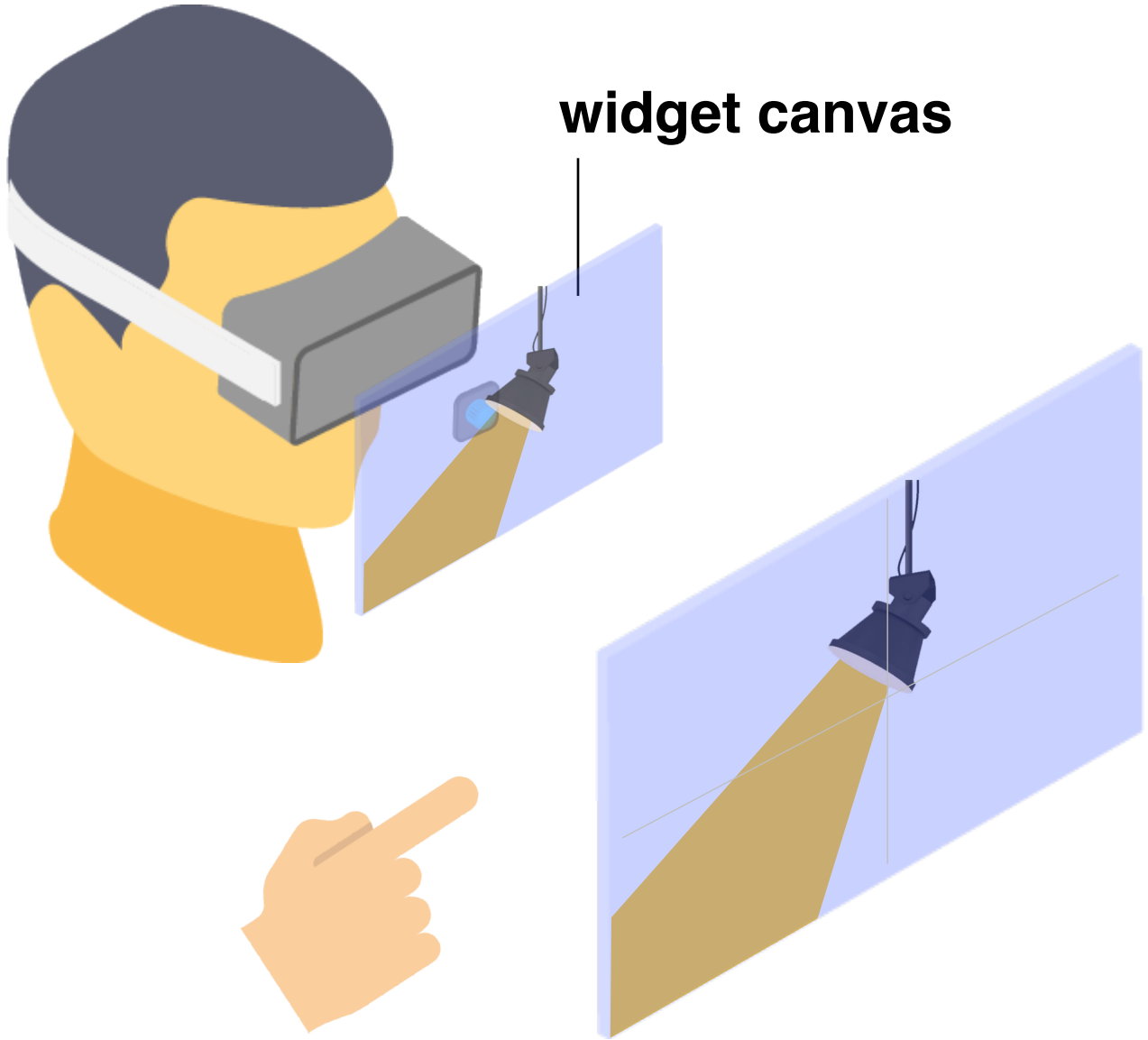
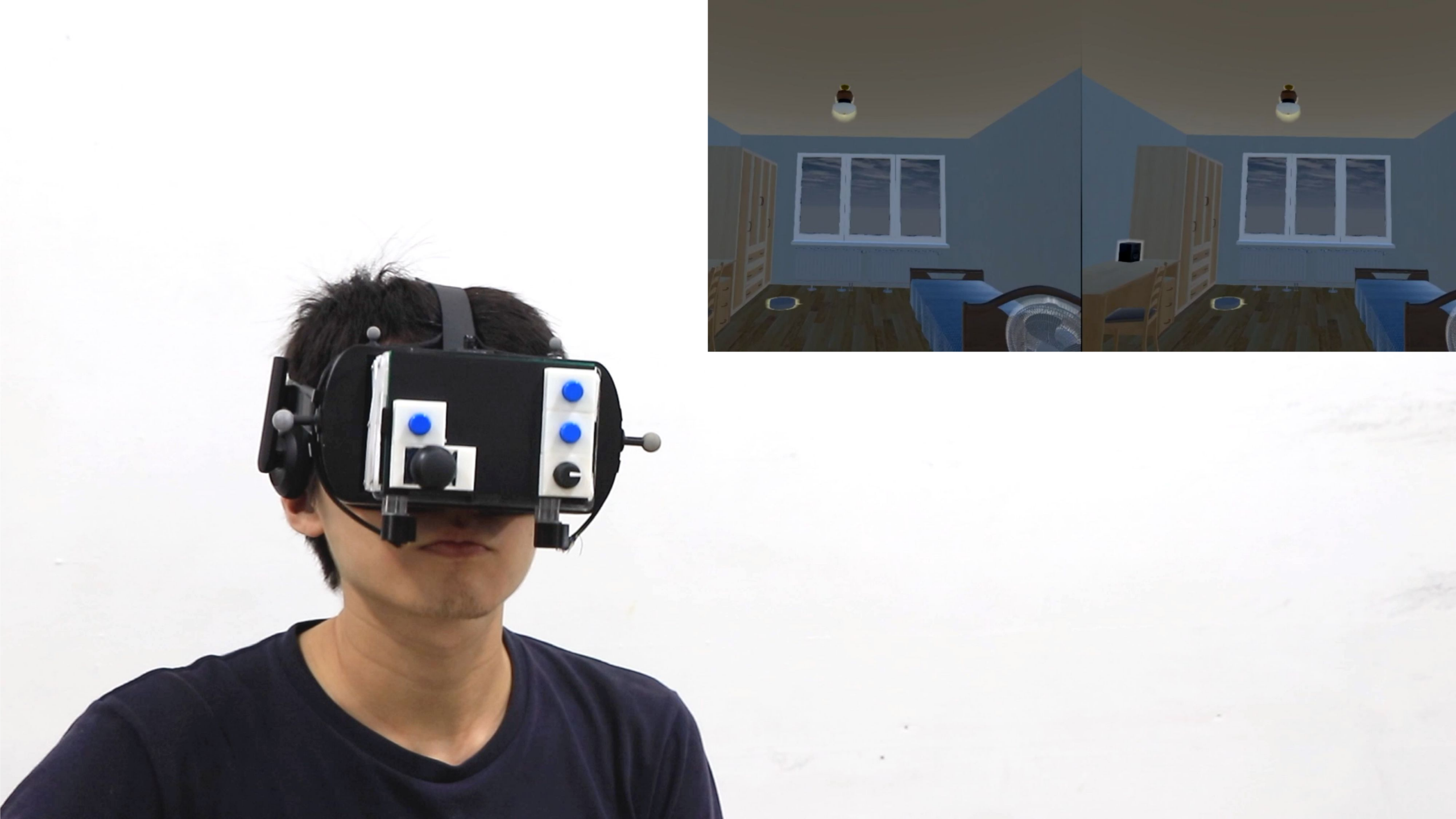
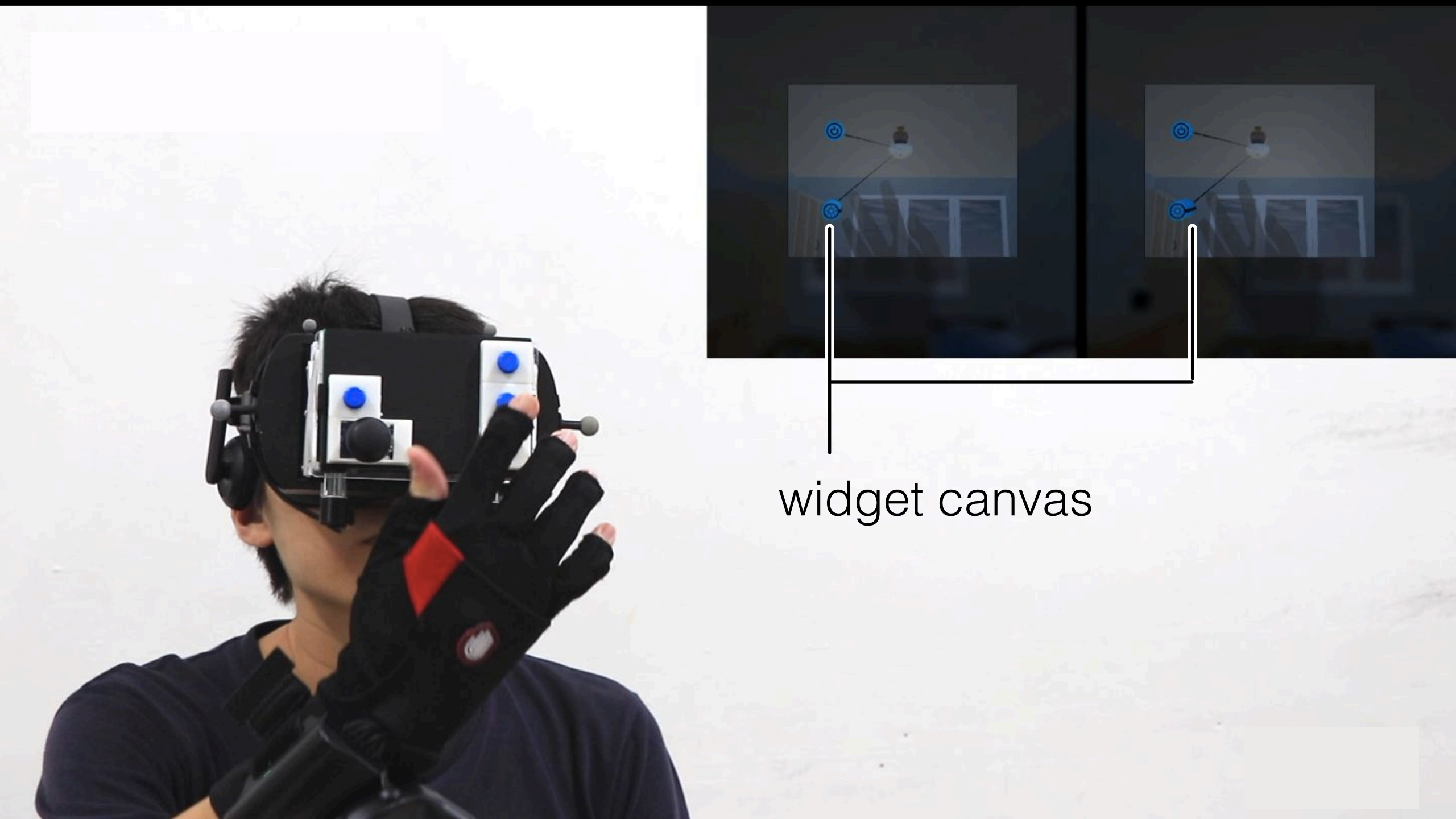


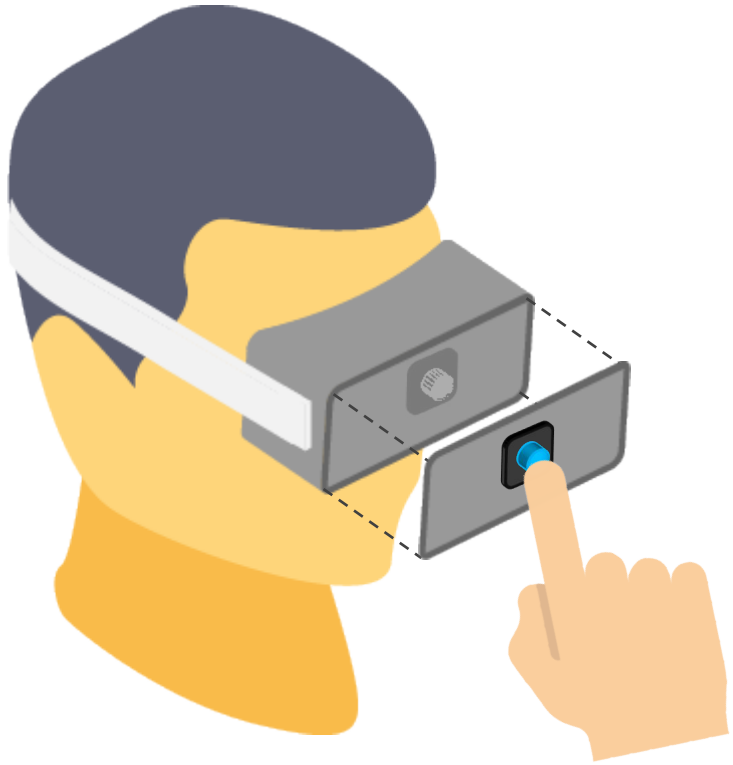
As the interaction ends, the widget canvas fades out.




widget canvas

direct manipulation on
the physical button

Implementation



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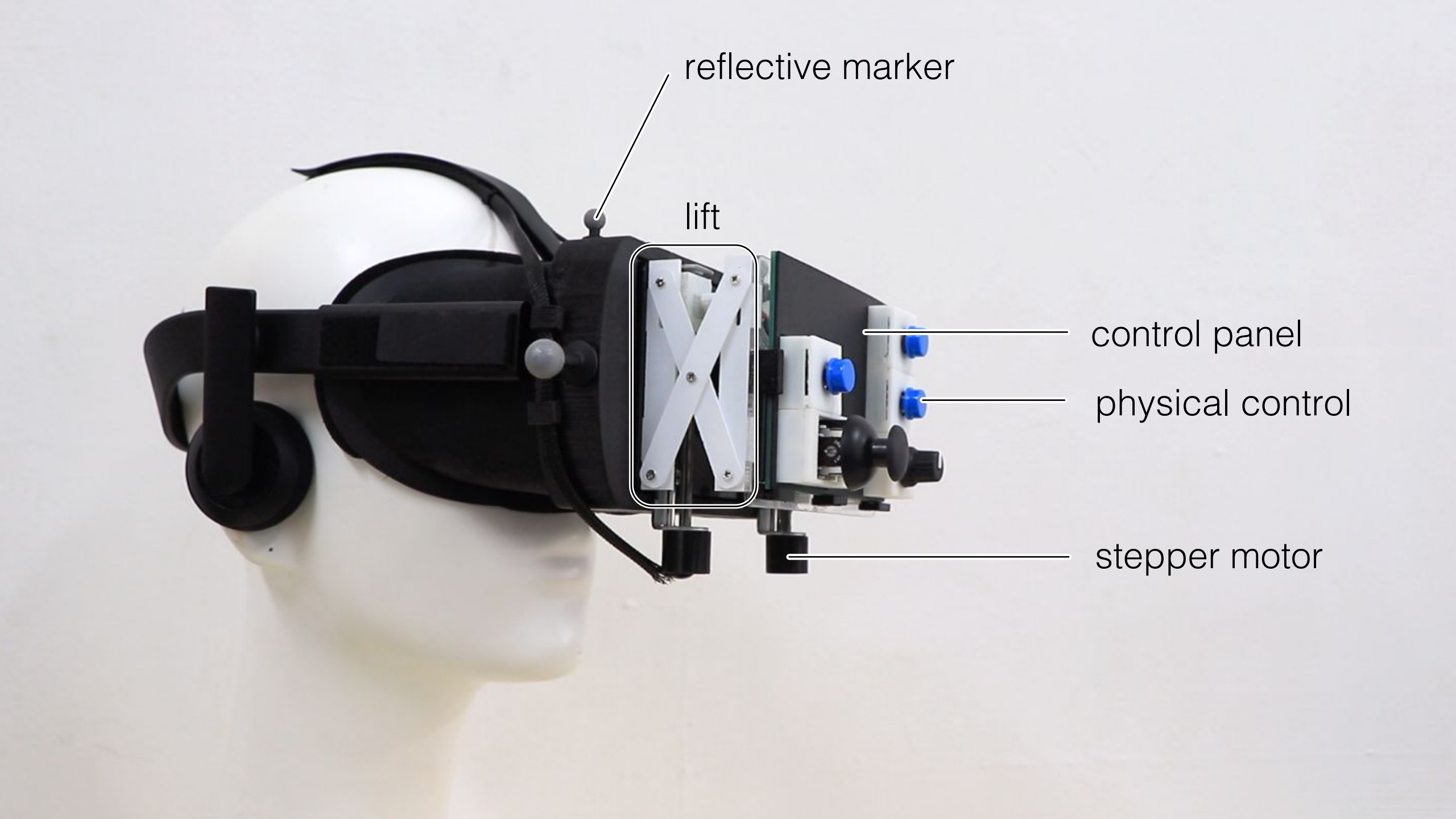
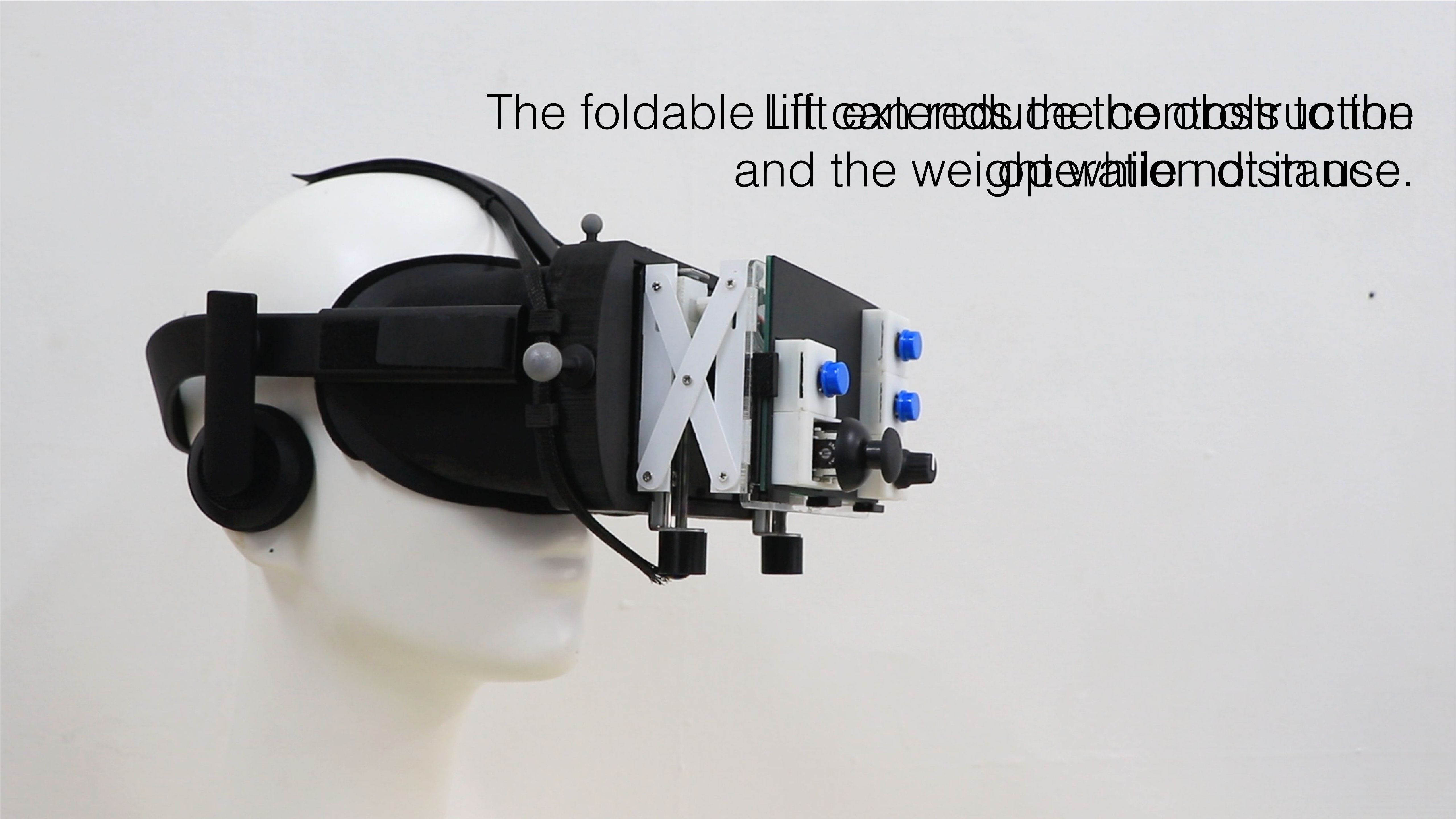
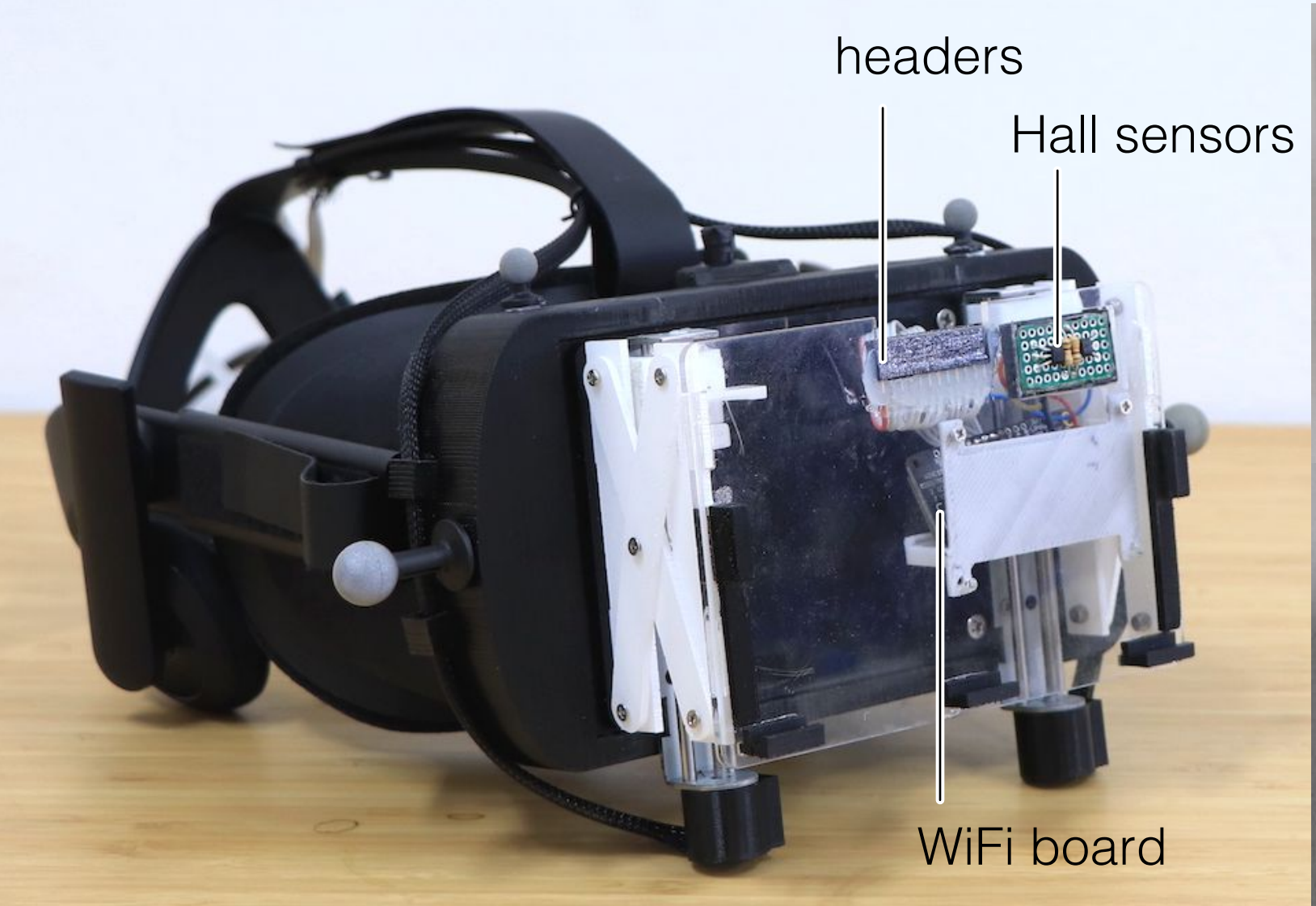

reflective marker
lift
control panel
physical control
stepper motor

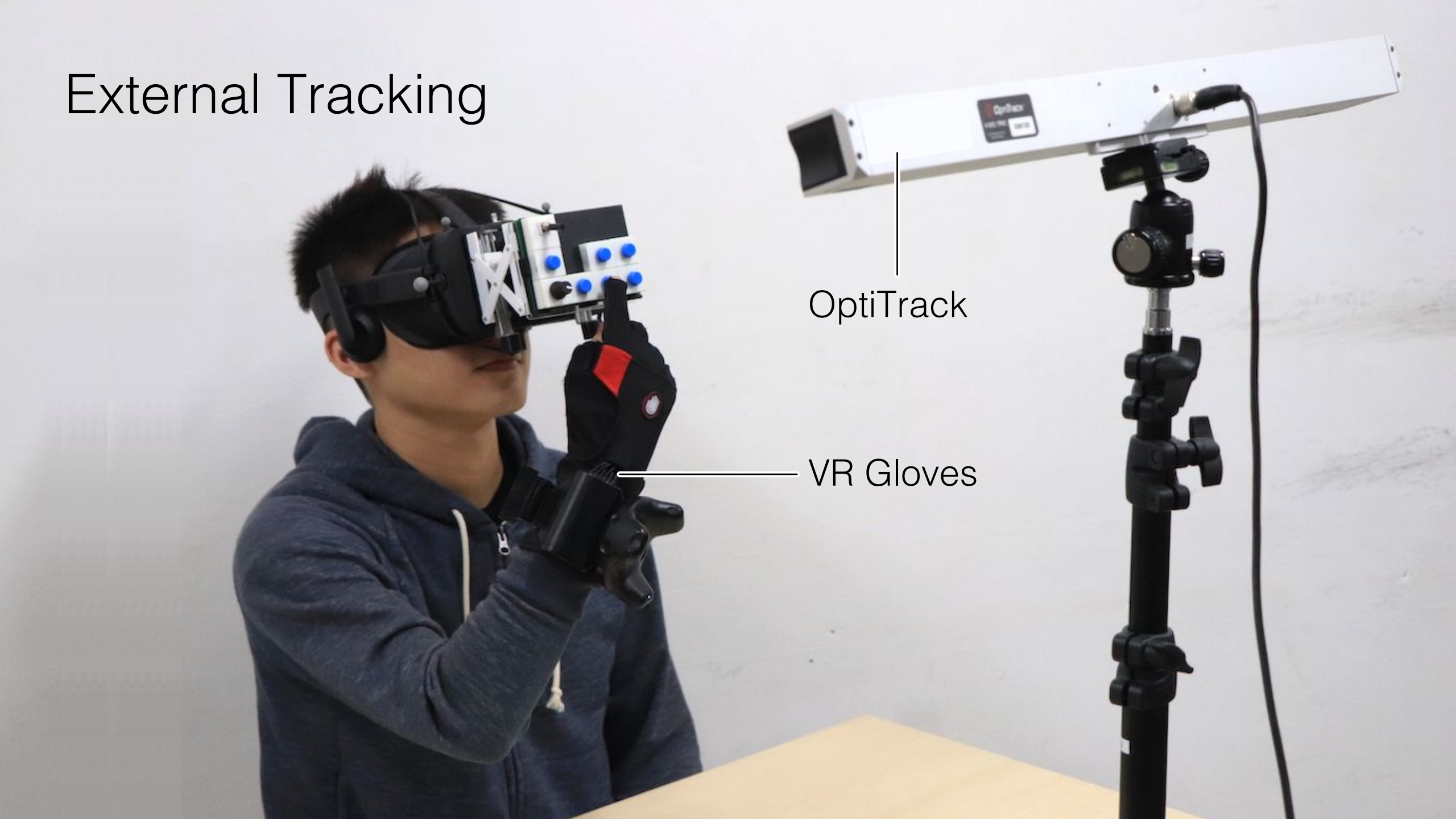

The foldable Lift reduces the obstruction
and the weight while in use.
Lift extends the controls to the
operation distance.

Control Panel




3x

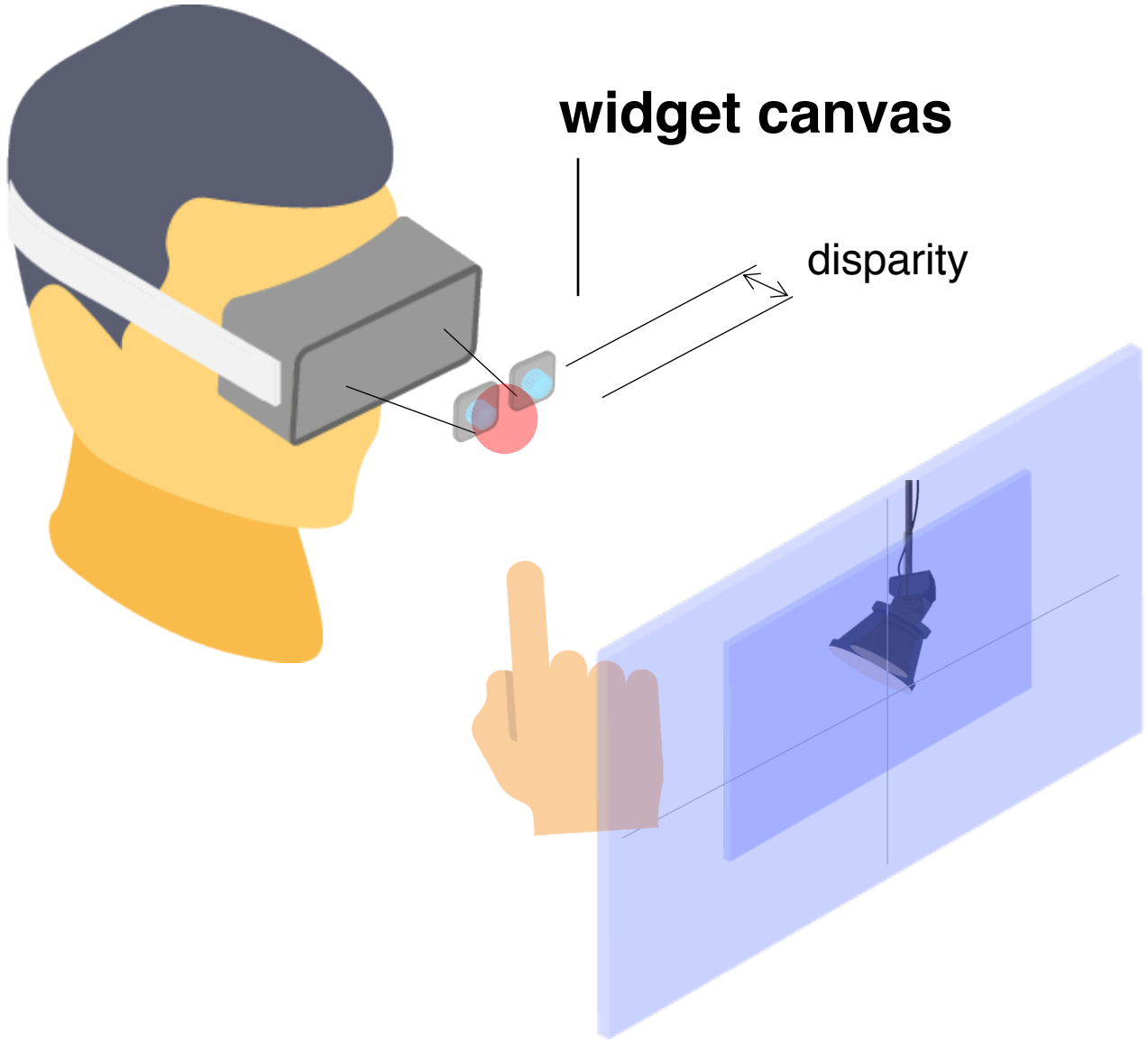
External Tracking



Interaction Design

- widget canvas
- palm-facing gesture

Task: turning on the light in virtual environment



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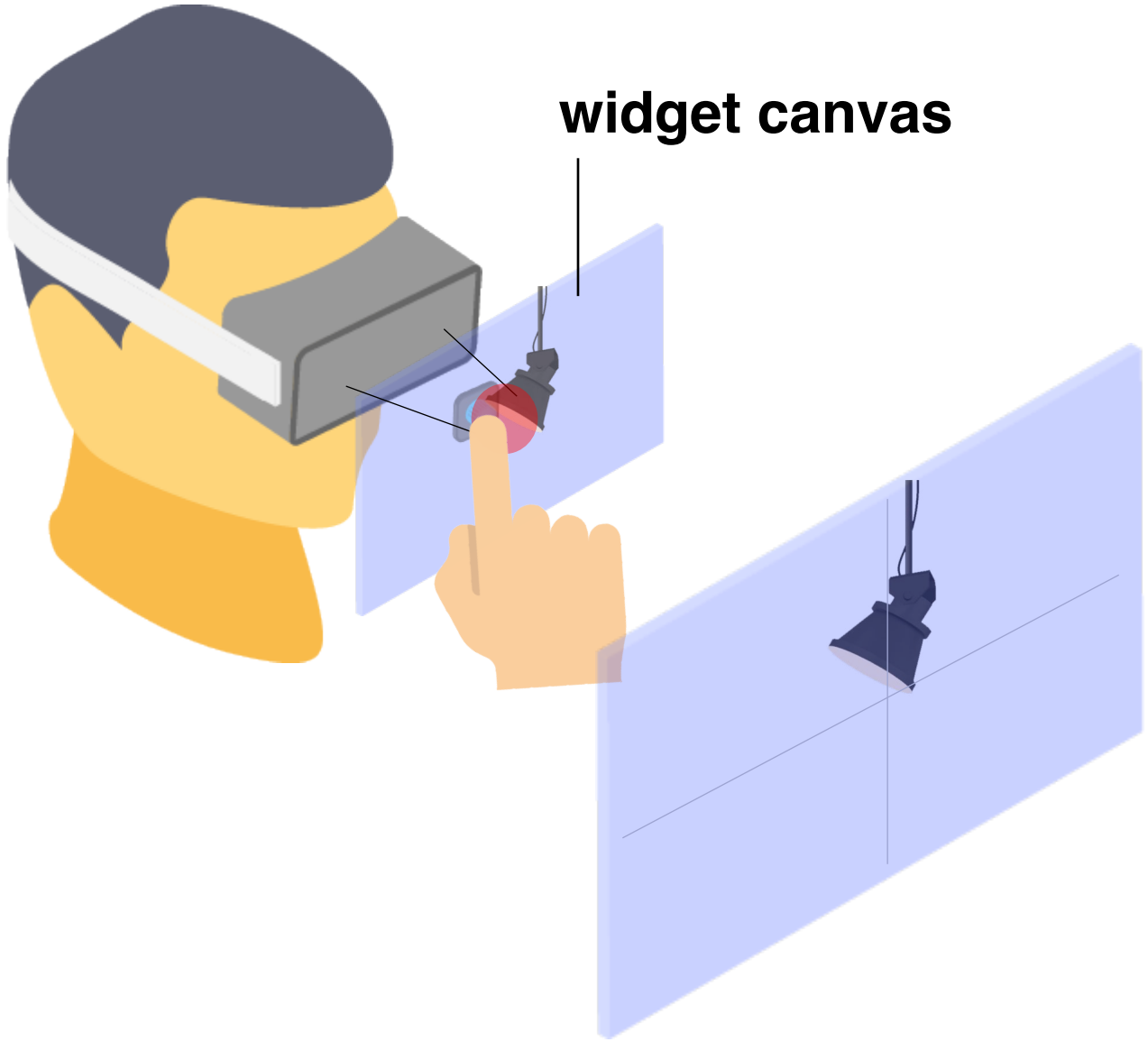
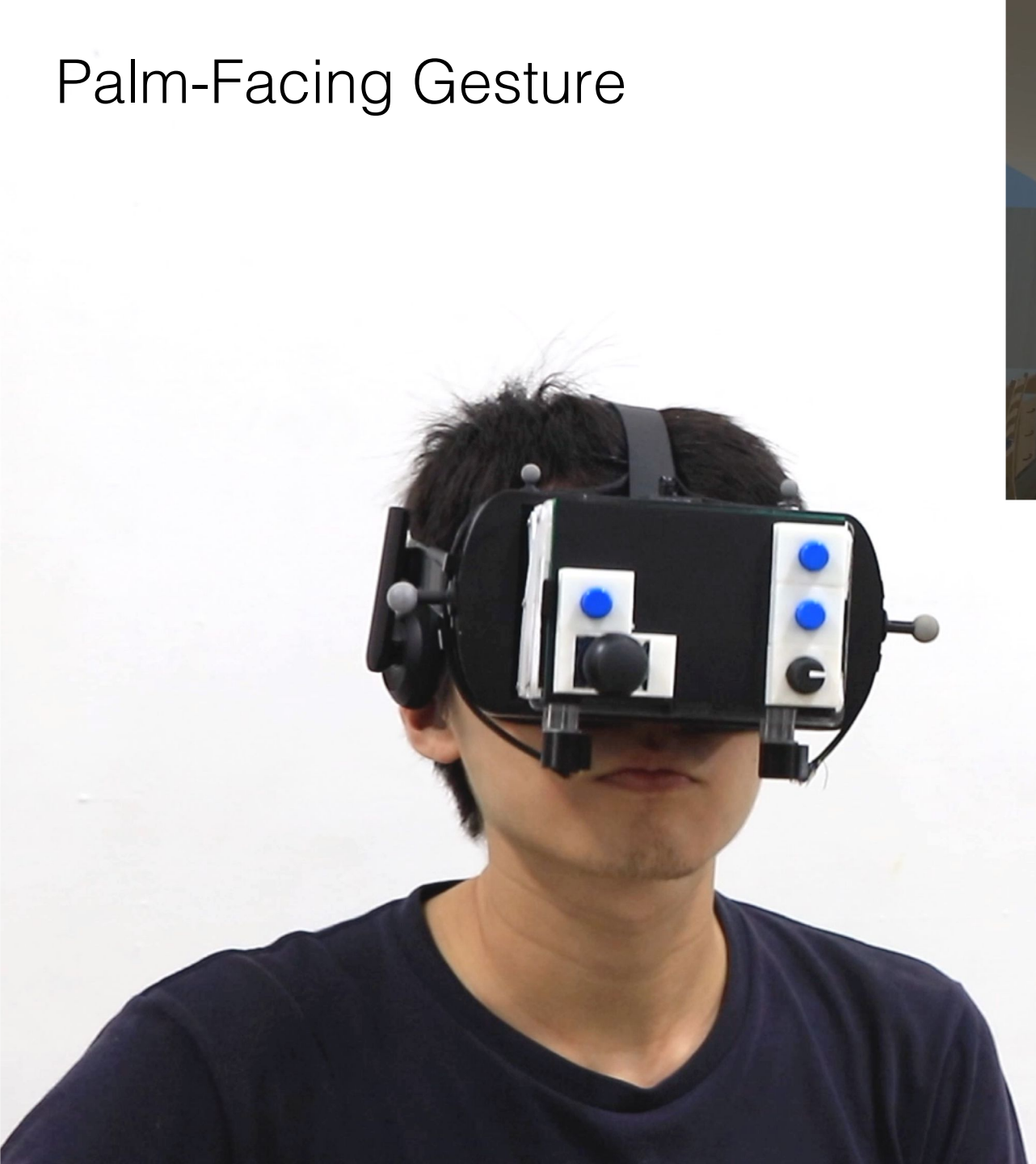


The widget canvas can avoid double vision during interactions.

Widget Canvas

The transition of widget canvas completes depending on the palm-facing gesture.

Palm-Facing Gesture



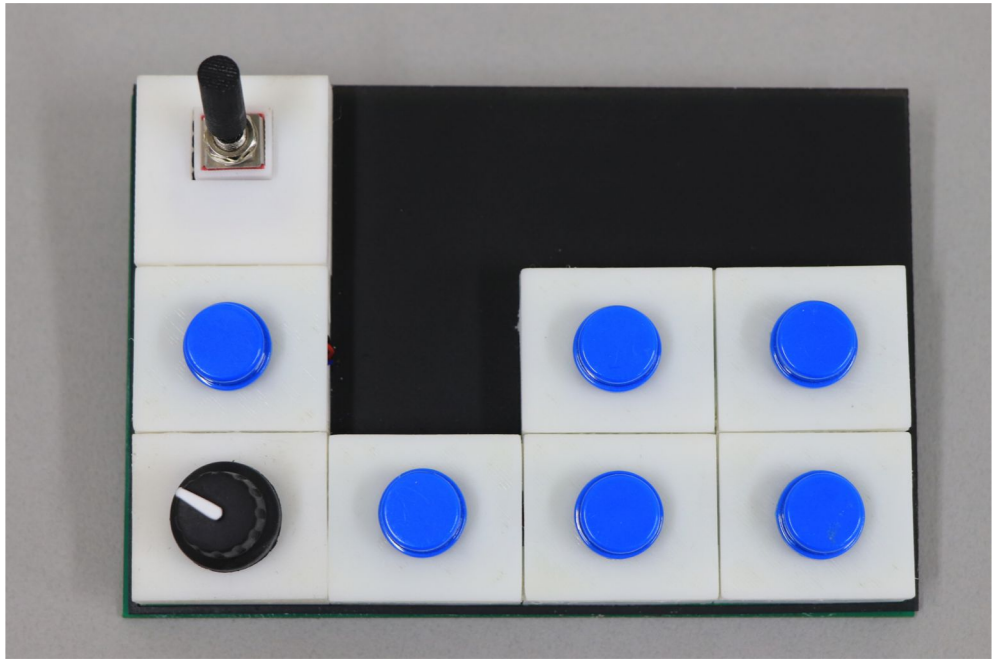
Facing palm toward HMD
to invoke widget canvas.

Example Use Cases

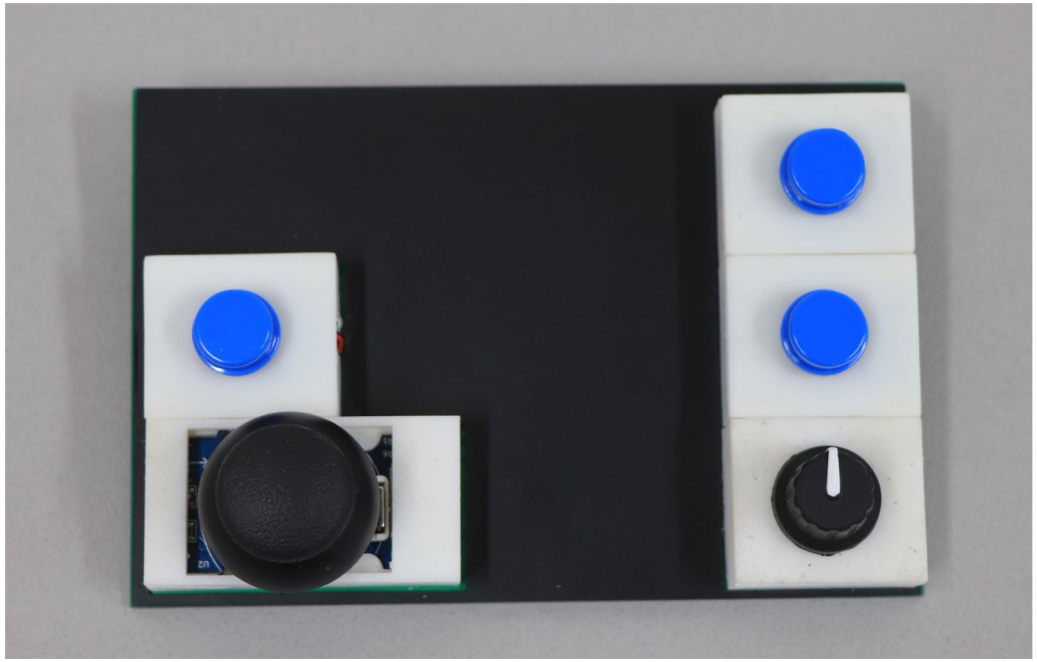
- 360 Video Player
- Smart Home Control

Layout for Control Panel

Fixed-Layout:
360° video player



Contextual Input:
smart home control



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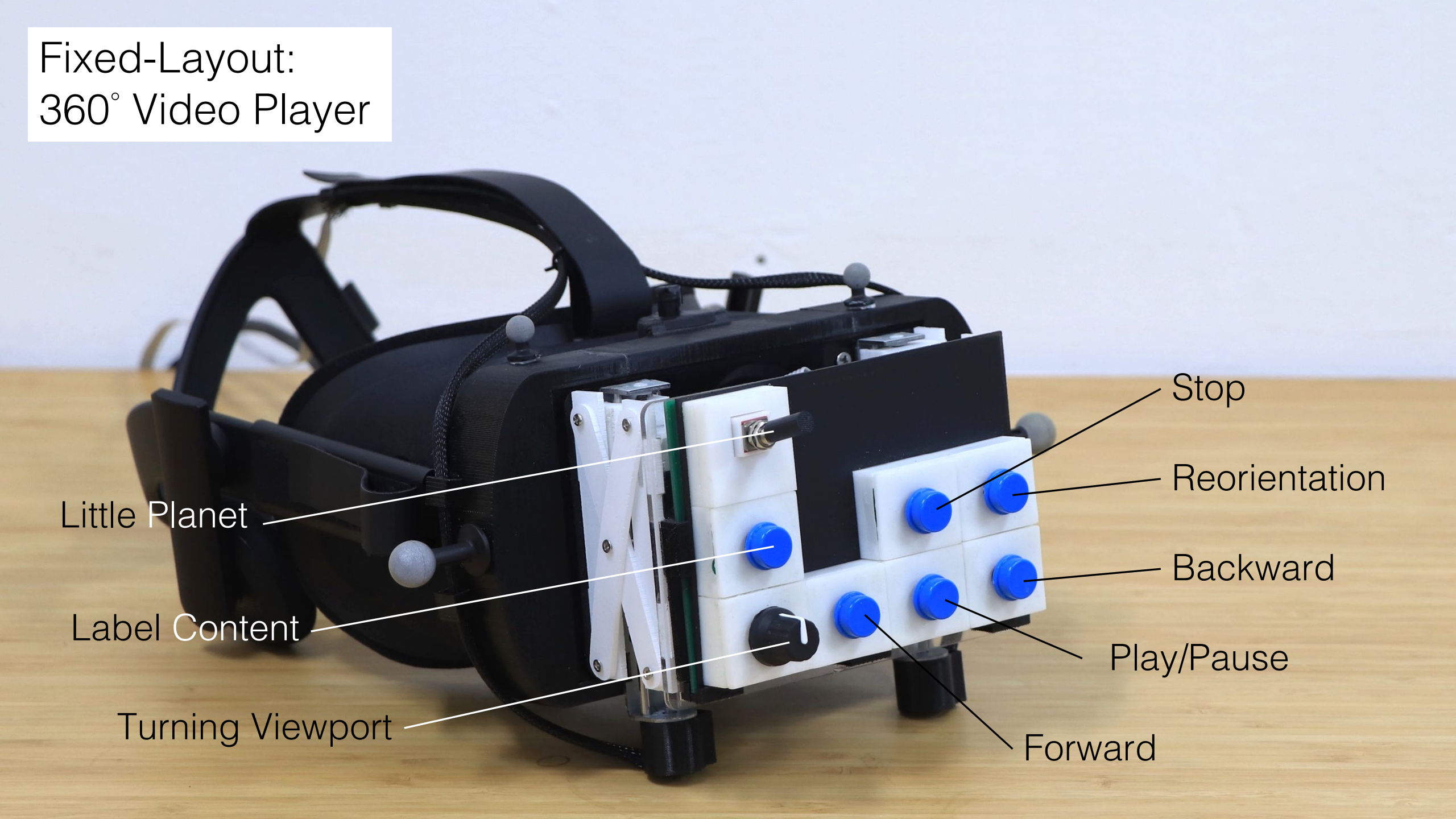
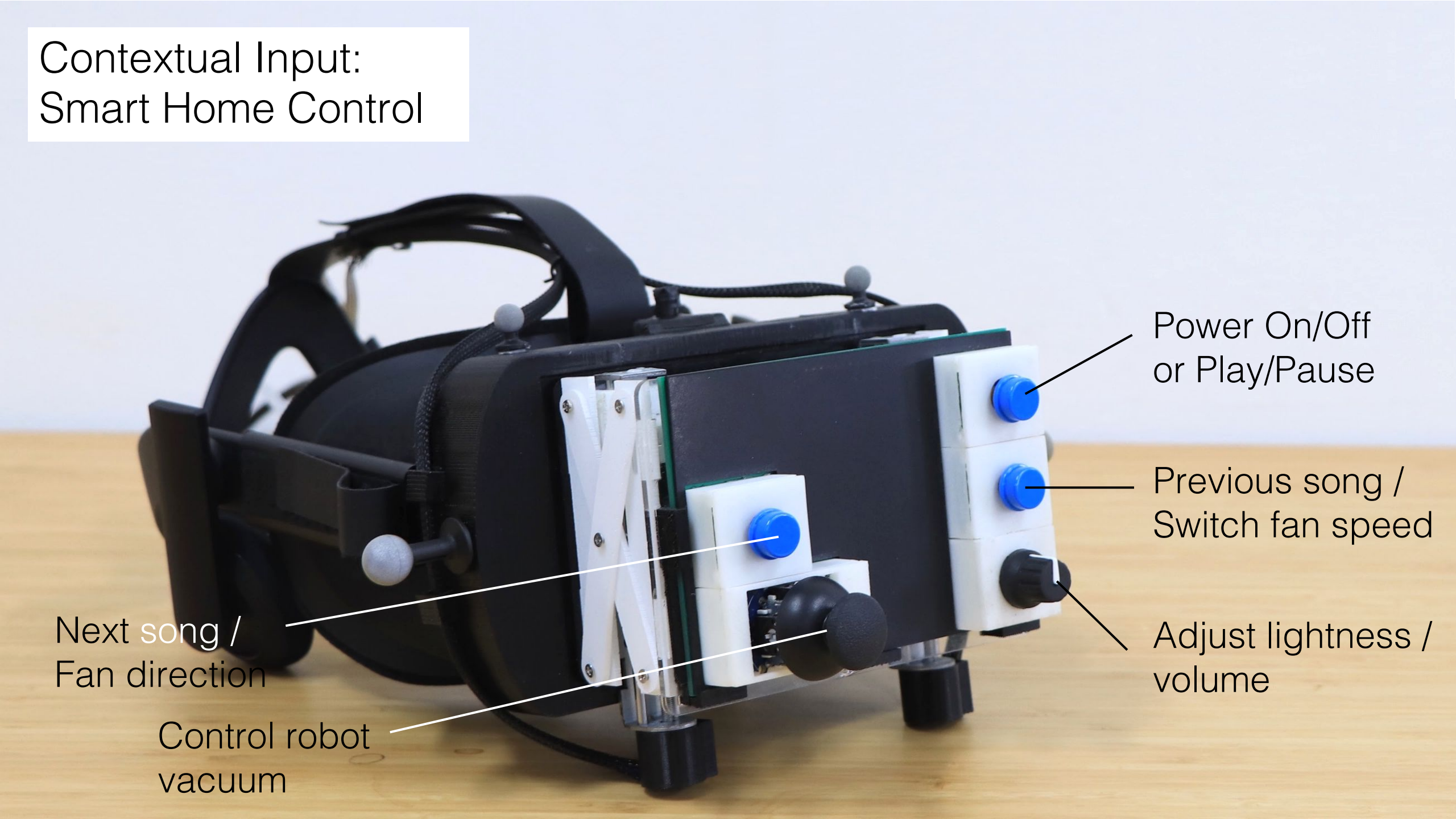


Fixed-Layout:
360° Video Player

Vremiere (CHI ’17)

Contextual Input:
Smart Home Control



Contextual Input:
Smart Home Control

user studies

1) Operation Distance

Investigate the nearest depth to place virtual controls.

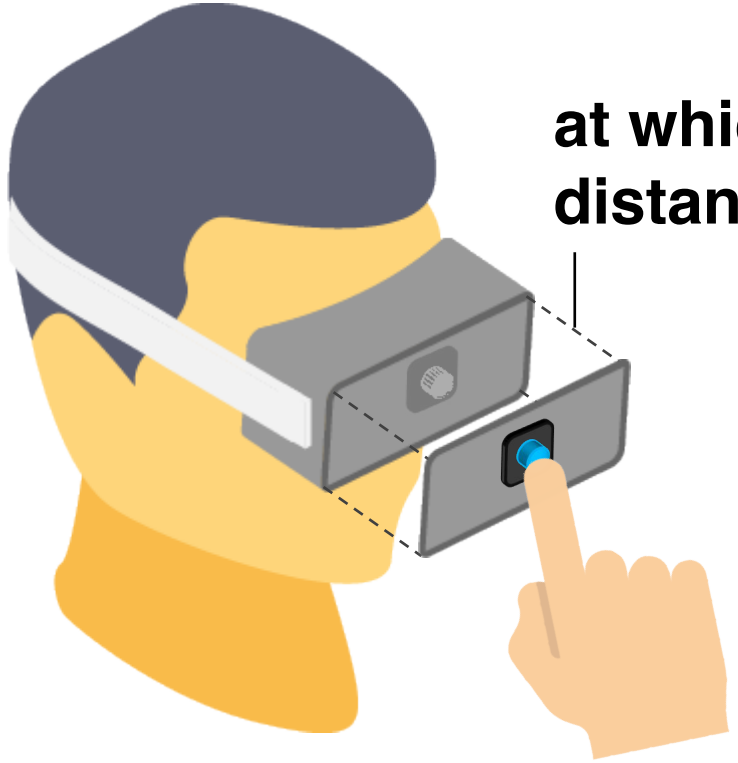
2) Enable / Disable Hand Reference

Investigate whether showing hand reference facilitates interaction.

3) Exploratory Study

Collect user feedback and preference of hand models.

Study 1 : Operation Distance



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Study 1 : Operation Distance

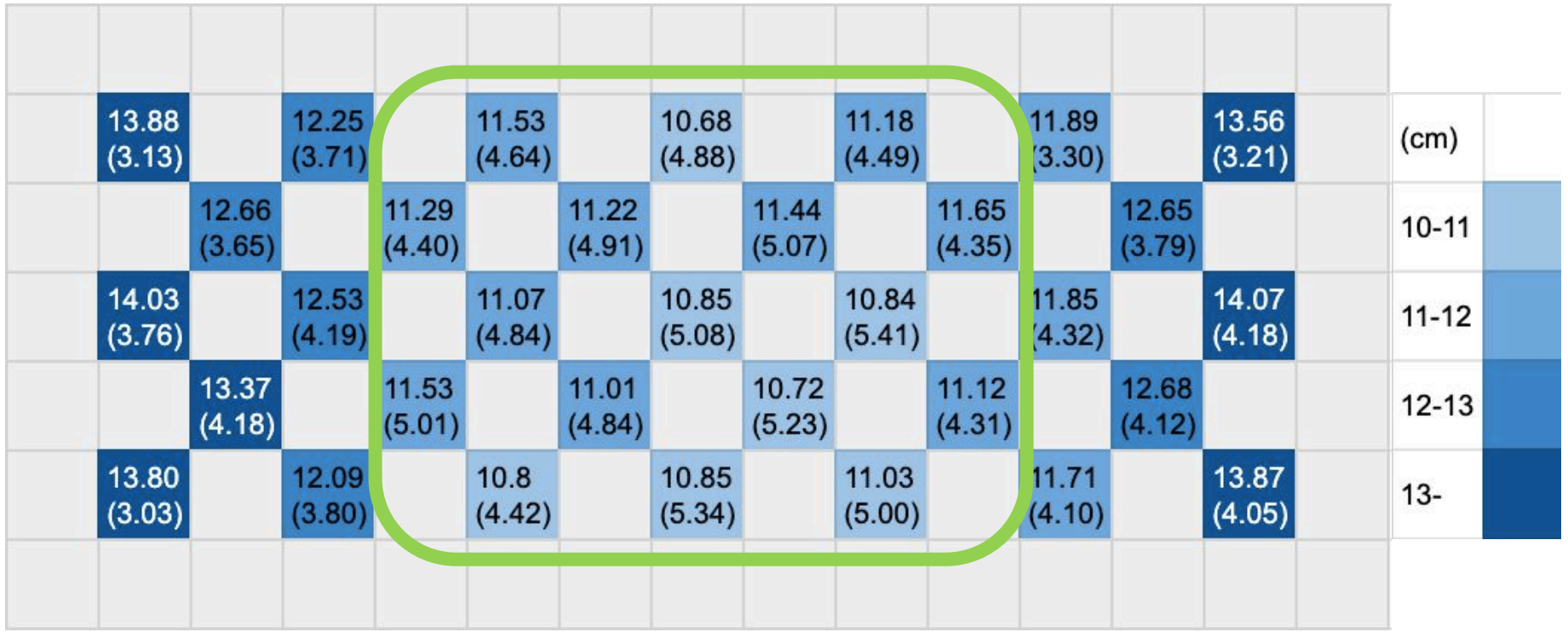
- We studied the **minimal depth** that the user **can perceive virtual controls comfortably**.
- 33 locations × 2 initial positions × 3 repetitions = 198 tasks
- 12 participants (5F, mean age = 22.6)
- Task: participants change the depth of a cylinder until it reaches the minimal depth and still be perceived comfortably.

Initial Position: Far

Initial Position: Near

Results

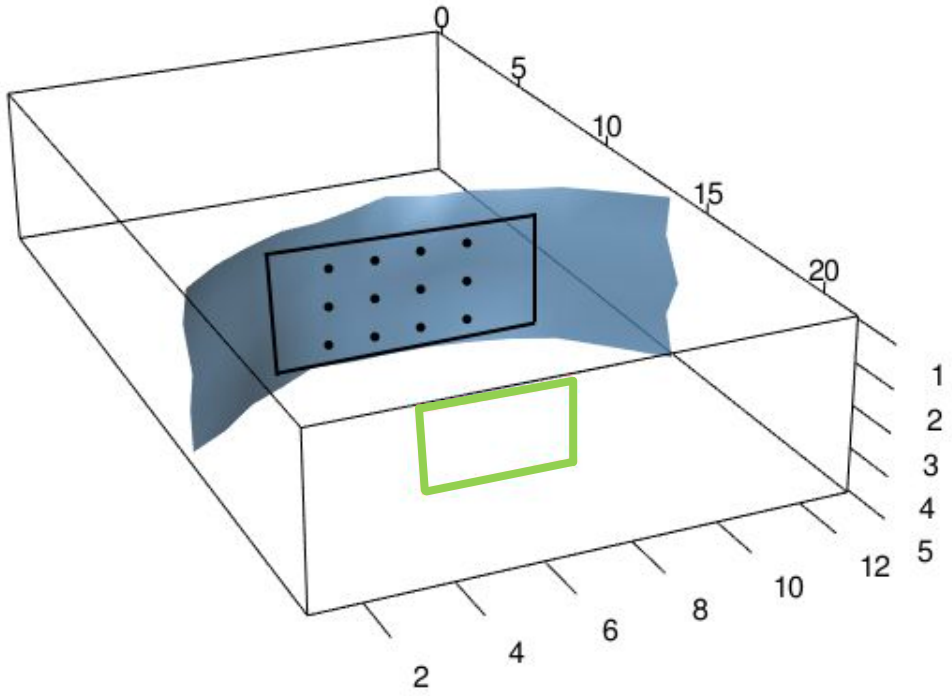
The overall average of 33 positions was 11.99 cm.



Operation Distance

We added two standard deviations to the average depth and took **20 cm** as the operation distance.

We picked 12 positions evenly over this region to place physical controls.



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Study 2: Enable / Disable Hand Reference

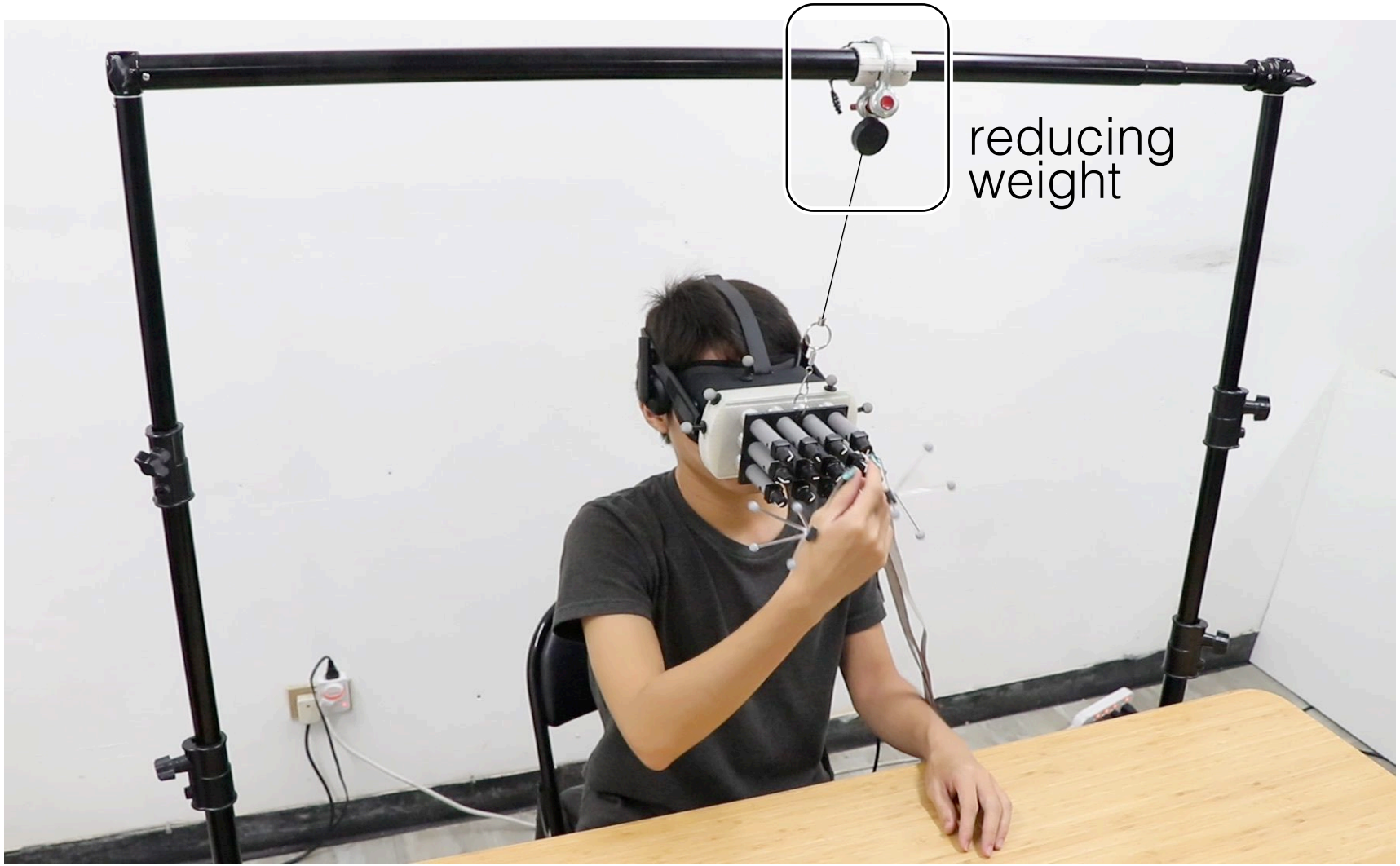
- Compare the performance with or w/o hand reference.
- **Interface:** showHand / noHand
- 2 interfaces × 12 positions × 5 repetitions = 120 tasks
- 12 participants (4F, mean age = 23.7)
- Task: rotate and press a knob randomized from 12 positions.

Study 2: HMD

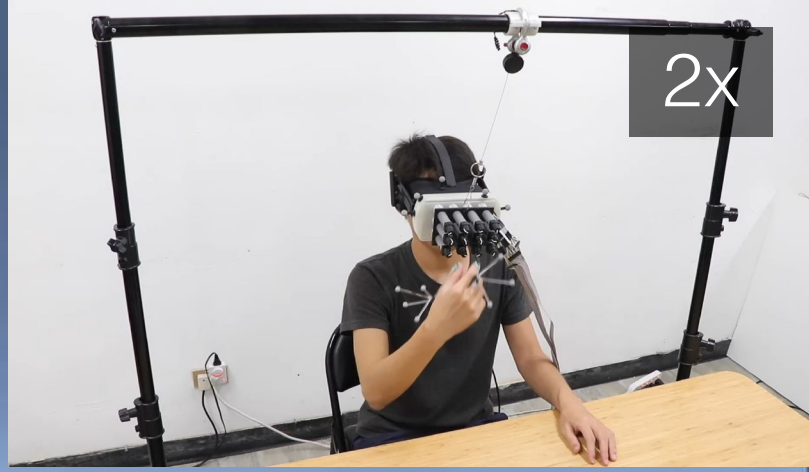
① knobs are fixed at the operation distance (20 cm) with plastic pipes

② using knobs to resemble typical tangible interactions

Study 2: System Setup



showHand



touch
me

noHand

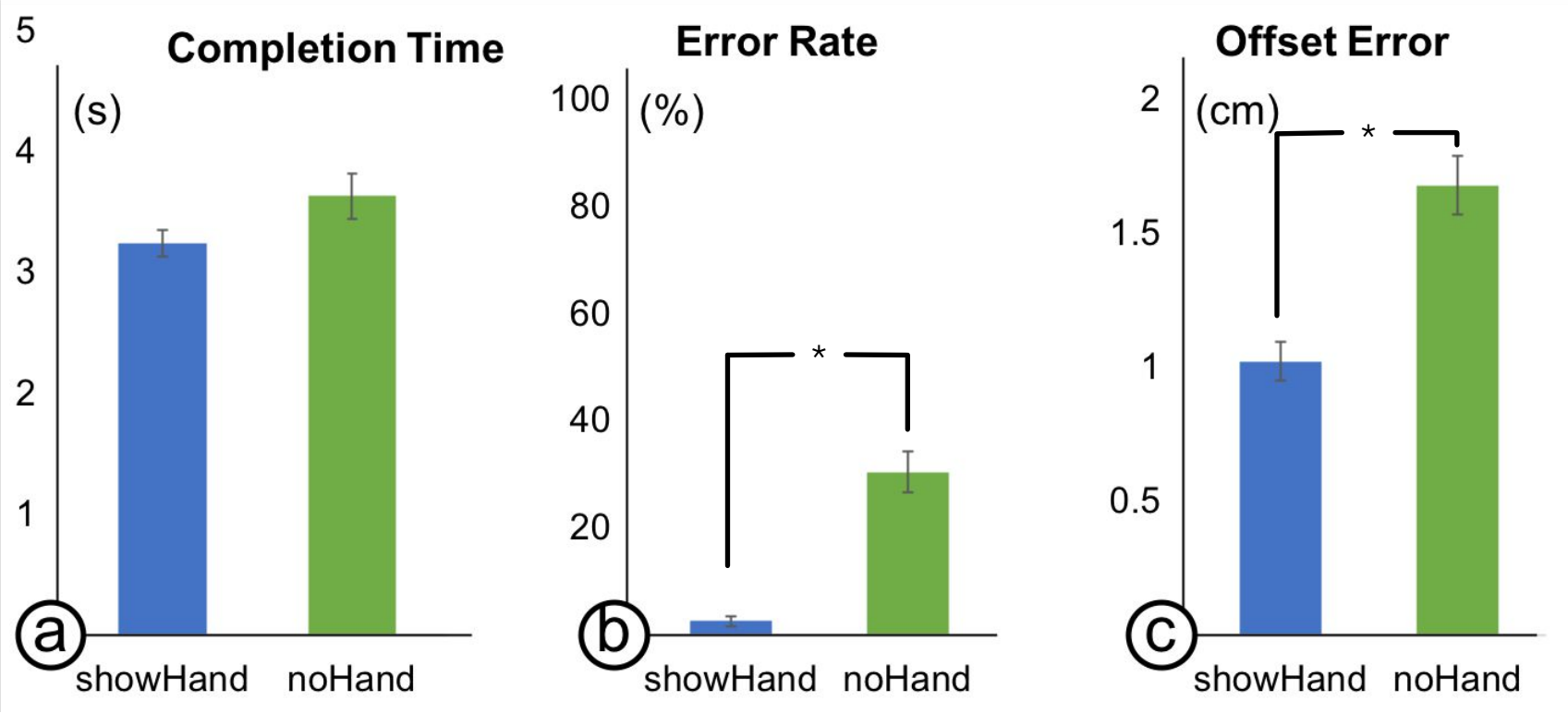
Measurements

- Completion time
- Error rate
- Offset distance (from the midpoint of fingertips to the target)
- Oculomotor of Simulated Sickness Questionnaire (SSQ)
- Mental demand, Physical demand, and Frustration in NASA-TLX

Results

Showing hand reference could make face widgets interactions more precise.

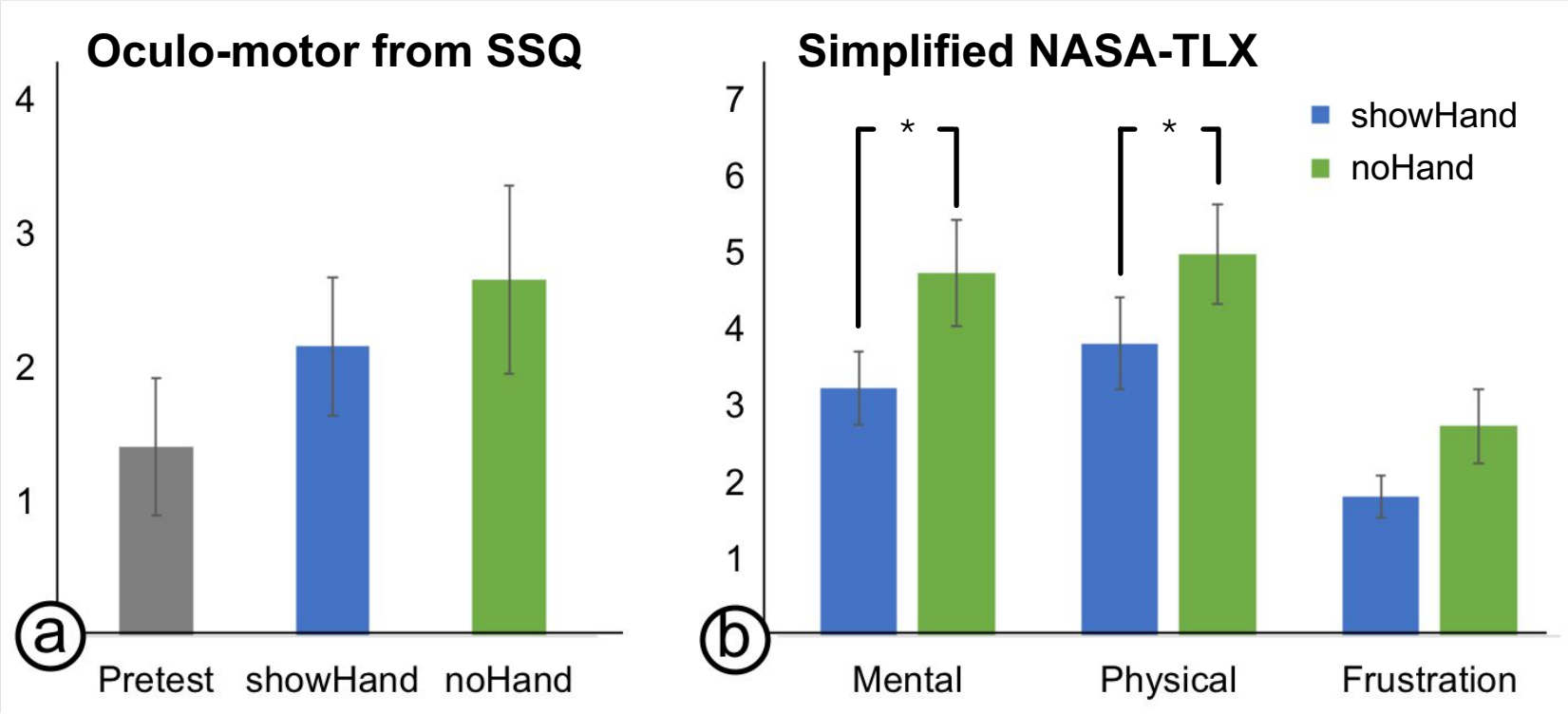
*: $p < .05$



Results

Showing hand reference did not cause eye strain and make face widgets interactions more effortless.

*: $p < .05$



Summary

Result: **Showing hand reference** allowed users to perform precise and effortless interactions.

Goal: We decide to provide hand reference to facilitate face widgets interaction during hovering and manipulating.

user studies

1) Operation Distance

Operation distance of **20 cm** from the eye position.

2) Enable / Disable Hand Reference

Investigate whether showing hand reference facilitates interaction.

3) Exploratory Study

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Exploratory Study

- Understanding the preference of hand models and gathering subjective feedback on FaceWidgets.
- 2 applications × 4 hand models = 8 times
- 8 participants (4F, mean age = 23.8)
- Task:
  - experience 1 minutes each time
  - rate the usability questions
  - rank the visualizations of hand model

Visualizations of Hand Model

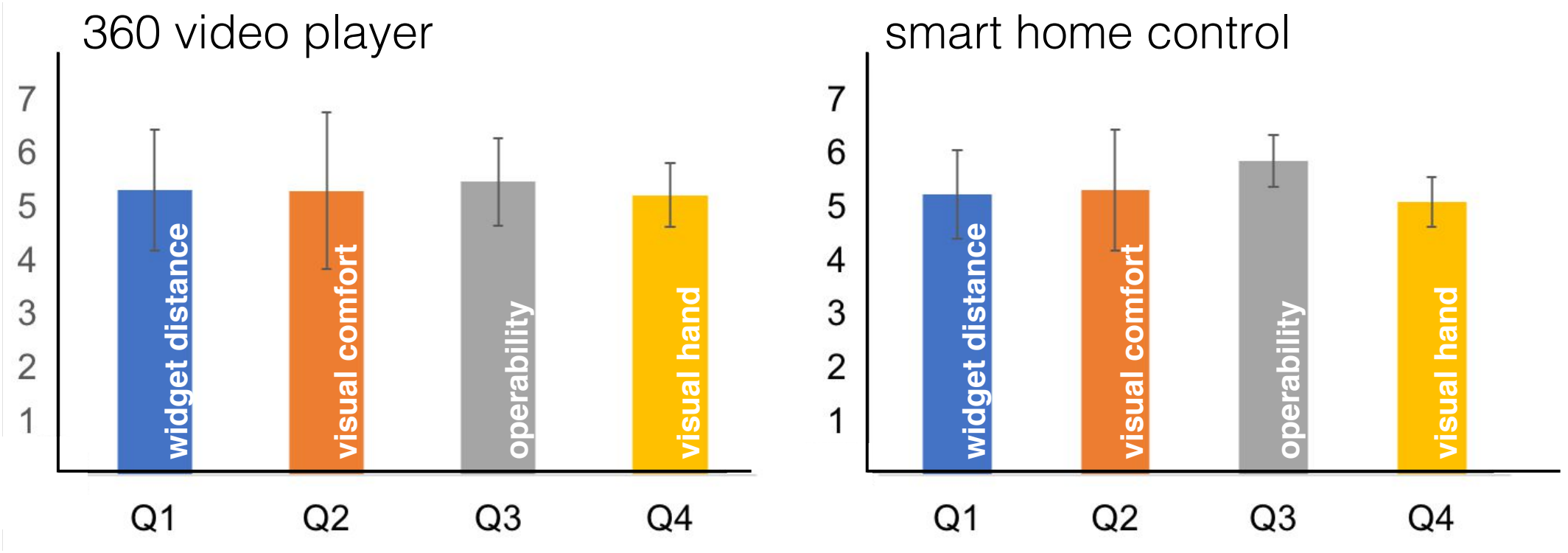
- Fingertips
- Transparent (LucidTouch, UIST ’07)
- Silhouette
- Realistic (Need a Hand? SAP ’16)

Usability Questions

- Use 7-point Likert scale to rate on four aspects:
  - Q1: Widget distance
  - Q2: Visual comfort
  - Q3: Operability
  - Q4: Visual Hand

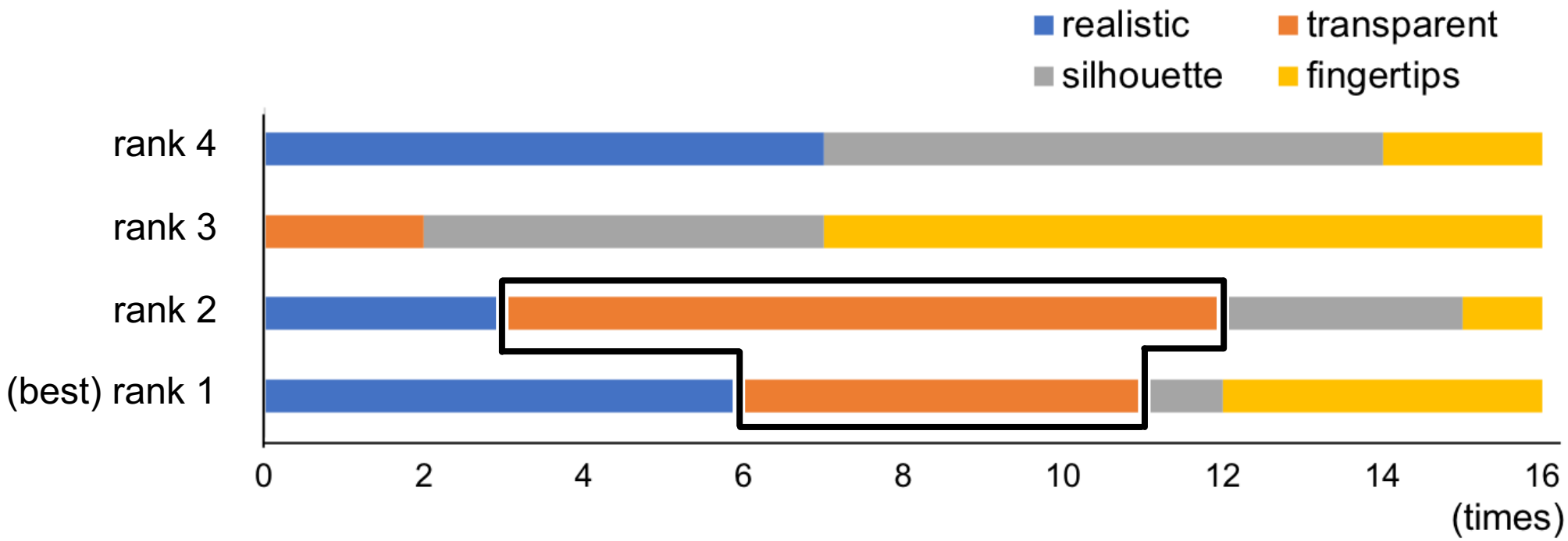
Results of Usability Questions

The ratings from participants were positive on four questions.



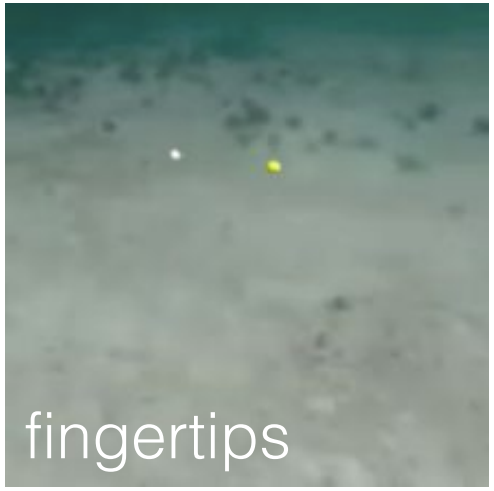
Preference Counts of Visualizations

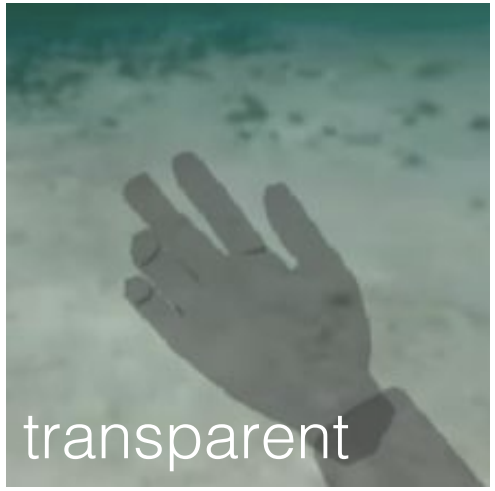
The preference varies between participants. The transparent had the most ranking on the 1st and 2nd place.



Feedback on Visualizations

Precise but lacks of sense of presence





Allowed the presence of hand w/o occlusion

Allowed the presence of hand w/o occlusion

Highest sense of presence but occlusion

Feedback on Visualizations

We chose transparent hand as our hand model.

Interview Discussion

- User Feedback
  - “I can simply flip my palm and select the functions.”
  - “How the objects were linked to the available controls in the smart home control application is easy and [intuitive].”
- Transition from 3D to 2D
  - “The pop-up window draws my attention away, and I felt like I was pulled out from the original world.”

user studies

1) Operation Distance

Operation distance of **20 cm** from the eye position.

2) Enable / Disable Hand Reference

Hand reference enhanced the interactions.

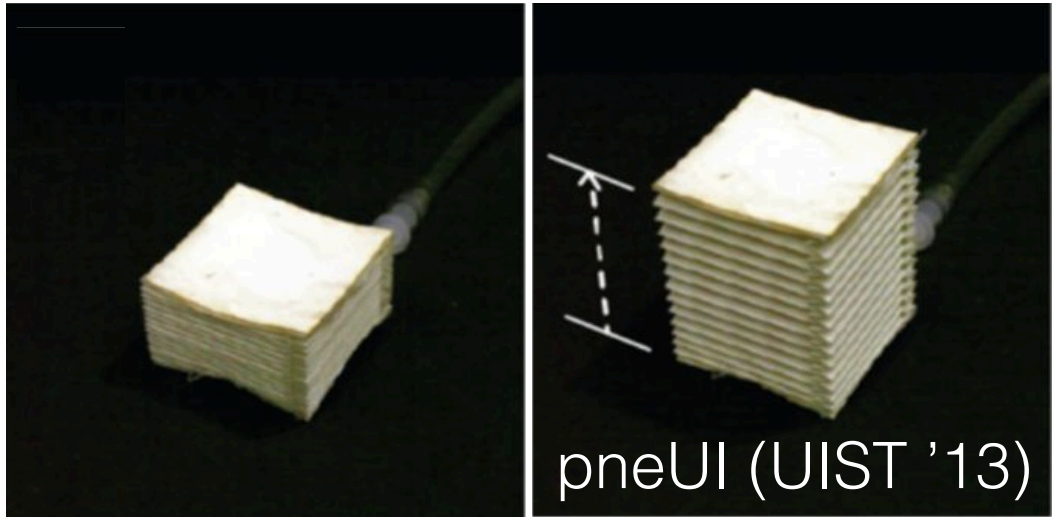
3) Exploratory Study

The **transparent hand** model worked the best.

Conclusion

Limitation

- The total weight of the prototype is about 1 kg.
  - Replacing stepper motors with lighter actuator (e.g., pneumatically-actuated materials).



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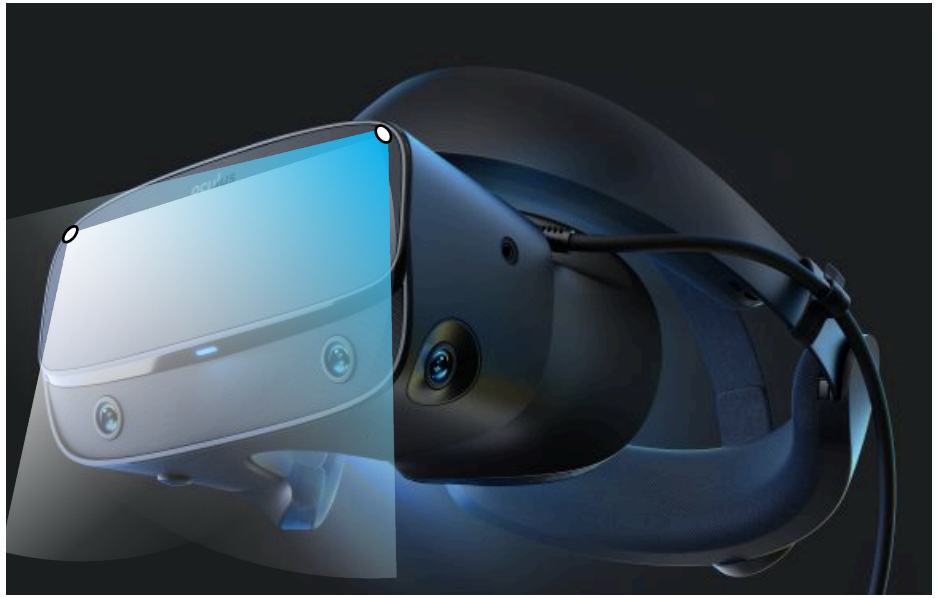
  - Replacing stepper motors with lighter actuator (e.g., pneumatically-actuated materials).
  - Lightweight material (e.g., cardboard in Nintendo Labo).

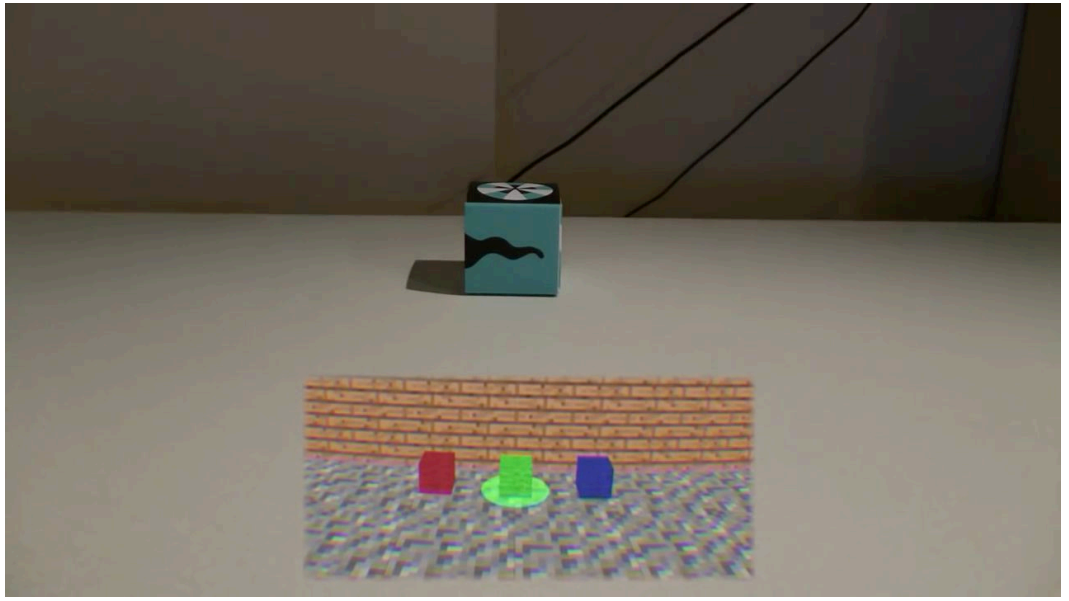
Limitation

- Detecting Hand Gesture with VR Gloves
  - Using wide angle cameras on HMD to capture hand.



Limitation

- Limited Number of Controls
  - Use Haptic Retargeting (CHI'16) that repurposes virtual controls to one or a small set of physical controls.



Contribution

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1. A HMD that integrates physical controls and lift on the backside for direct manipulation in VR.
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3. Studies suggested the operation distance, the necessity of hand reference, and the appropriate hand model.

FaceWidgets:

Exploring Tangible Interaction on Face with Head-Mounted Displays

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Thank you for your attention!

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Hoping to start Ph.D. in HCI in 2020.