CHI 2018
Engage with CHI

Pervasive Human Computer Interaction
Department of Computer Science and Technology
Tsinghua University

Eyes-Free Target Acquisition in Interaction Space around the Body for Virtual Reality

Yukang Yan, Chun Yu, Xiaojuan Ma, Shuai Huang, Hasan Iqbal, Yuanchun Shi

清華大學
Tsinghua University

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

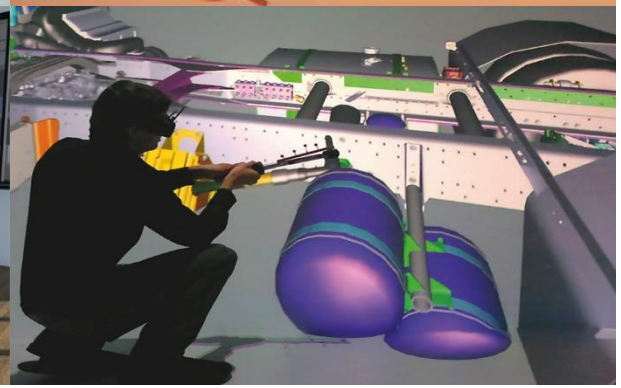
Target Acquisition in VR

Games

Learning

Design

Simulation



Target Acquisition in VR

First visually search, then reach hand

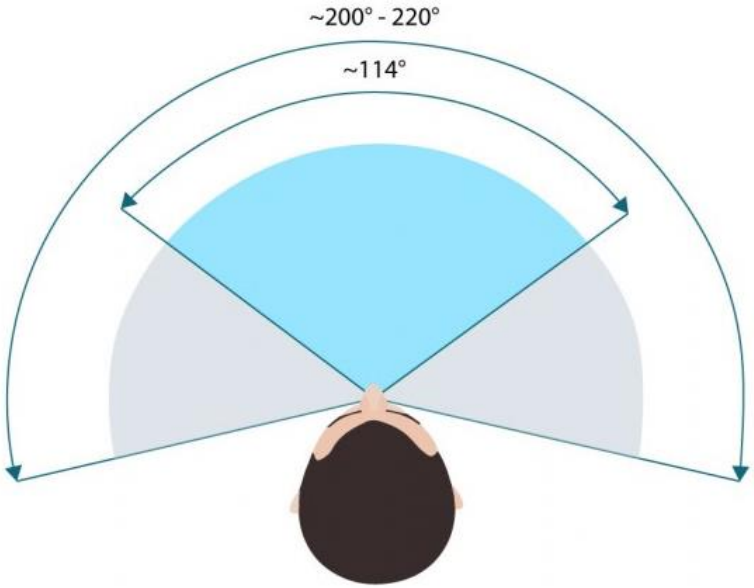
UX Issues of an **Eyes-Engaged** Approach

User Behavior		**User Experience**
• Search and move	->	Low efficiency
• Head Rotation	->	Fatigue, Sickness
• Focus Switch	->	Distractions

Keywords

Target Acquisition in VR

Eyes-Free



Around Body

Target Acquisition in VR

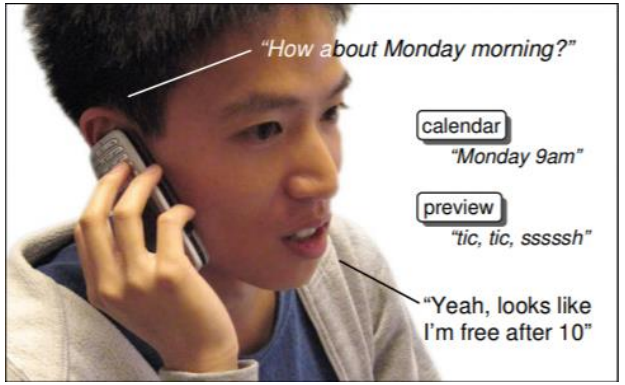
Issues about **Eyes-Engaged** Approach

User Behavior		**User Experience**
• Search and move	->	Low efficiency
• Head Rotation	->	Fatigue, Sickness
• Focus Switch	->	Distractions

Eyes-free Interaction in literature

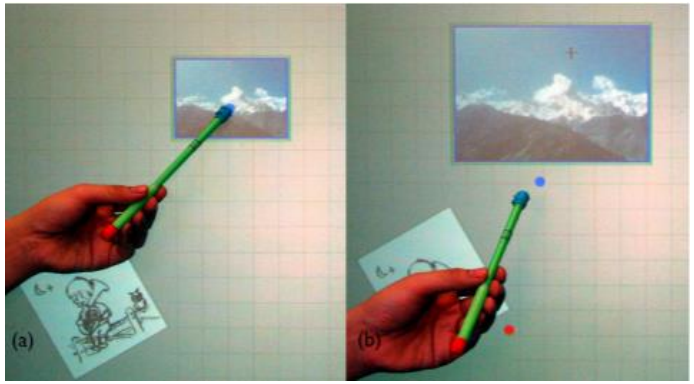
CHI 2011

CHI 2007



CHI 2008

EuroITV 2012



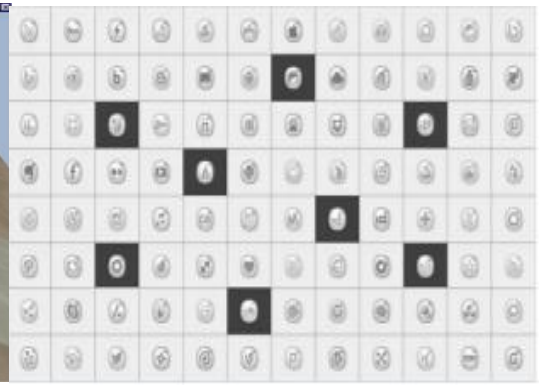
UIST 2013

IMWUT 2017

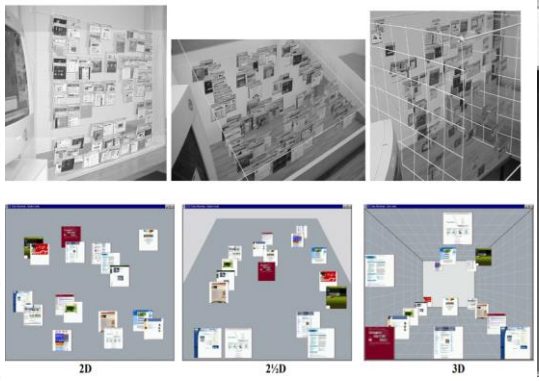
Proprioception and Spatial Memory

Spatial Memory

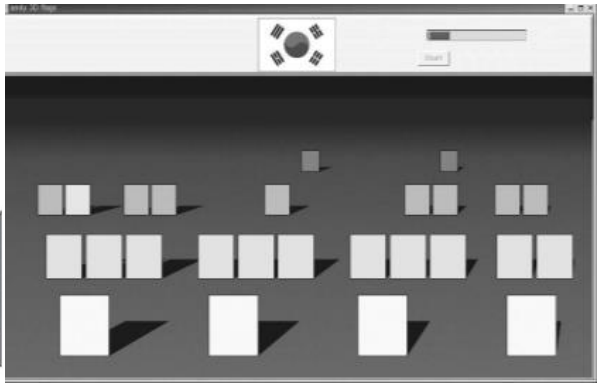
UIST 1998



CHI 2017

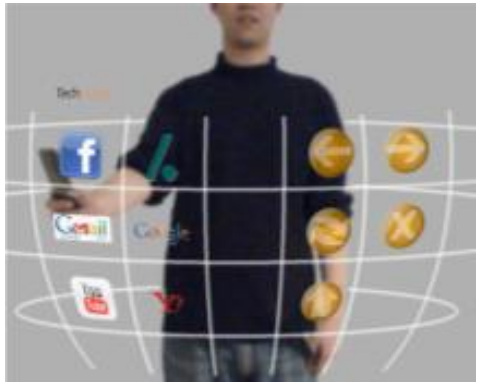


CHI 2002

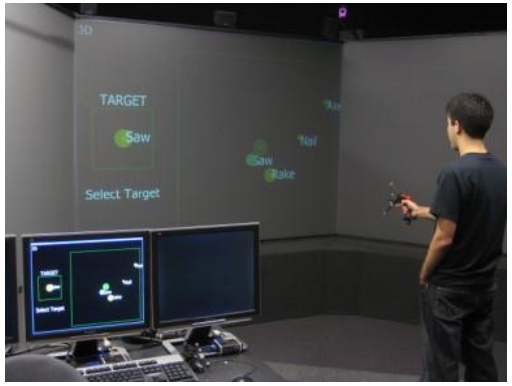


AUI 2004

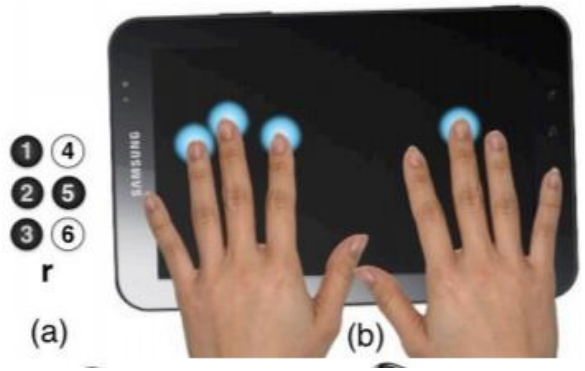
Proprioception



UIST 2009



IJHCS 2011



GI 2012

UIST 2014

RESEARCH QUESTION

RQ1. Subjective Acceptance of Eyes-Free Target Acquisition

RQ2. Control Accuracy of Eyes-Free Target Acquisition

OUTLINE

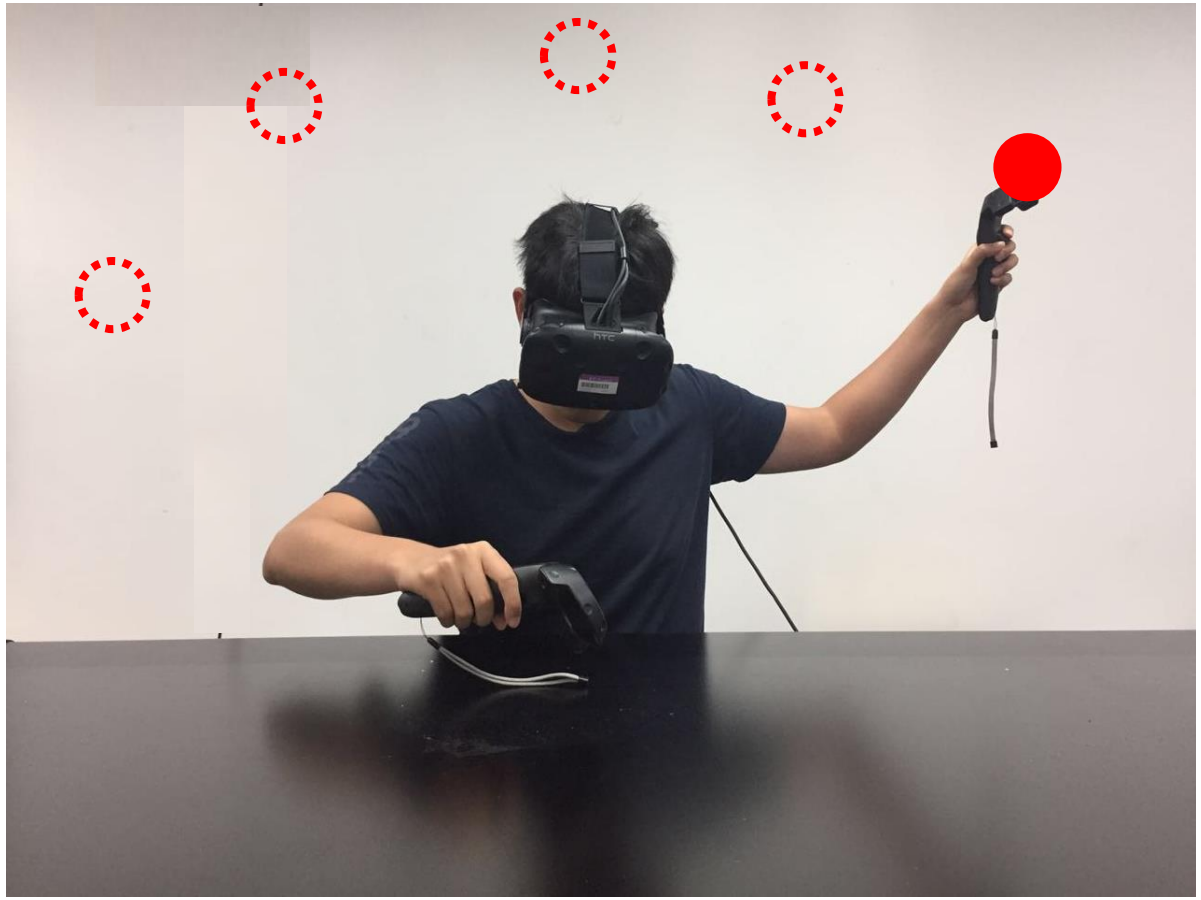
- User Study 1. (Research Question 1)
- User Study 2. (Research Question 2)
- User Study 3. (Eyes-free vs. Eyes-Engaged)
- Discussion

OUTLINE

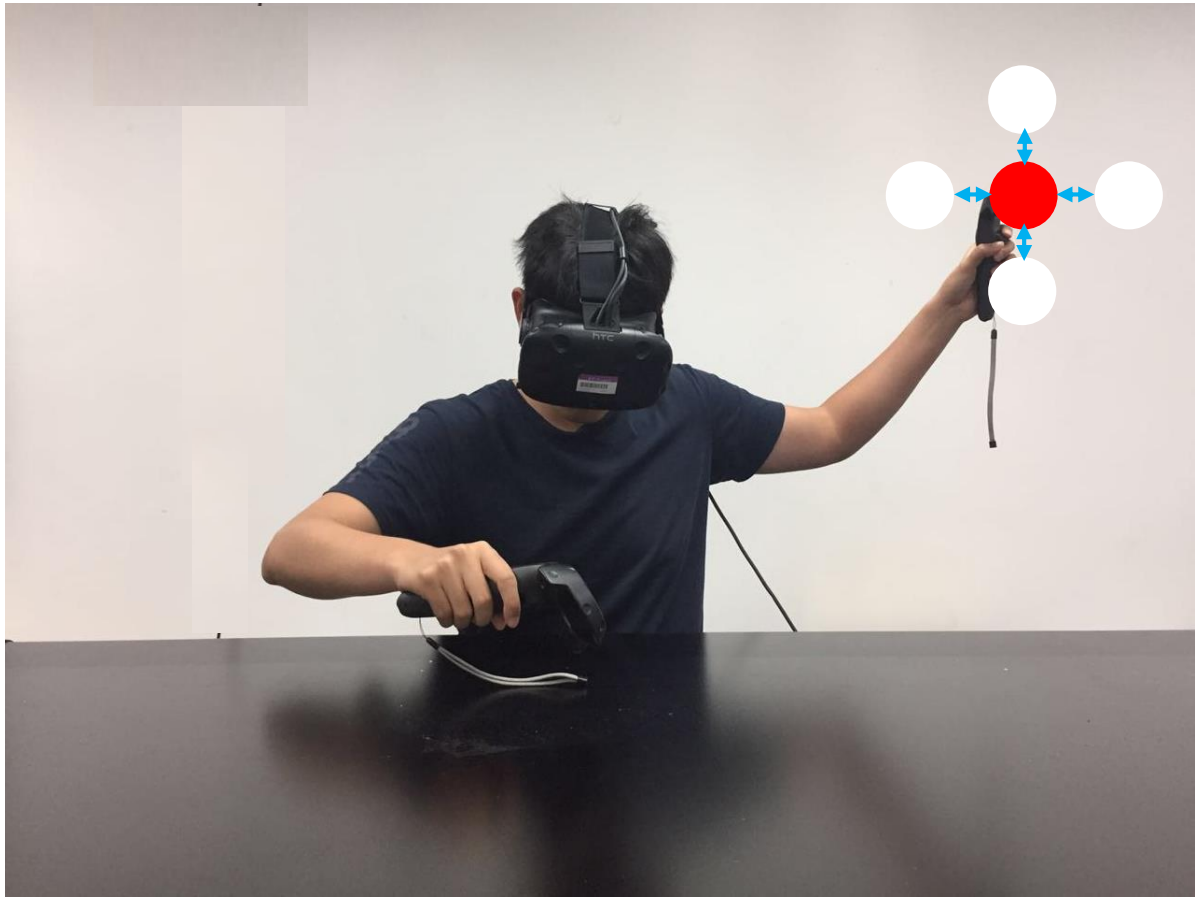
- User Study 1. (Research Question 1)
- User Study 2. (Research Question 2)
- User Study 3. (Eyes-free vs. Eyes-Engaged)
- Discussion

STUDY1: Subjective Acceptance

Target Position

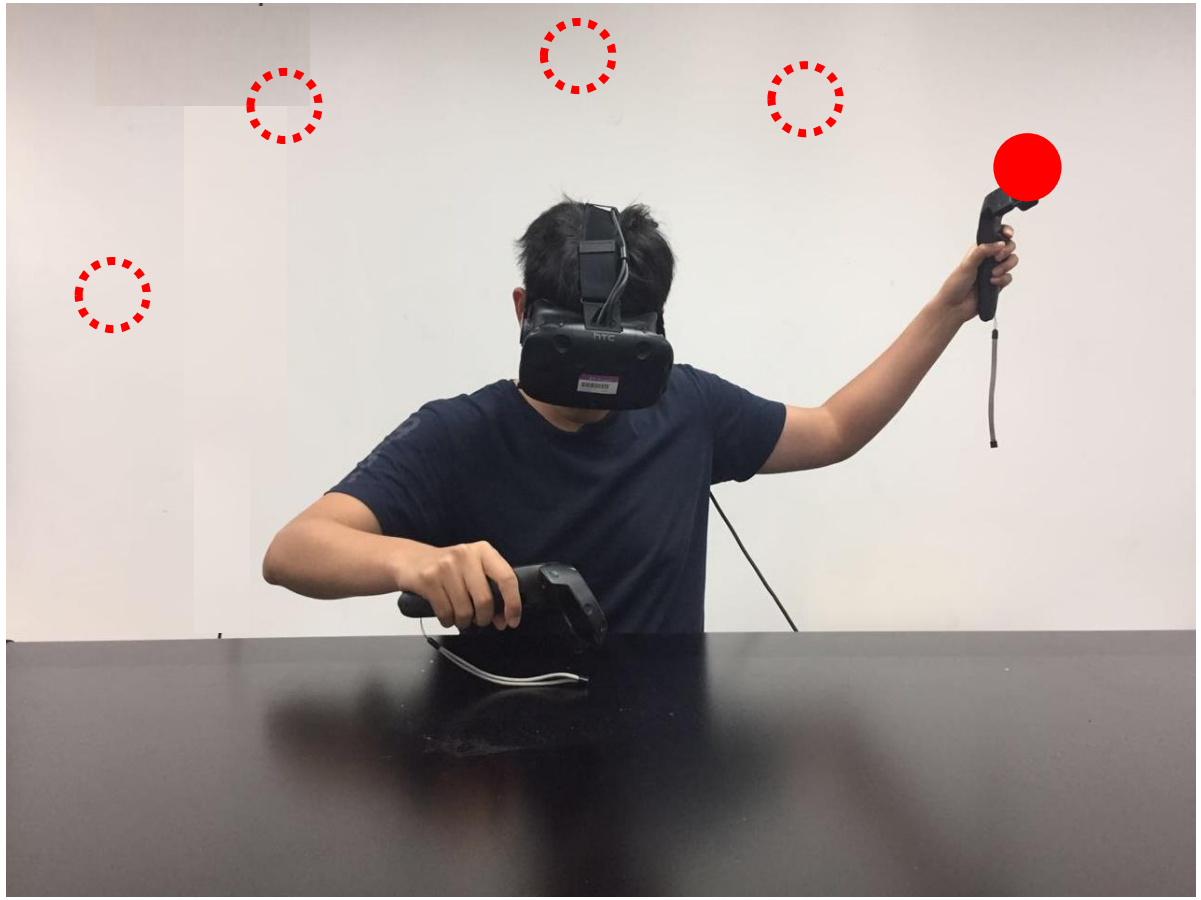


Target Density

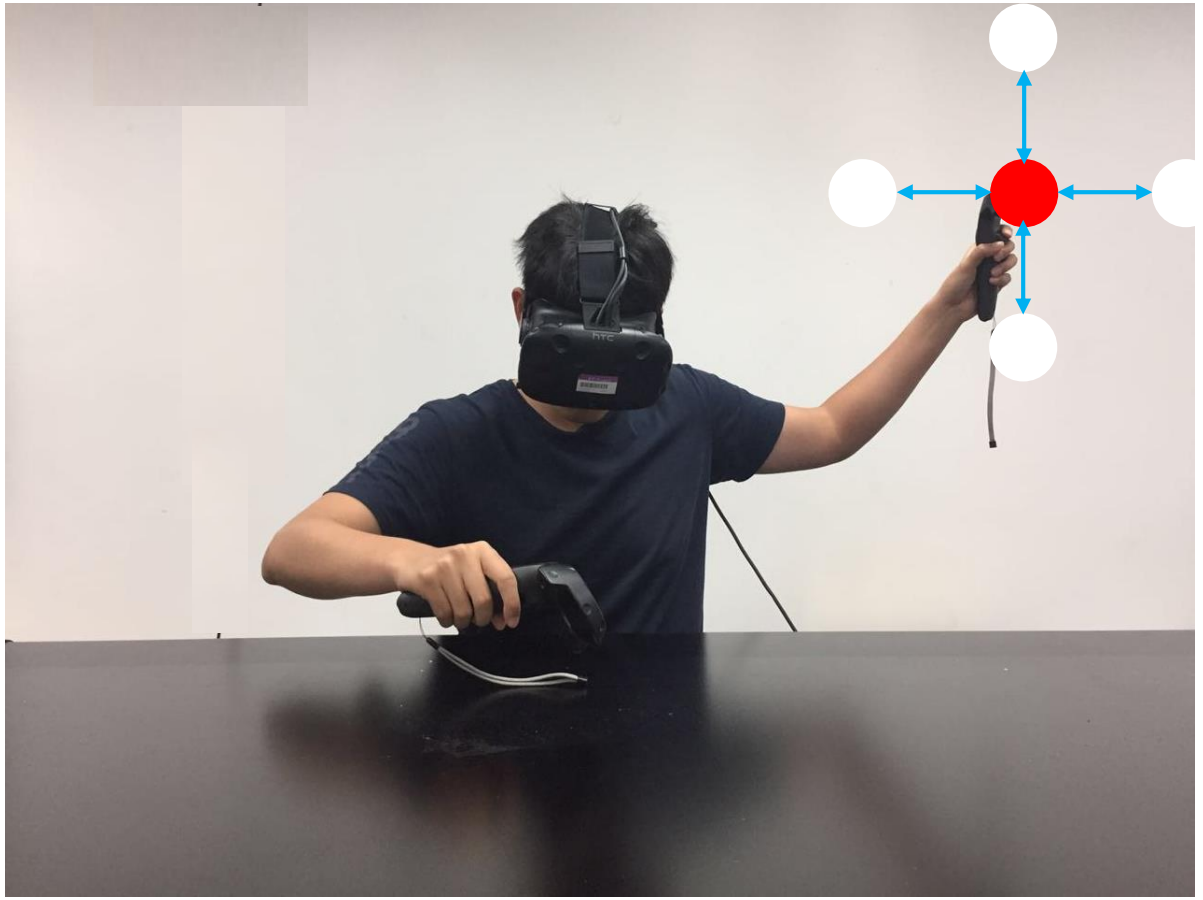


STUDY1: Subjective Acceptance

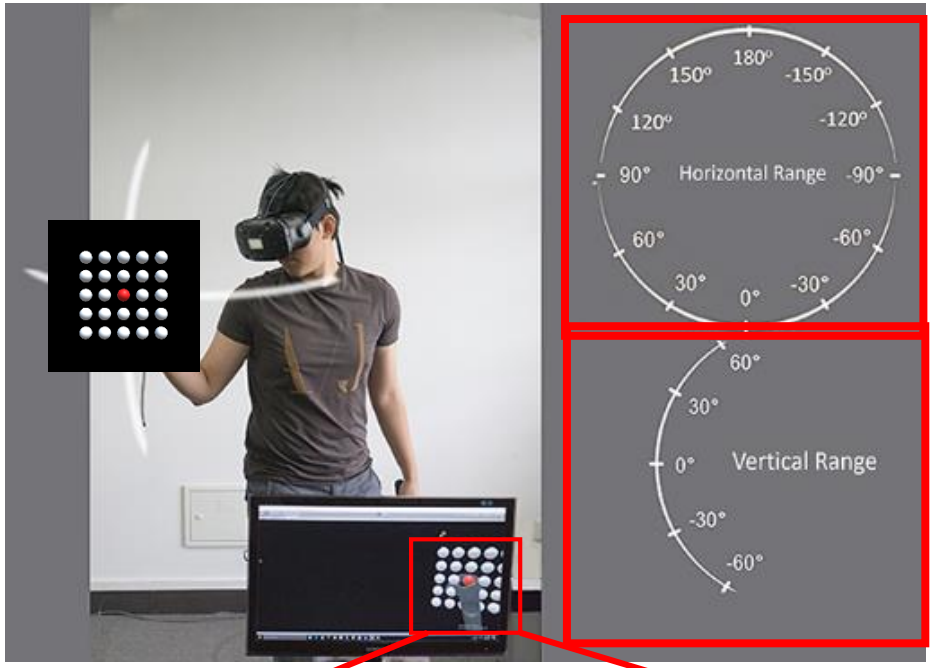
Target Position



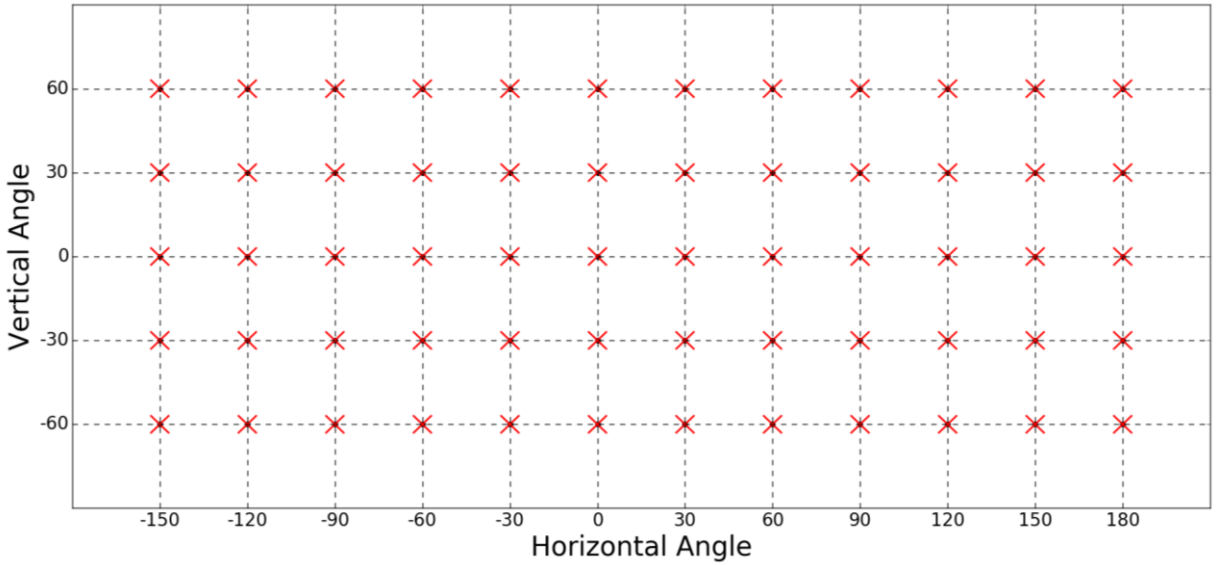
Target Distance



STUDY1: Subjective Acceptance

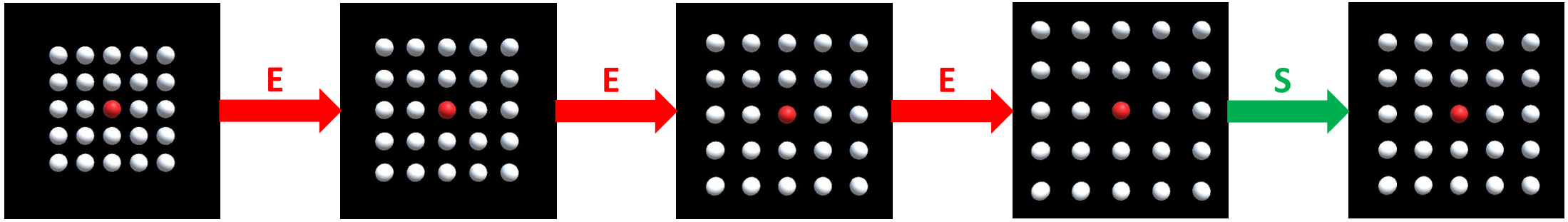


Different target positions (5×12)

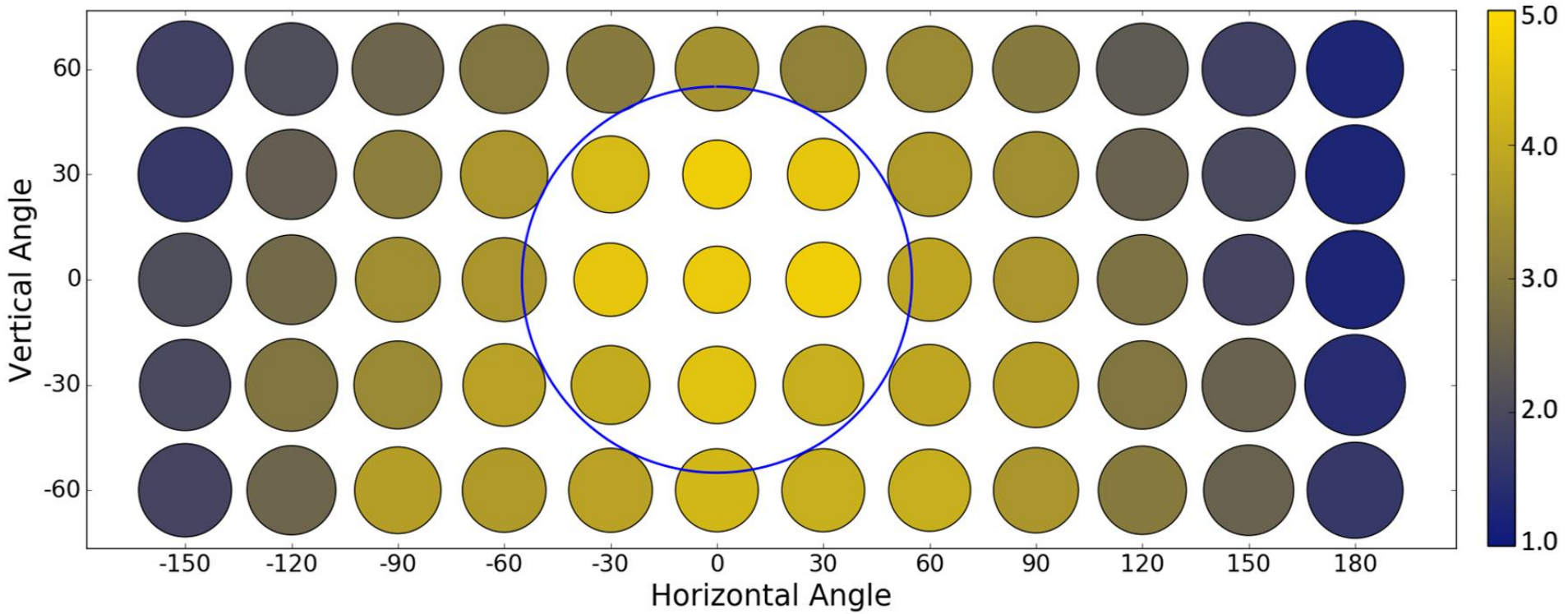


Enlarge or Shrink

Different target densities (distances)



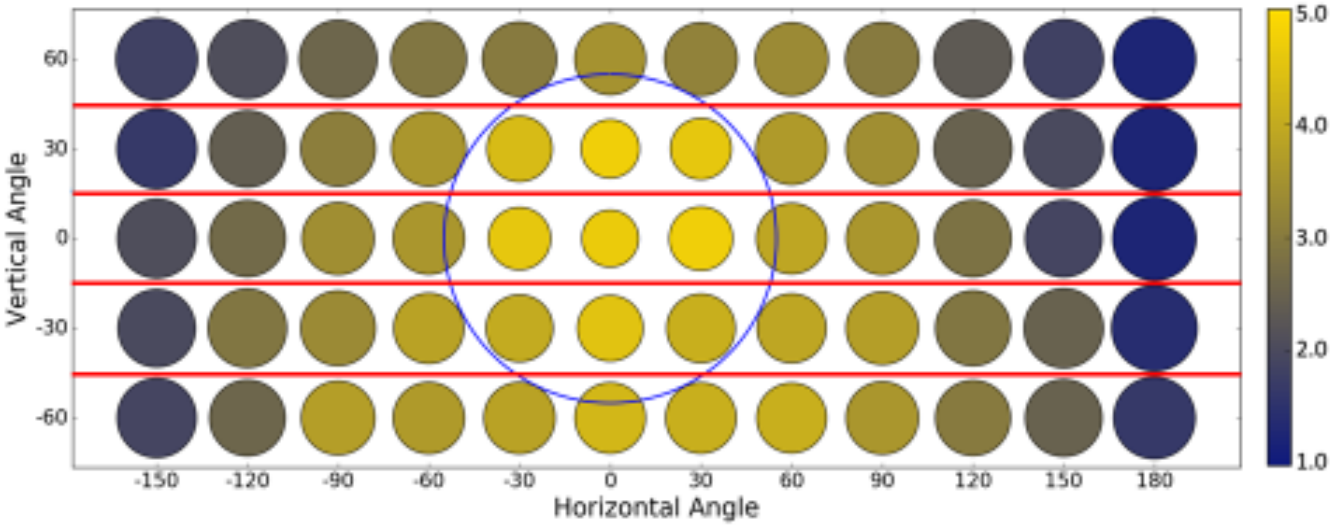
STUDY1: Subjective Acceptance



	Vertical	Horizontal	Sit/Stand	Left/Right	In FOV
Distance	✔	✔	✖	✖	✔
Comfort	✔	✔	✖	✔	✔

✔ represents significant effect, ✖ represents no significant effect

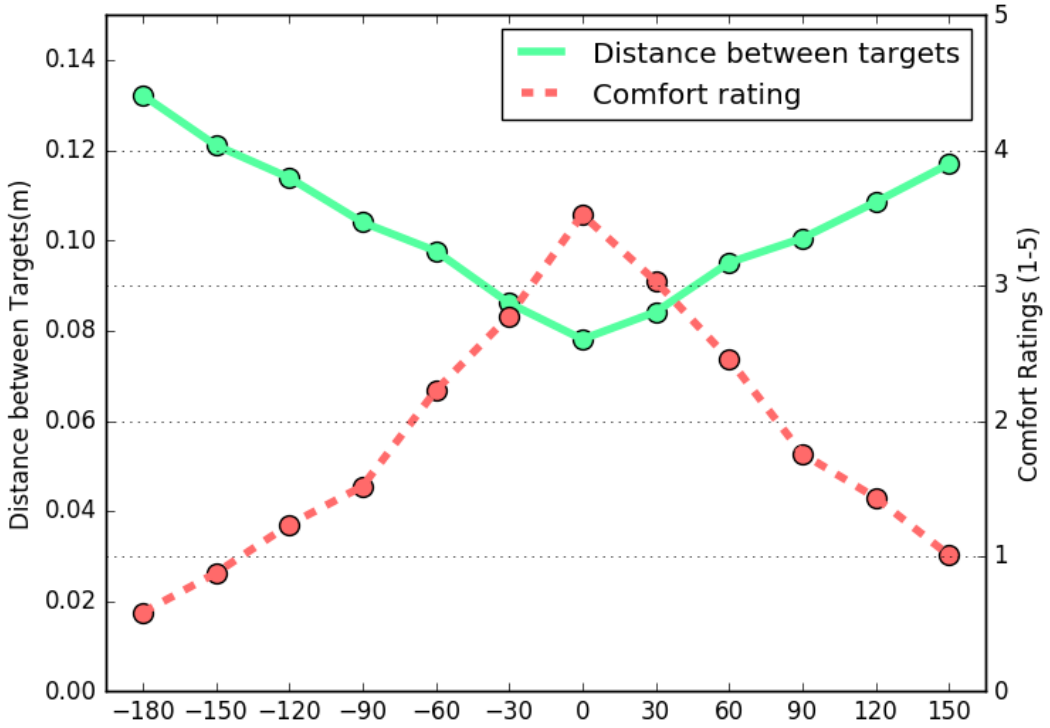
STUDY1: Subjective Acceptance



	Vertical	Horizontal	Sit/Stand	Left/Right	In FOV
Distance	✔	✔	✖	✖	✔
Comfort	✔	✔	✖	✔	✔

✔ represents significant effect, ✖ represents no significant effect

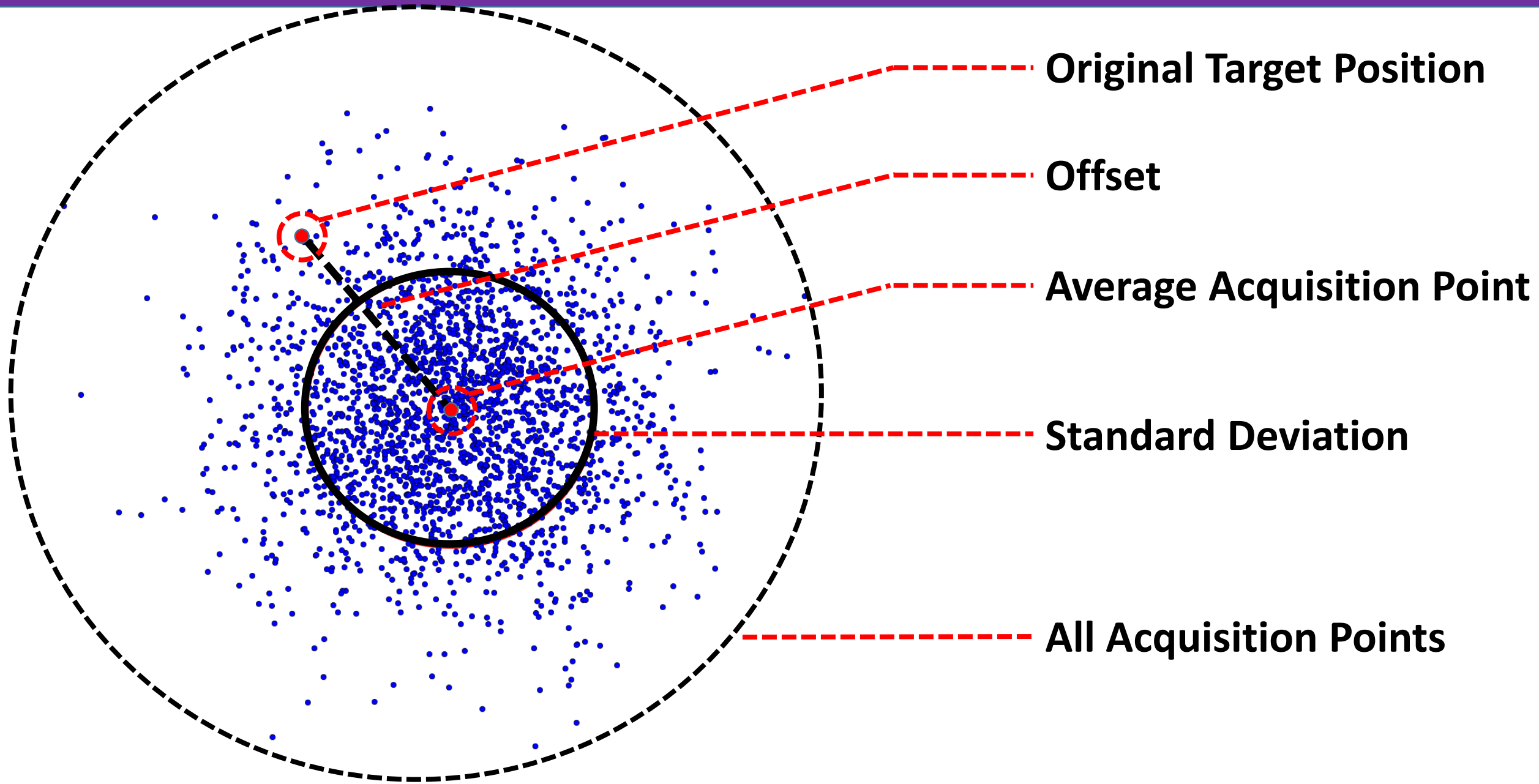
Symmetrical Pattern on Horizontal Angles



OUTLINE

- User Study 1. (Research Question 1)
- User Study 2. (Research Question 2)
- User Study 3. (Eyes-free vs. Eyes-Engaged)
- Discussion

STUDY2: Control Accuracy



STUDY2: Control Accuracy

Independent Factor

- The position of the targets relative to the user body (5 vertical levels × 12 horizontal levels)
- The number of rotations before the acquisition (towards 12 horizontal directions)

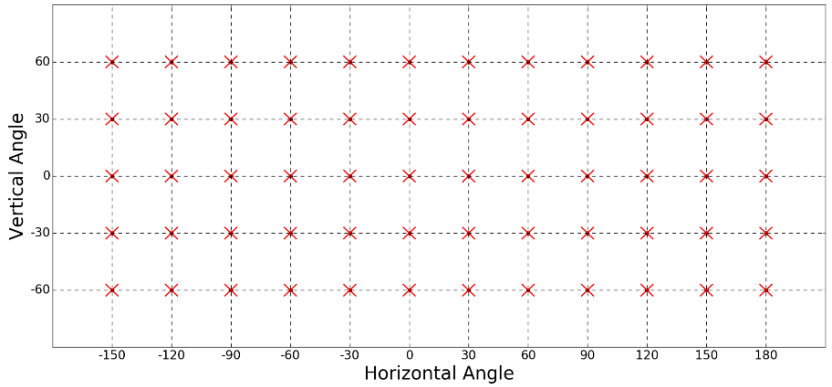


Figure 1. Angular Coordinates of Target

Metrics of Accuracy

- ***Spatial offset****: The Euclidean distance between the target position and the acquisition point*
- ***Angular offset****:* The distance between spherical coordinates (horizontal degrees, vertical degrees)

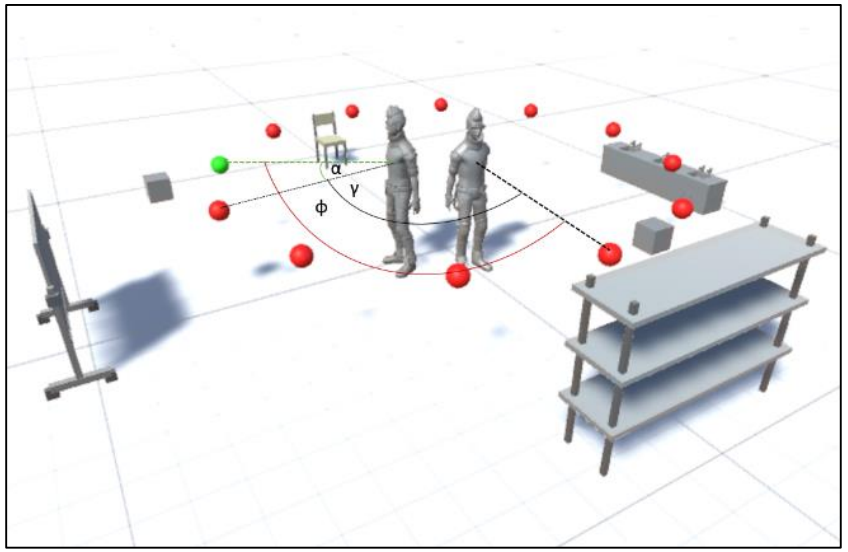
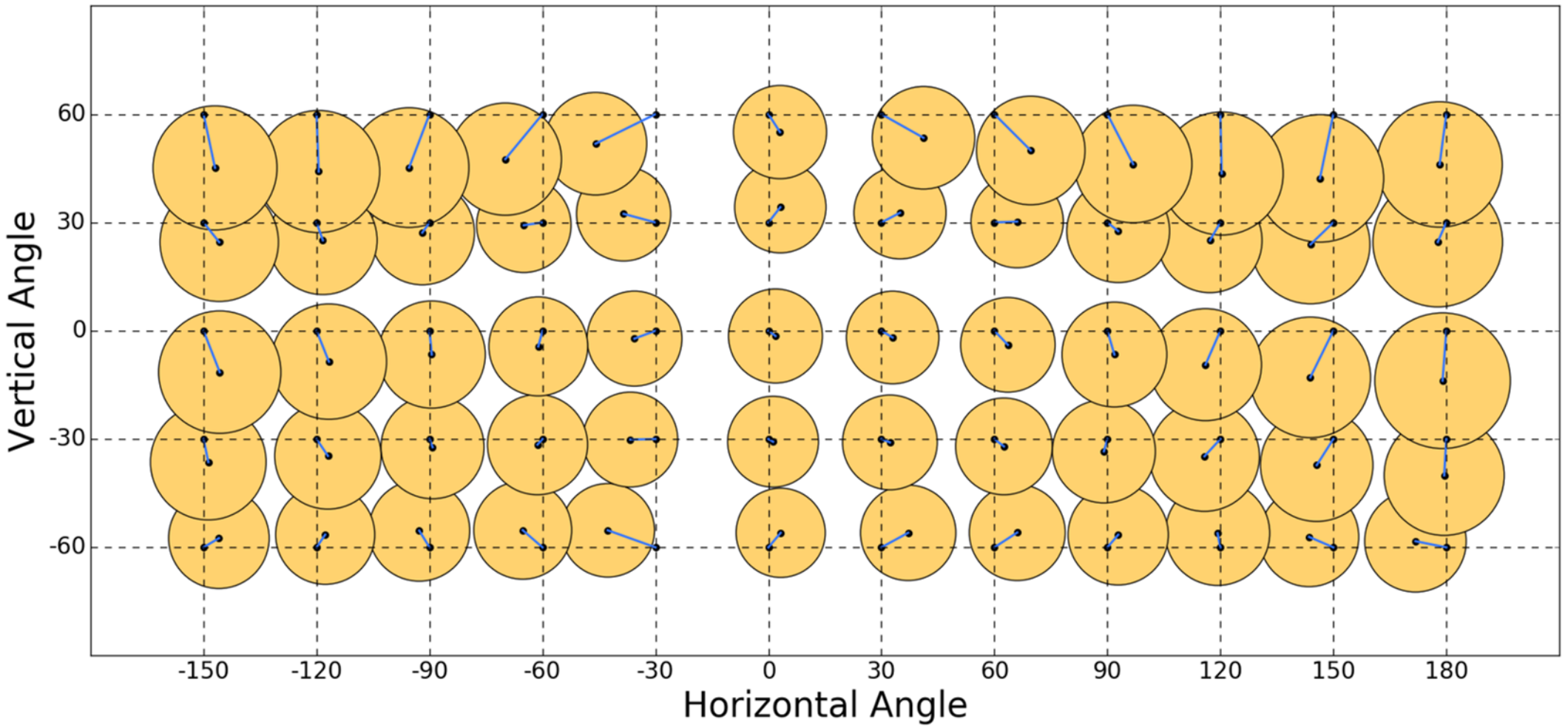


Figure 2. Illustration of the Experiment

Metric of Head Movement

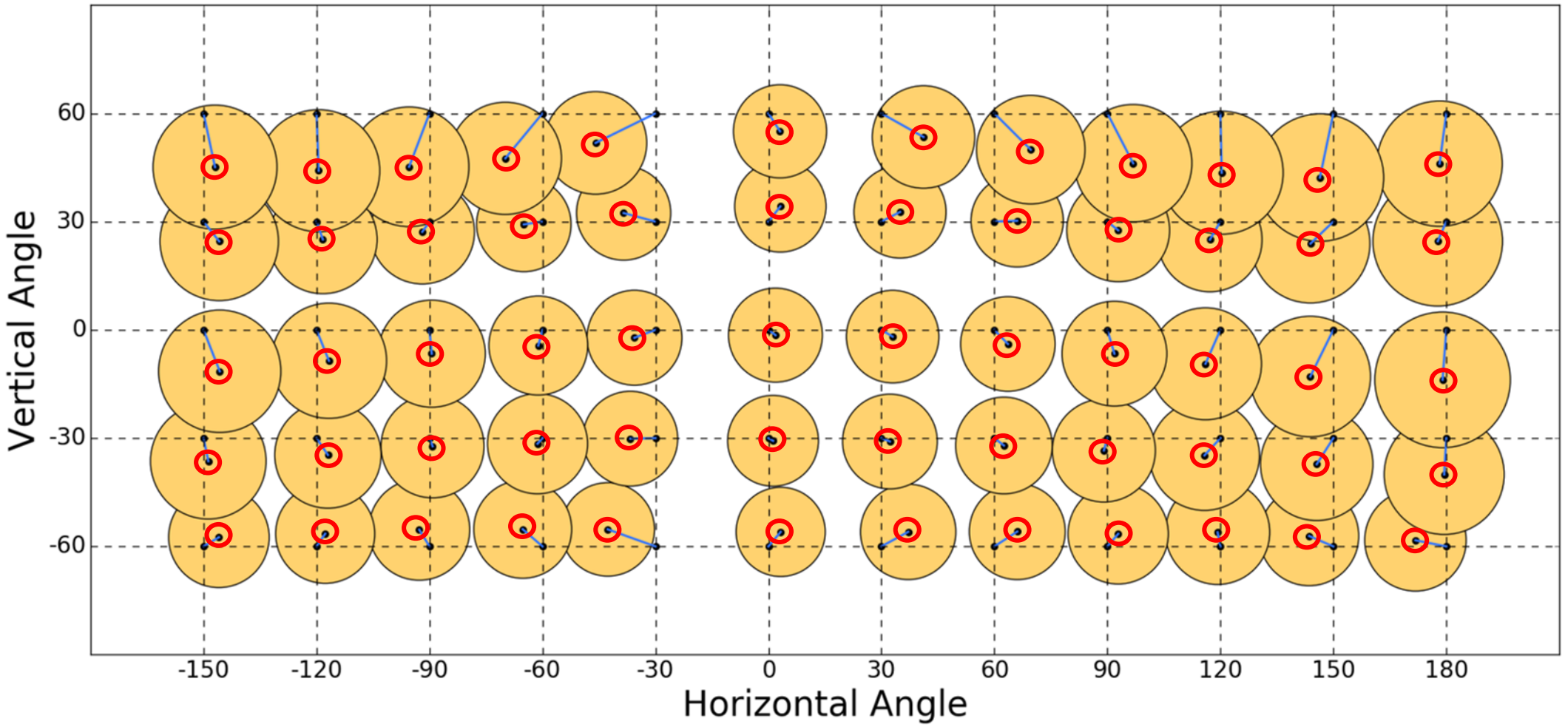
- The amplitude of the head movement during the Acquisition

STUDY2: Control Accuracy



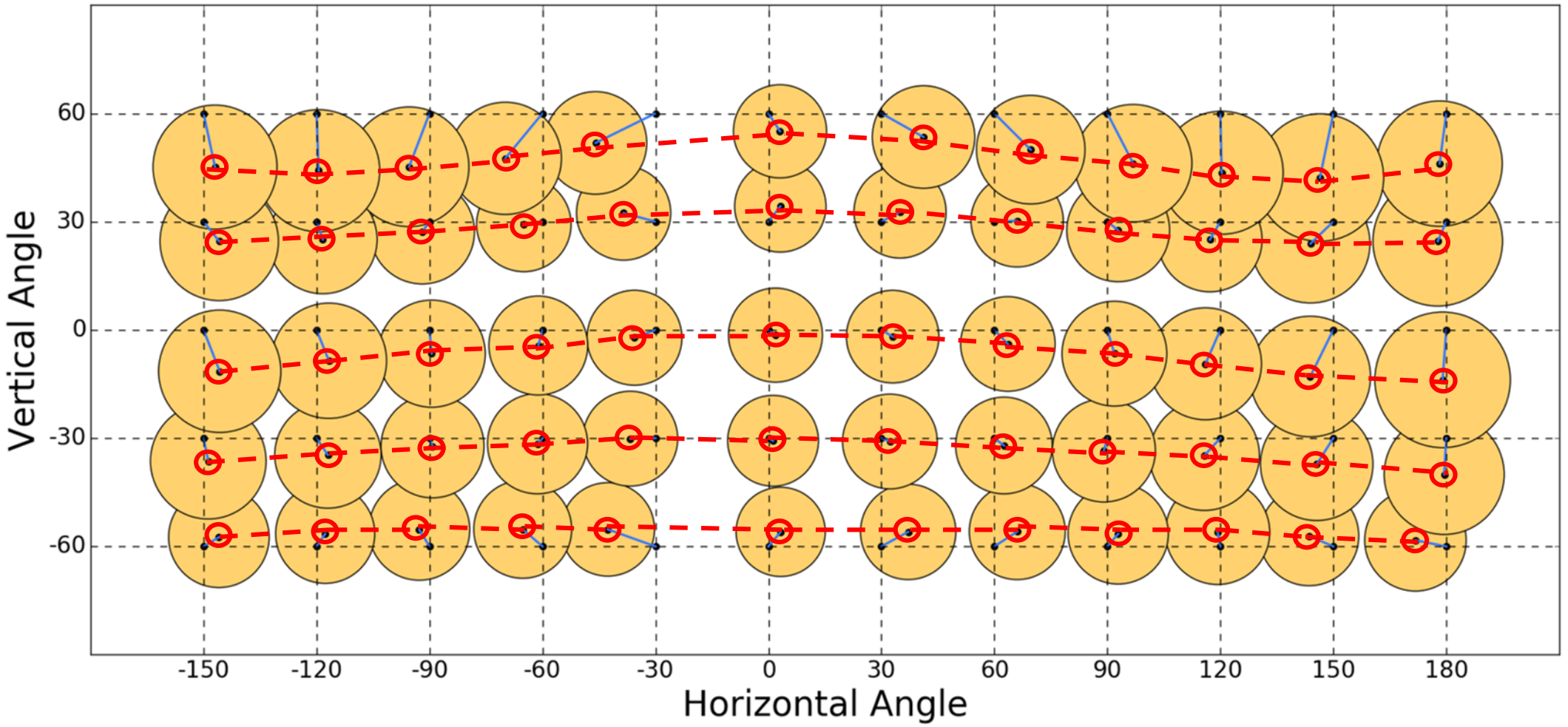
STUDY2: Control Accuracy

Averaged Positions of the Acquisition Points



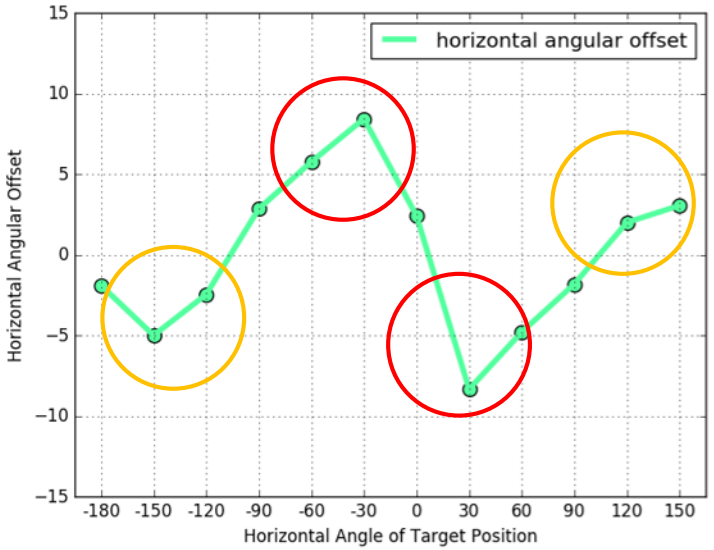
STUDY2: Control Accuracy

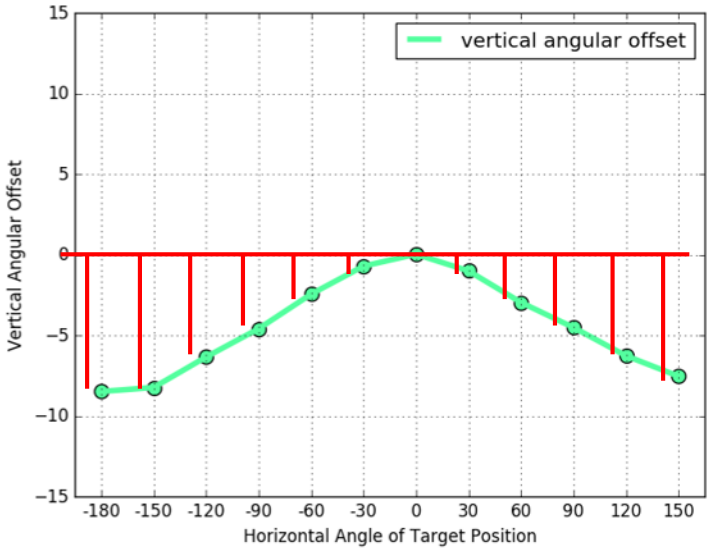
Tendency of Offsets on Different Vertical Angles



STUDY2: Control Accuracy

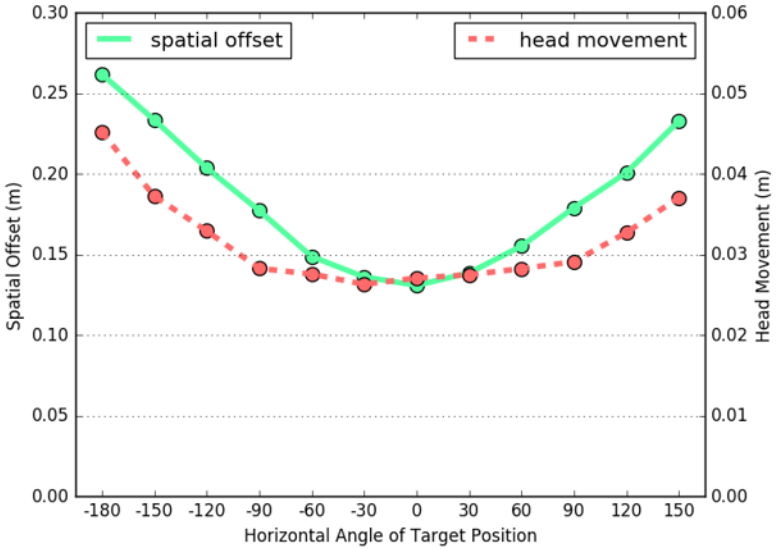
Centrosymmetric Pattern of Horizontal Offsets

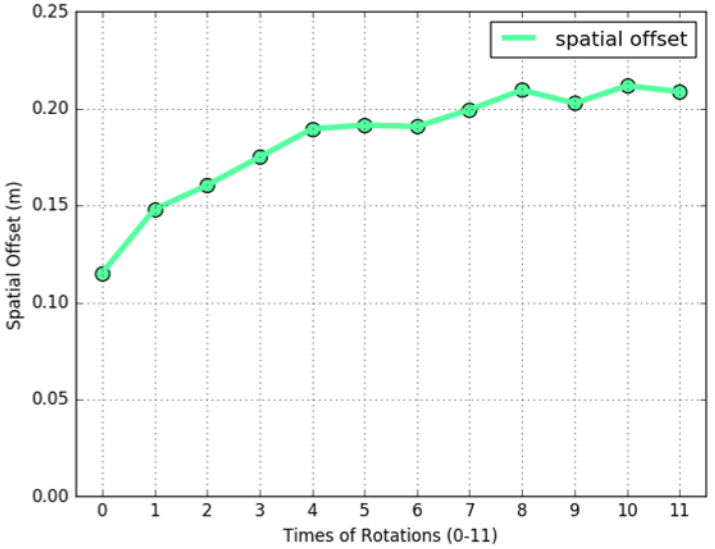




Negative Vertical Offsets with Increasing Values

Increasing Head Movement Amplitude

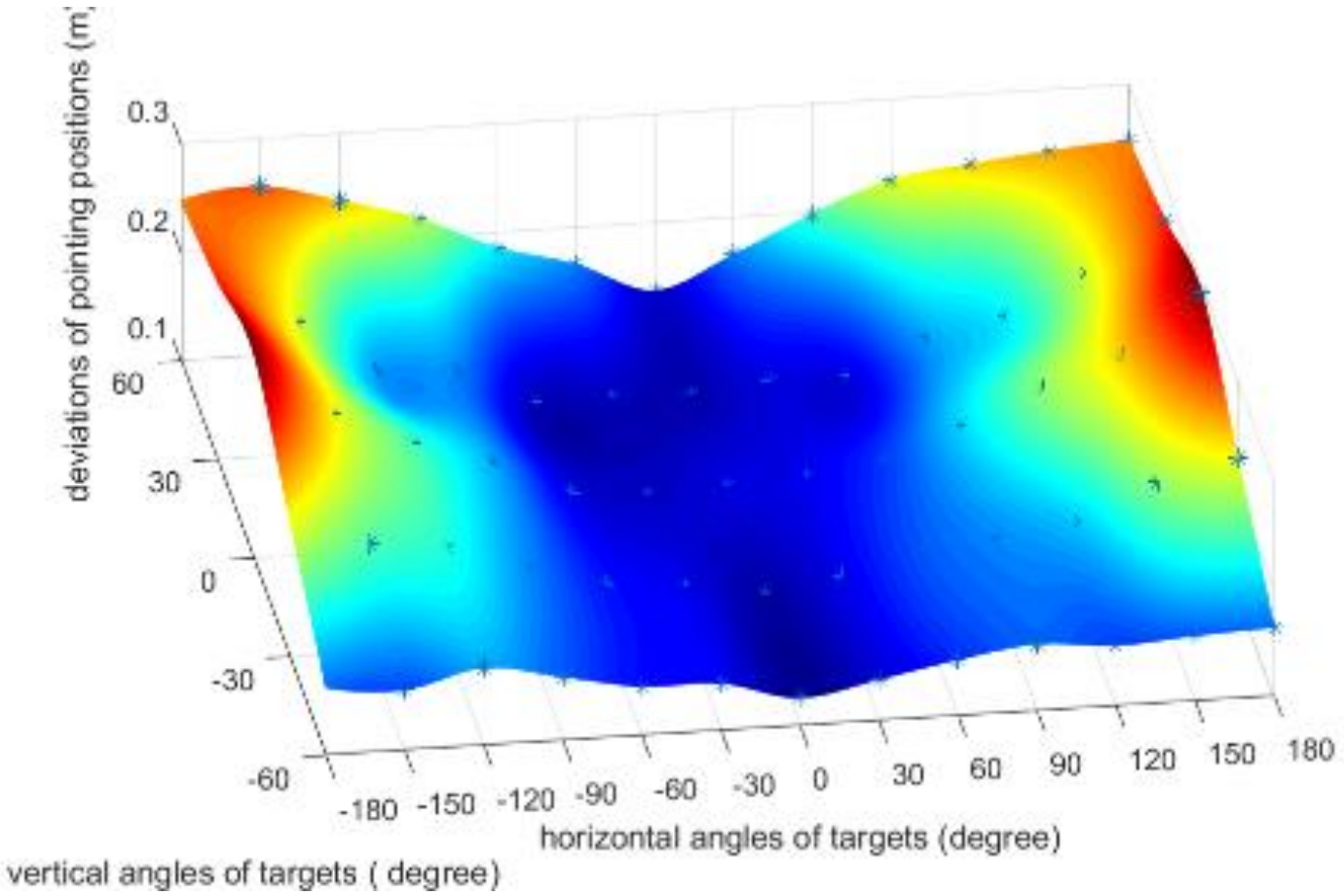




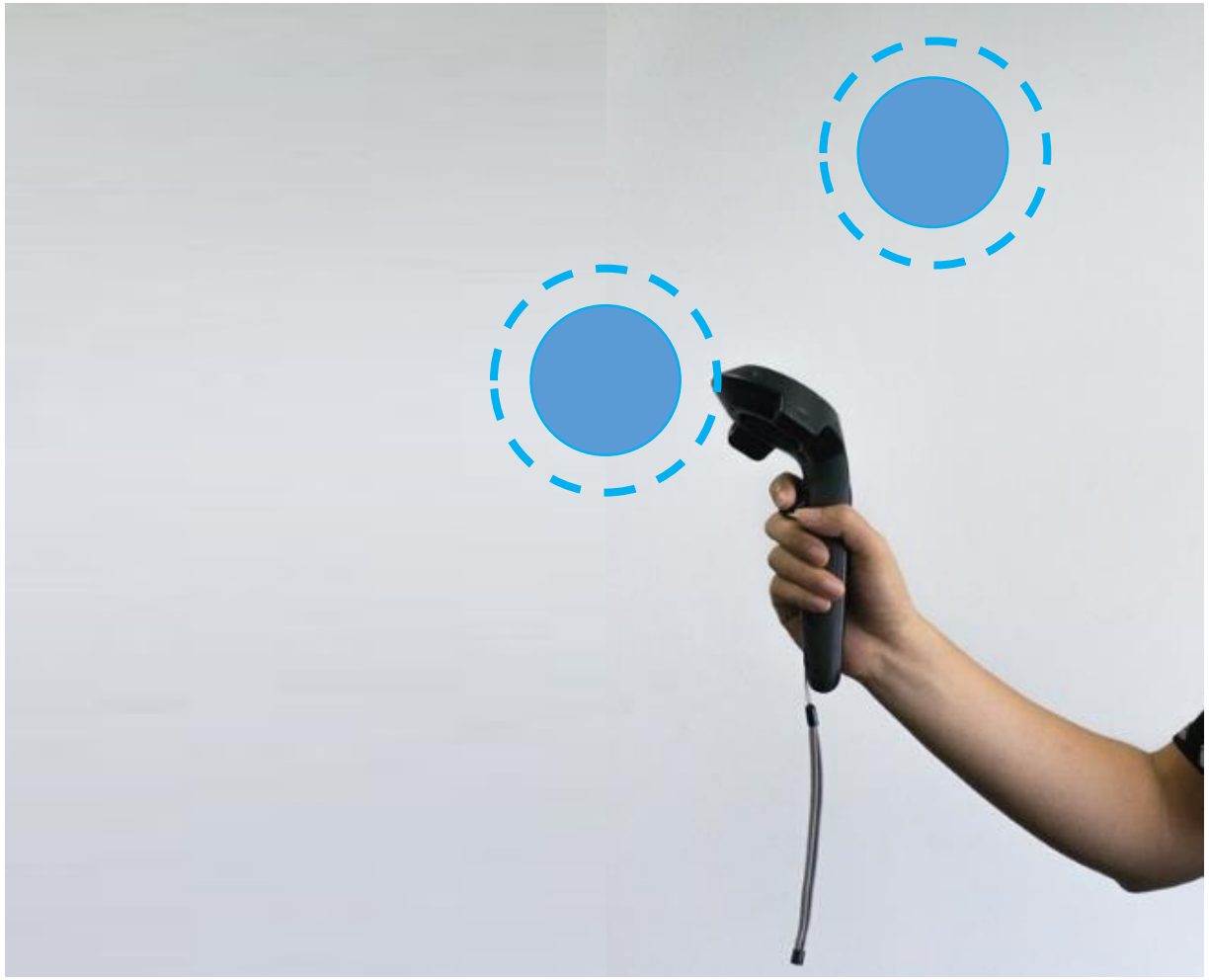
Increasing Spatial Offsets after More Times of Rotations

STUDY2: Control Accuracy

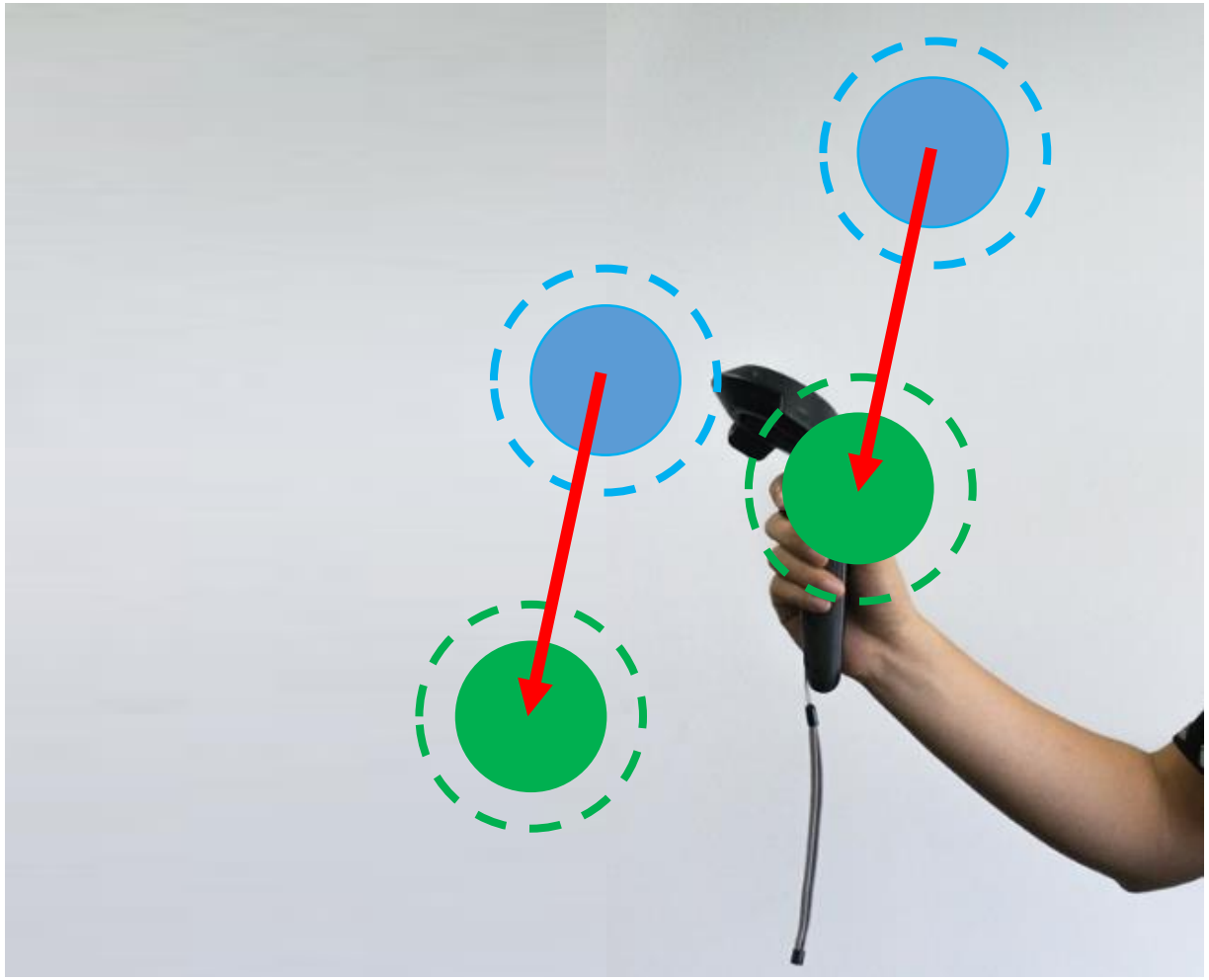
Interpolation For Offsets



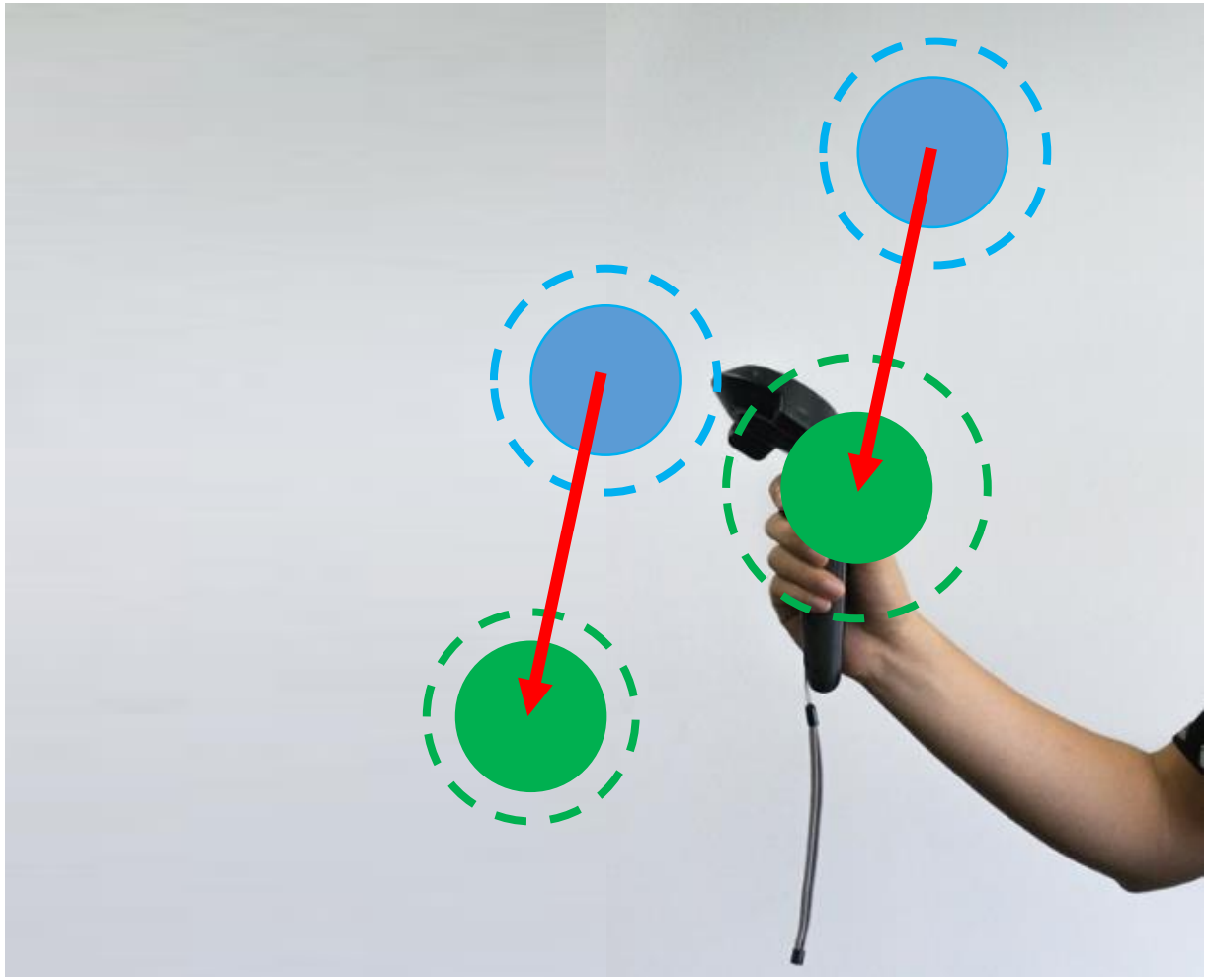
Recognition of Target Acquisition



Considering the Offsets



Considering the Deviations



OUTLINE

- User Study 1. (Research Question 1)
- User Study 2. (Research Question 2)
- User Study 3. (Eyes-free vs. Eyes-Engaged)
- Discussion

STUDY3: Comparison

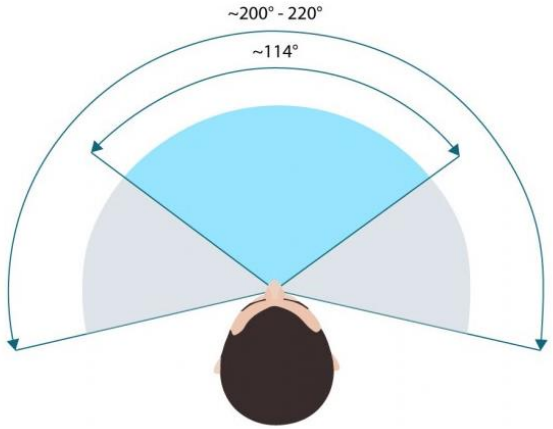
Experiment Design ($2 \times 2 \times 2$)

Independent Factor 1:

Approach: Eyes-Engaged / Eyes-Free

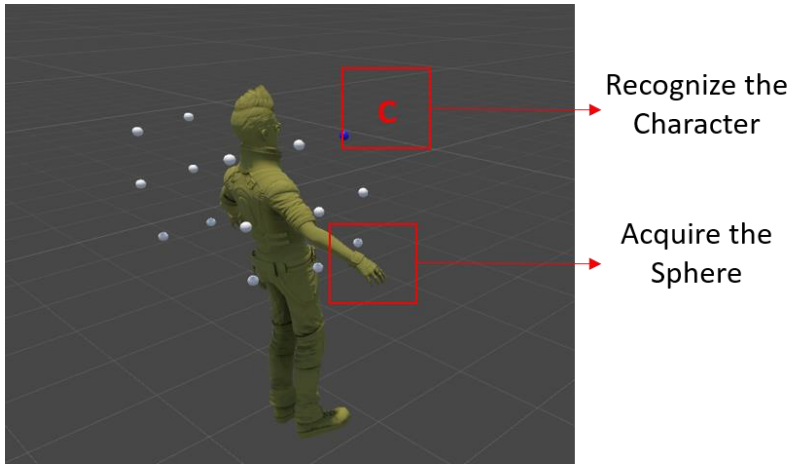
Independent Factor 2:

FOV Size: 30/110 degrees



Independent Factor3:

Whether there was another **Second Task**



Measurement

- ***Acquisition Time (Speed):*** The duration between when the target appears and when participants click the button to confirm the acquisition.
- ***Acquisition Accuracy:*** The frequency that participants acquire the correct target.
- ***Second Tasks Misses:*** The number of misses of recognizing the character ‘a’.
- ***Subjective Scores:*** The scores that participants rated for subjective feelings.

$$16\ participants \times 2\ approaches \times 2\ FOV\ sizes \times 2\ Task\ Types \times 6\ trials \times 18\ acquisitions = 13824\ acquisitions$$

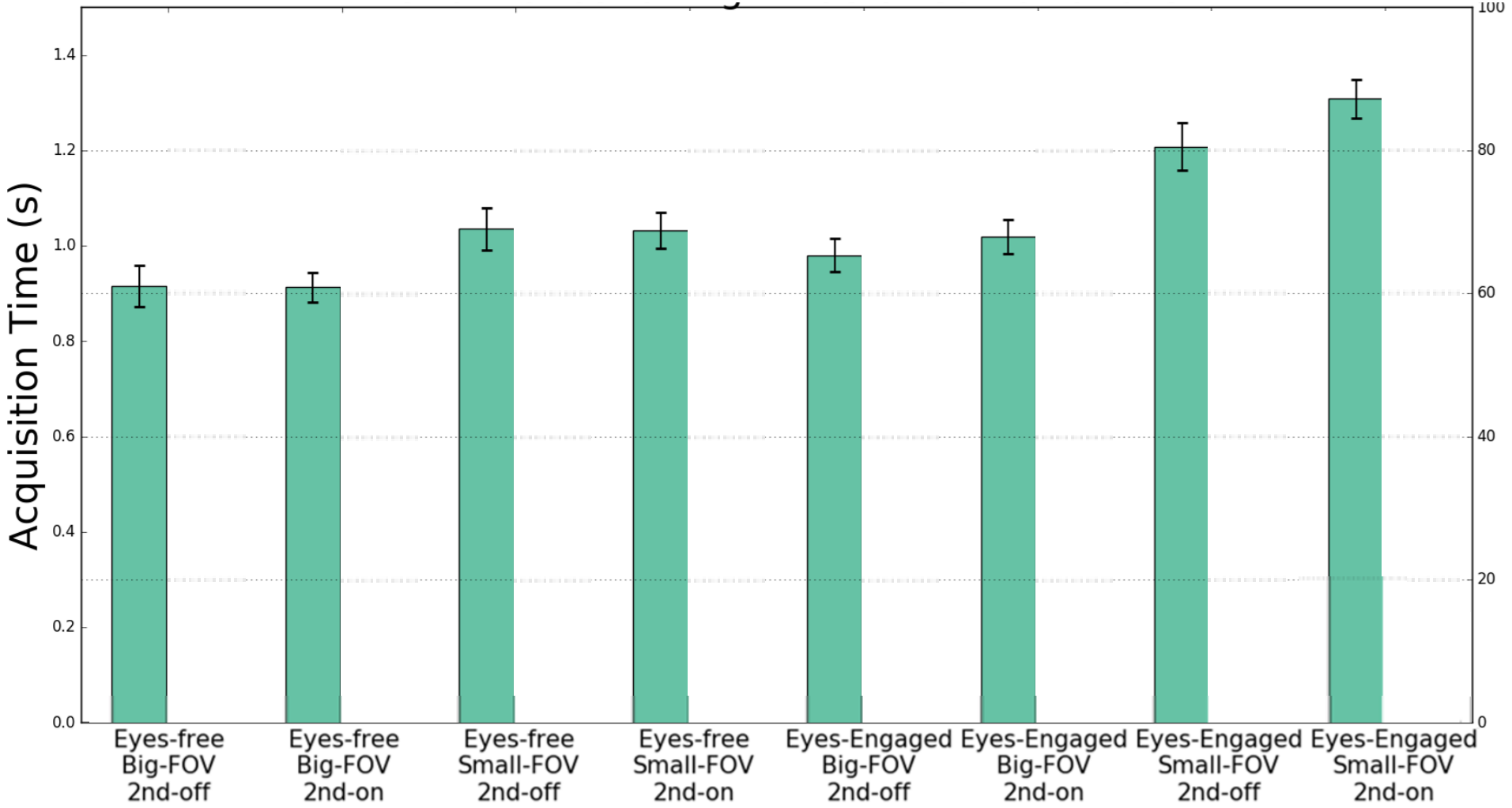
Hypothesis

H1: The eyes-free approach should result in higher *acquisition speed*, less *distraction* to ongoing tasks, less *fatigue*, and less *sickness*.

H2: The eyes-free approach should have a satisfying *acquisition accuracy* after we optimized the acquisition recognition.

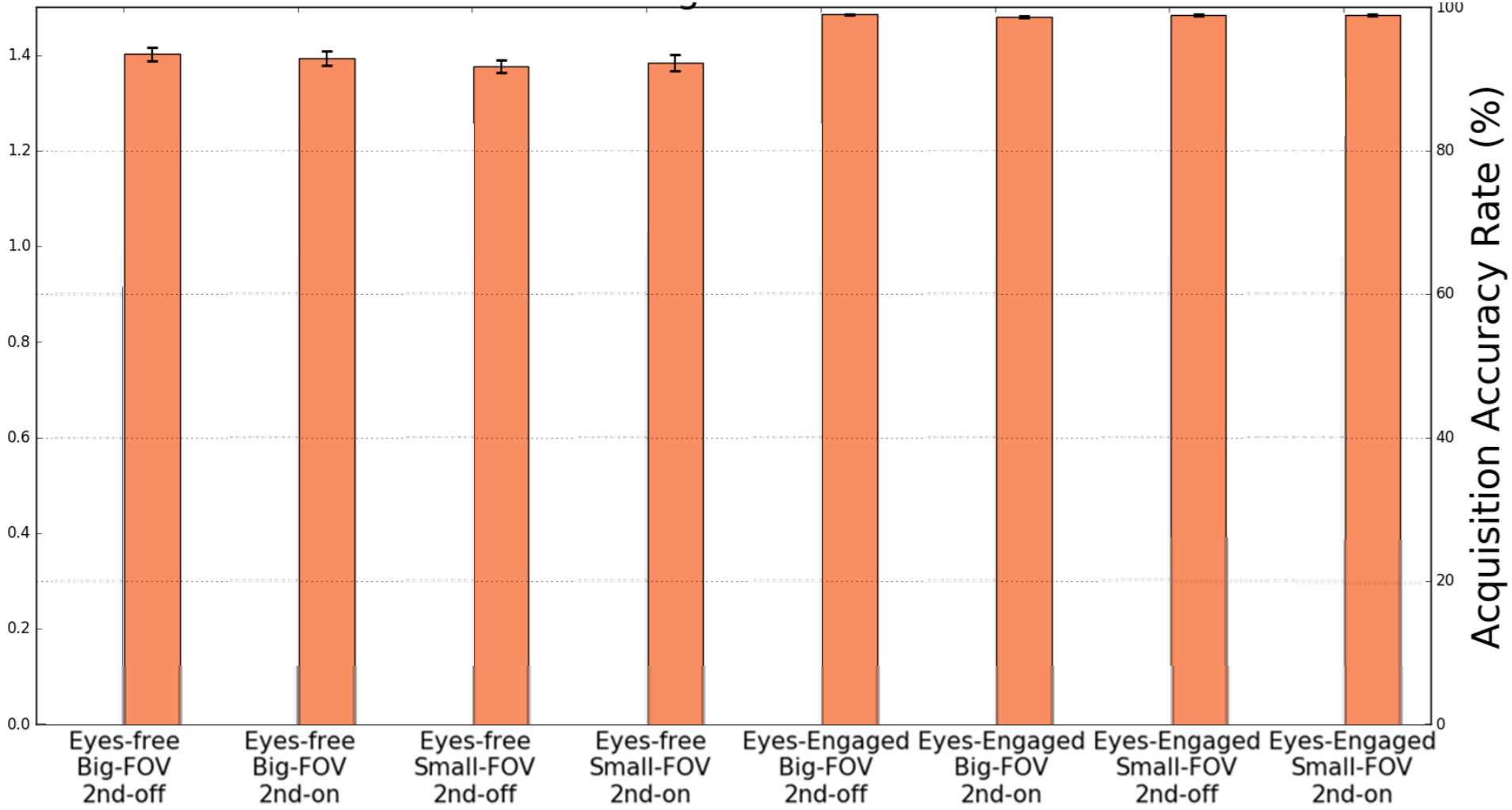
H3: Users would *prefer* the eyes-free approach than the eye-engaged approach, especially when the FOV is small or there is another ongoing task.

Acquisition Time of Different Conditions



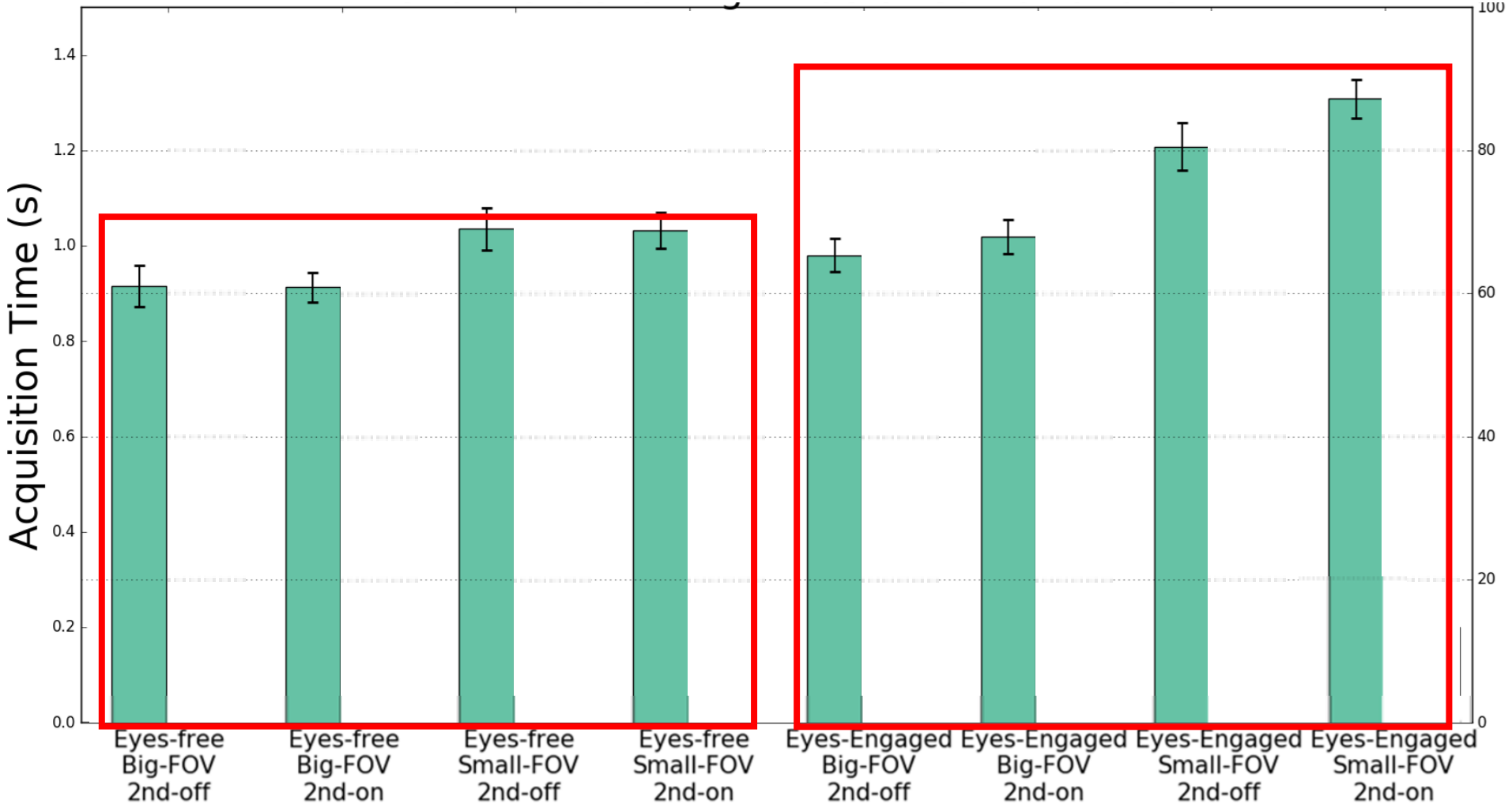
STUDY3: Comparison

Acquisition Accuracy of Different Conditions

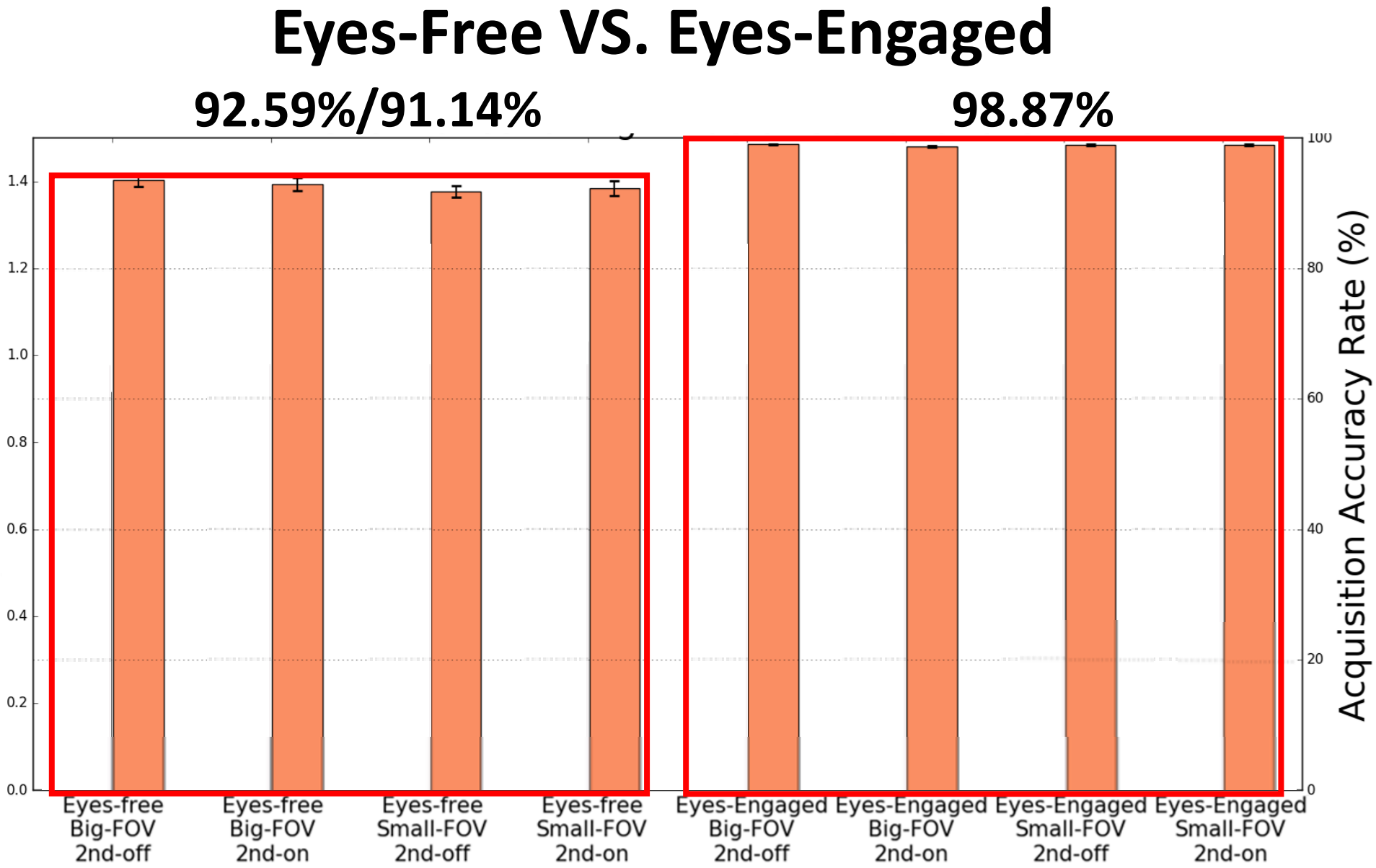


STUDY3: Comparison

Eyes-Free VS. Eyes-Engaged

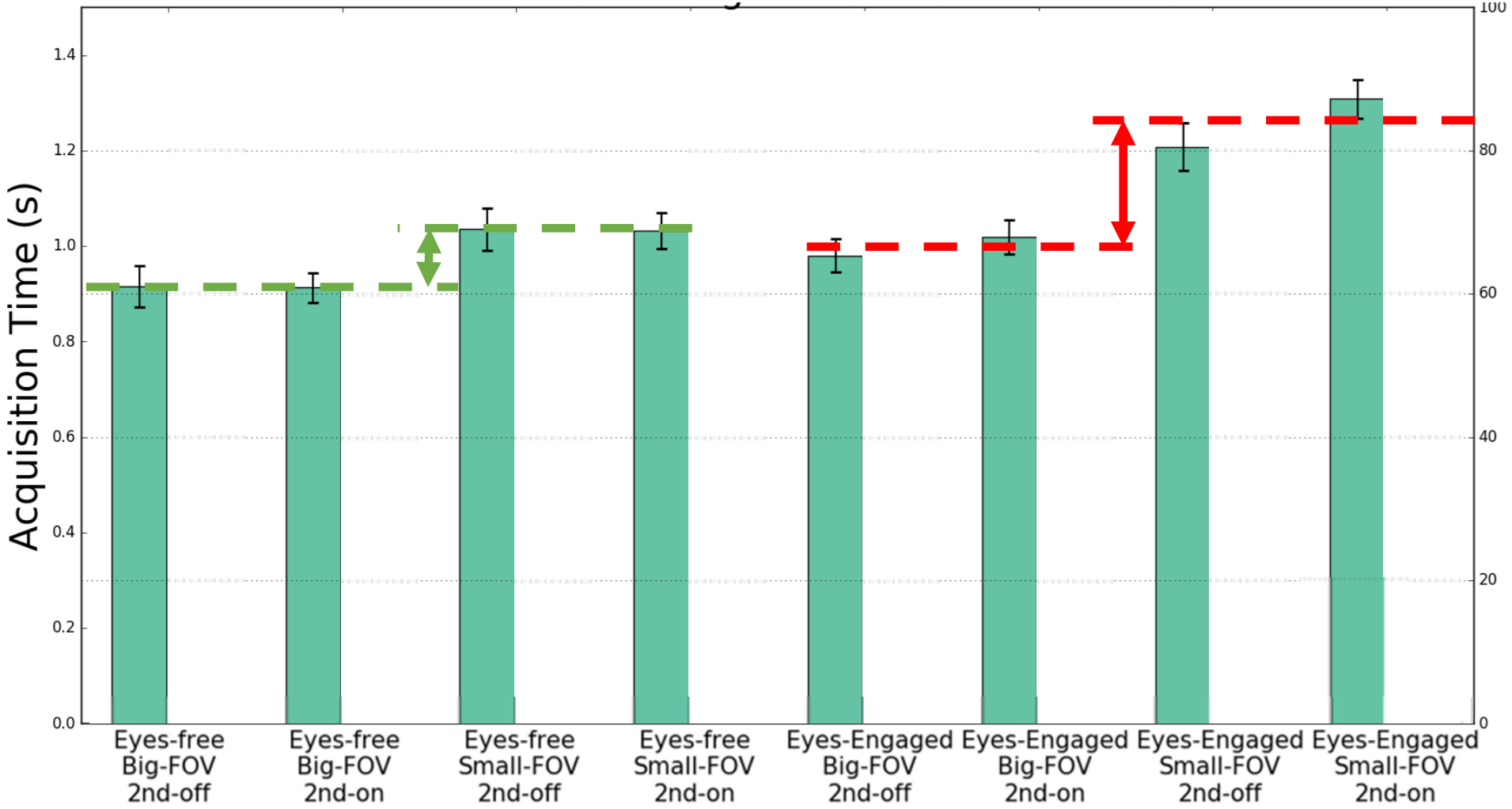


STUDY3: Comparison



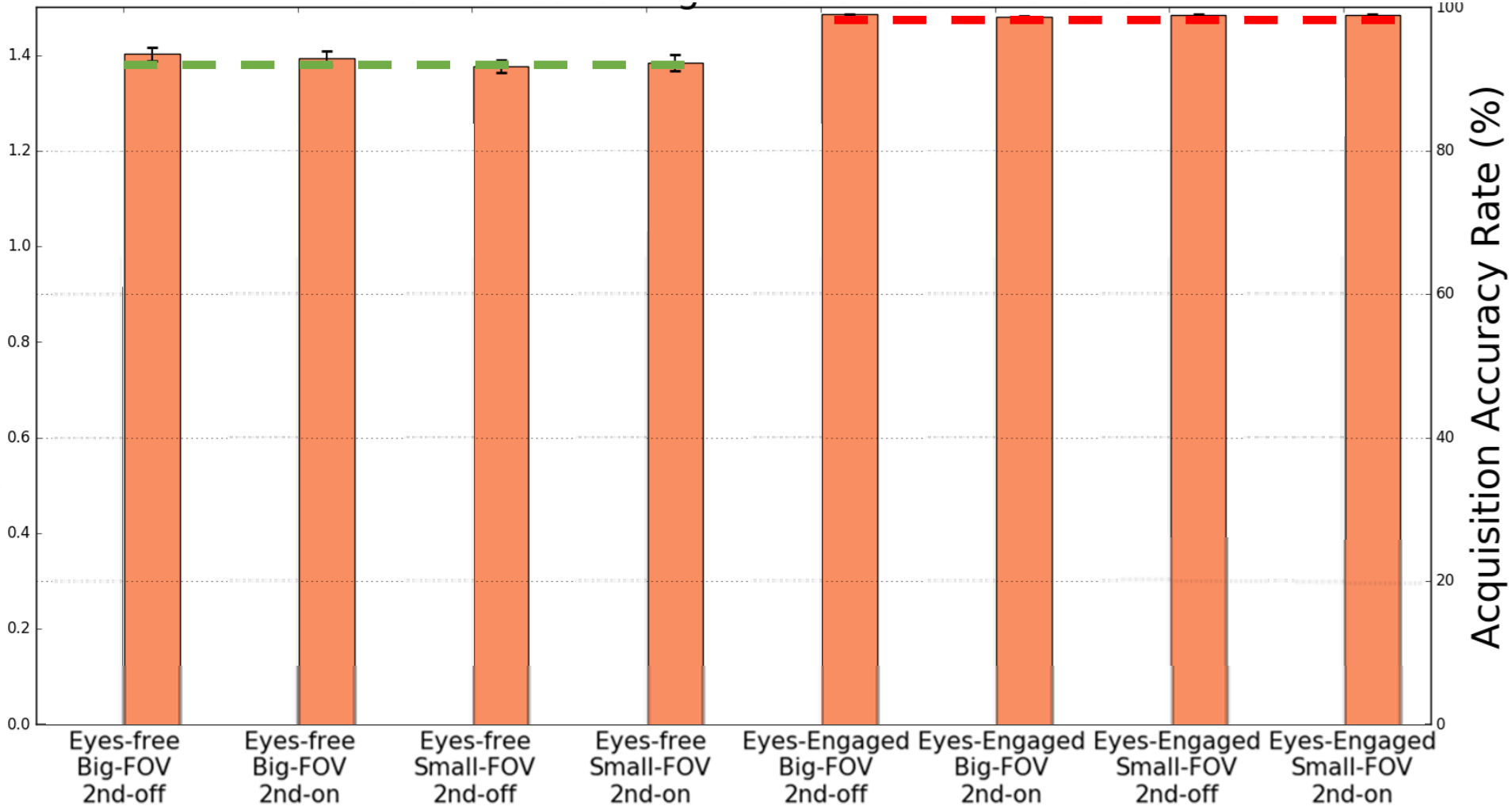
STUDY3: Comparison

FOV size: 110 degrees VS. 30 degrees



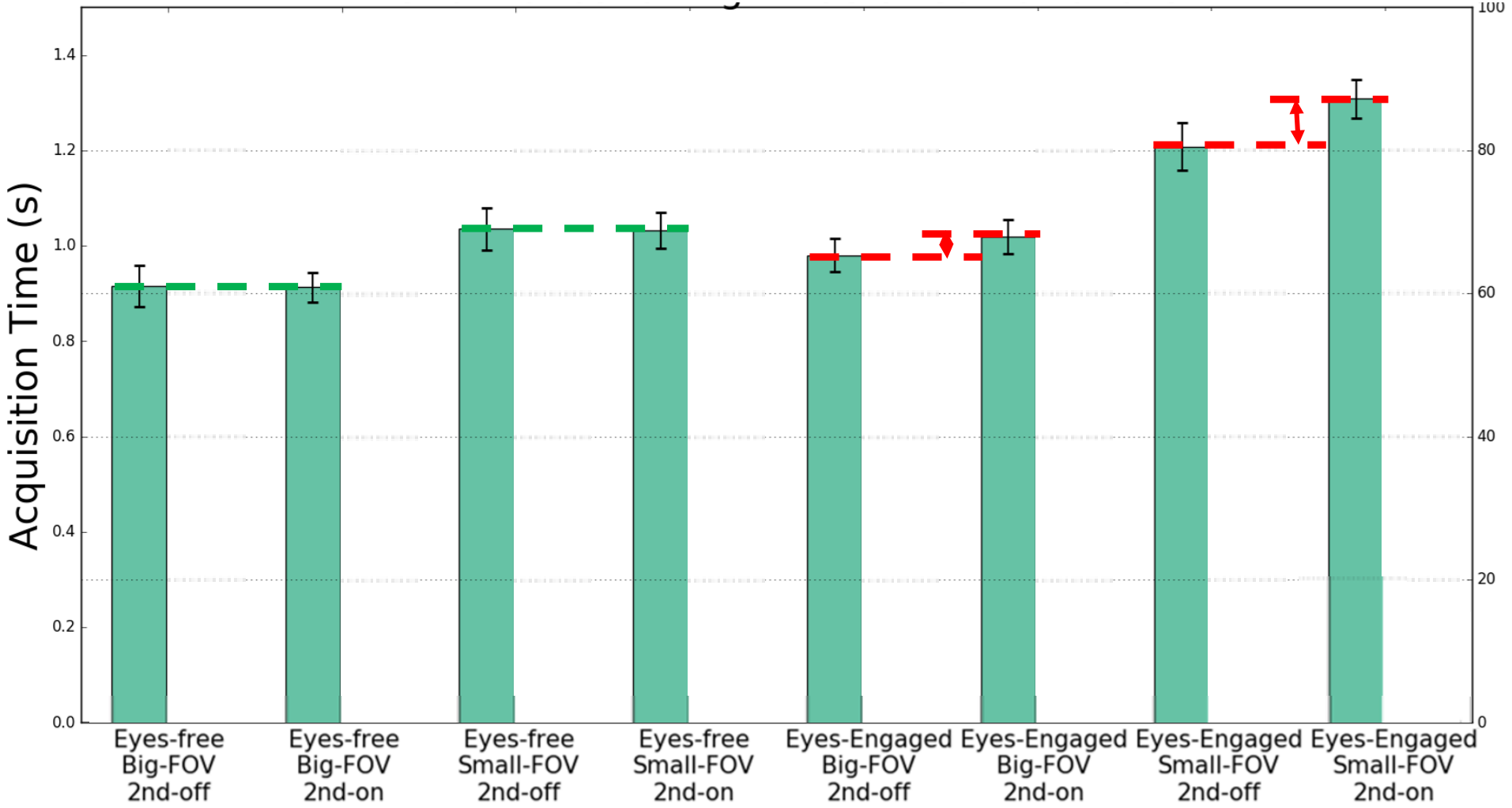
STUDY3: Comparison

FOV size: 110 degrees VS. 30 degrees



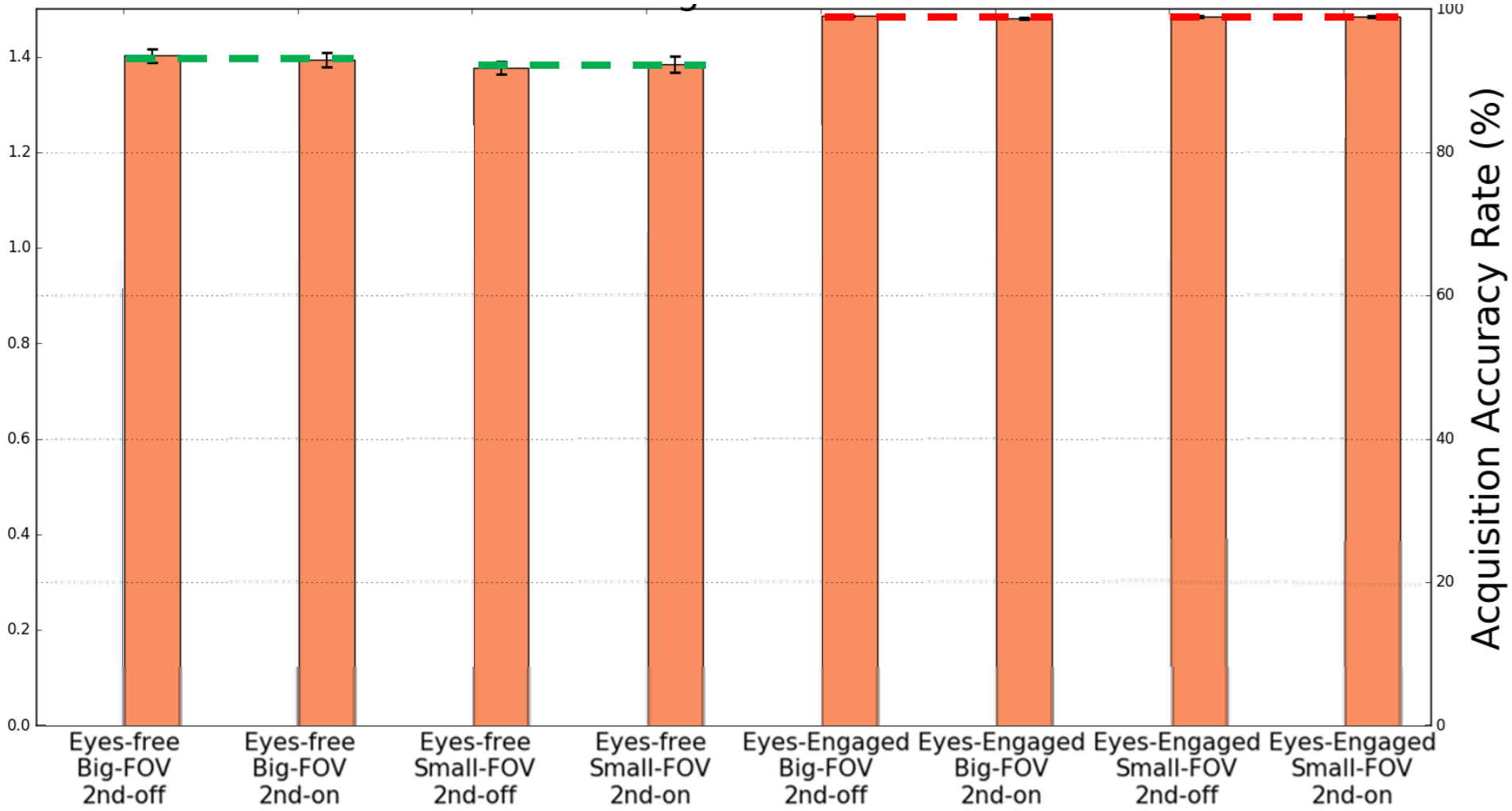
STUDY3: Comparison

Second Task: On VS. Off

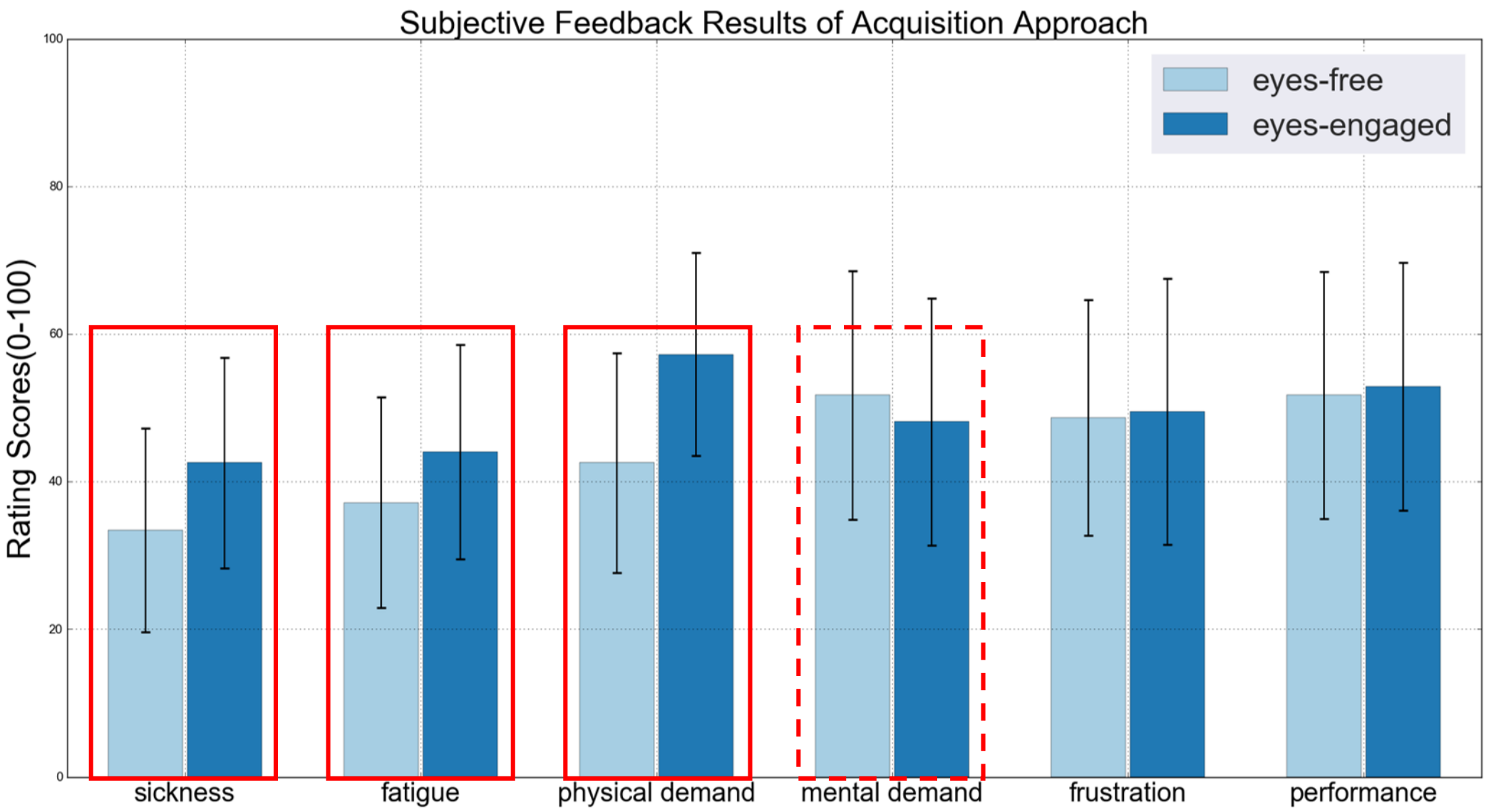


STUDY3: Comparison

Second Task: On VS. Off



STUDY3: Comparison



Hypothesis

- ✓ The eyes-free approach should result in higher *acquisition speed*, less *distraction* to ongoing tasks, less *fatigue*, and less *sickness*.
- ✓ The eyes-free approach should have a satisfying *acquisition accuracy* after we optimized the acquisition recognition.
- ✓ Users would *prefer* the eyes-free approach than the eye-engaged approach, especially when the FOV is small or there is another ongoing task.

OUTLINE

- User Study 1. (Research Question 1)
- User Study 2. (Research Question 2)
- User Study 3. (Eyes-free vs. Eyes-Engaged)
- Discussion

DISCUSSION

Target Layout for Eyes-Free Acquisition

- Consistent with daily experience: light switch.
- Paired objects on two sides: pen and paper.

DISCUSSION

Target Layout for Eyes-Free Acquisition

- Consistent with daily experience: light switch.
- Paired objects on two sides: pen and paper.

The Second Task in Real Applications

- Higher intensity: searching for the enemies in the game.
- Higher sensitivity for focus switch: shooting the bullet.

DISCUSSION

Target Layout for Eyes-Free Acquisition

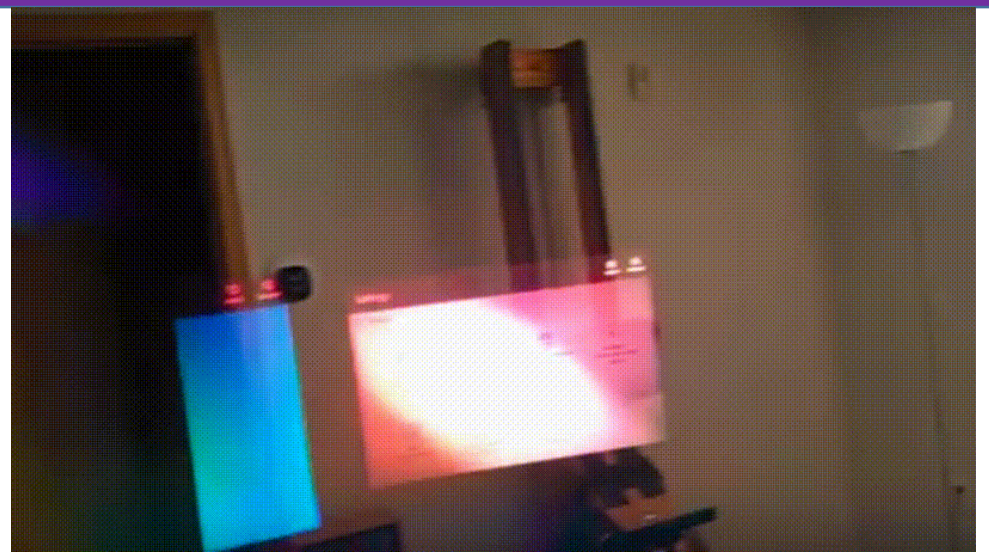
- Consistent with daily experience: light switch.
- Paired objects on two sides: pen and paper.

The Second Task in Real Applications

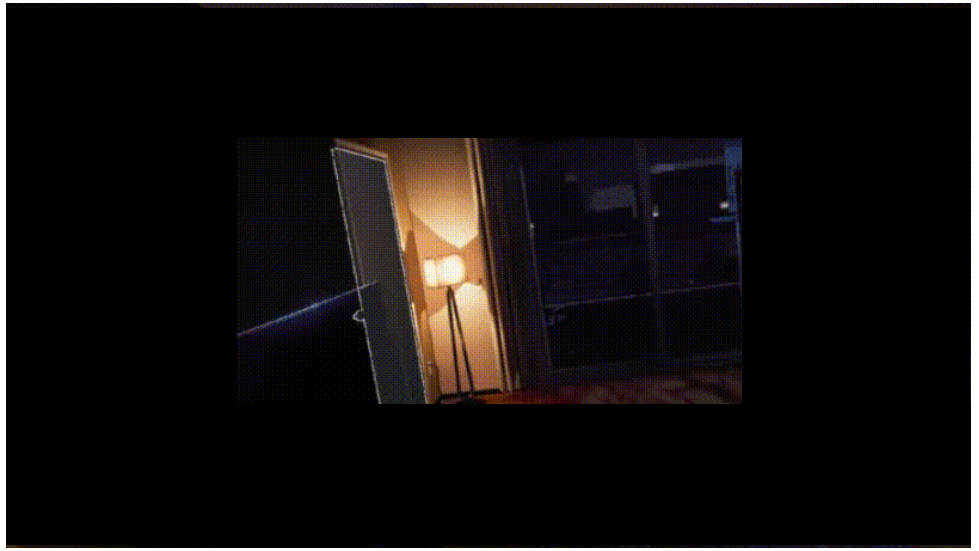
- Higher intensity: searching for the enemies in the game.
- Higher sensitivity for focus switch: shooting the bullet.

Eyes-free Target Acquisition on AR HMD Devices

- The FOV size: 30 degrees in **STUDY3**
- The real environment V.S. pure black



30-degree View in AR device



30-degree View in VR device

FUTURE WORK

Feedback, Multi-Layer Layout, Reference Frame

- Haptic, auditory feedbacks
- Multiple layers of targets in different depth
- Absolute, relative to the body, the controller

Thanks