Lean Into It

Exploring Leaning-Based Motion Cueing Interfaces for Virtual Reality Movement

Alexandra Kitson
Simon Fraser University
Surrey, BC, Canada
akitson@sfu.ca

Abraham M. Hashemian
Simon Fraser University
Surrey, BC, Canada
hashemia@sfu.ca

Ekaterina R. Stepanova
Simon Fraser University
Surrey, BC, Canada
erstepan@sfu.ca

Ernst Kruijff
Bonn-Rhein-Sieg University
Germany
ernst.kruijff@h-brs.de

Bernhard E. Riecke
Simon Fraser University
Surrey, BC, Canada
ber1@sfu.ca

Motivation

There is a need for **effective, easy to use, and low-cost locomotion interfaces** in virtual reality (VR).

User-powered motion cueing: small, physical motions indicating that there is motion without having to actually move the complete distance [1-3].

Motion cueing might help create a **convincing, simple, and relatively inexpensive locomotion interface**.

Recent developments in 3D navigation interfaces have begun to take advantage of this potential of incorporating **body-centric physical cues** [1,2,4-6].

Task

Search task: find five red spheres (**Figure 1: bottom**).

Spheres were placed approximately equidistant apart and the user started in the middle of the virtual environment (**Figure 1: top**).

Five interfaces (one joystick and four motion cueing interfaces) were tested by the user in random order.

Participants gave **talk-aloud feedback** while the experimenter transcribed their responses and behaviour on-the-fly.

After experiment: **open-ended interview** and **online questionnaire** to assess 12 aspects of user experience using 11-point Liket scale.

User Study and Analysis

Oculus Rift DK2 head-mounted display.

TrackIR 4: PRO tracking system: inexpensive optical motion tracking system to measure yaw and pitch about a central pivot point at each chair's base that controlled simulated self-motion.

XBox controller as Joystick.

Within-subjects design.

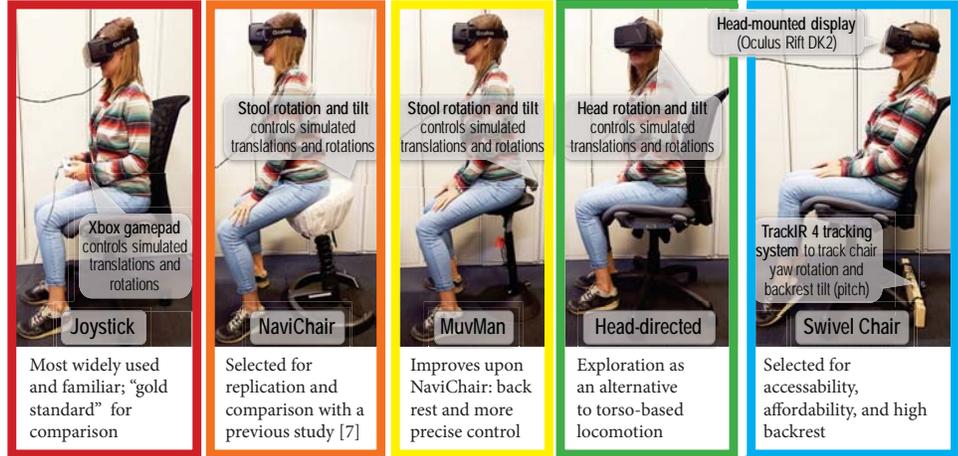16 student volunteers (6 female) mean age 26.7 years.

Qualitative analysis: two researchers open and axial coded interviews in NVivo to generate themes.

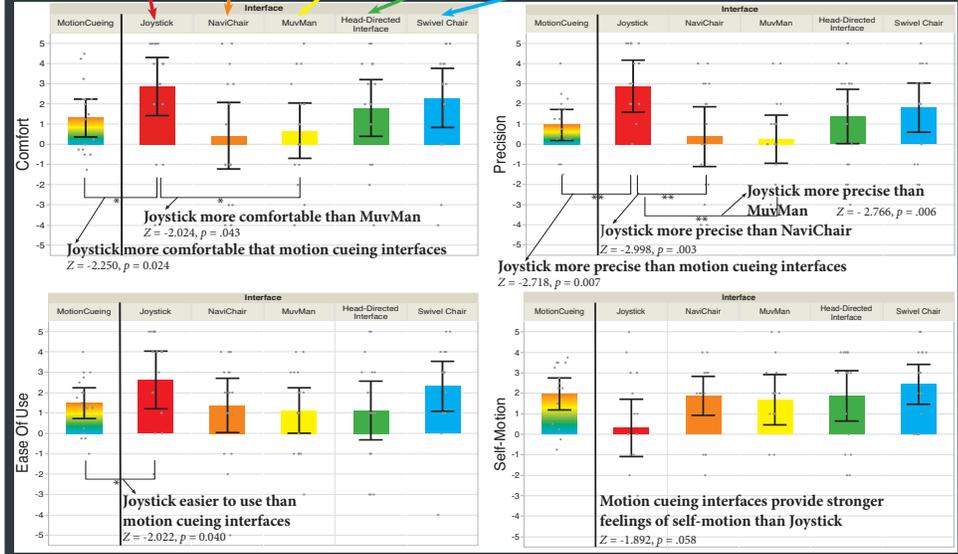**Quantitative analysis #1**: five interfaces against each other for each questionnaire item using Friedman test.

Quantitative analysis #2: Joystick against grouped motion cueing interfaces using repeated-measures Wilcoxom signed rank tests.

Figure 1. 19th Century Town built in Unity. Participants are tasked to find five red spheres using five different locomotion interfaces, one sphere for each interface. Left: top-down view where circles represent the sphere's locations and the X is the starting point.

Joystick — Xbox gamepad controls simulated translations and rotations — Most widely used and familiar; "gold standard" for comparison

NaviChair — Stool rotation and tilt controls simulated translations and rotations — Selected for replication and comparison with a previous study [7]

MuvMan — Stool rotation and tilt controls simulated translations and rotations — Improves upon NaviChair: back rest and more precise control

Head-directed — Head rotation and tilt controls simulated translations and rotations — Exploration as an alternative to torso-based locomotion

Swivel Chair — Head-mounted display (Oculus Rift DK2); TrackIR 4 tracking system to track chair yaw rotation and backrest tilt (pitch) — Selected for accessability, affordability, and high backrest

Quantitative Results

Comfort — Joystick more comfortable than MuvMan $Z = -2.024$, $p = .043$ — Joystick more comfortable that motion cueing interfaces $Z = -2.250$, $p = 0.024$

Precision — Joystick more precise than MuvMan $Z = -2.766$, $p = .006$ — Joystick more precise than NaviChair $Z = -2.998$, $p = .003$ — Joystick more precise than motion cueing interfaces $Z = -2.718$, $p = 0.007$

Ease Of Use — Joystick easier to use than motion cueing interfaces $Z = -2.022$, $p = 0.040$

Self-Motion — Motion cueing interfaces provide stronger feelings of self-motion than Joystick $Z = -1.892$, $p = .058$

Qualitative Results

Three broad categories emerged: **control, usability,** and **user experience**.

Control subcategories: controllability, rotation, looking and walking simultaneously, zero-point, speed and sensitivity, and backwards and strafe.

Usability subcategories: comparison to other interfaces, intuitiveness and naturalness, comfort and stability, familiarity, and physical attributes.

User Experience subcategories: dizziness, nausea, and motion sickness; experiential; VE.

Swivel Chair and Joystick were reported to have **high controllability, usability, and favourable user experience**; **MuvMan and NaviChair** had major issues with **controllability**; **Head-Directed** had an issue with **not** being able to **simultaneously look around and walk**.

Conclusions

Positive: comfort in interfaces with a **backrest**.

Negative: velocity-control for rotation **disorienting** and **motion sickness** inducing.

Promising: Motion cueing interfaces are **more fun** and **more natural** feeling than using a joystick.

Future design considerations: perceived safety and controllability.

Quantitative data: quick way of assessing interfaces.

Qualitative data: valuable in understanding **underlying issues**; allowed us to make **design guidelines** for future iterations.

References

[1] M. Marchal, et al., "Joyman: A human-scale joystick for navigating in virtual worlds," in Proceedings of IEEE Symposium on 3D User Interfaces, Washington, USA, 2011, pp. 19–26.
[2] A. Harris, et al., "Human Joystick: Wii-leaning to Translate in Large Virtual Environments," in VRCAI '14, NY, NY, USA, 2014, pp. 231–234.
[3] E. Kruijff, et al., "On Your Feet! Enhancing Self-Motion Perception in Leaning-Based Interfaces through Multisensory Stimuli," presented at the ACM Symposium on Spatial User Interaction (SUI '16), Tokyo, Japan, 2016, pp. 149–158.
[4] L. Lichtenstein, et al., "A Feedback- controlled Interface for Treadmill Locomotion in Virtual Environments," ACM Trans Appl Percept, vol. 4, no. 1, Jan. 2007.
[5] S. Beckhaus, et al., "Intuitive, hands-free travel interfaces for virtual environments," in New Directions in 3D User Interfaces Workshop of IEEE VR, 2005, pp. 57–60.
[6] A. Kitson, et al., "NaviChair: Evaluating an Embodied Interface Using a Pointing Task to Navigate Virtual Reality," in Proceedings of SUI, New York, USA, 2015, pp. 123–126.