Perception-Driven Soft-Edge Occlusion for Optical See-Through Head-Mounted Displays

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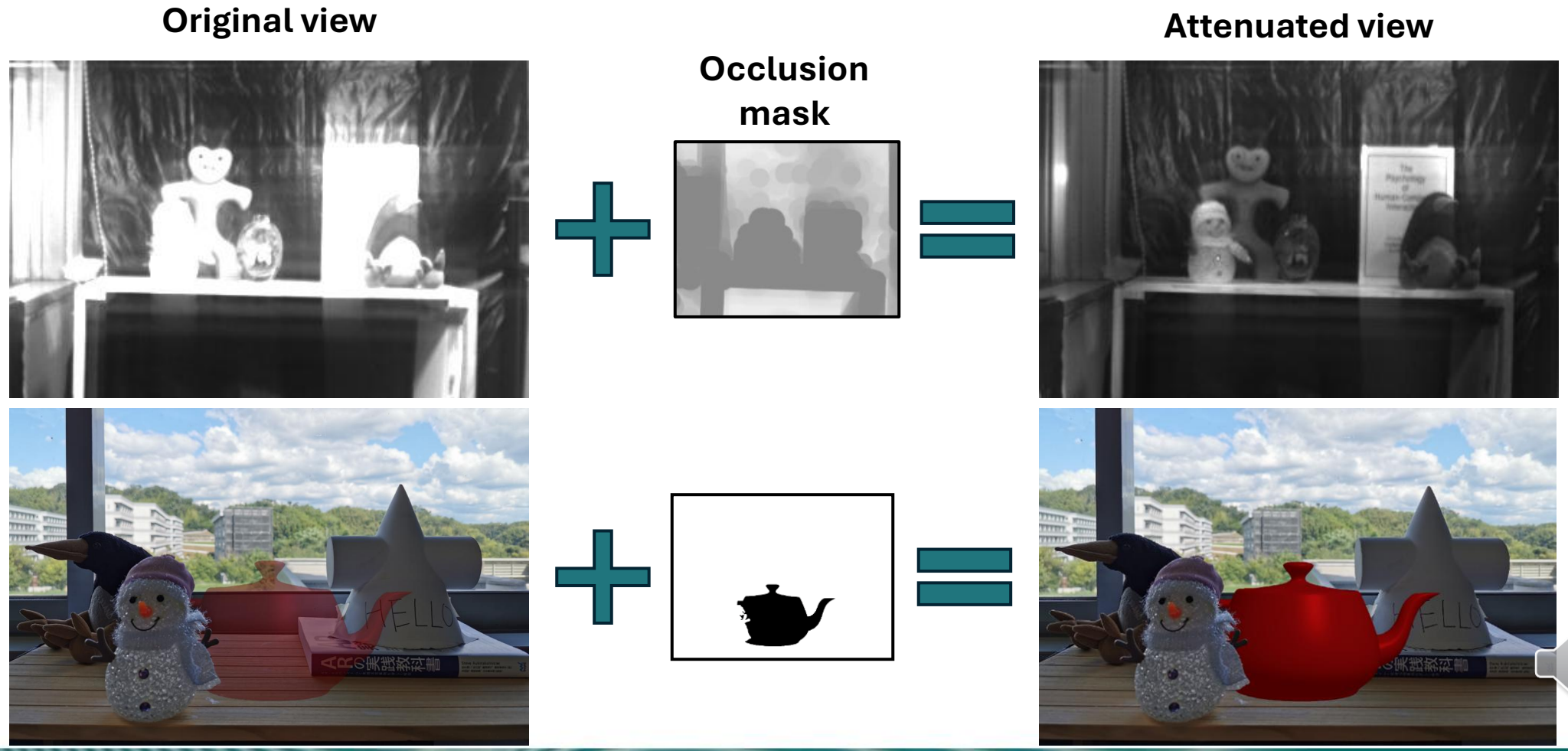
Bright Ambient Light

Bright ambient light can cause issues for cameras, the human visual system, and optical see-through head-mounted displays (OST-HMDs)

Bright view for camera and human eyes

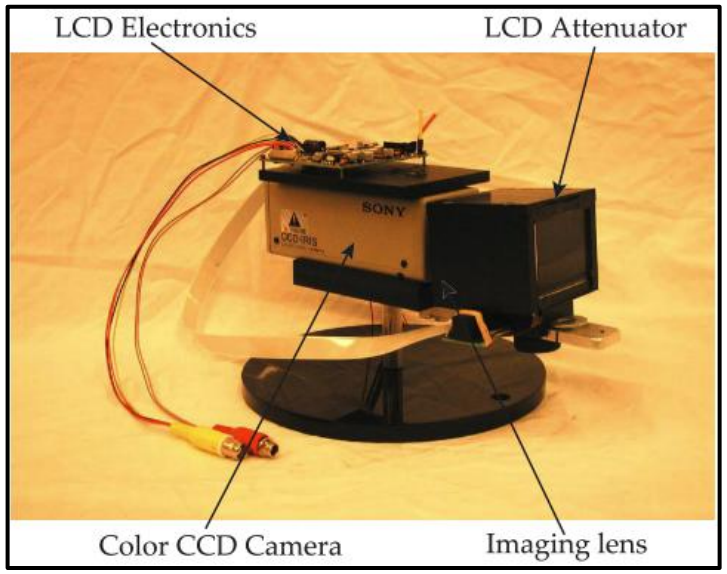
Semi-transparent virtual image in an OST-HMD

Selective Light Attenuation by Occlusion Mask

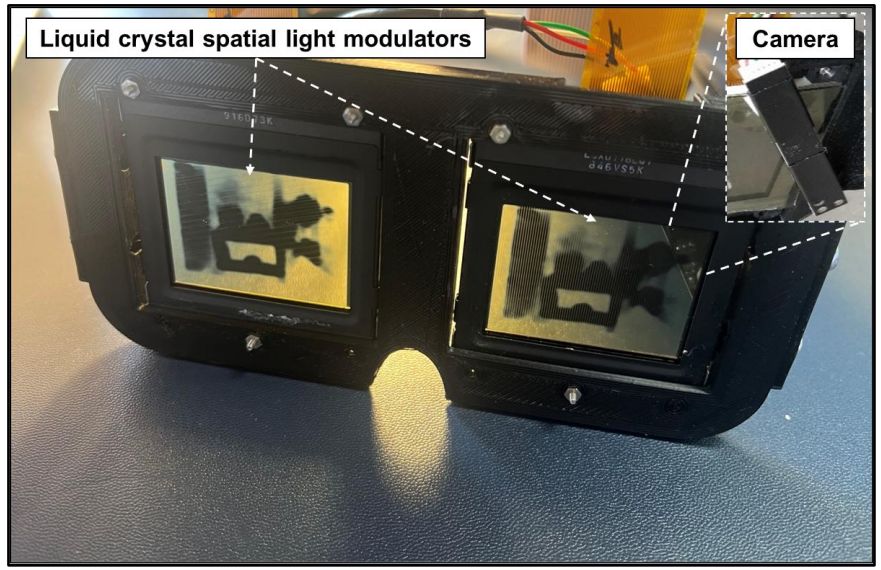


Occlusion Devices Using SLMs

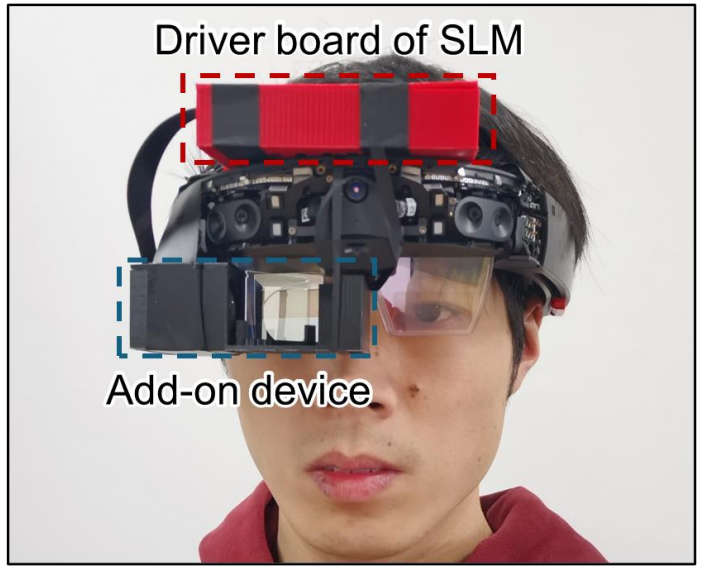
Occlusion mask is often achieved using transmissive and reflective spatial light modulators (SLMs)



Adaptive Dynamic Range Camera
(Nayar & Branzoi, 2003)
Image Processing



Smart Dimming Sunglasses
(Hu et al., 2024)
Vision Augmentation

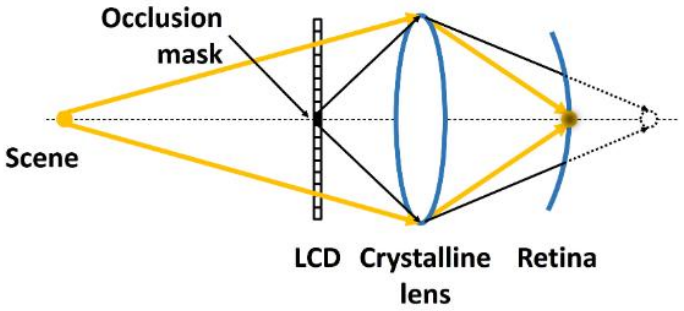


Add-on Occlusion for HoloLens 1
(Zhang et al., 2023)
OST-HMDs

Soft-Edge and Hard-Edge Occlusion

Soft-edge occlusion

Compact but blurry

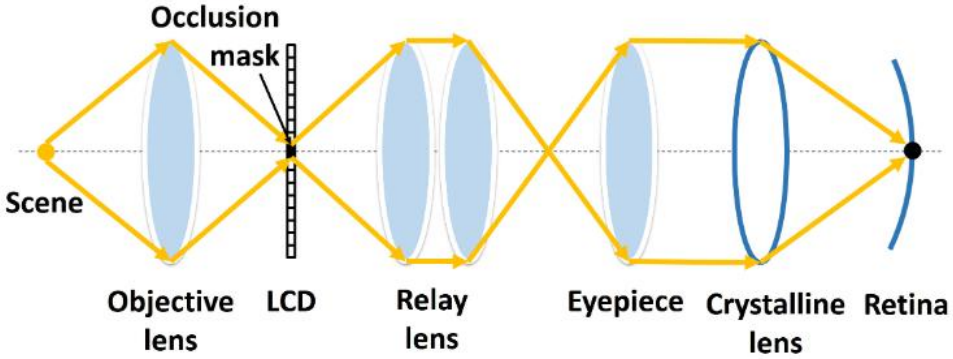


Defocused occlusion mask

(Itoh et al., 2017)

Hard-edge occlusion

Sharp but bulky

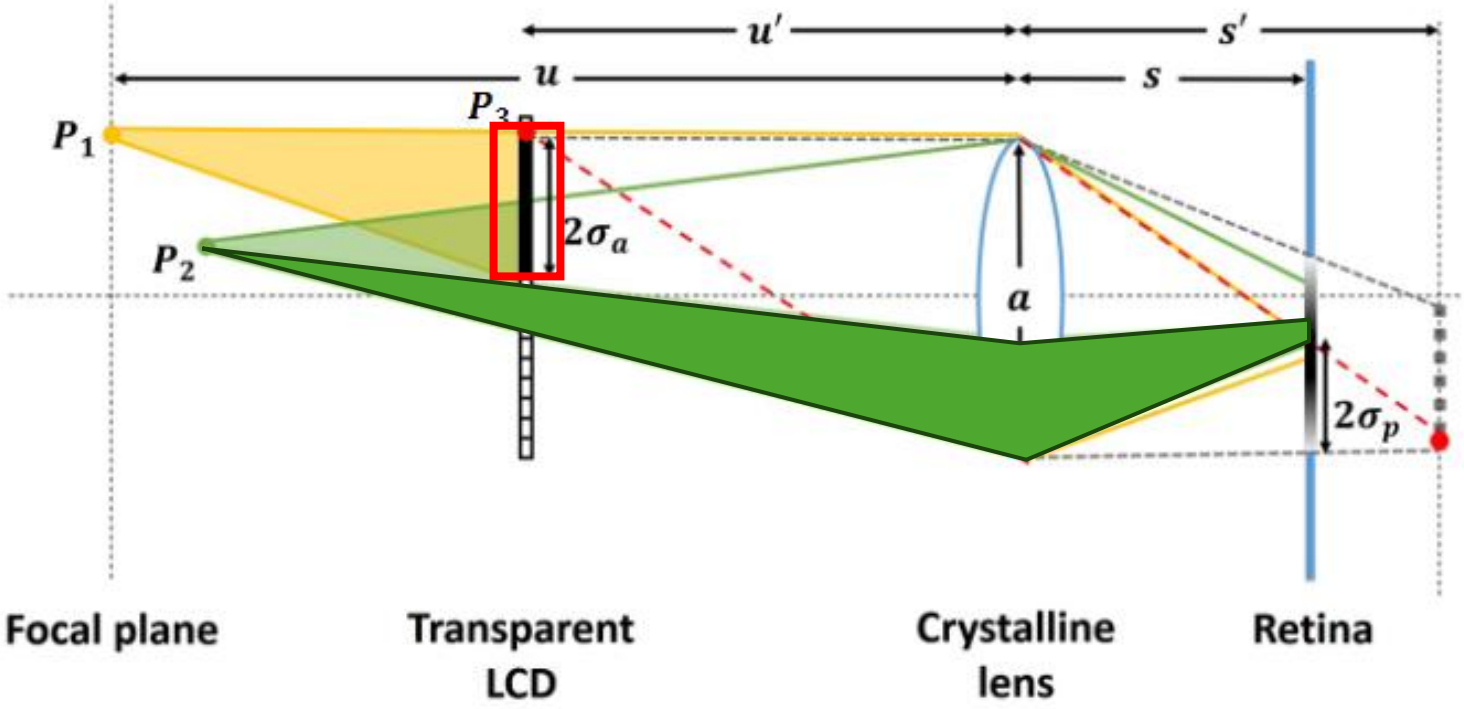


Lenses align focus for both scene and occlusion mask

(Wilson & Hua, 2021)

Soft-edge Occlusion on a Single LCD

Completely blocking all light rays requires expanding the occlusion mask



Expanding the occlusion mask leads to occlusion leakage [1]

[1] Itoh, Y., Hamasaki, T., & Sugimoto, M. (2017). Occlusion Leak Compensation for Optical See-Through Displays Using a Single-Layer Transmissive Spatial Light Modulator. *IEEE Transactions on Visualization and Computer Graphics*, *23*(11), 2463–2473. https://doi.org/10.1109/TVCG.2017.2734427

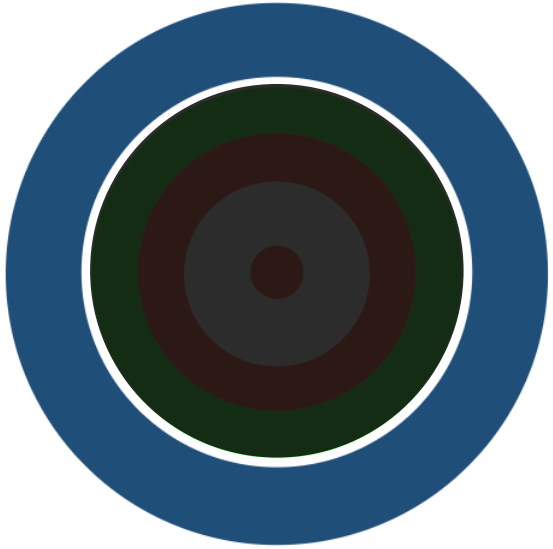
Proposed Method

Human Visual Perception of Blur

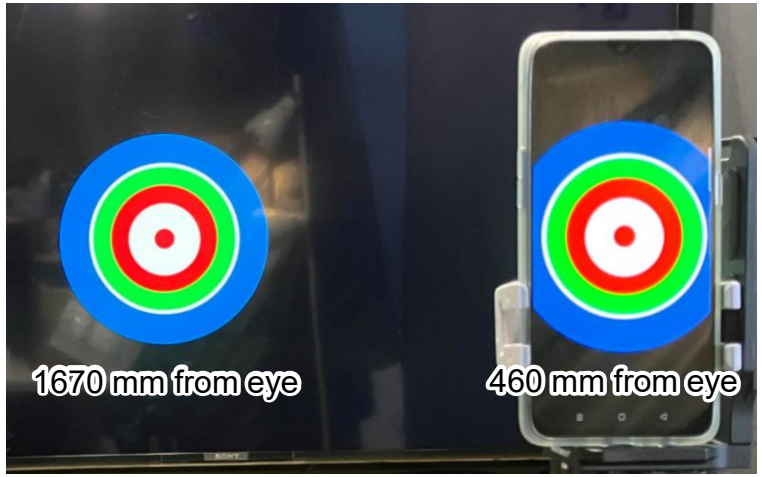
Proposed Method

Perception-Driven Soft-Edge Occlusion

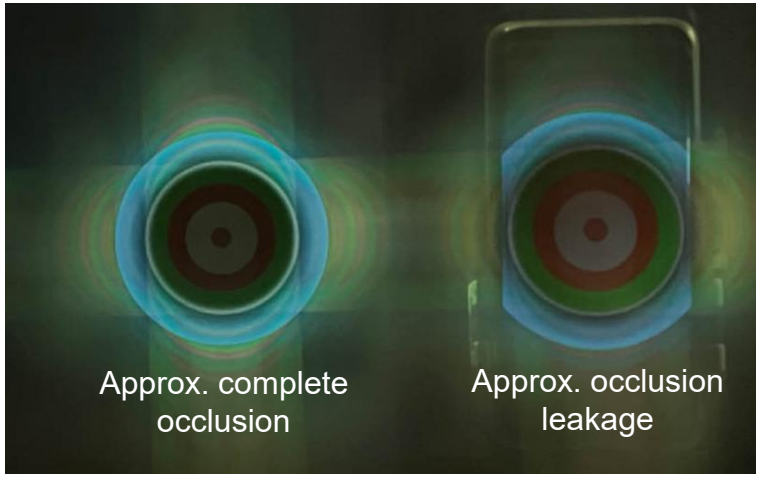
A ring-based quantitative pattern guides users to select the optimal mask size



Complete occlusion:
only the white ring
remains visible



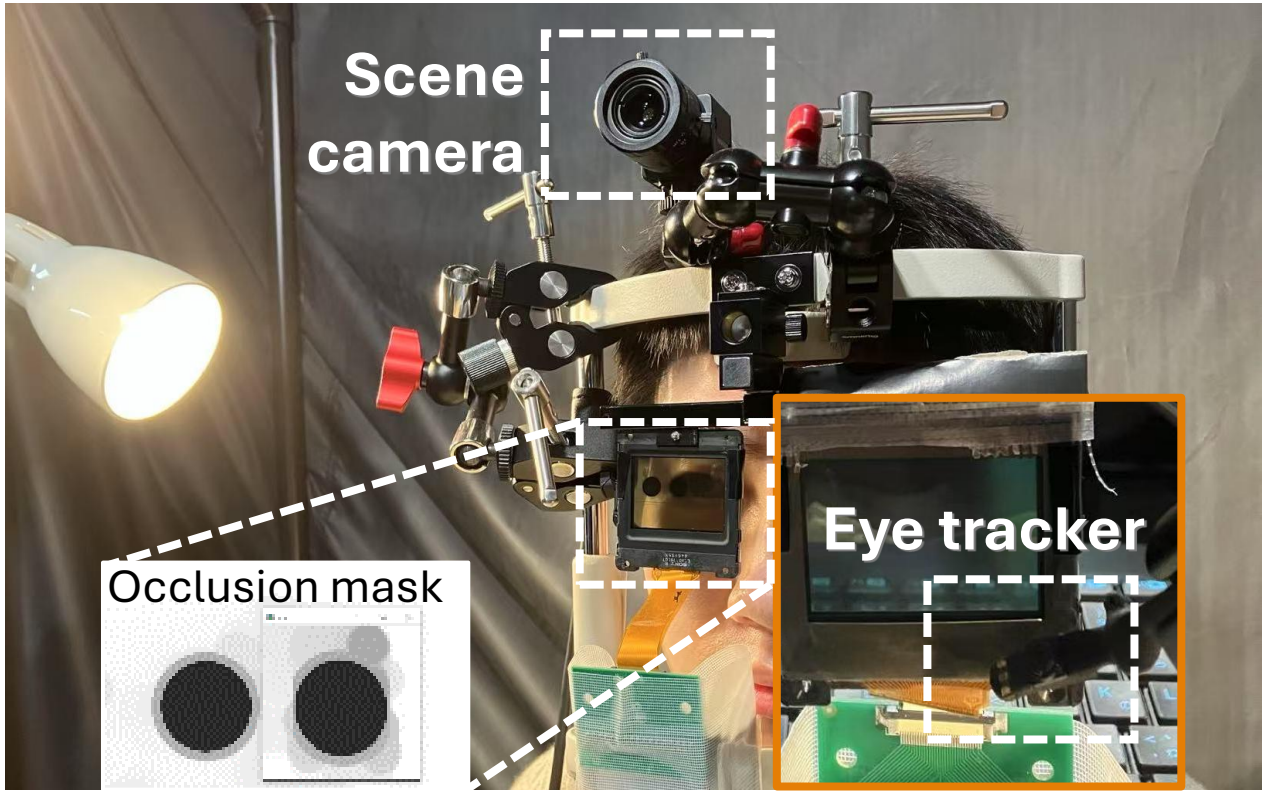
Real scene



View through occlusion masks

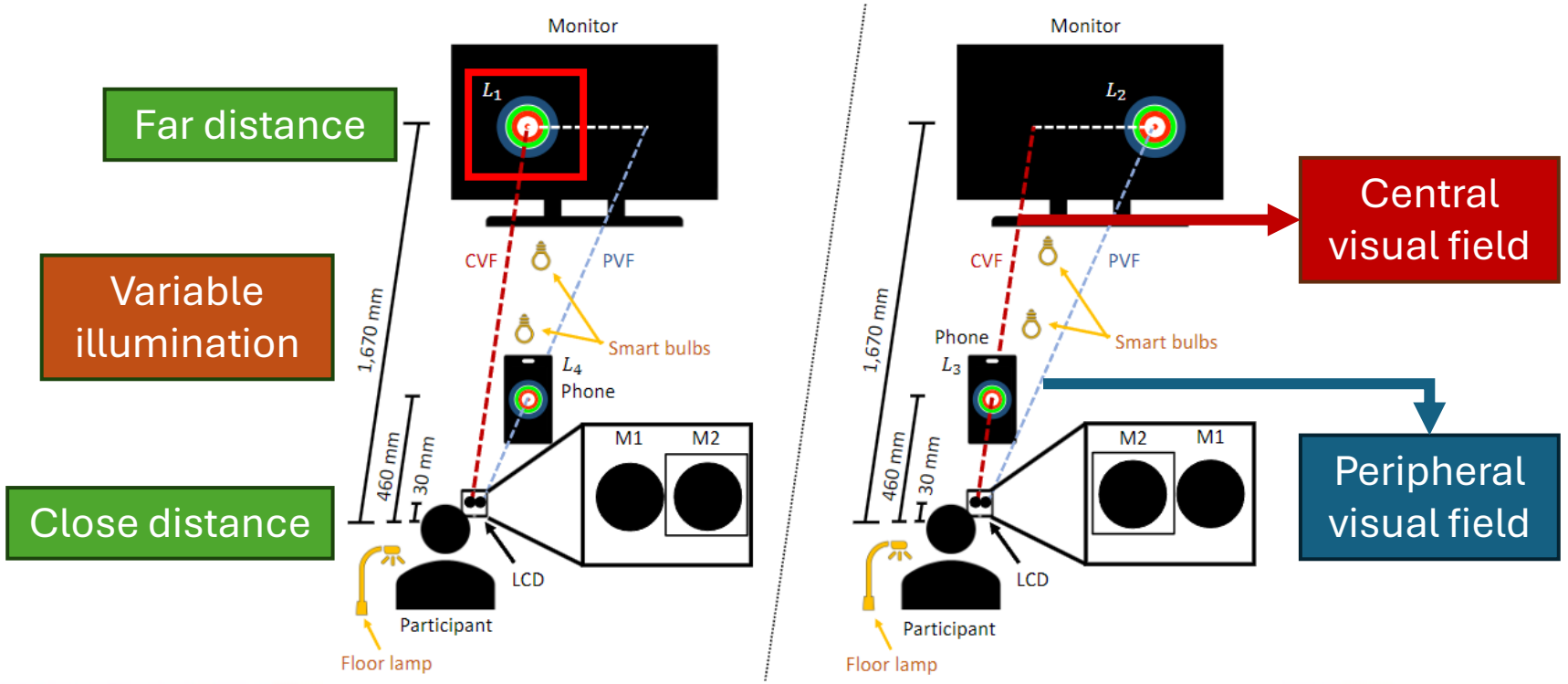
Experimental Setup

We developed a model of pupil size and user-preferred mask size based on the point spread function (PSF)



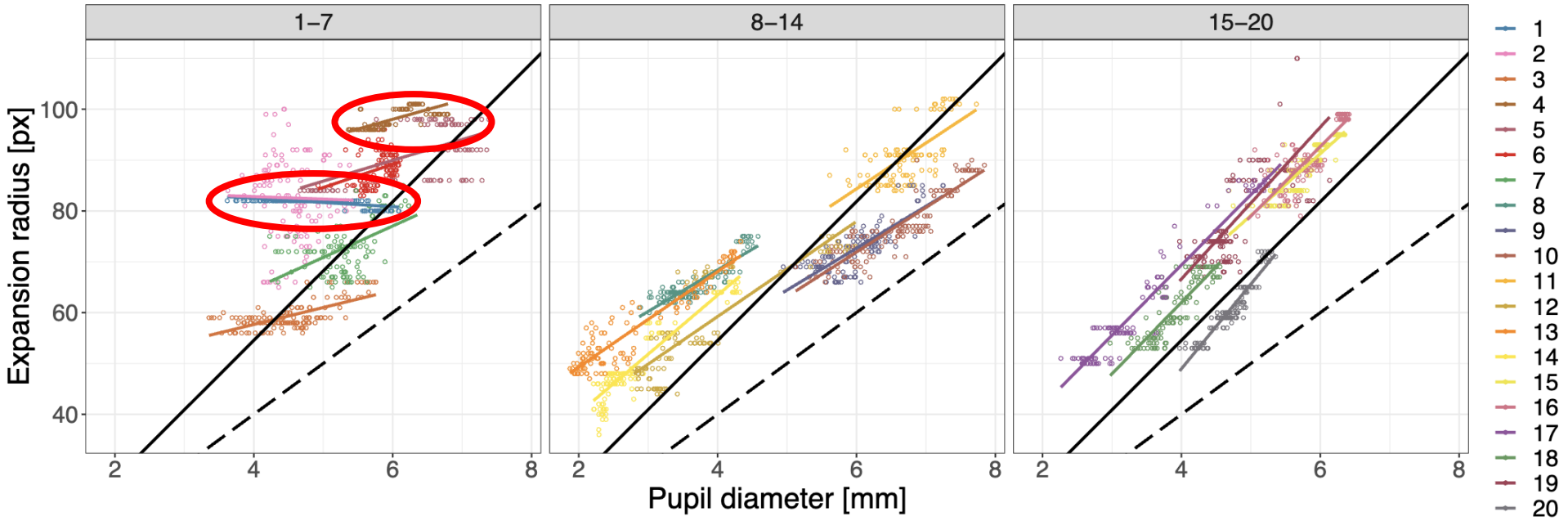
Calibration and Evaluation

- **Calibration is only required at the central field of view at far distance**
- **Evaluation is conducted with patterns at four locations**



Individual Differences Across 20 Participants

Preference Calibration Results



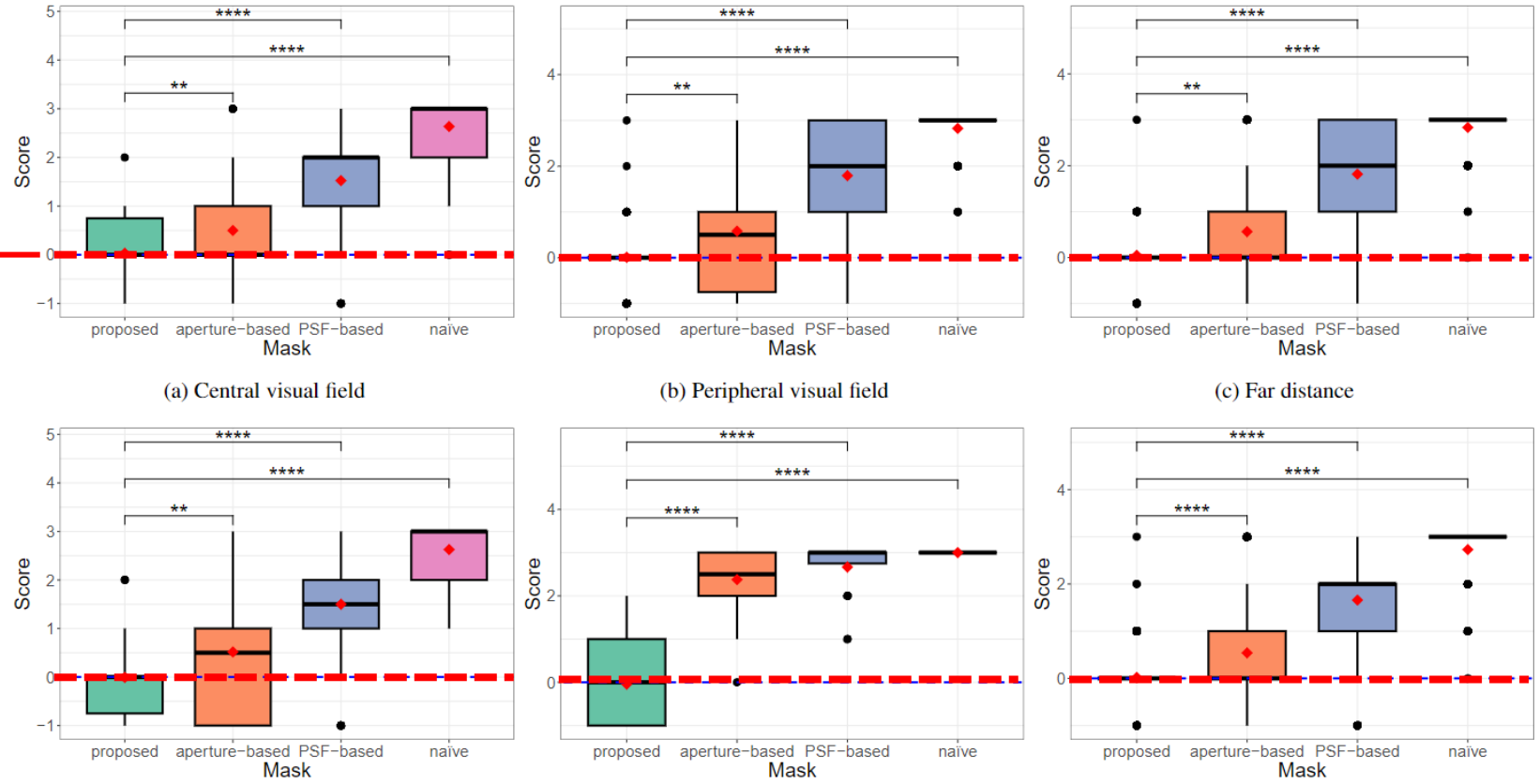
- **Slope**: sensitivity of preferred mask size to pupil variation
- **Intercept**: perceived blur border

Evaluation Results for Different Size Masks

Insufficient occlusion

Complete occlusion

Occlusion leakage

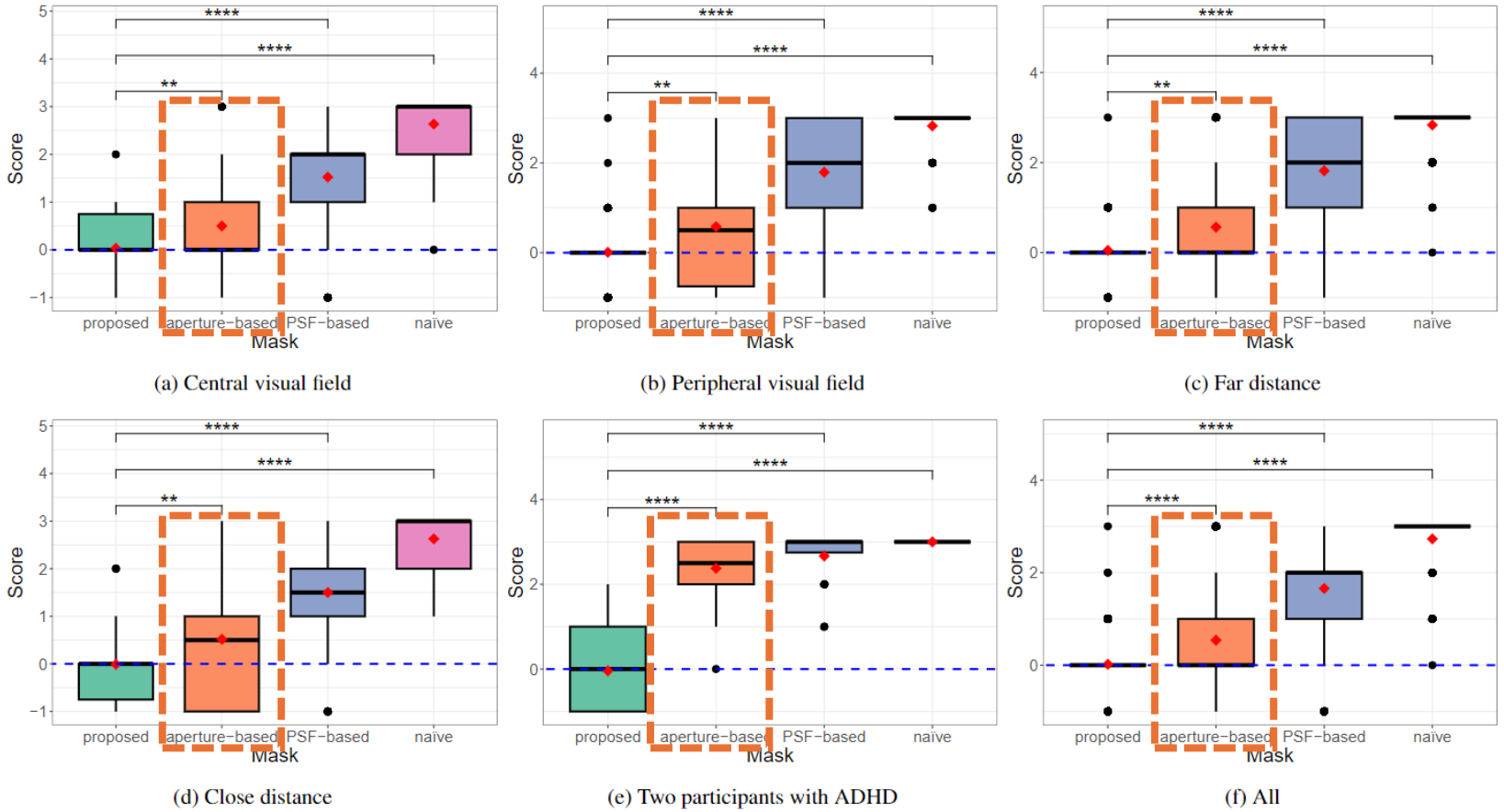


(a) Central visual field (b) Peripheral visual field (c) Far distance

(d) Close distance (e) Two participants with ADHD (f) All

Results

Narrower Blurry Borders



(a) Central visual field (b) Peripheral visual field (c) Far distance

(d) Close distance (e) Two participants with ADHD (f) All

Masks that theoretically cause occlusion leaks can appear **smaller** in human visual perception

The blurry borders perceived by the human eye are **narrower** than theoretical predictions

Summary

- Perception-driven soft-edge occlusion on a single transmissive LCD achieves complete occlusion in human vision
- First user study on expanded soft-edge occlusion in human vision
- Participants perceive different mask sizes under the same pupil sizes
- Human eyes perceive narrower blurry borders of the soft-edge occlusion than theoretical predictions

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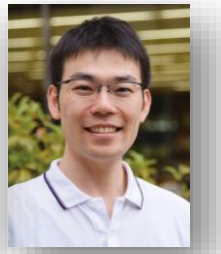
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Thank you for attending!