# Bare-Hand Continuous VR Locomotion Using Beyond-FOV, Around-HMD Unimanual Gestures

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## Motivation

**Continuous locomotion control in bare-hands VR remains challenging in seated and space-constrained environments and in accessibility-oriented scenarios**

Modern VR enables natural, controller-free hand interaction with virtual objects using HMD-mounted cameras. However, controller-free VR locomotion is remains challenging for users who are:

- *seated, reclined, or lying in bed*
- *limited by available space,*
- *unable to use lower-limb movement due to accessibility needs.*

Most controller-free methods avoiding lower-body movement use:

- *gaze or head-directed navigation*
- *arm swinging*
- *within field-of-view (FOV) hand gestures*

These approaches have several key limitations:

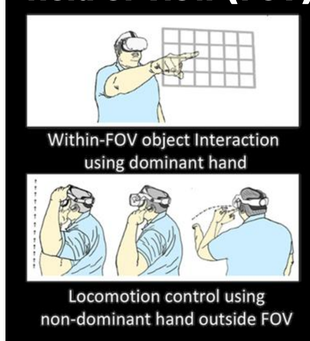
- *interference between locomotion control & object interaction*
- *visual occlusion of virtual objects inside the HMD viewport,*
- *increased physical fatigue,*
- *reduced support for simultaneous object interaction & locomotion*

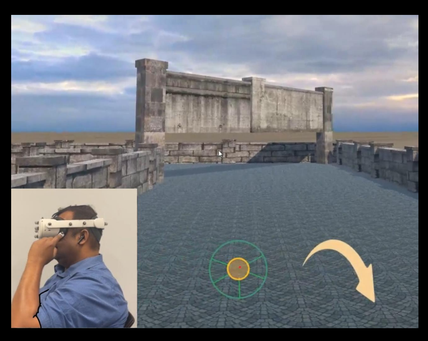
## Research Gap

A posture-flexible, space-efficient bare-hand locomotion technique enabling simultaneous navigation & object interaction without lower-limb movement while preserving natural head and gaze-driven look-around behavior.

## Core Idea

**Locomotion control using one-handed gestures around VR head-mounted display (HMD) outside field of view (FOV)**



We present **Beyond-FOV locomotion**, a bare-handed continuous VR locomotion technique that leverages:

- *above-neck,*
- *around-HMD,*
- *unimanual (one-handed) gestures performed outside the FOV*

Rather than placing bare-hand locomotion controls within the visible interaction space, **Beyond-FOV positions locomotion input around the headset using the non-dominant hand.**

Our design:

- *decouples locomotion from within-FOV object interaction,*
- *preserves the visual workspace,*
- *reduces gestural interference and viewport occlusion,*
- enables *simultaneous locomotion and manipulation without explicit mode switching.*

The dominant hand remains free to interact with virtual objects while locomotion occurs independently outside the visual workspace.

**Beyond-FOV Locomotion supports:**

- *directional movement, turning*
- *crouching, and jumping*

without requiring lower-limb movement, controller input, or direct contact with the HMD.

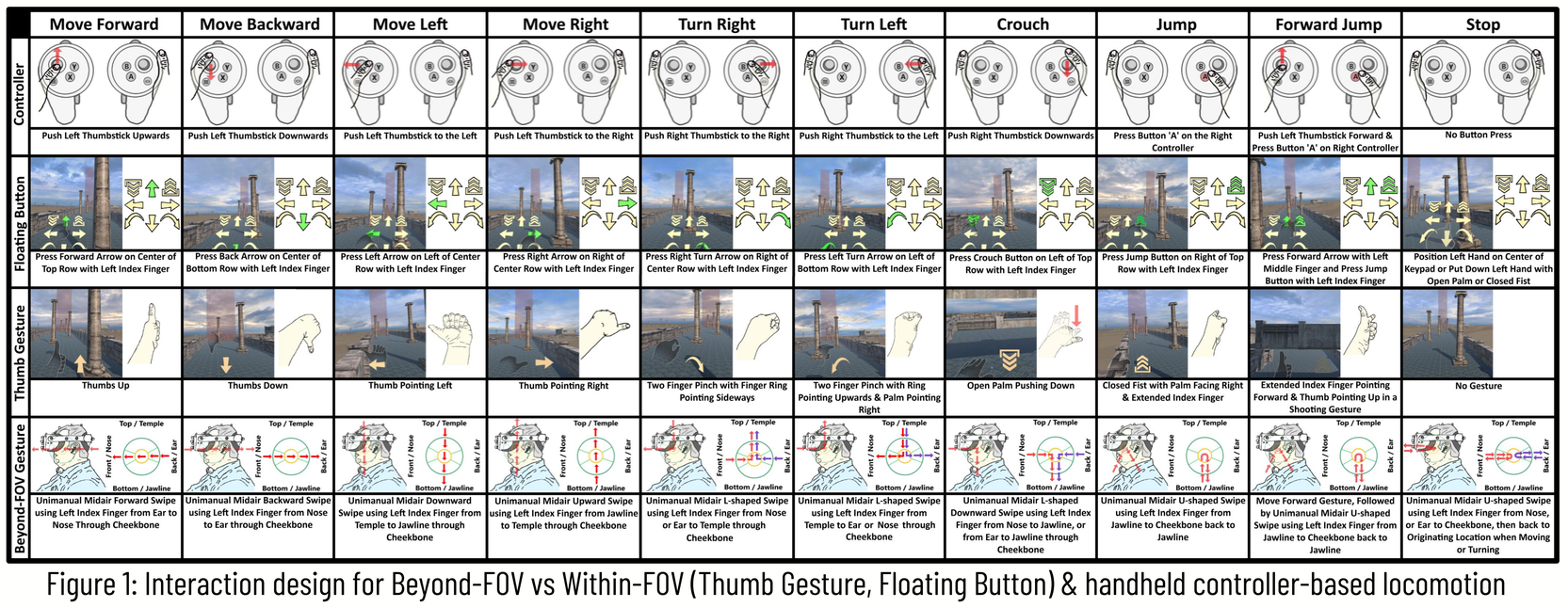



Figure 1: Interaction design for Beyond-FOV vs Within-FOV (Thumb Gesture, Floating Button) & handheld controller-based locomotion

## Research Question

How does Beyond-FOV Locomotion compare to within-FOV hand gesture-based non-controller techniques in bare-hands VR?

## Experiment Setup

### Apparatus & Environment

- *Meta Quest 2 HMD with Unity-based VR environment*
- *Vicon optical motion tracking for Beyond-FOV gesture tracking*
- *Participants seated on stationary, non-swiveling chairs*
- *Locomotion performed using controller, within-FOV manual input (Floating Button, Thumb Gesture), or Beyond-FOV gestures*

### Compared Locomotion Techniques

- Controller: *standard thumbstick locomotion baseline*
- Floating Button: *within-FOV virtual keypad interaction*
- Thumb Gesture: *within-FOV thumb orientation gestures*
- Beyond-FOV: *above-neck around-HMD unimanual gestures*

## Tasks

Participants completed progressively complex navigation tasks:

1. *Directional navigation*
2. *Navigation with turning, jumping, and crouching*
3. *Simultaneous locomotion and object interaction*

## Study Design

- Within-subjects study (N = 16)
- Latin-square counterbalancing
- Objective + subjective evaluation
- IRB Approved

## Measures

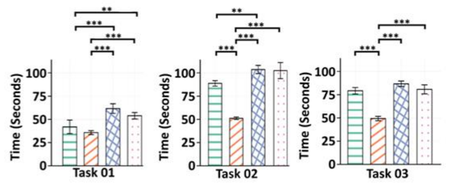
- Task Completion Time
- Nasa-TLX
- SUS
- DAQ
- SSQ
- Post-study qualitative feedback

## Results

Beyond-FOV (B) · Controller (C) · Floating Button (F) · Thumb Gesture (T)

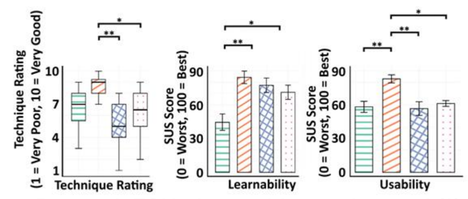
* : p < .050 , ** : p < .010, *** : p < .001

### Performance



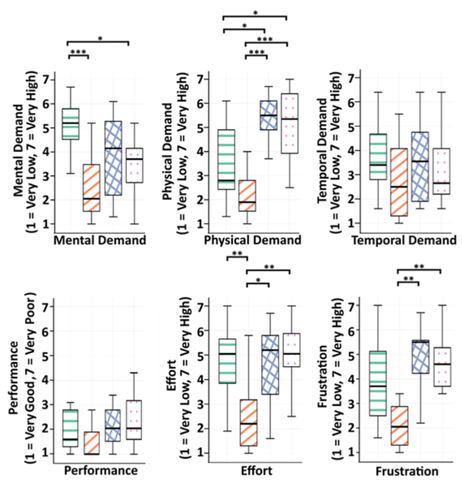

- Beyond-FOV faster than within-FOV for all tasks
- Closer to baseline (Controller)

### Technique Rating, Usability, Learnability



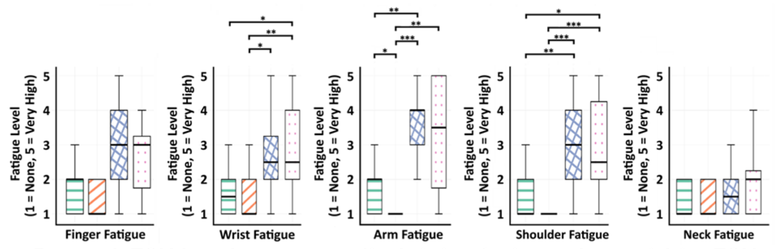

- Controller rated best, Beyond-FOV rated better than other within-FOV locomotion techniques
- Beyond-FOV showed lower learnability during onboarding
- Beyond-FOV achieved usability comparable to other bare-hand approaches after familiarization.

### Workload



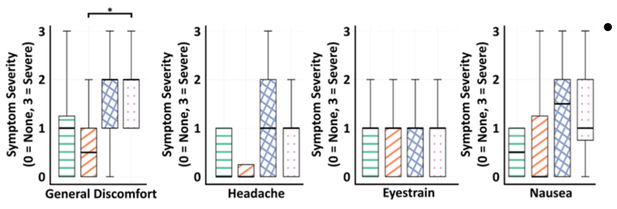

- Compared to within-FOV, Beyond-FOV reported
  - *Similar effort*
  - *Reduced frustration*
  - *Less physical demand*
  - *Better performance*
- But Beyond-FOV is more mentally demanding
  - *Additional cognitive effort for out of view interaction.*
  - *More practice to learn*

### Fatigue




- Beyond-FOV has less upper-limb joint fatigue than within-FOV

### Cybersickness / Comfort




- Beyond-FOV better or comparable to Within-FOV

## Takeaway

Beyond-FOV locomotion performs better than (or comparable to) within-FOV techniques while better supporting simultaneous navigation and object interaction, warranting further investigation.

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