GazeRing: Enhancing Hand-Eye Coordination with Pressure Ring in Augmented Reality

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Outline

- Background
- Related Work
- Our Method
- Experiment
- Demo
- Limitations and Future Work

Background

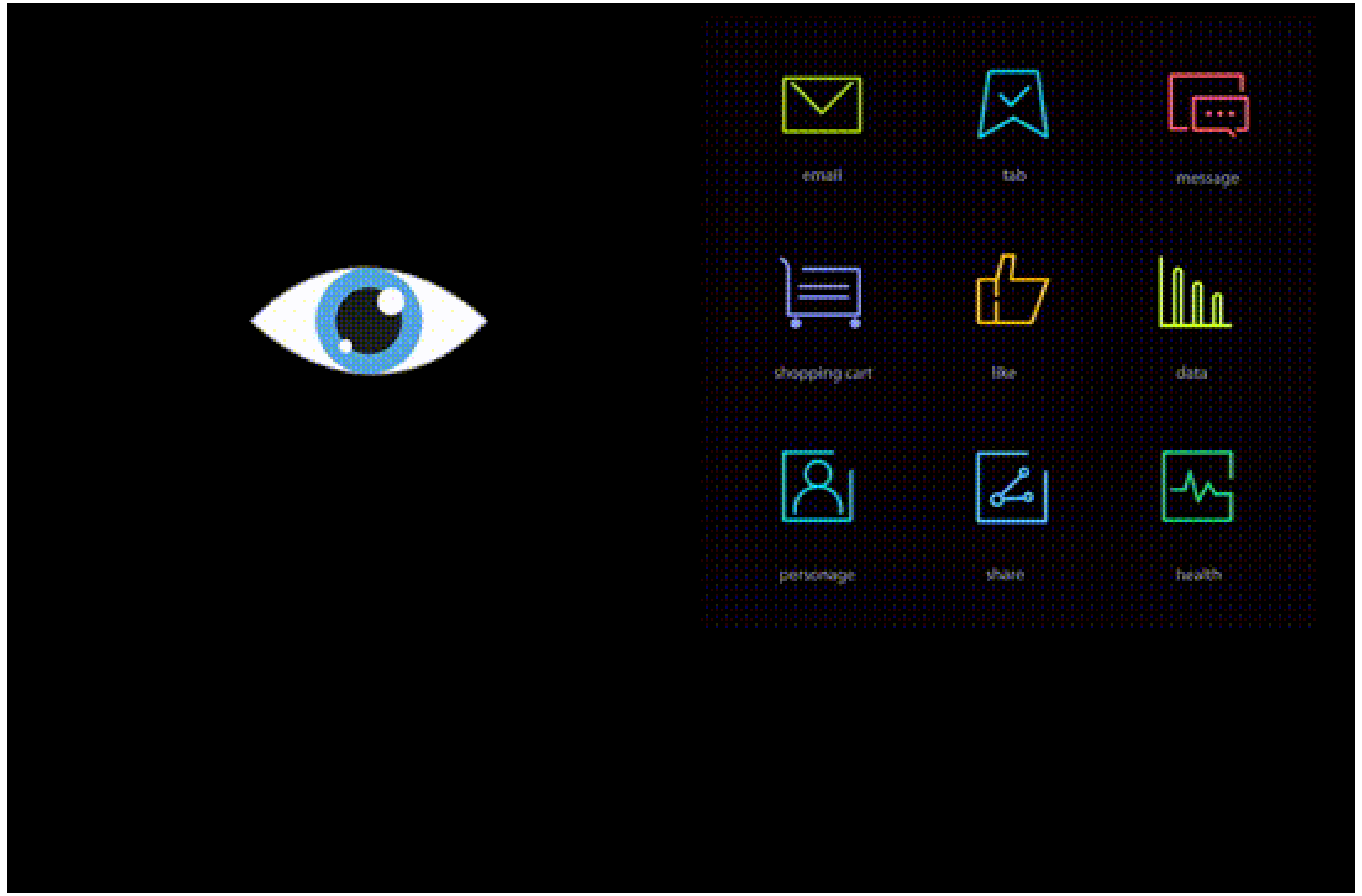
- Augmented reality integrates virtual and physical world, providing an immersive experience.

AR in medicine

AR in office work

Background

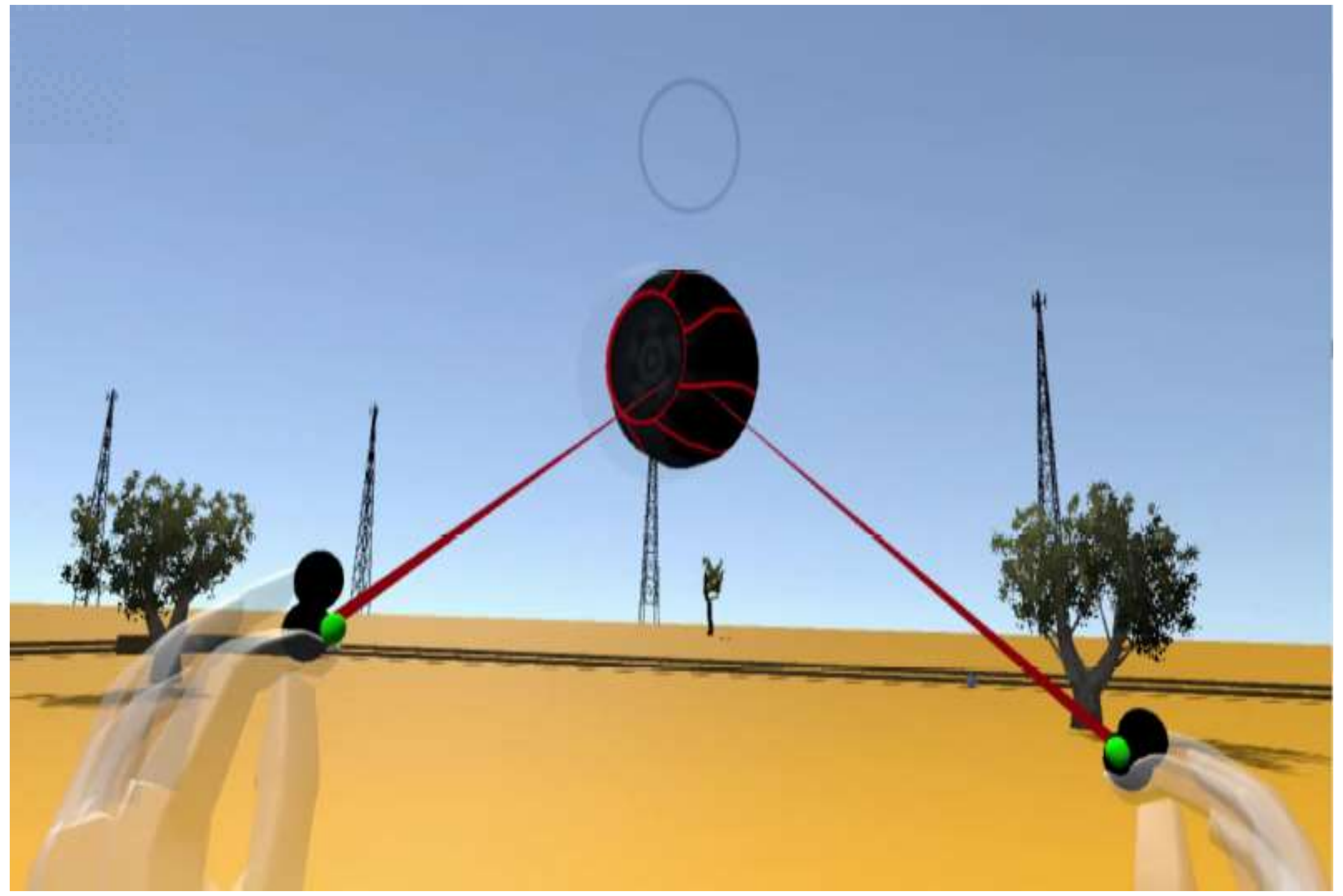
Its core interaction, hand-eye coordination, combines the speed of eye gaze for selection with the precision of hand gestures for manipulation.



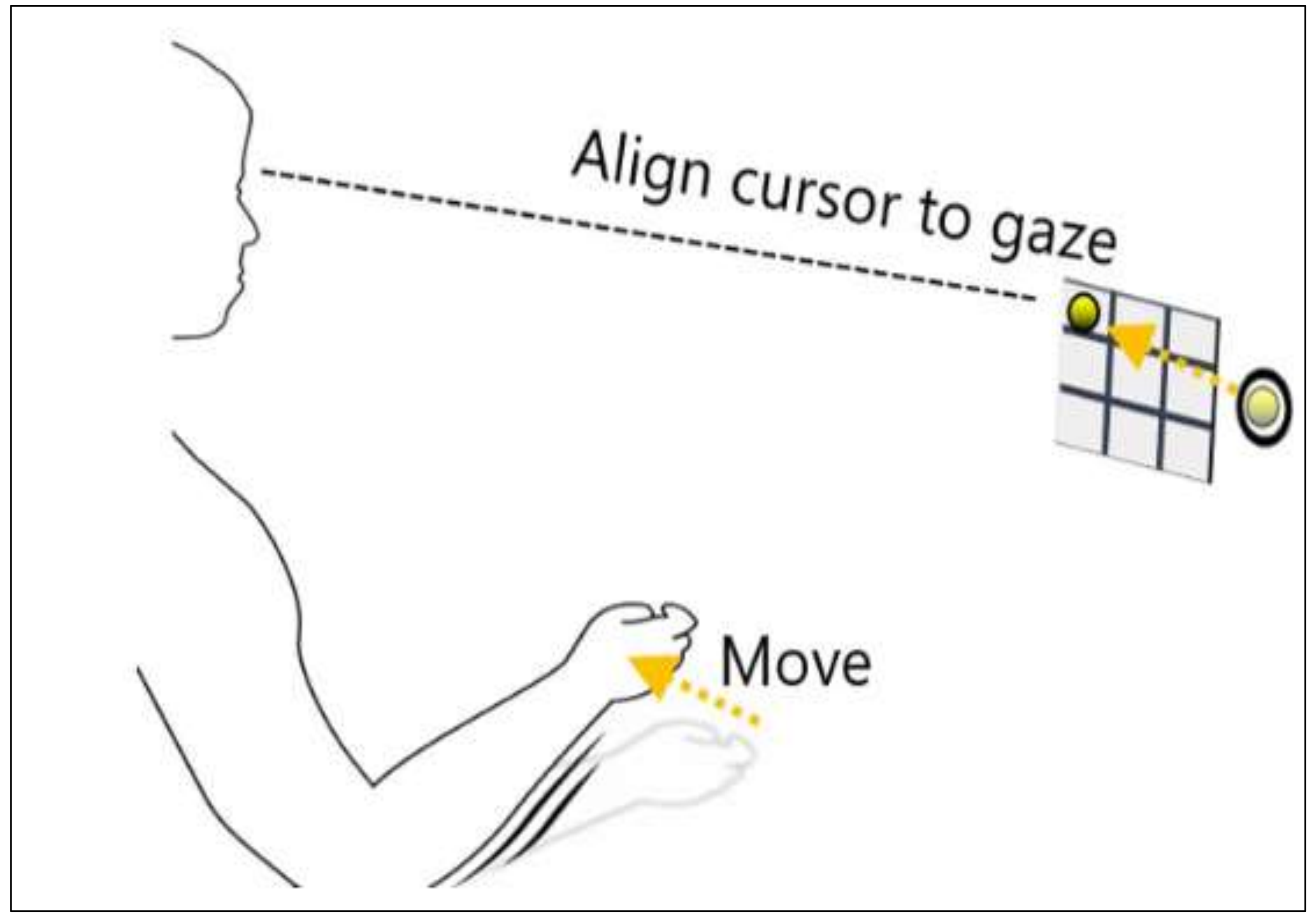
Hand-eye coordination

Related Work

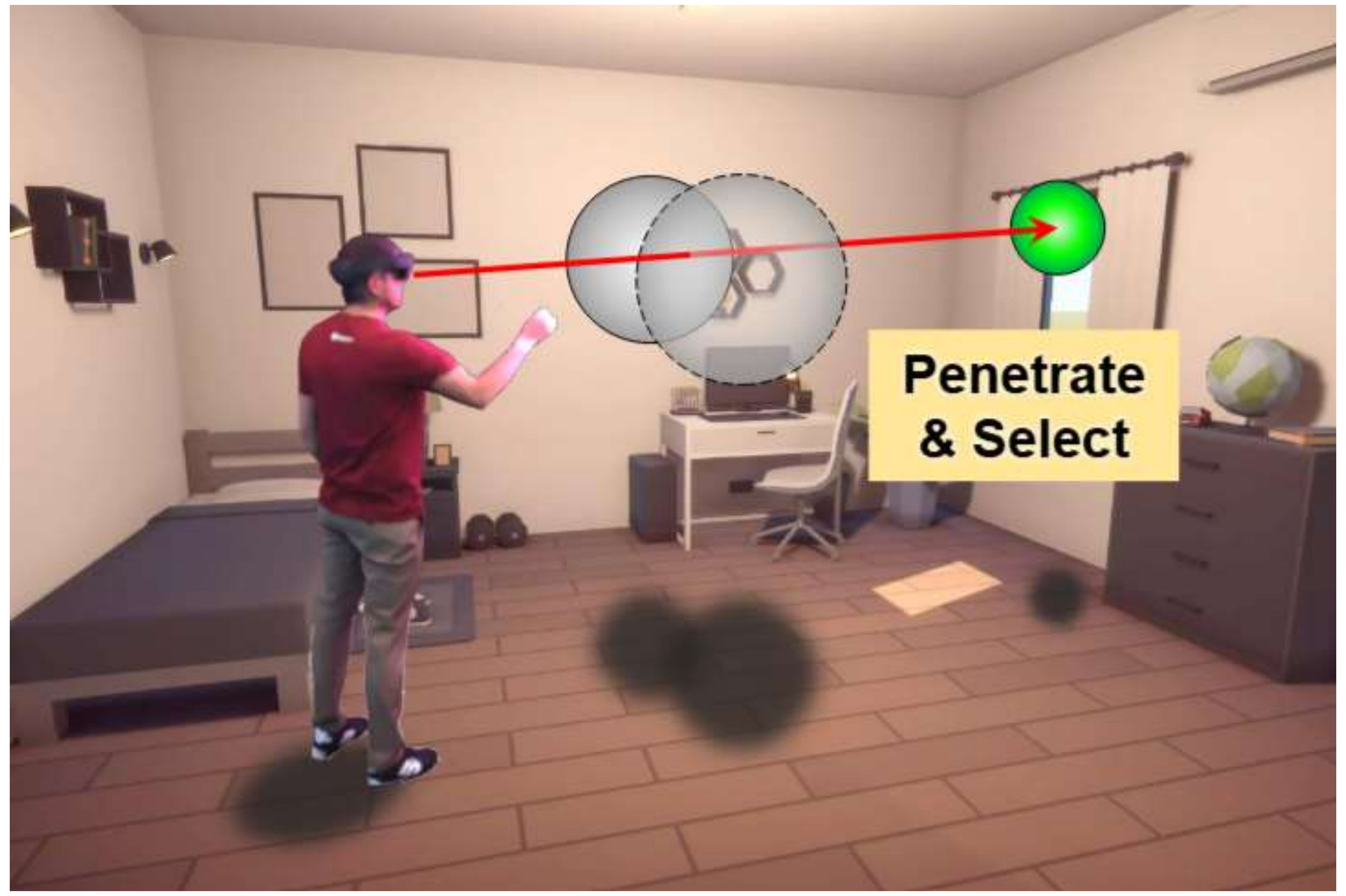
Many studies follow the principle of "gaze selects, hand manipulates," which has been proven effective in various scenarios, such as 3D object manipulation, menu selection, and more.



SUI [Pfeuffer *et al.*, 2017]



ETRA [Lystbæk *et al.*, 2022]



IEEE VR [Bao *et al.*, 2023]

Related Work - Challenge

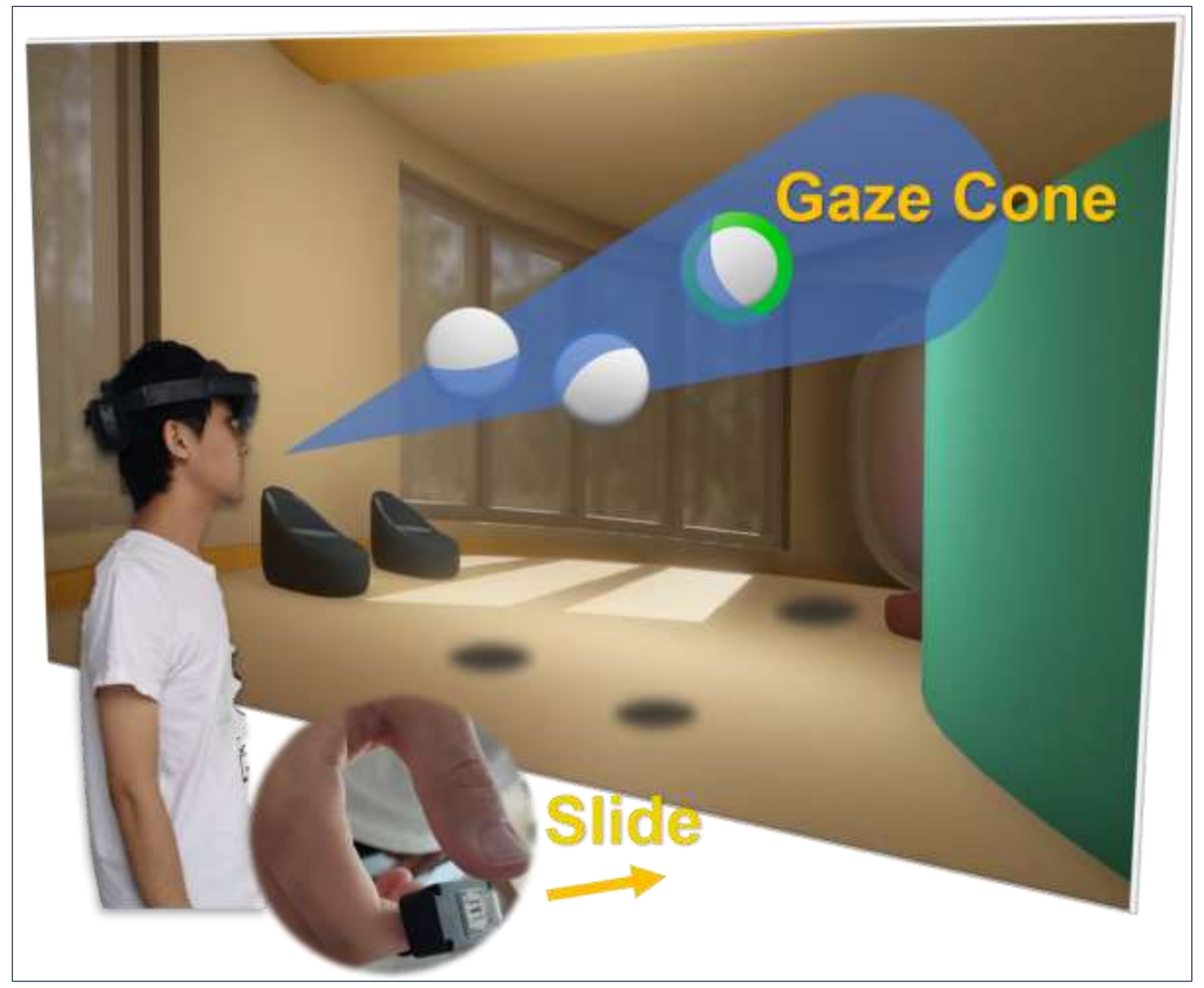
- However, hand-eye coordination faces limitations in practical use, as it is only effective when the hands are within the view of XR headset's cameras.
- This means these **hand gestures are often obvious and conspicuous**.
- Previous research also found that **users preferred subtle interactions** over obvious hand gestures in public, due **to privacy concerns and social acceptance** [Tung *et al.*, 2015].

Related Work - Inspiration

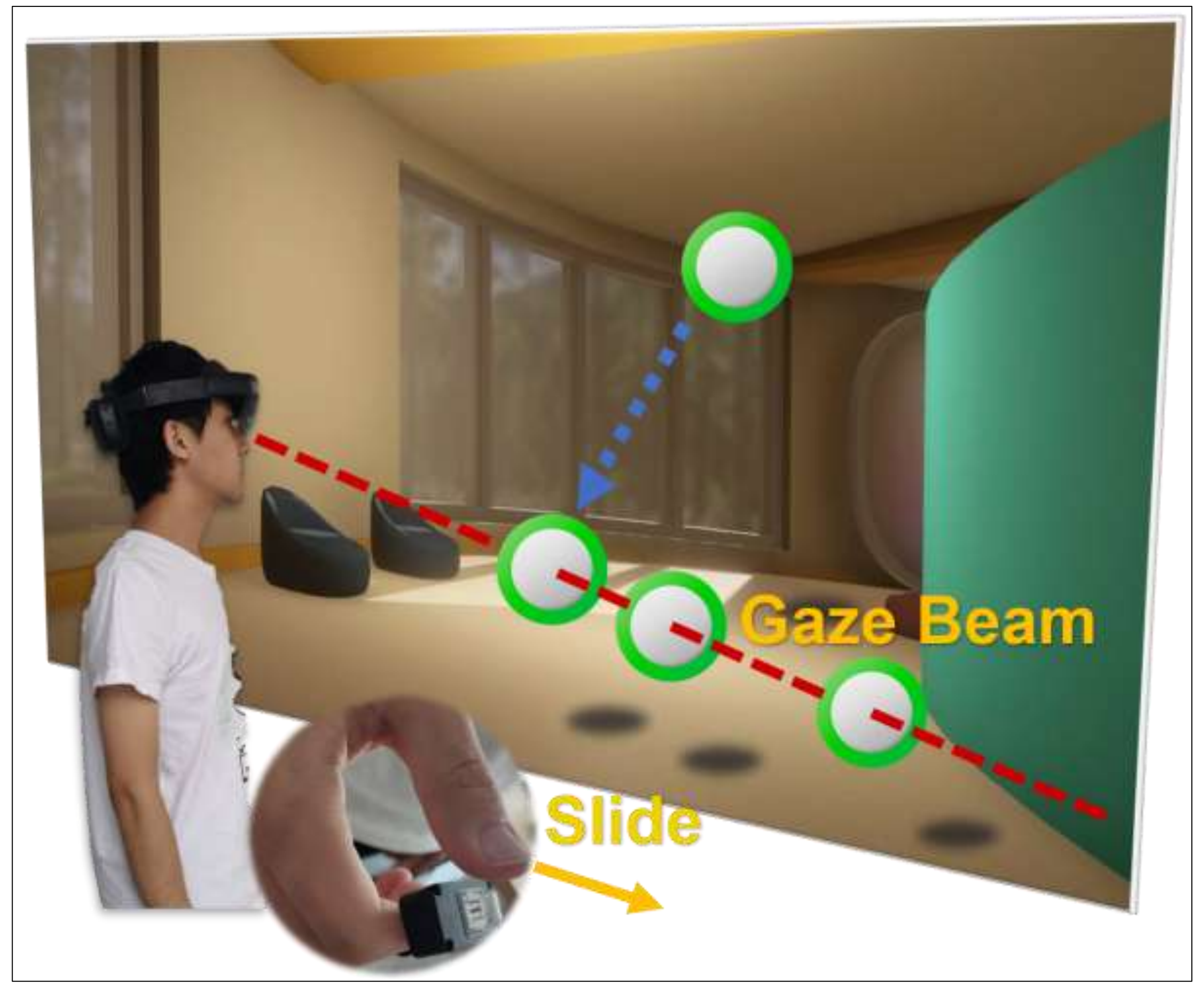
- Recently, smart rings have become popular due to their subtle nature, enabling 2 to 4 sliding directions. Ring-based interactions can offer an alternative to the traditional "hand" component of hand-eye coordination.

Our Method - Contribution

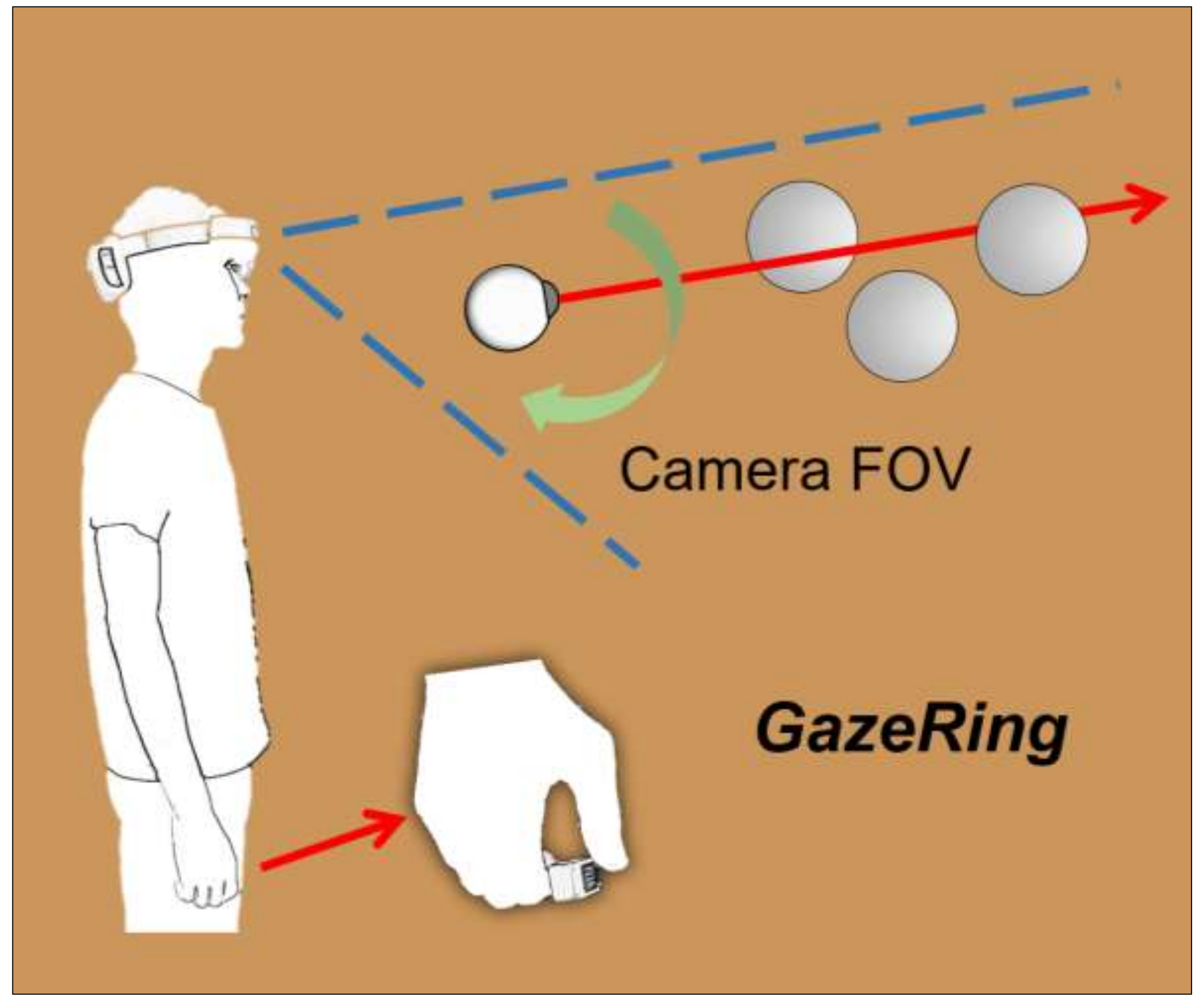
- We propose ***GazeRing*****, a novel multimodal interaction technique** that combines eye gaze with a smart ring, **enabling private and subtle hand-eye coordination**.
- We design a pressure-sensitive ring, supporting sliding interactions **in eight directions for rapid 3D object manipulation** and introduce two control modes (fingertip-tap and fingertip-slide).
- We evaluate the performance of *GazeRing* in object selection and translation tasks, demonstrating its **advantages in scenarios involving occlusion or inaccurate eye tracking**.



(a) Select within gaze cone



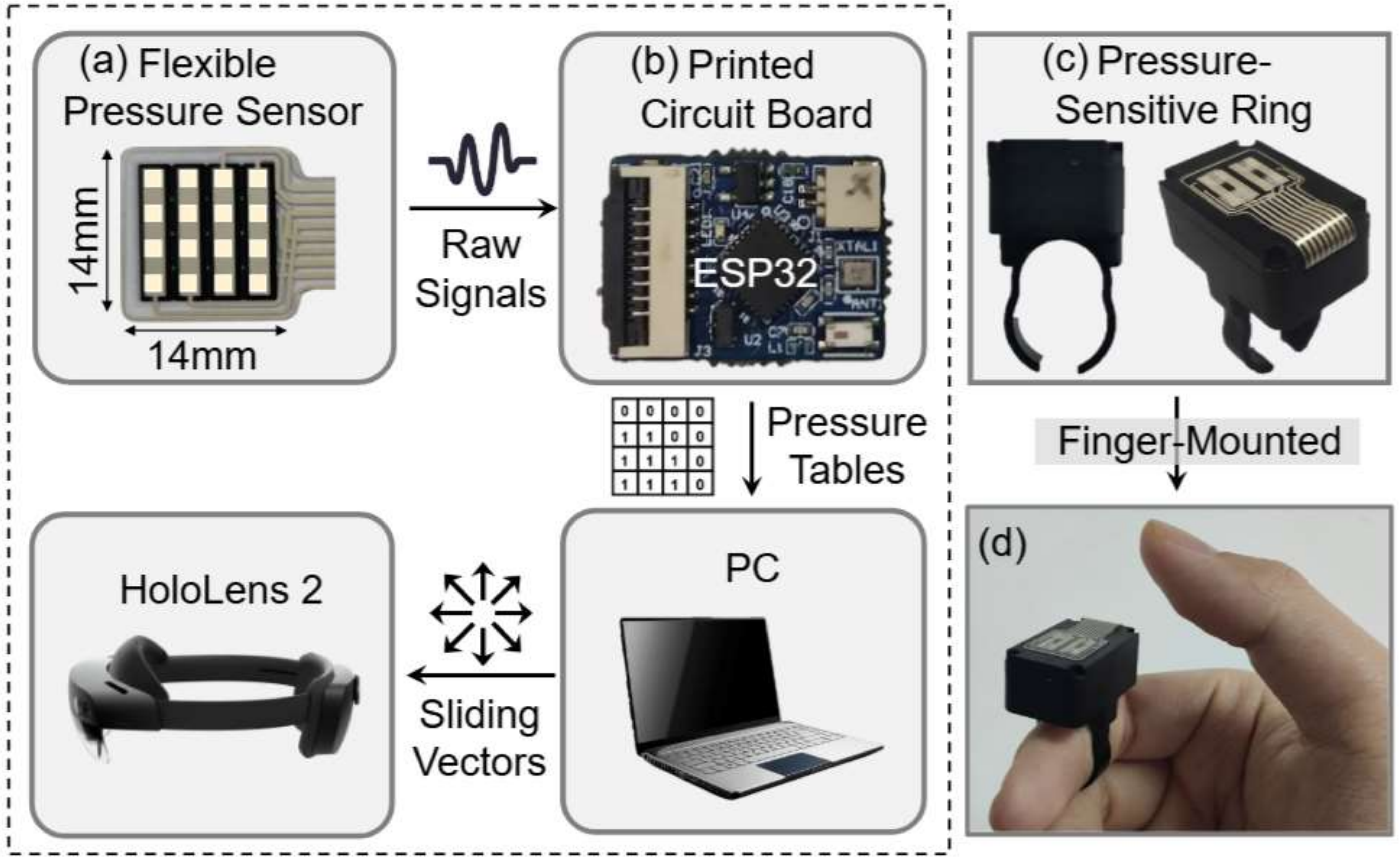
(b) Translate along gaze beam



(c) Allow hands outside camera view

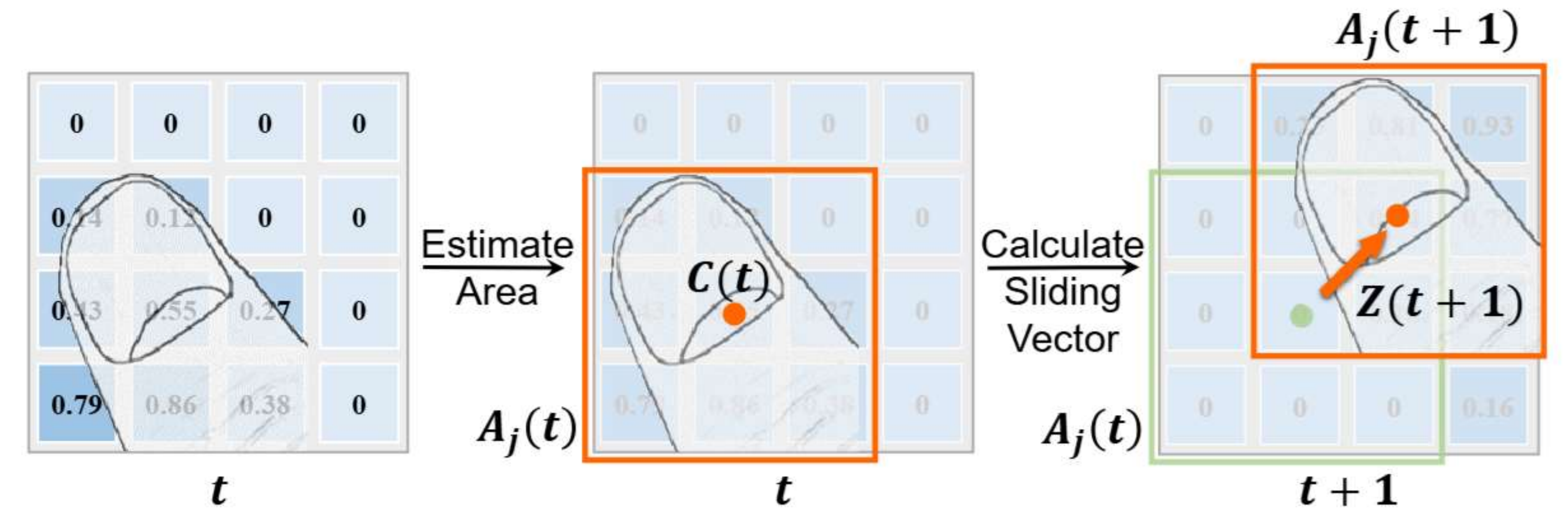
Our Method - Hardware Implementation

- Flexible Pressure Sensors (FPS)
  - ➢ $14 \times 14 \times 0.1$ mm^3
  - ➢ 16 distributed sensor units
- Printed Circuit Board (PCB)
  - ➢ $19 \times 14 \times 5$ mm^3
  - ➢ ESP32 chip
  - ➢ Bluetooth module
- Pressed Amplitude Calculation
  - ➢ Process average value every 50ms
  - ➢ Normalize voltage to percentage result

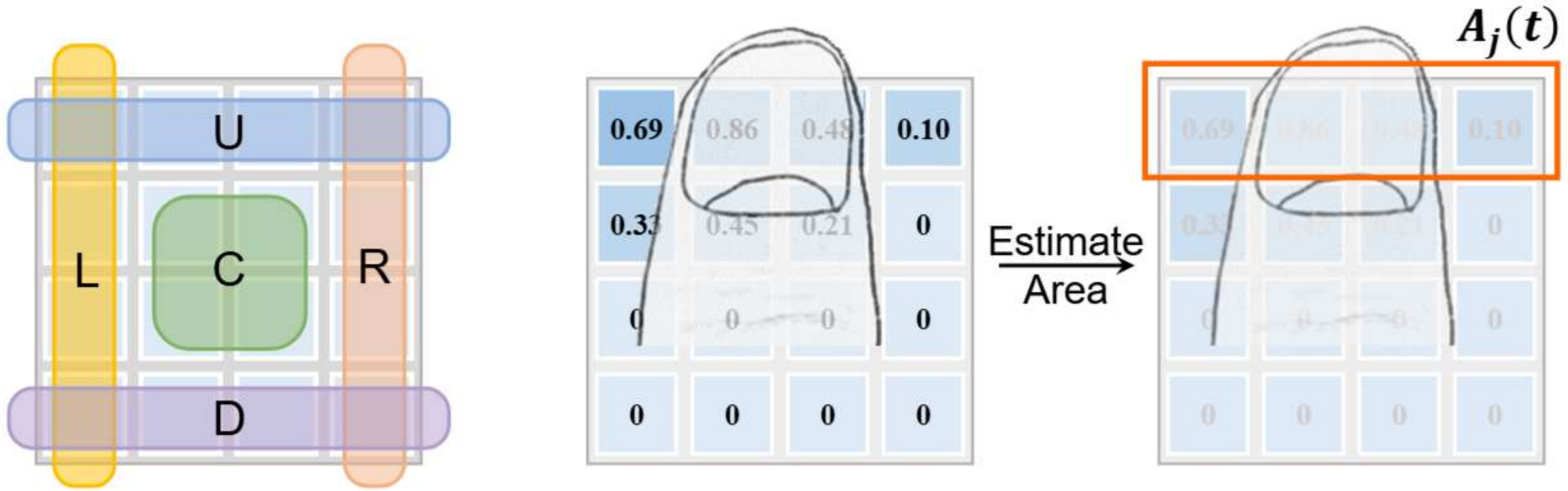


Our Method - Control Modes of Pressure Ring

- Fingertip-Slide Mode
  - ➢ Sliding vectors of eight directions
    - ◆ left, right, up, down
    - ◆ left-up, right-up, left-down, and right-down
  - ➢ Long-press recognition
    - ◆ 1.5 second
- Fingertip-Tap Mode
  - ➢ Partition of tapping areas
    - ◆ left, right, up, down, center
  - ➢ Long-press recognition
    - ◆ 1.5 second



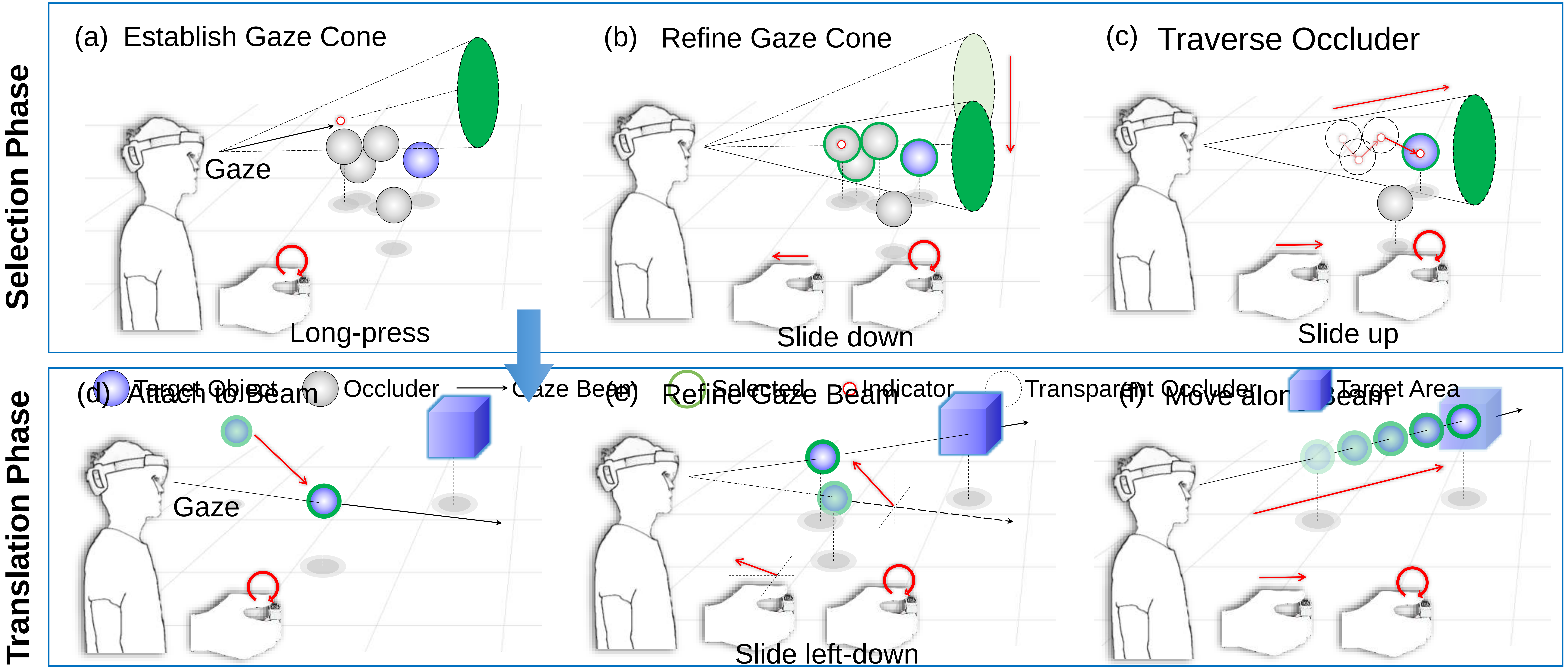
(a) Fingertip-slide mode.



(b) Fingertip-tap mode.

Our Method

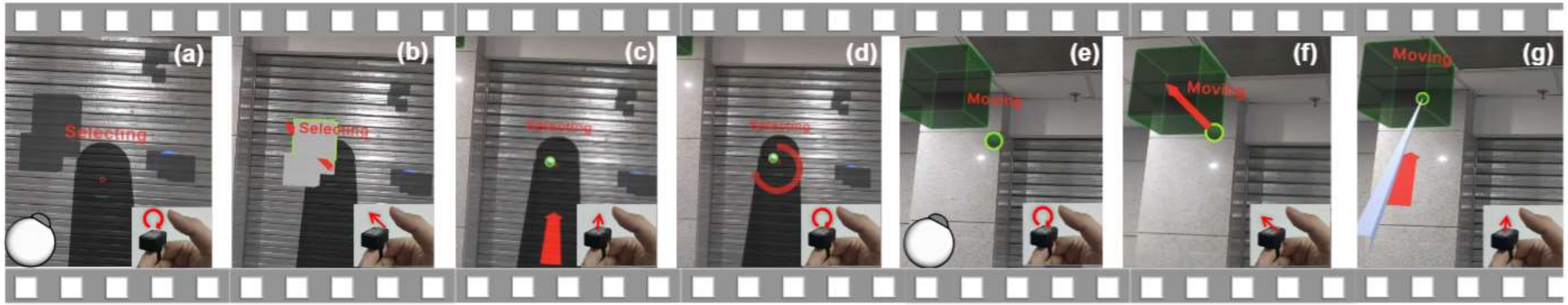
- By integrating gaze and the pressure ring, we design a set of strategies for object selection and translation which consists of two phases, each with three steps.



Experiment – Tasks Design

- We designed four scenarios, with two tasks: **No Occlusion (NO) Task** and **Heavy Occlusion (HO) Task**, each under two eye-tracking accuracy conditions: **Accurate Eye Tracking (Acc-Eye, 1.5°)** and **Insufficient Eye Tracking (Ins-Eye，4°)**.
- The goal is to find spheres of different colors in the scene and place them into the corresponding colored target area.

(a) Heavy Occlusion Task (b) No Occlusion Task



Establish Gaze Cone | Refine Gaze Cone | Traverse Occluder | Confirm Target | Attach to Gaze Beam | Refine Gaze Beam | Move Along Beam

Experiment – Experimental Setup

- We compared four private and subtle interaction techniques: two GazeRing techniques proposed in this paper(**GazeRing-Slide interaction (*GR-S*)** and **GazeRing-Tap interaction (GR-T)**), as well as **Gaze-only Interaction (Gaze)** and **Gaze-Speech Interaction (GS).**
- Users: 16 participants(14 males, 2 females)

➢Objective Measures:

- Average Finish Time
- Finish Rate
- Invalid Selection Count
- Average Selection Time
- Average Adjust Distance

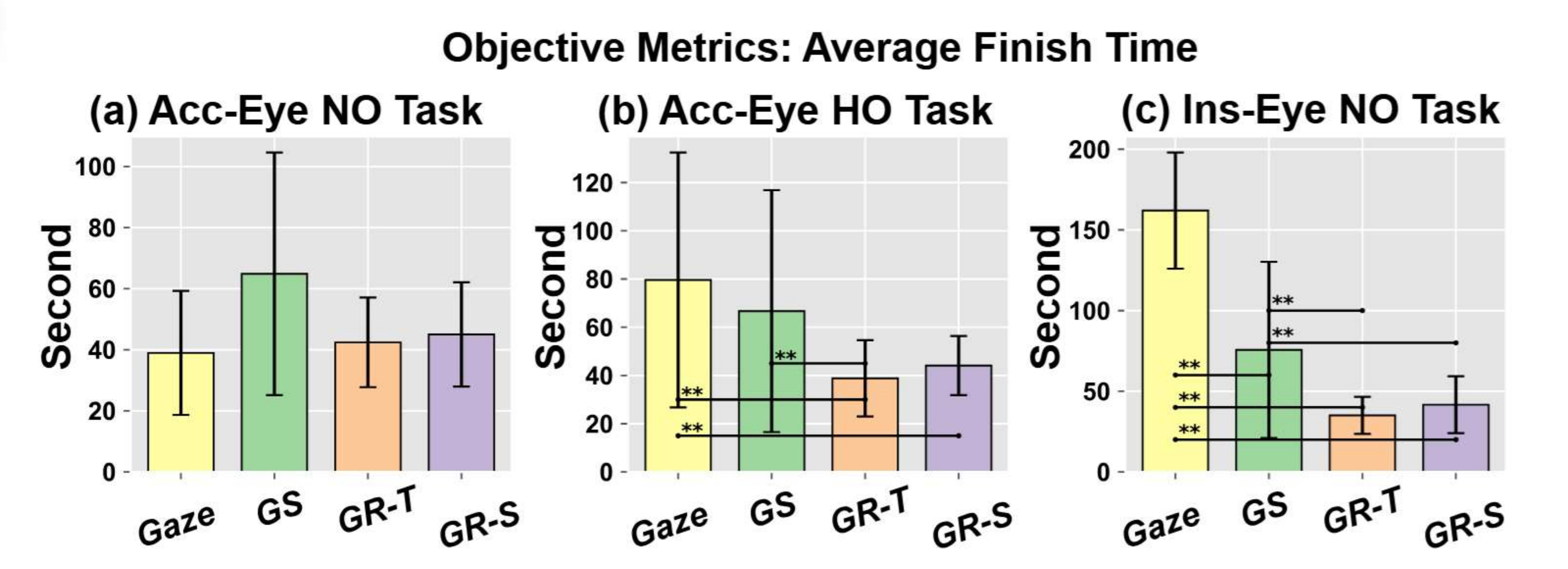
➢Subjective Measures:

- NASA-TLX
- Occlusion Impact
- Ring Observing Frequency
- User Preference
- Open Question

Experiment - Results of Objective Measures

Evaluation on Gaze-only Interaction:

- Our findings indicate that even without occlusion, insufficient eye tracking significantly reduced the efficiency of ***Gaze***, with its finish time being nearly three times that of ***GR-S*** and ***GR-T***.
- ***Gaze*** lacks robustness and is significantly less efficient than ***GR-S*** and ***GR-T***.
- Therefore, we will not further analyze ***Gaze*** in the **Ins-Eye HO Task**.



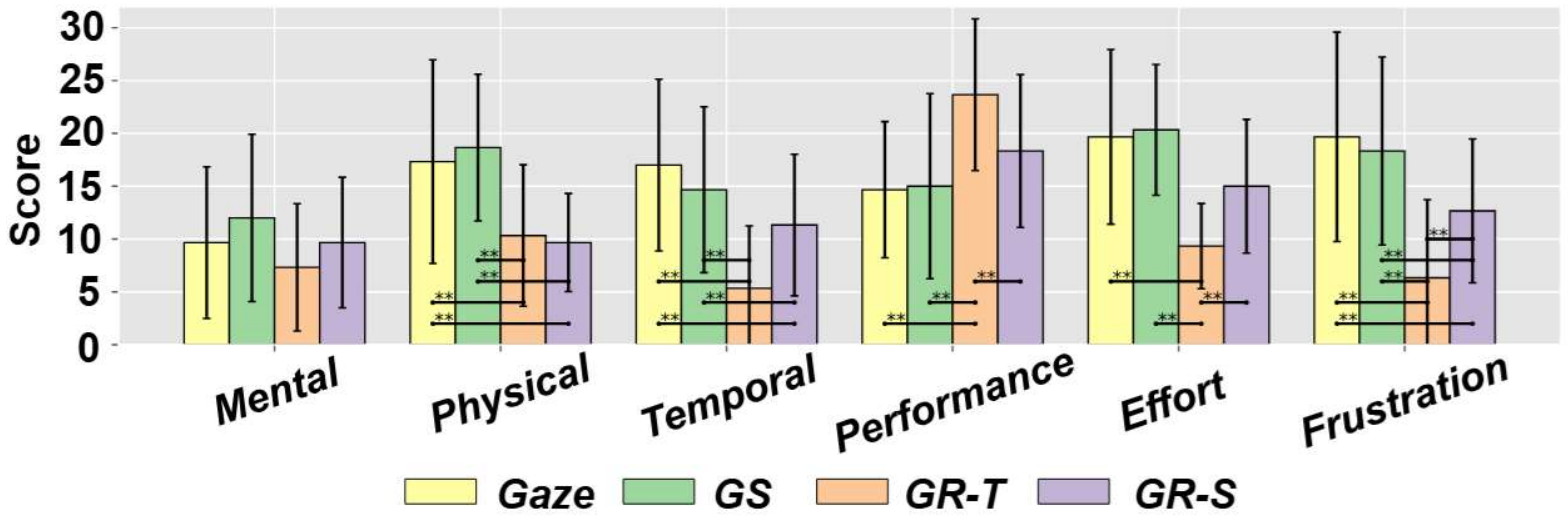
Experiment - Results of Objective Measures.

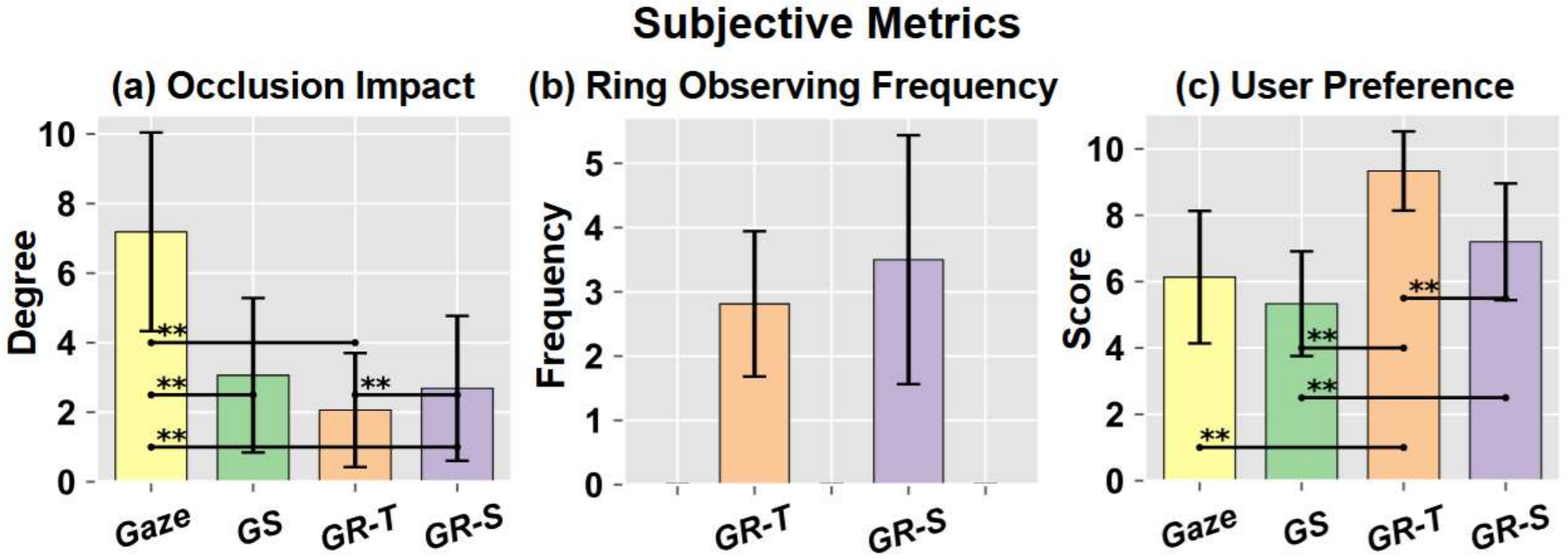
Comparison among GR-S, GR-T and GS:

- ***GR-S*** and **GR-T** interactions demonstrated good efficiency and accuracy even in the presence of occlusion or inaccurate eye tracking, with no significant difference between the two techniques.

Experiment - Results of Subjective Measures.

- The results from NASA-TLX indicate that **our *GazeRing* techniques outperformed *Gaze* and *GS* in terms of task load**.
- In the subjective evaluation, our method **was the least affected by occlusion**, and users expressed **a stronger preference for *GazeRing***.





Demo


Eye-Gaze and Ring-Touch Combined Interaction Mechanism
Selection Phase
Establish Gaze Cone
Refine Gaze Cone
Traverse Occluder
Confirm Target
Here is the example video.

Limitations and Future Work

- Participants with larger thumbs experienced accidental touches due to the ring's small sensor area. Future work will include FPS of various sizes to better accommodate different users.
- The current GazeRing only supports object selection and translation. Future iterations will include object rotation and scaling to improve the system.
- Future research will expand the dataset to include individuals of various ages and backgrounds, with a higher proportion of female participants.

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Thank you!

Our demo video is available at:
https://zhimin-wang.github.io