Noisy Vestibular Stimulation Modulates Self-Motion Perception

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Introduction

Visual-vestibular conflict is thought to cause significant problems in virtual reality (VR), such as sickness and low immersion [1].

Conflicts between senses tend to be resolved in favour of more reliable cues according to Bayesian models [2].

We recently proposed noisy vestibular stimulation reduces vestibular reliability and achieves sensory re-weighting. In support of this, stimulation facilitates quicker self-motion illusions (vection) [3].

In this study, we examine if noisy vestibular stimulation coupled to expected vestibular cues can also reduce sickness in VR.

In addition, we assess if noisy stimulation affects sensitivity to real-world movements.

Methods

Simulator sickness

- Participants followed a path actively and passively.
- Vestibular stimulation (bone-conducted vibration, BCV) applied:

1. Coupled with large visual acceleration: 3˚/s^2
2. Random vibration: ~1 pulse per second
3. Control: no stimulation

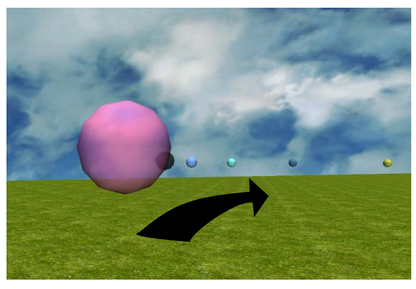
Display conditions

CAVE

HMD

Task

collect the targets

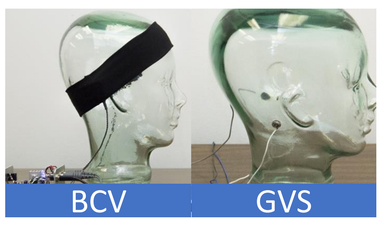


- Simulator Sickness Questionnaire (SSQ) completed after each trial.

Self-motion estimation

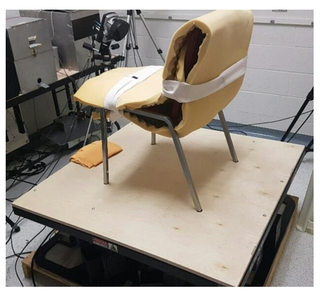
- Participants were moved left and right by different distances.
- Stimulation (BCV, or noisy galvanic vestibular stimulation, GVS) was applied throughout movements.

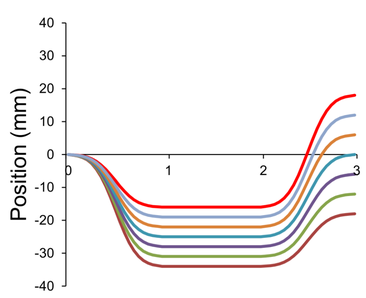
Stimulation



Task

did you finish on the right or left?

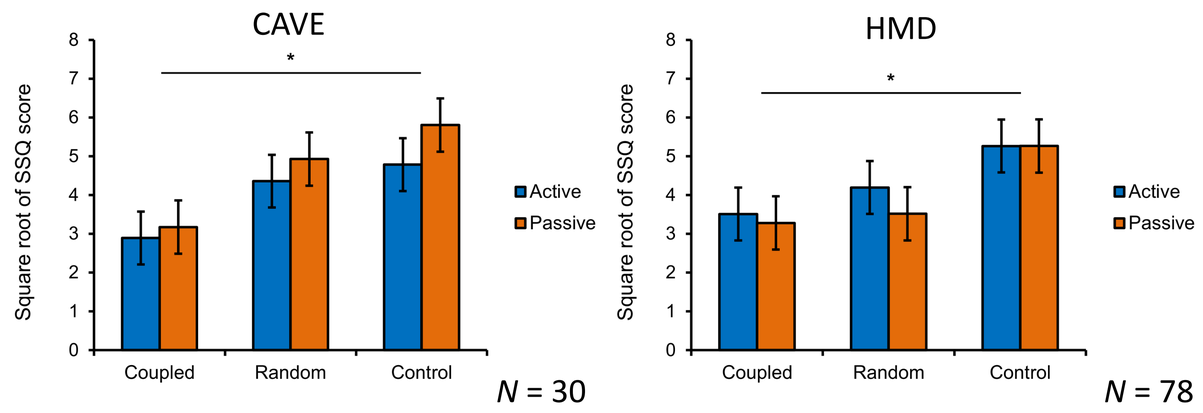




- Psychometric functions were constructed to assess sensitivity

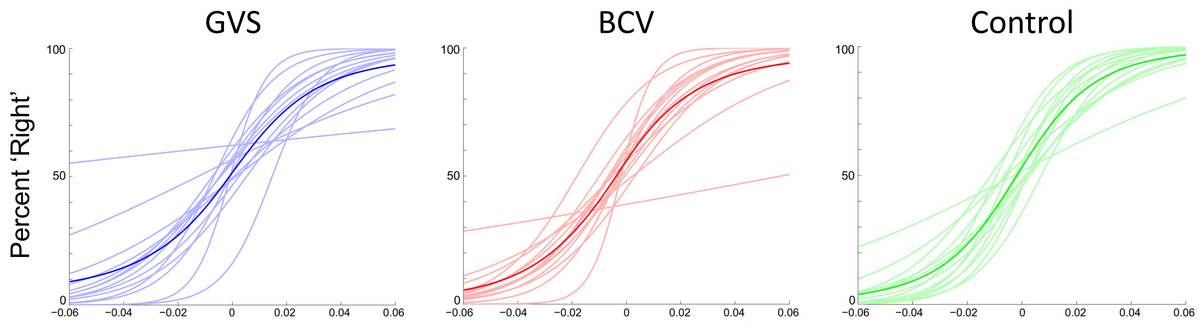
Results

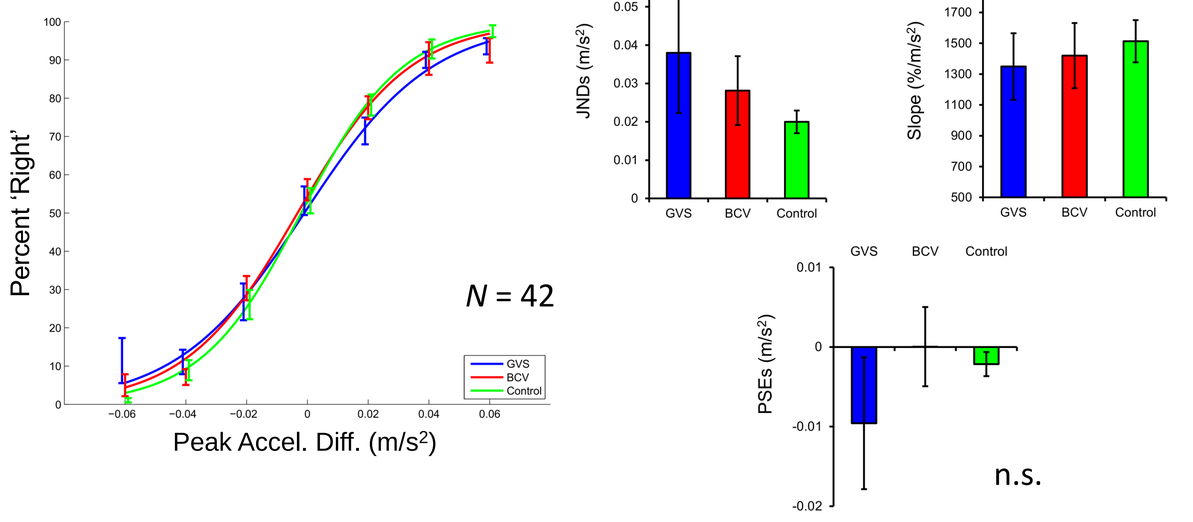
Simulator sickness [4]



- Sickness was lower when transient noisy stimulation was coupled to visual accelerations.
- The effect was replicated in a commercial head mounted display.
- Vibration applied randomly was not effective.

Self-motion estimation





- JNDs and slopes indicate very high sensitivity despite small movements (16—34 mm).
- Contrary to predictions, sensitivity to self-motion was unchanged when BCV or GVS were applied.

Conclusions

Noisy vestibular stimulation appears to reduce multisensory conflicts by adjusting weights in the sensory integration process.

Sickness in VR might be combatted through cheap, non-invasive, and easy to administer vestibular stimulation.

Despite effects on vection and sickness, self-motion estimation may not be disrupted by noisy stimulation.

Noisy vestibular stimulation shows early promise as a practical tool for improving the VR experience.

References

[1] Keshavarz et al. *Frontiers in Psychology*, **2015,** *6*, 472.
[2] Ernst & Bülthoff. *Trends in Cognitive Sciences*, **2004,** *8*, 162.
[3] Weech, S. & Troje, N.F.. *Multisensory Research*, **2017,** *30,* 65.
[4] Weech, S. Moon, J., & Troje, N. F., **submitted** *(PLoS One)*. Influence of bone-conducted vibration on simulator sickness in virtual reality.

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