CHI 2024
Surfing the World

전남대학교 CHONNAM NATIONAL UNIVERSITY

University of South Australia

The RayHand Navigation:

A Virtual Navigation Method with Relative Position between Hand and Gaze-Ray

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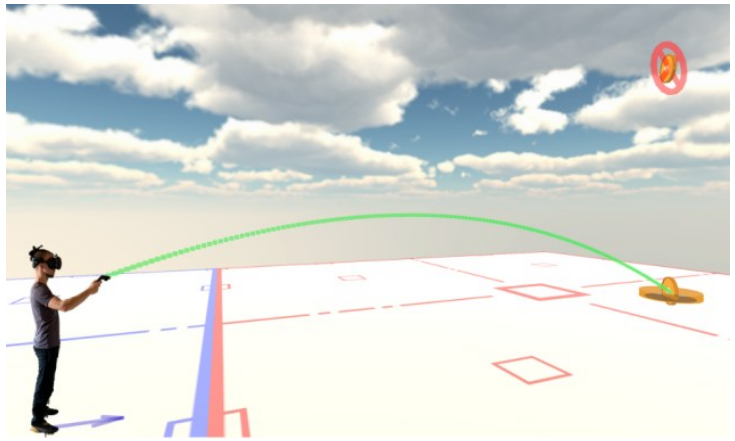
Motivation

Navigation in VR

Spatial awareness
Immersion ↑
Large physical area X

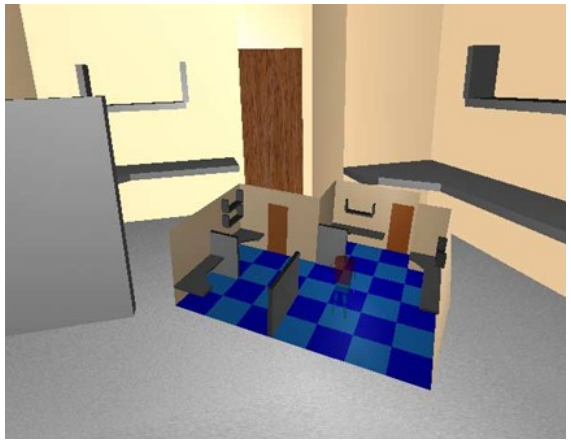
Walking-based

Treadmill [1]



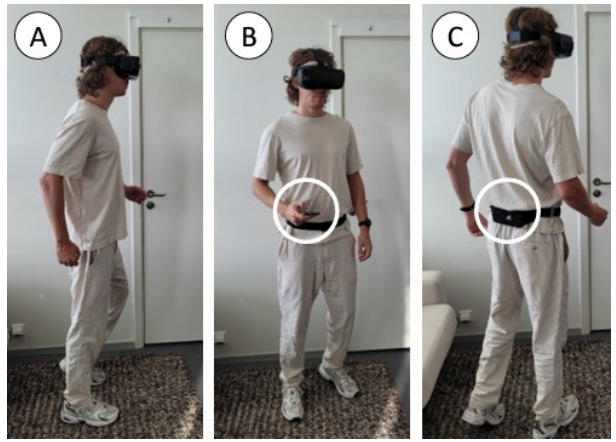
Selection-based

Teleportation [2]



Manipulation-based

World In Miniature (WIM) [3]



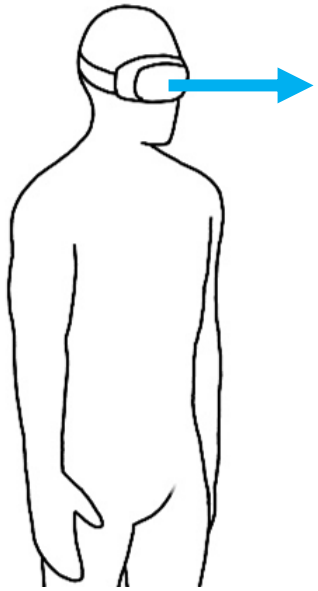
Steering-based

Body-steering [4]

[1] Souman, J. L., Giordano, P. R., Frissen, I., Luca, A. D., & Ernst, M. O. (2010). Making virtual walking real: Perceptual evaluation of a new treadmill control algorithm. ACM Transactions on Applied Perception (TAP), 7(2), 1-14.
[2] Matviienko, A., Müller, F., Schmitz, M., Fendrich, M., & Mühlhäuser, M. (2022, April). Skyport: Investigating 3d teleportation methods in virtual environments. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (pp. 1-11).
[3] Pausch, R., Burnette, T., Brockway, D., & Weiblen, M. E. (1995, September). Navigation and locomotion in virtual worlds via flight into hand-held miniatures. In Proceedings of the 22nd annual conference on Computer graphics and interactive techniques (pp. 399-400).
[4] Hedlund, M., Lundström, A., Bogdan, C., & Matviienko, A. (2023, December). Jogging-in-Place: Exploring Body-Steering Methods for Jogging in Virtual Environments. In Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia (pp. 377-385).

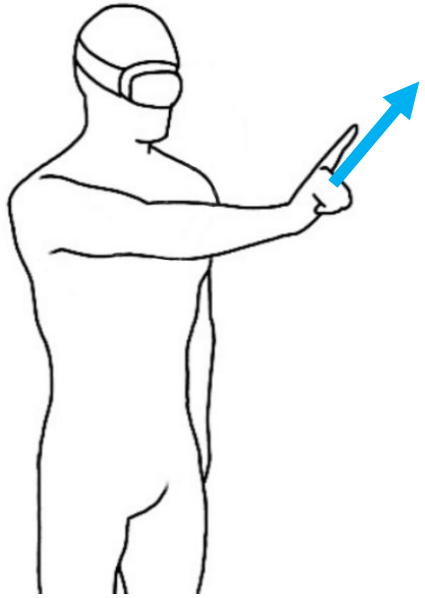
Motivation

Single input modality's limitations



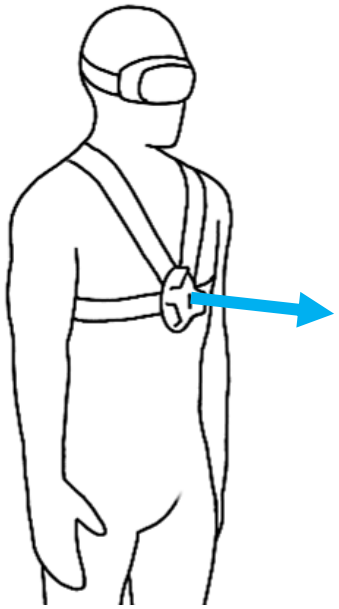
Gaze

Midas touch



Hand

Conflicting with
other hand interaction

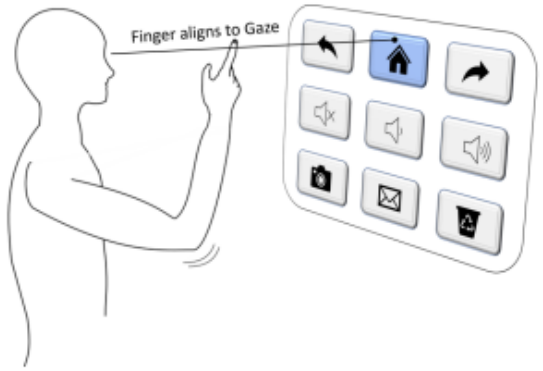
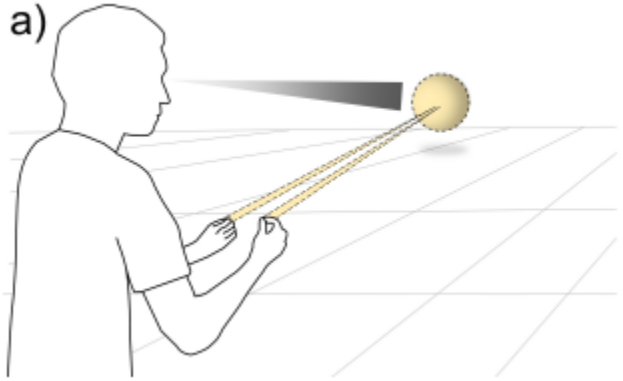


Torso

High level of
physical demand

Motivation

Combine gaze and hand interaction

Selection	Manipulation	Navigation
 Gaze&Finger [5]	 Gaze + Pinch [6]	?

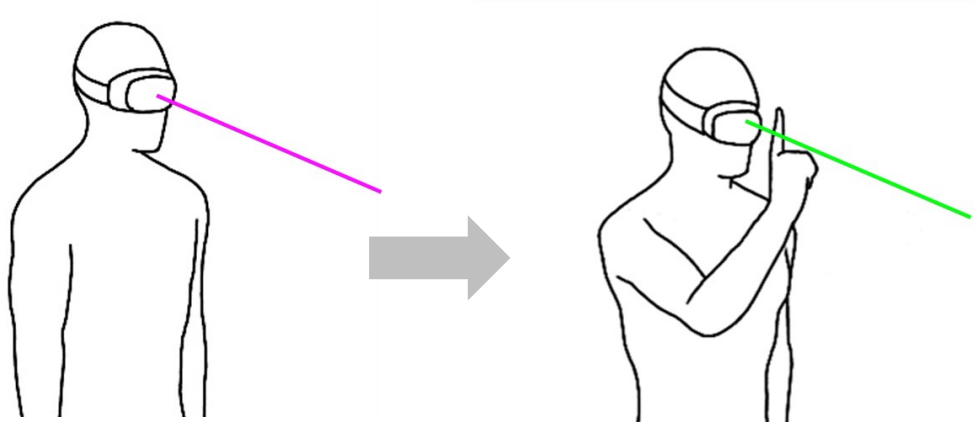
We designed a novel navigation technique named RayHand that combines gaze ray and hand interactions.

[5] Wagner, U., Lystbæk, M. N., Manakhov, P., Grønbæk, J. E. S., Pfeuffer, K., & Gellersen, H. (2023, April). A fitts' law study of gaze-hand alignment for selection in 3d user interfaces. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (pp. 1-15)
[6] Pfeuffer, K., Mayer, B., Mardanbegi, D., & Gellersen, H. (2017, October). Gaze+ pinch interaction in virtual reality. In Proceedings of the 5th symposium on spatial user interaction (pp. 99-108).

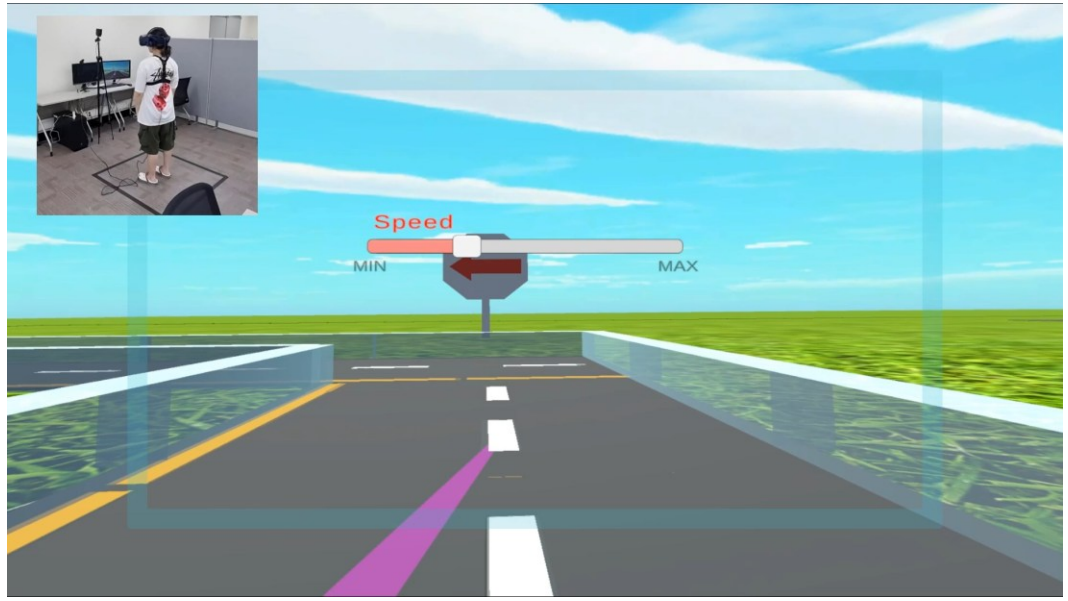
RayHand navigation

Navigation start

- The gaze-ray: initial direction of the navigation
- **Placing a hand on the gaze-ray → Navigation starts**
- The gaze loses the control of the gaze ray & hand takes the control of it
  : decoupling the navigation and looking-around activities



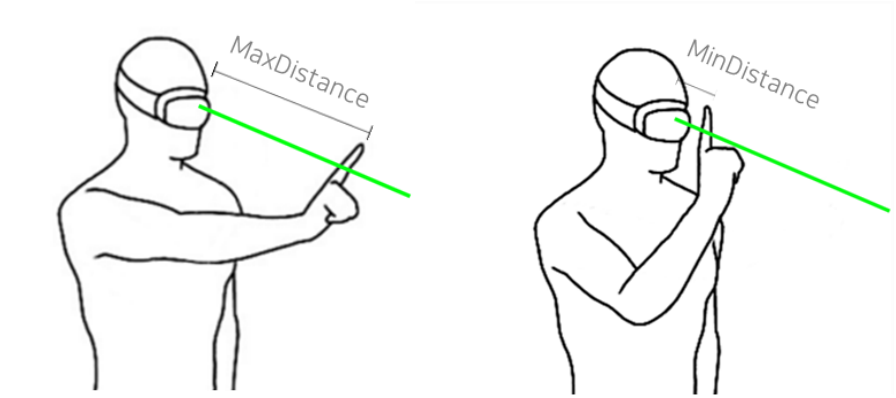
Navigation start



RayHand navigation

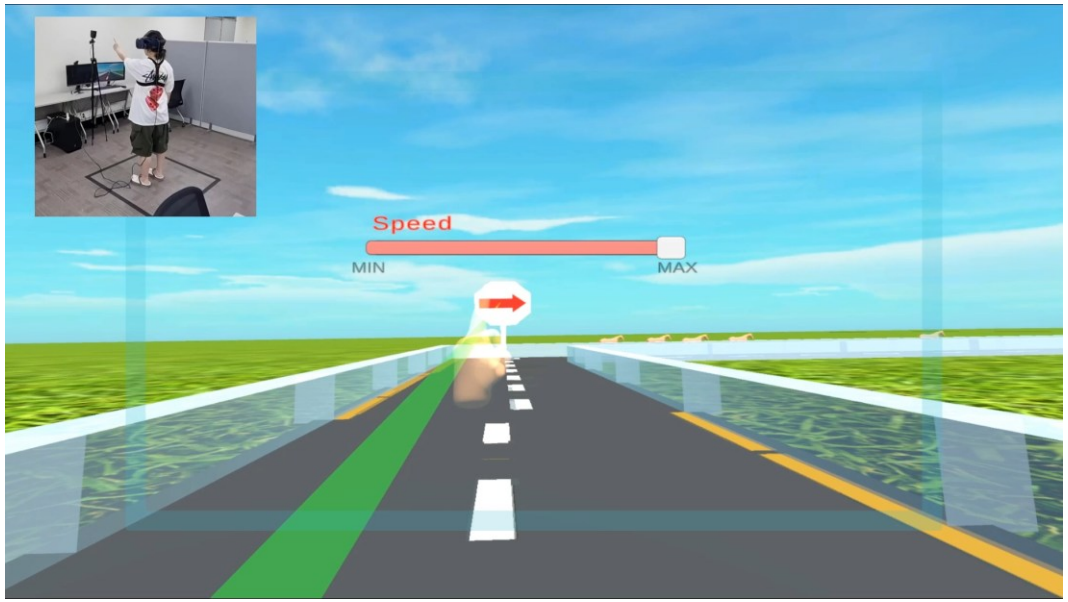
Speed

- The translation speed is determined by the **distance between the hand and head**
- **Move hand forward → faster**
- **Move hand backward → slower**



$$d = \frac{(CurrentDistance - MinDistance)}{(MaxDistance - MinDistance)}$$

$$speed = maxspeed \times d + minspeed \times (1 - d)$$

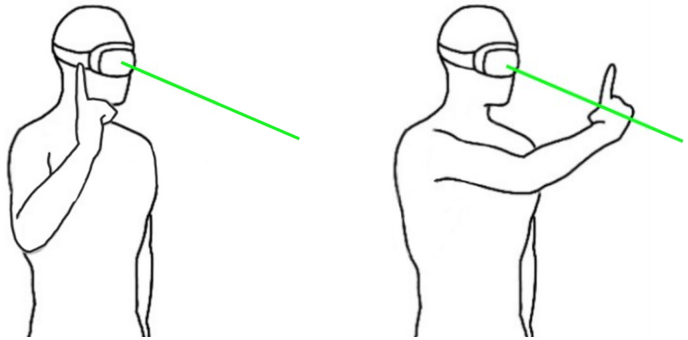


RayHand navigation

Direction

- The direction is changed by **the hand's relative position to the ray**
- **Move the hand left relative to the ray → turn left**
- **Move the hand right relative to the ray → turn right**

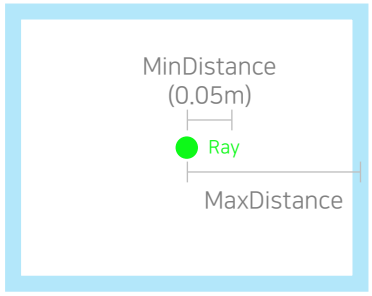
Direction



Turn right

Turn left

Rotation speed



Hand tracking Area

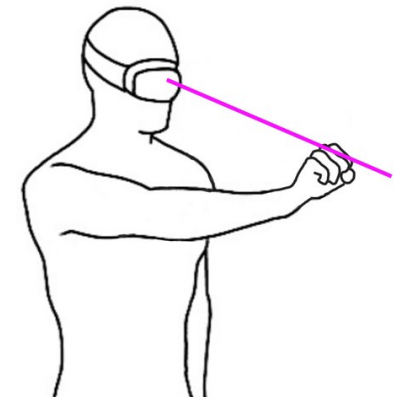
$$d = \frac{(CurrentDistance - MinDistance)}{(MaxDistance - MinDistance)}$$

$$speed = maxspeed \times d + minspeed \times (1 - d)$$

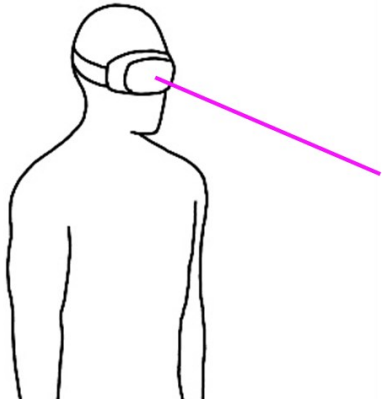
RayHand navigation

Navigation stop

- **Fist gesture or simply holding down the hand → Navigation stops**
- The gaze ray is updated by the eye again



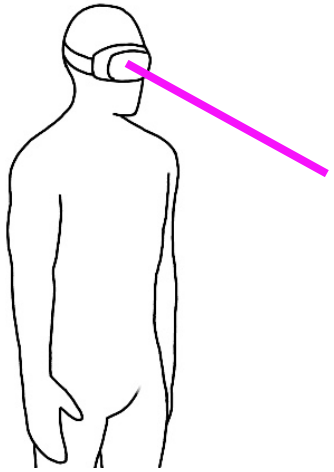
Fist gesture



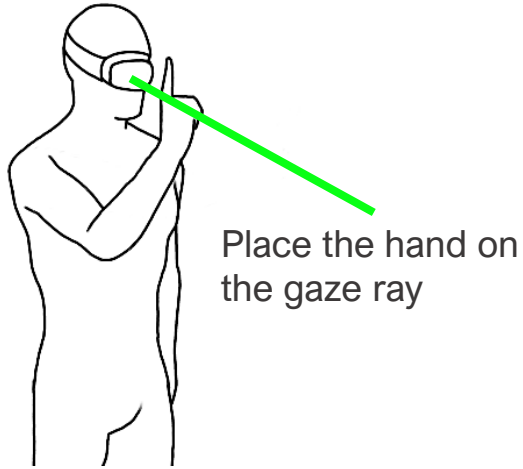
Hold down
the hand

RayHand navigation

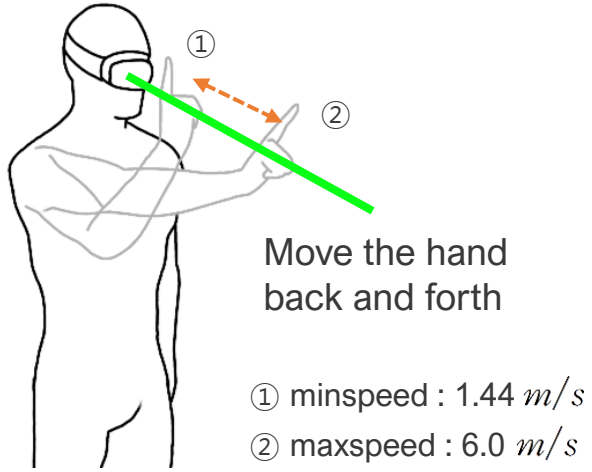
- Resolves the Midas touch issue (decoupling looking-around and navigation activities)
- No additional input device is required
- Support control of the speed and direction



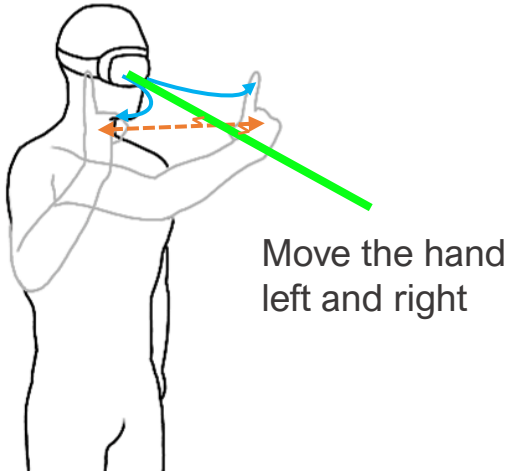
Stop (navigation)



Start (navigation)



Speed control



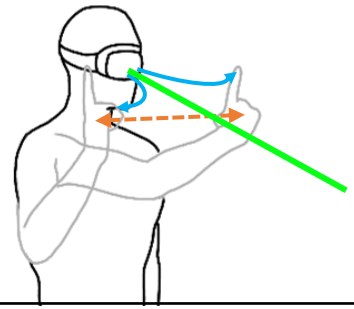
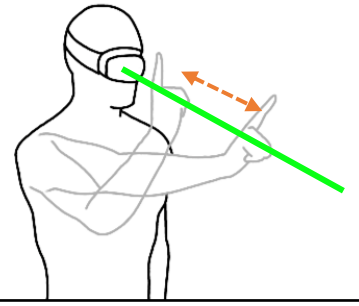
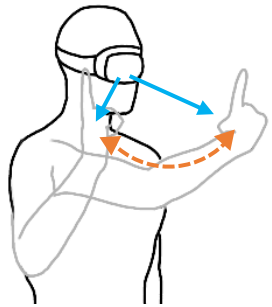
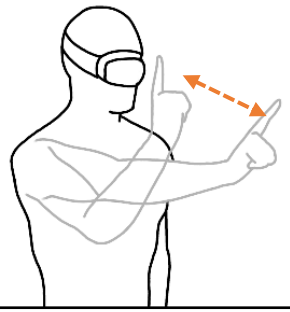
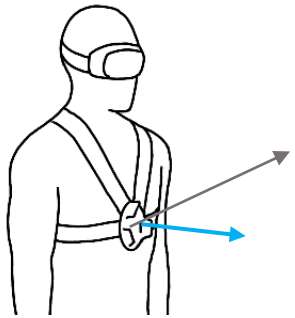
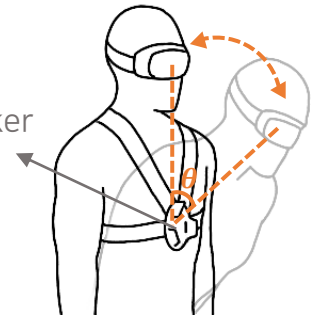
Direction control

User study

Condition

Multi-modalities

Single modality

Condition \ Control	Translation Direction	Translation Speed
RayHand Gaze + Hand		
Head - Hand Only Hand		
Torso - Leaning Only Torso		

User study

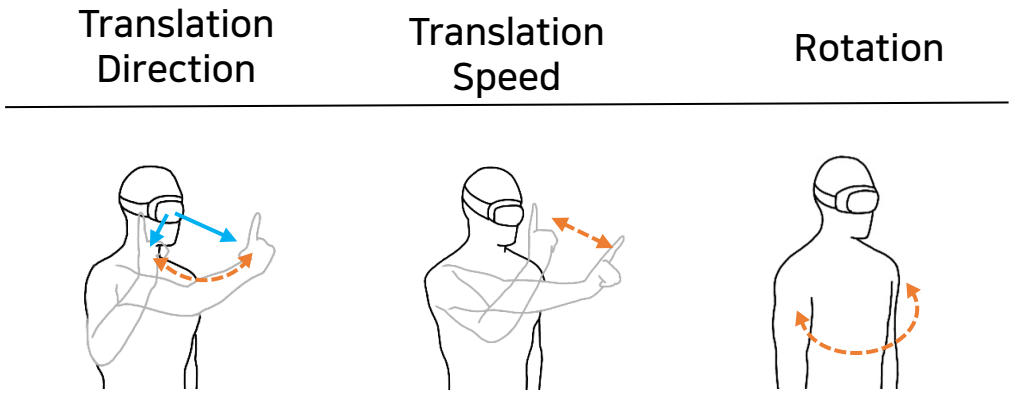
Condition: head-hand

Only Hand

- Translation direction: head-to-hand direction
- Translation speed: distance between the hand and head
- Rotation: physical body turning

$$d = \frac{(CurrentDistance - MinDistance)}{(MaxDistance - MinDistance)}$$

$$speed = maxspeed \times d + minspeed \times (1 - d)$$



User study

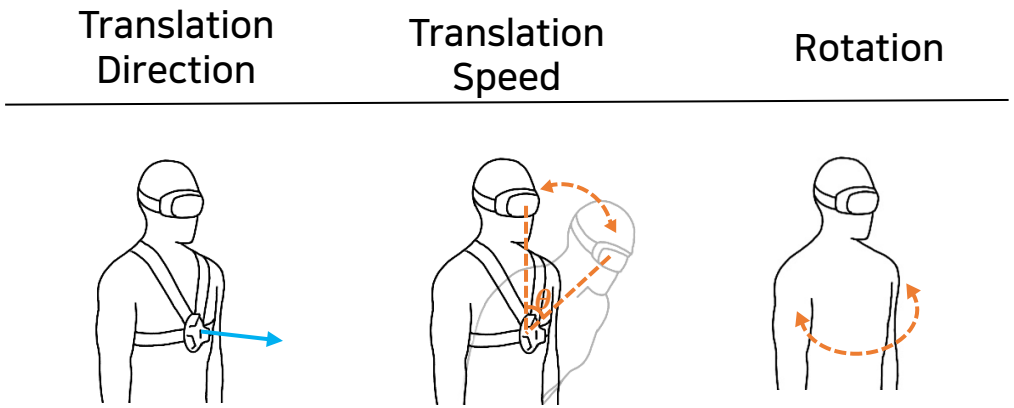
Condition: torso-leaning

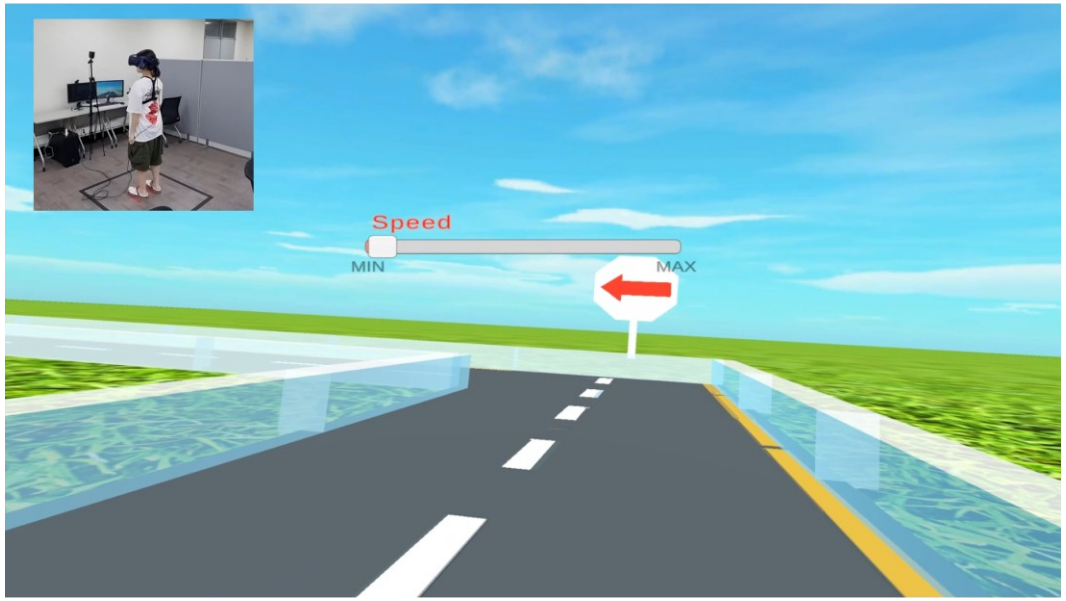
Only Torso

- Translation direction: torso-facing direction
- Translation speed: leaning level
- Rotation: physical body turning

$$d = \frac{(CurrentDegree - MinDegree)}{(\max Degree - MinDegree)}$$

$$speed = maxspeed \times d + minspeed \times (1 - d)$$

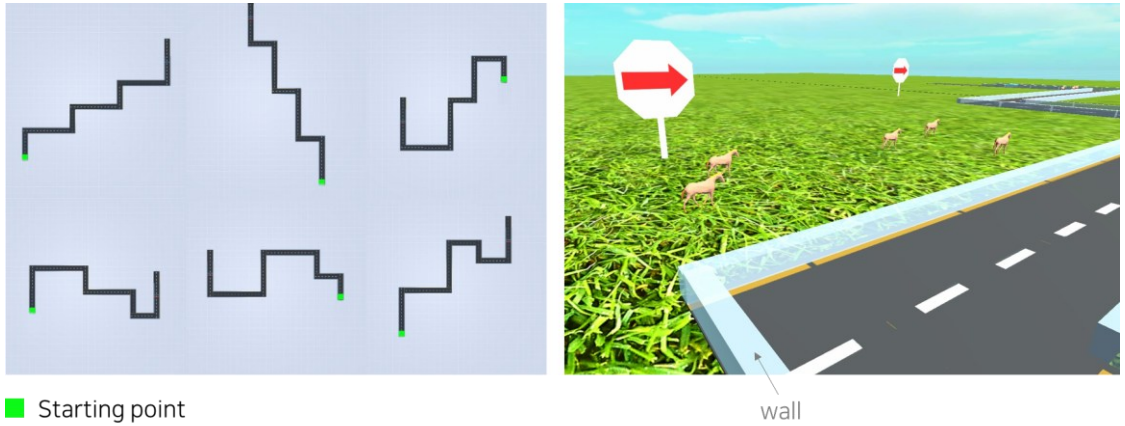




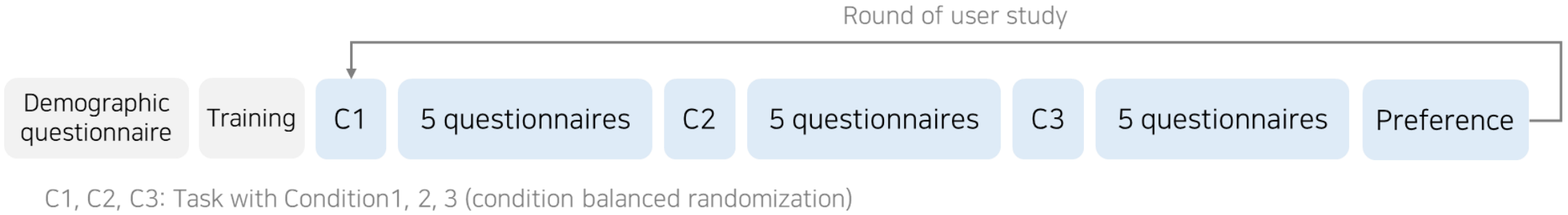
User study

Task

- Navigating to the destination **without bumping into the walls** while **counting horses** on the field



- Within-subject and repeated measures design
- 27 participants (17 female and 10 male)



Measures

- Objective measure
  - Total navigation time
  - Total distance
  - Average speed
  - The sum of head rotation and position change
  - The number of times bumping into the wall
  - Incorrect horse counting

- Subjective measure
  - Mental effort: Subjective mental effort questionnaire (SMEQ)
  - Task load: NASA Task Load Index (NASA-TLX)
  - Usability: System Usability Scale (SUS)
  - Simulator sickness: Simulator Sickness Questionnaire (SSQ)
  - User experience: short version of User Experience Questionnaire (UEQ-S)

Results

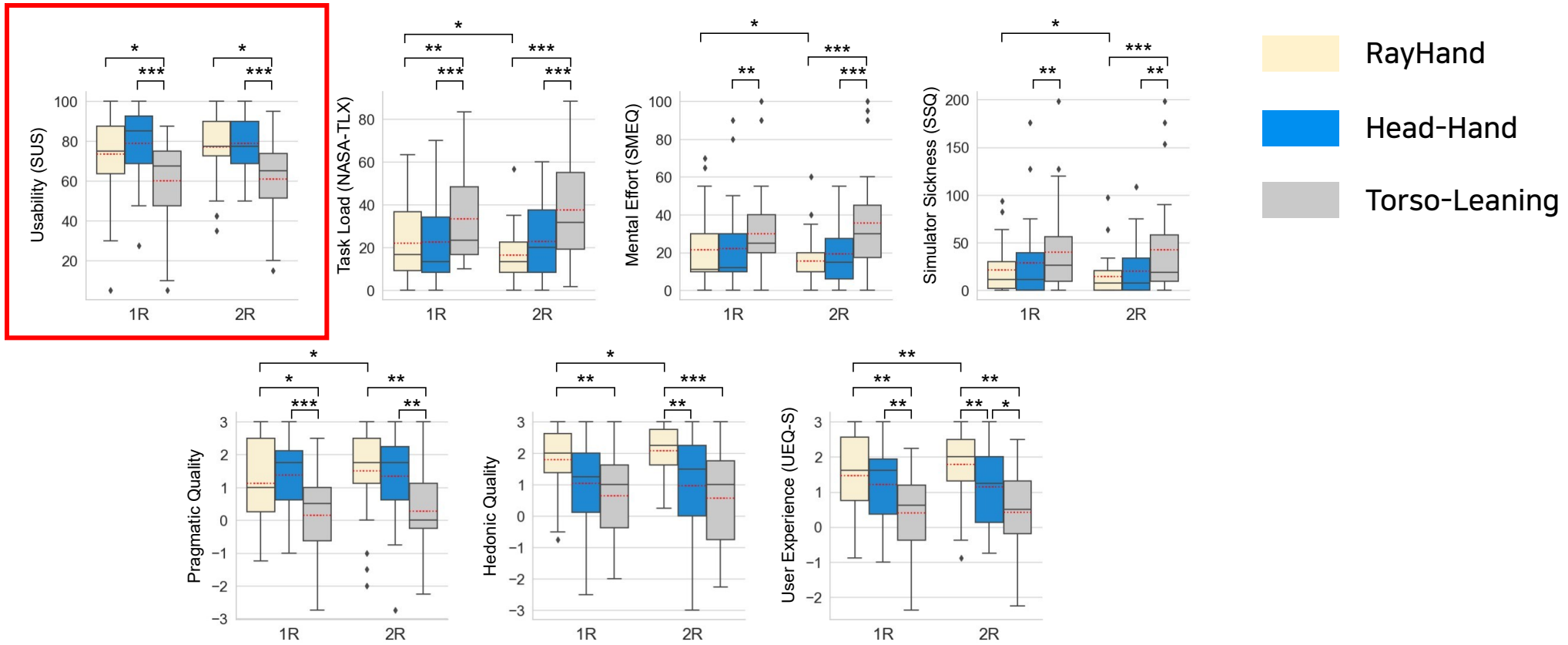
Subjective measures

- **Three navigations** have **'okay' or higher** levels in **usability.**
- The **RayHand and head-hand** navigations were **better** than the torso-leaning navigation in **usability, task load, mental effort, simulator sickness, and user experience measurements**.

1R
RayHand: Good (73.43)
Head-Hand: Good (78.89)
Torso-Leaning: Okay (60.09)

2R
RayHand: Good (76.94)
Head-Hand: Good(78.70)
Torso-Leaning: Okay (60.93)

Bangor's adjective scale of usability



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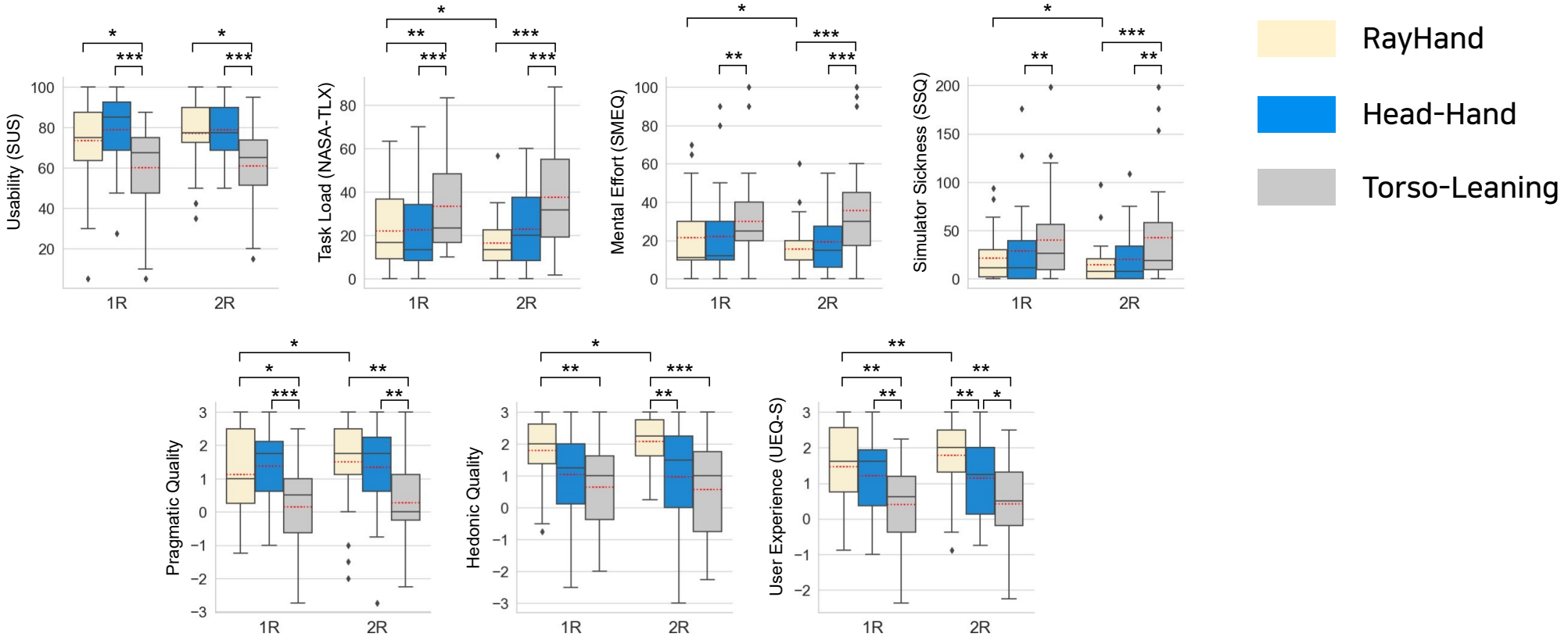
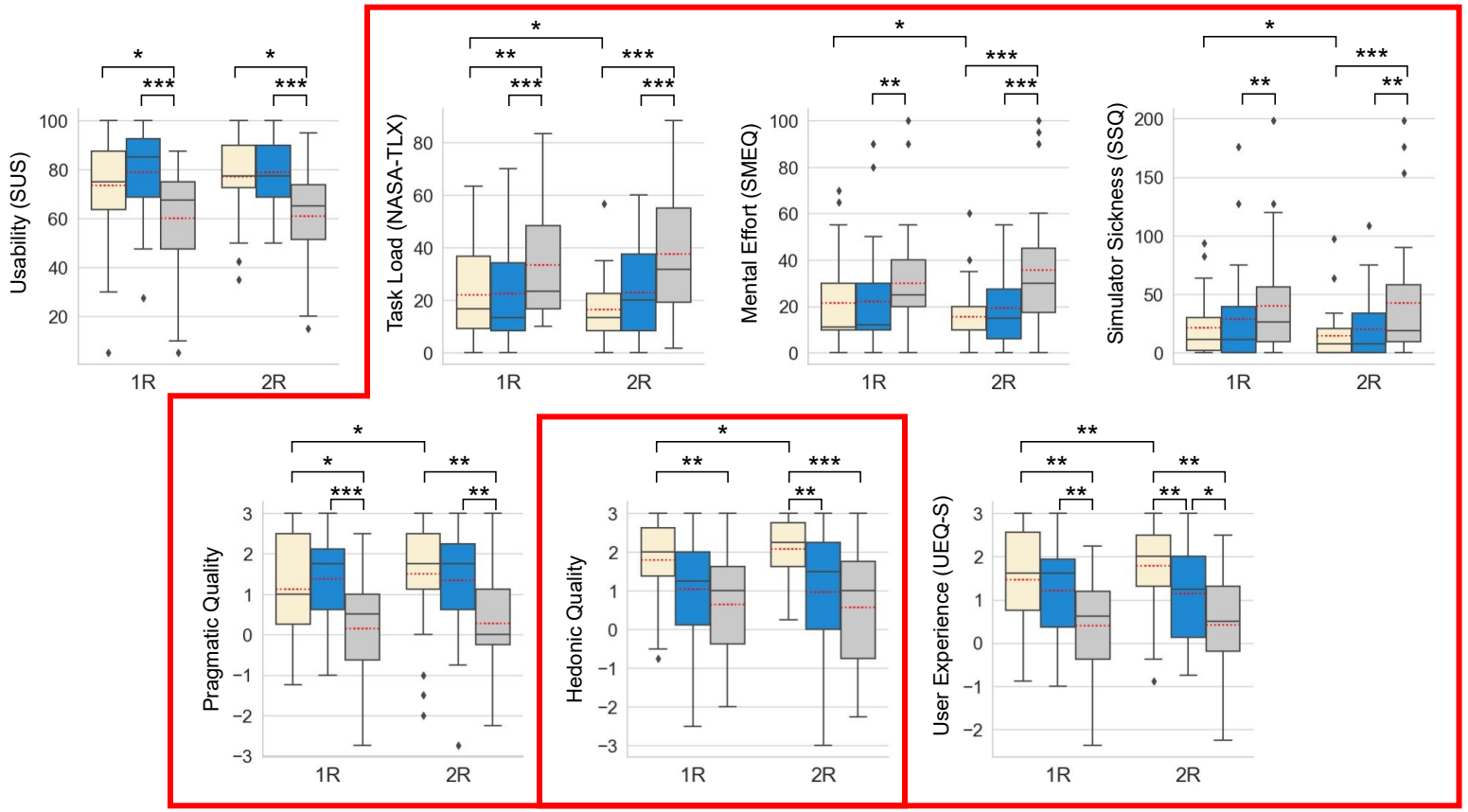


Results

Subjective measures

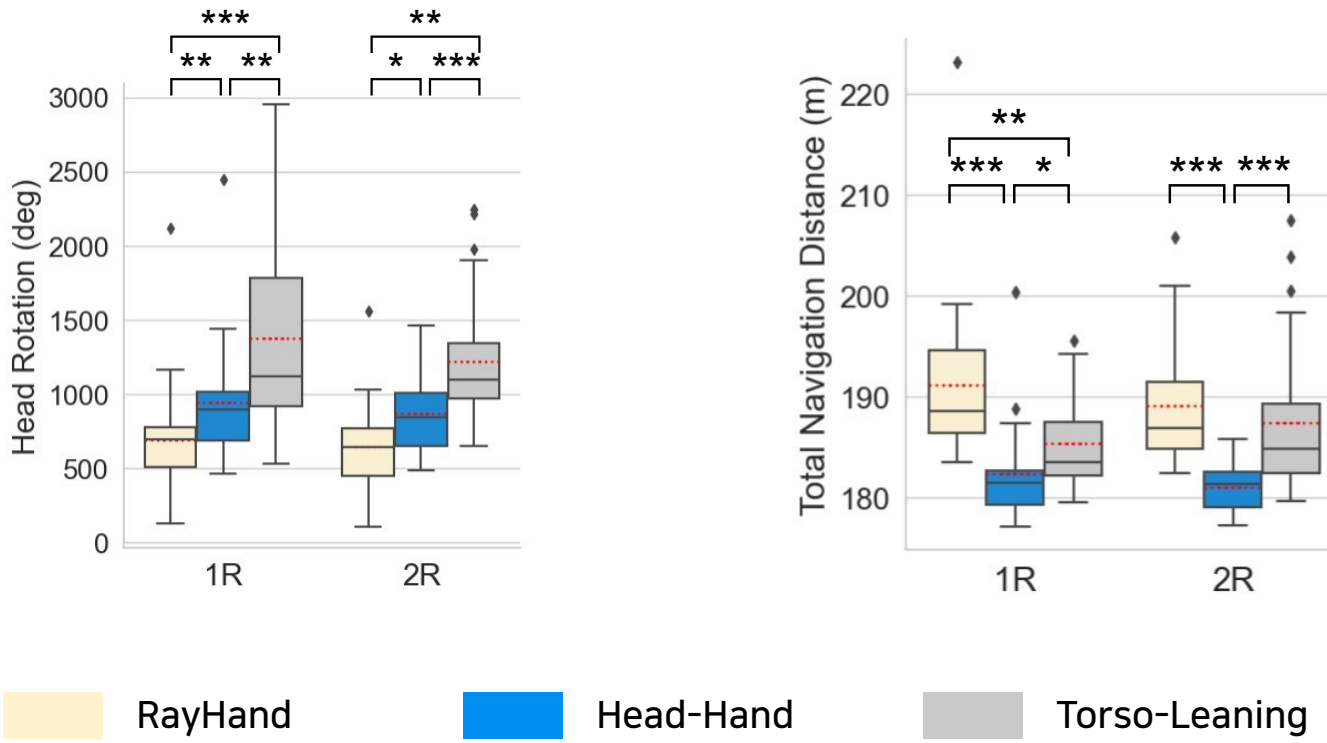
- The **RayHand** navigation supported **higher hedonic** quality
- The **RayHand** navigation showed **learning effect** in all subjective measures except the usability



Results

Objective measures

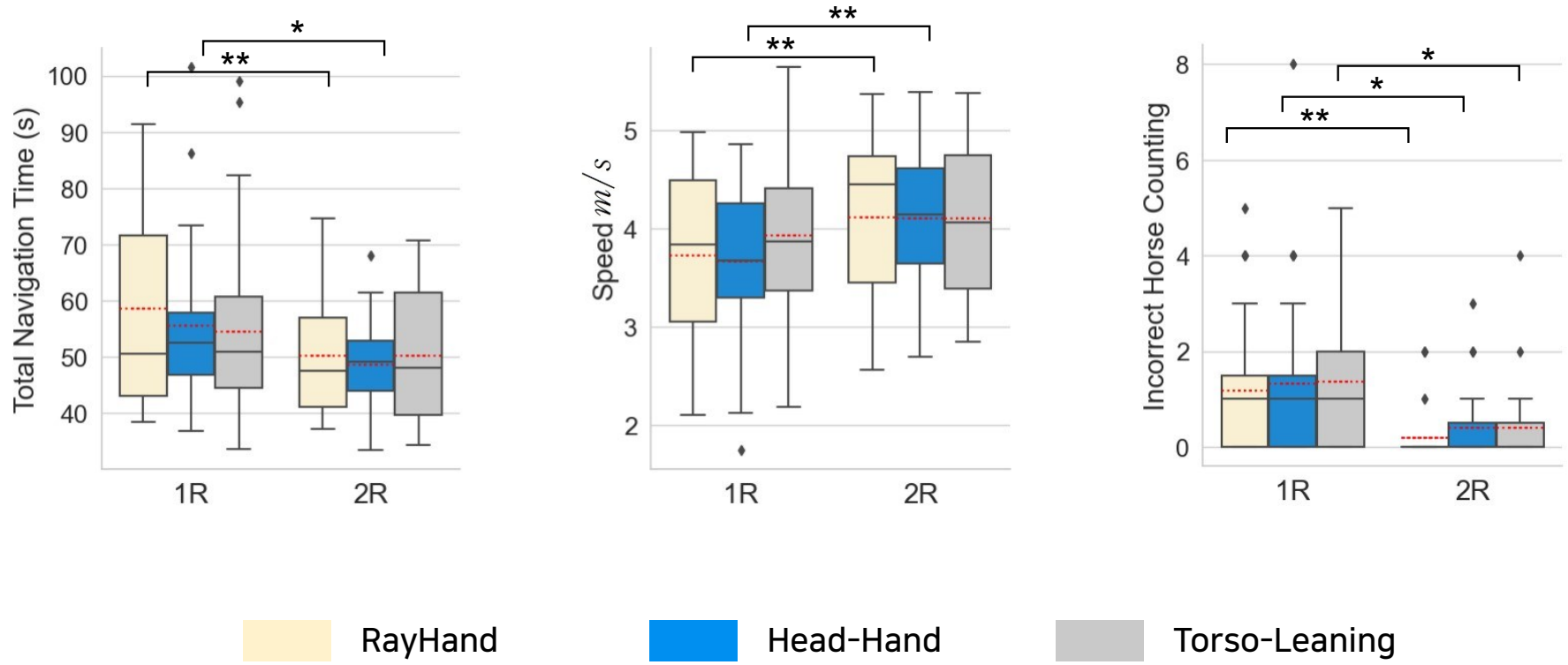
- The **RayHand** navigation had significantly **less head rotation**
- The **head-hand** navigation had significantly **less total navigation distance.**



Results

Objective measures

- **No significant difference among the three** conditions in **total navigation time, speed, and incorrect horse counting**.



Results

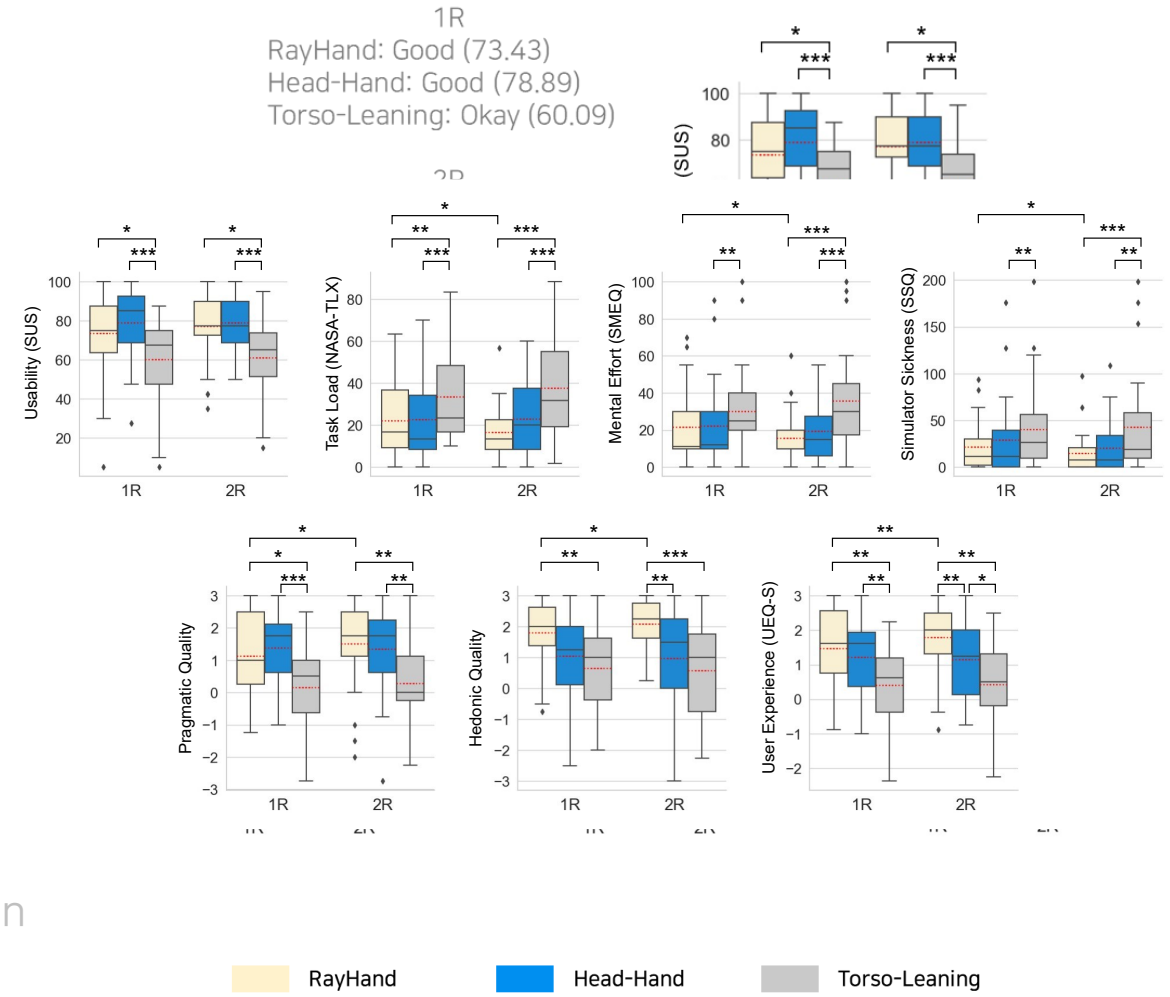
Observation

- **RayHand** navigation required **less amount of body movement** → stay inside of the area

Designated interaction area

Key findings and discussion

- **All three navigations** supported **positive user experience**
- The **RayHand and head-hand navigations served better user experience** compared to the torso-leaning navigation.
- Benefit of RayHand navigation:
  - stay inside of the small area & lower simulator sickness
  - high hedonic quality
- The **RayHand navigation showed a significant learning effect** in mental effort, task load, simulator sickness and user experience.



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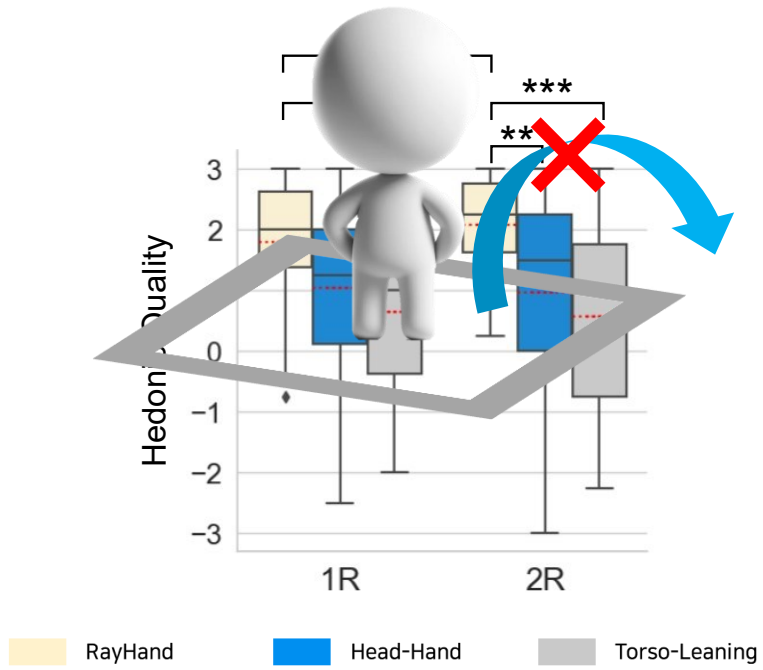

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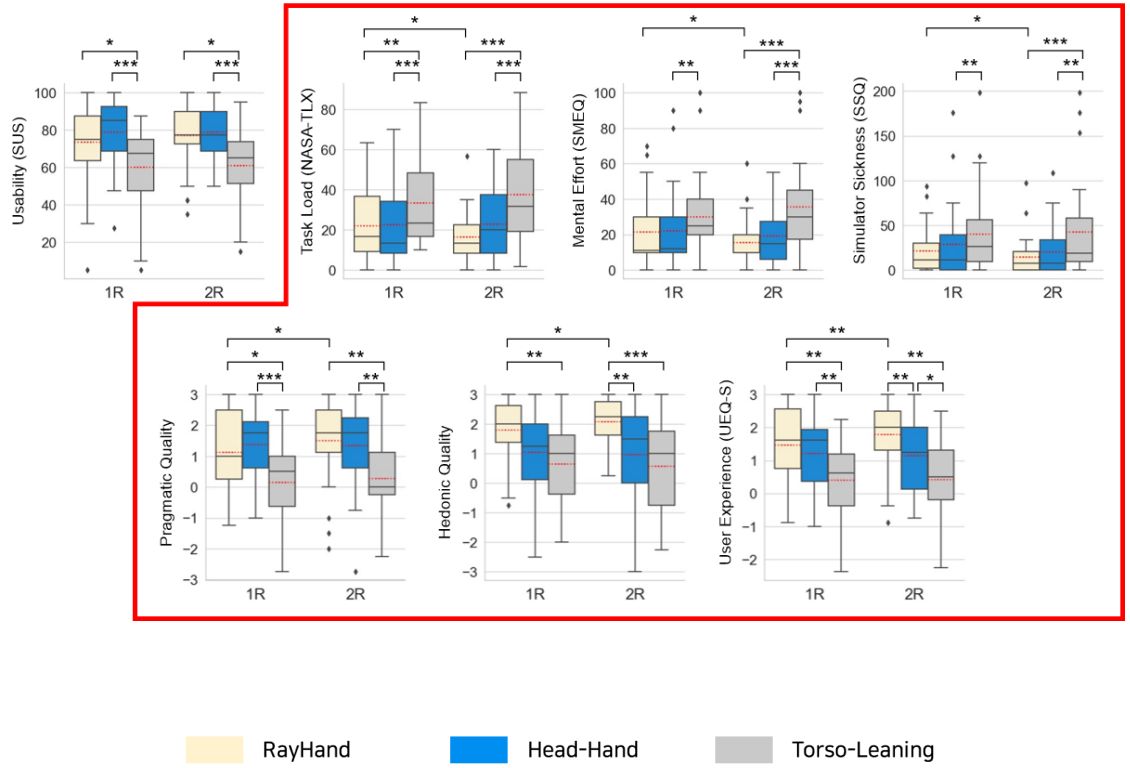

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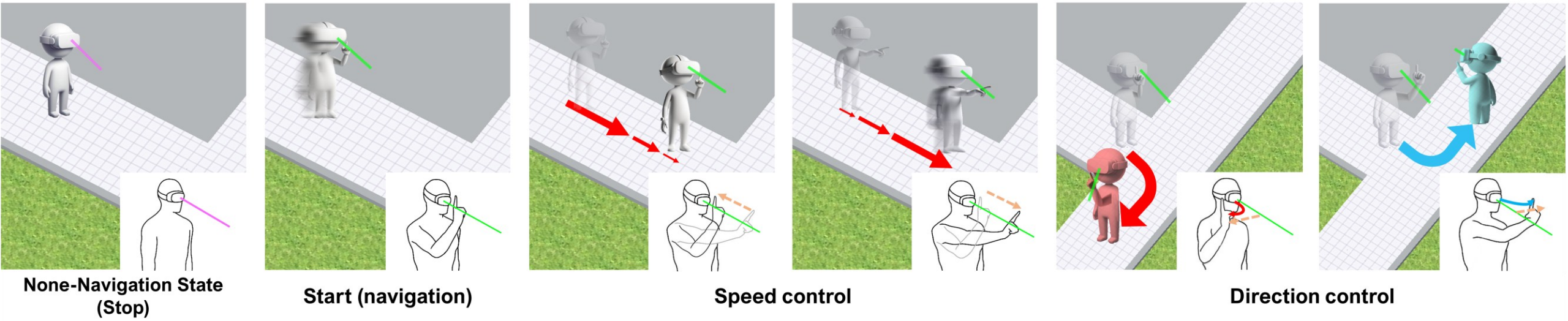

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Website: https://sites.google.com/view/arvrlab/home

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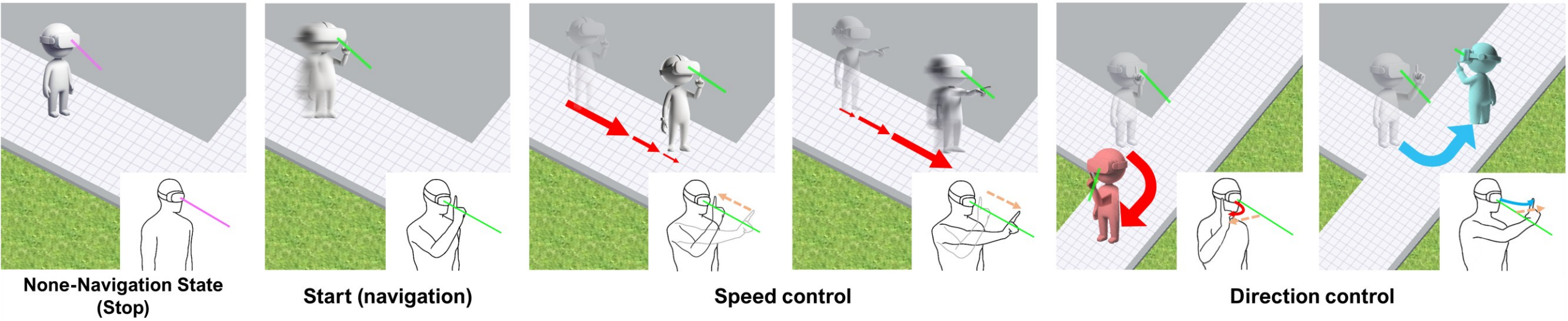

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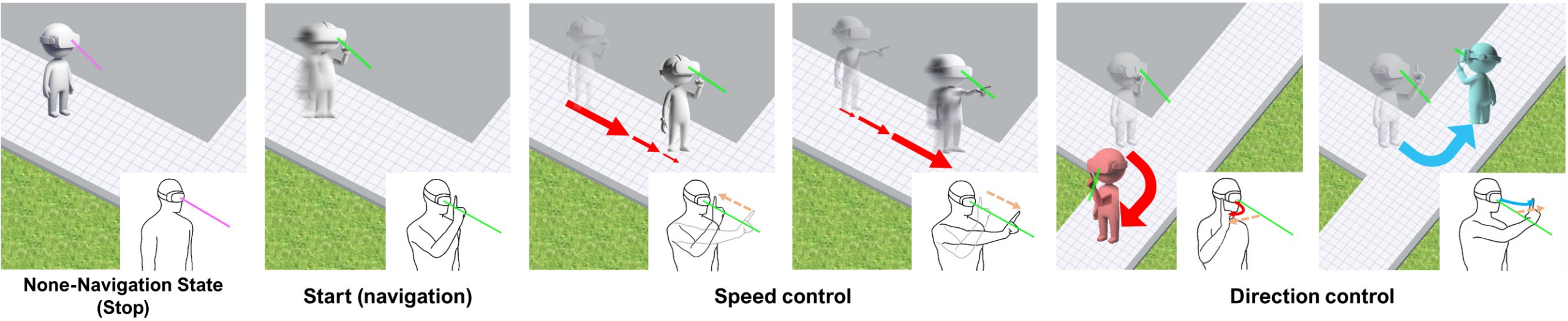

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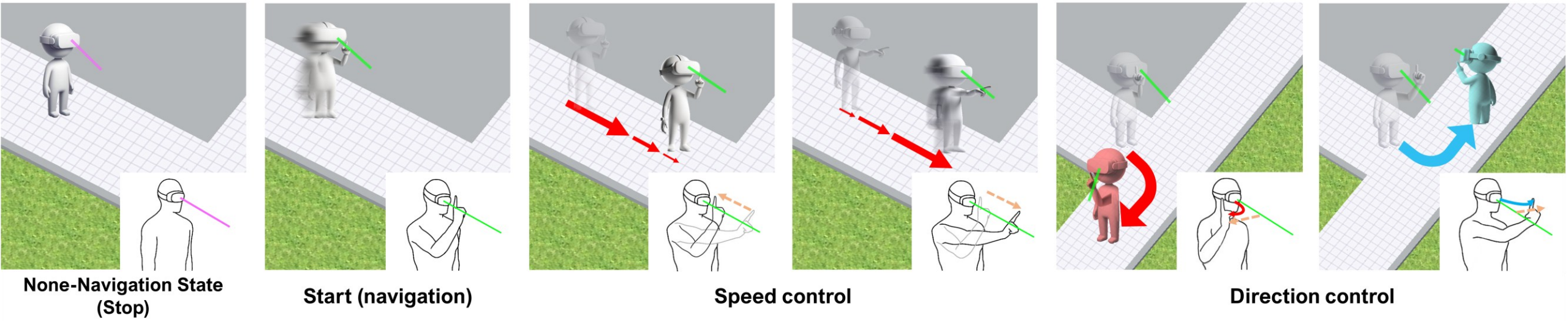

The RayHand Navigation:

A Virtual Navigation Method with Relative Position between Hand and Gaze-Ray

Website: https://sites.google.com/view/arvrlab/home

CHI 2024
Surfing the World

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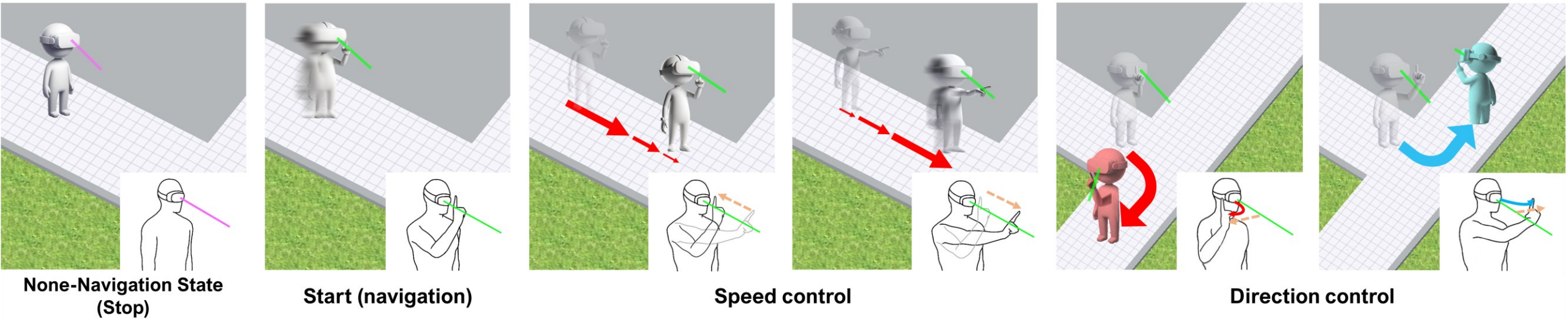

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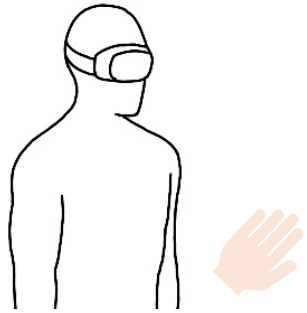
RayHand Potential – support other interaction

1) RayHand: on/off mechanism

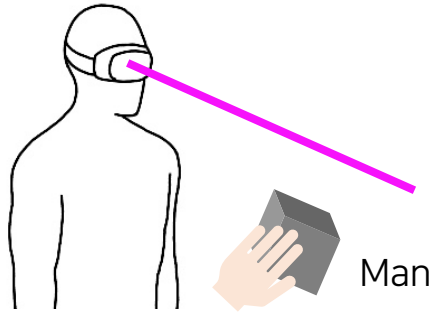
Raise the hand



Navigation start

Head-Hand (on/off X)

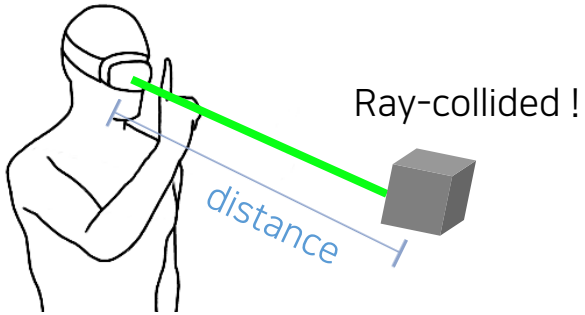
Raise the hand & the hand is not on the ray …



Manipulate !

RayHand (on/off O)

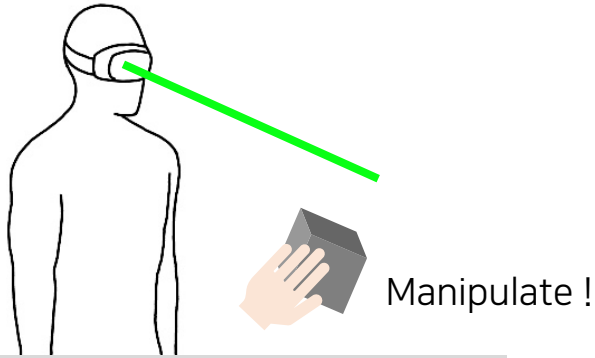
2) calculate the distance between the user and object (collided by the ray) → adaptive speed control



Navigating

Adaptive speed

If, distance is less than an arm's length …



Manipulate !

Slow down or stop

Designated interaction area

- minimum area for interacting without colliding with surrounding objects
- All three navigation use leaning (torso) and arm (hand) → smaller than 1m

About 0.88m [7]

Torso-leaning

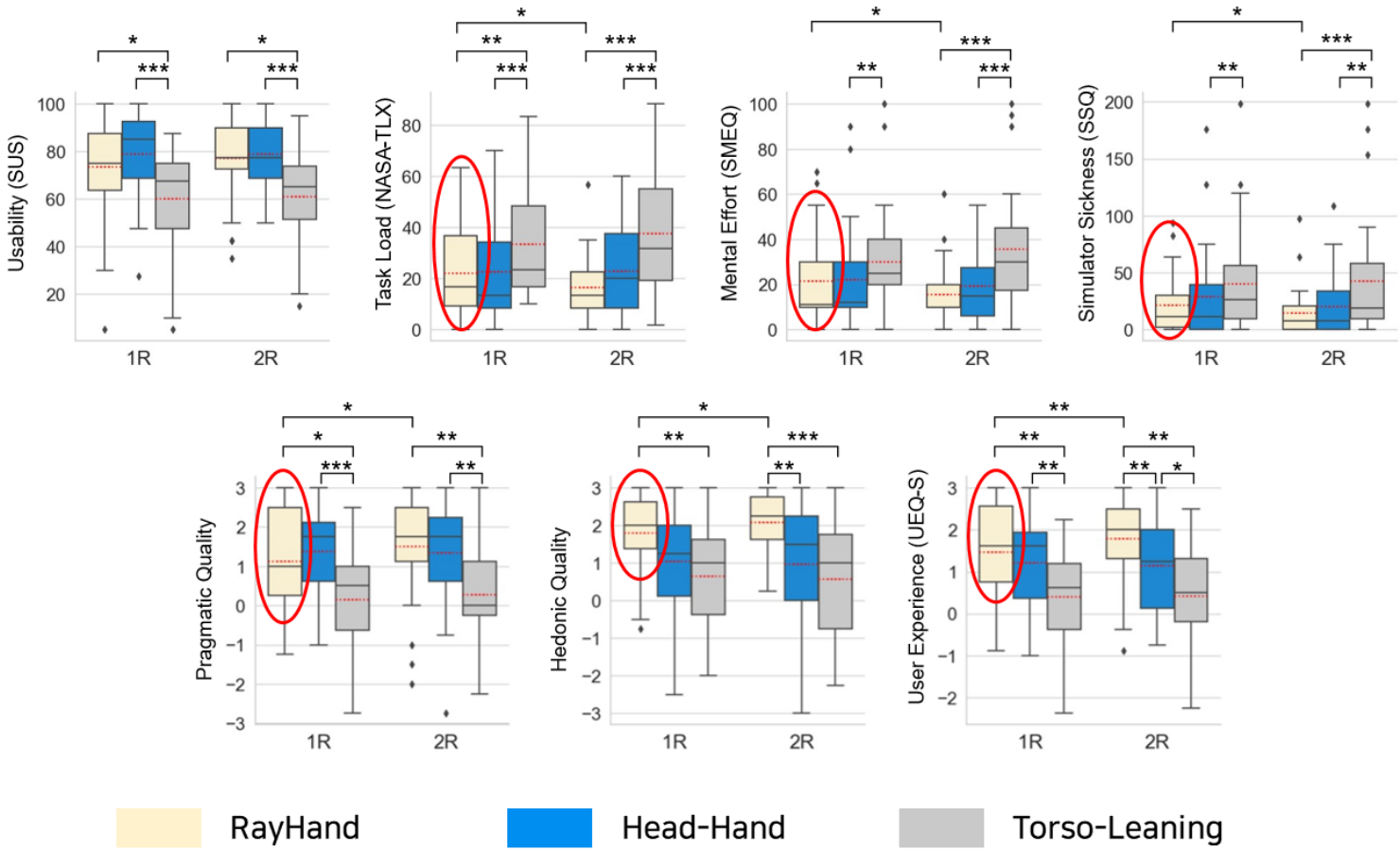
About 0.78m [7]

RayHand
Head-hand

[7] C. C. Gordon, C. L. Blackwell, B. Bradtmiller, J. L. Parham, P. Barrientos, S. P. Paquette, B. D. Corner, J. M. Carson, J. C. Venezia, B. M. Rockwell, M. Mucher, and S. Kristensen, "2012 Anthropometric survey of U.S. army personnel: Methods and summary statistics," U.S. Army Natic Soldier Res., Develop. Eng. Center, Natick, MA, USA, Tech. Rep., 2014, p. 240. [Online]. Available: https://apps.dtic.mil/sti/citations/ADA611869

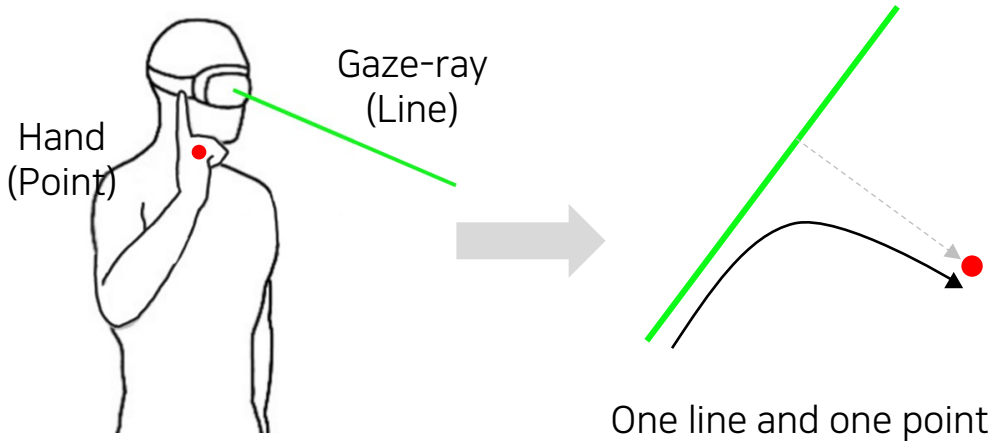
Learning Effect – always good?

- RayHand did not show a lower user experience in first round.

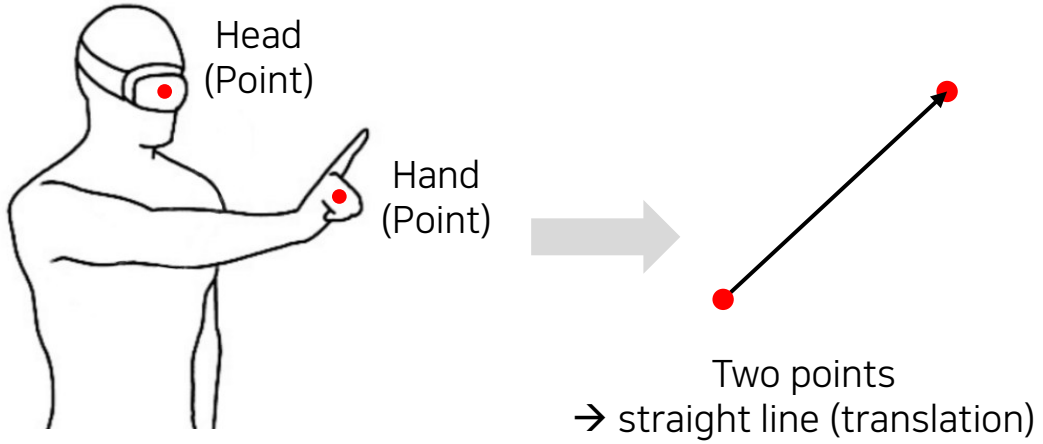


Head-Hand: rotation by hand?

- RayHand : gaze-ray (line) & hand (point)
- Head-hand: head (point) & hand (point)



RayHand



Head-Hand