Vection is facilitated by bone-conducted vibration and galvanic vestibular stimulation

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Introduction

Virtual reality (VR) is everywhere in modern perception-action experiments. However, self-motion perception in the virtual environment is not the same as in the natural world.

Example 1: Visually-evoked illusions of self-motion (vection) take a few seconds to emerge after visual motion onset (Guerraz & Bronstein, 2008).

Example 2: Mundane tasks in VR can result in extensive symptoms of simulator sickness (Kennedy et al., 1993).

According to the sensory-mismatch hypothesis, these examples are caused by a lack of vestibular stimulation in the presence of visual ego-motion.

Is noisy vestibular stimulation sufficient to combat sensory-mismatch?

Hypotheses

1) Noisy vestibular stimulation at visual motion onset will decrease vection latency
2) Reducing sensory mismatch with vestibular stimulation can mitigate simulator sickness

Stimulation Techniques

Galvanic vestibular stimulation (GVS)

- Electrical current stimulation of vestibular afferent nerves via electrodes
- Good Vibrations Engineering Vestibulator
- Non-directional, 40 Hz noise signal

GVS was applied to both mastoid processes

Bone-conducted vibration (BCV)

- Causes small linear accelerations of otolith organs (Curthoys et al., 2014)
- RadioEar B71 bone vibrators
- Non-directional, 500 Hz pure tone

BCV was applied to both mastoid processes

Body vibration (BV)

- Haptic cue to body acceleration
- Aura Interactor Cushion
- 60 Hz vibration to the lower back

Aura Interactor was used to vibrate lower back

Experiment 1

Does vestibular stimulation at visual motion onset facilitate vection?

Vection experiment

Apparatus was a large 3-screen CAVE. Squares rotated around participant at 30 deg/s FOV 85 deg (v) x 285 deg (h)

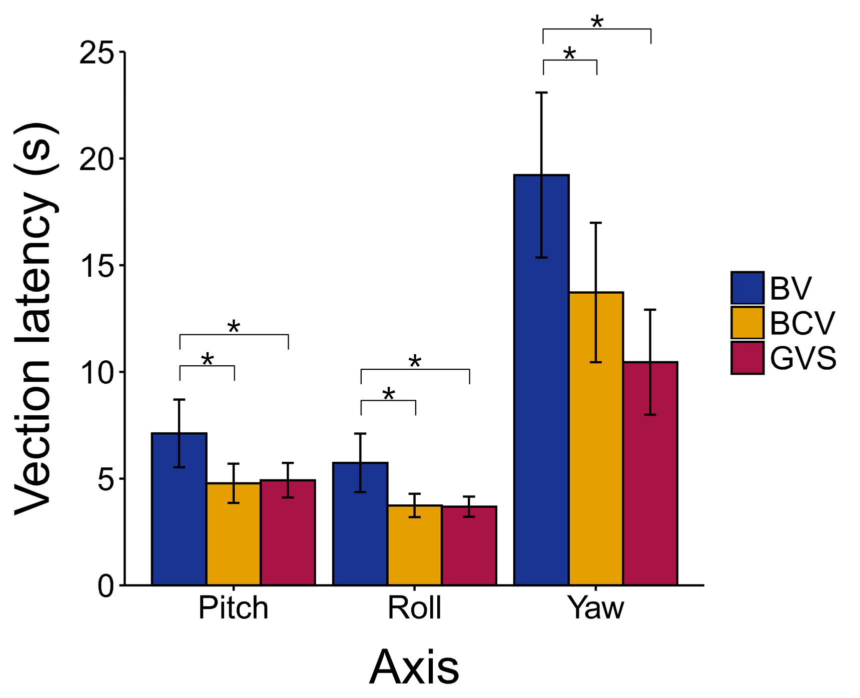
Task: "Push the button if and when you feel the illusion of self motion."

Three groups:

1) **Body vibration (BV)**
2) **Bone conducted vibration (BCV)**
3) **Galvanic vestibular stimulation (GVS)**

Measure: Latency of vection following visual motion onset

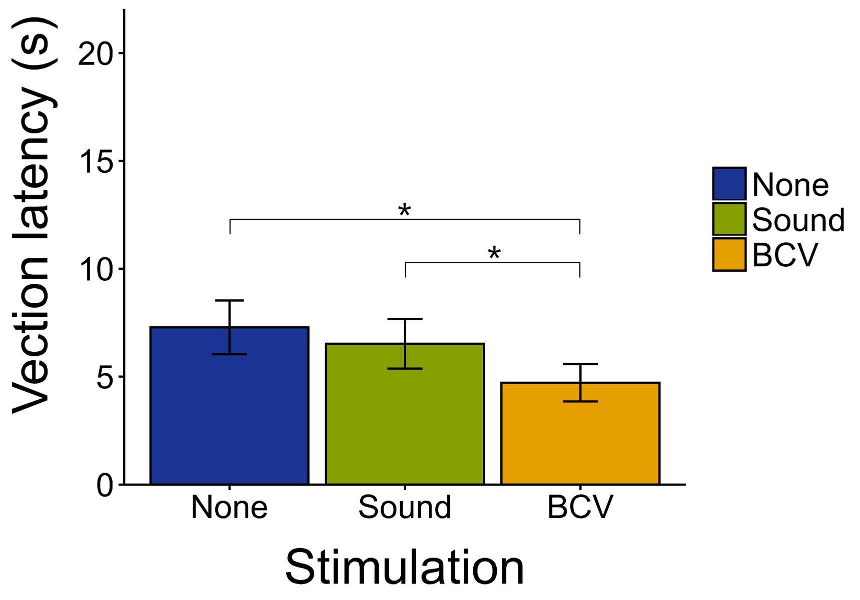
Results 1



Both BCV and GVS reduced vection latency when compared to body vibration. This was the case for all axes of rotation
* *ps* < .05, *N* = 12

Control experiment

Does **500 Hz sound** produce the same effect as **BCV**?



BCV reduced vection latency in roll axis when compared to 500 Hz sound administered through headphones
* *ps* < .05, *N* = 13

Interpretation

Vestibular stimulation facilitated vection, sound and body vibration did not.

Experiment 2

Does BCV during VR navigation reduce simulator sickness?

Path navigation in VR

Apparatus was a Christie Holostation: Stereo (shutter glasses) and motion parallax (head-tracking), high-resolution, low latency, FOV 90 deg (v) x 160 deg (h)

Task: "Hit all the targets as you navigate the virtual environment."

Three groups:

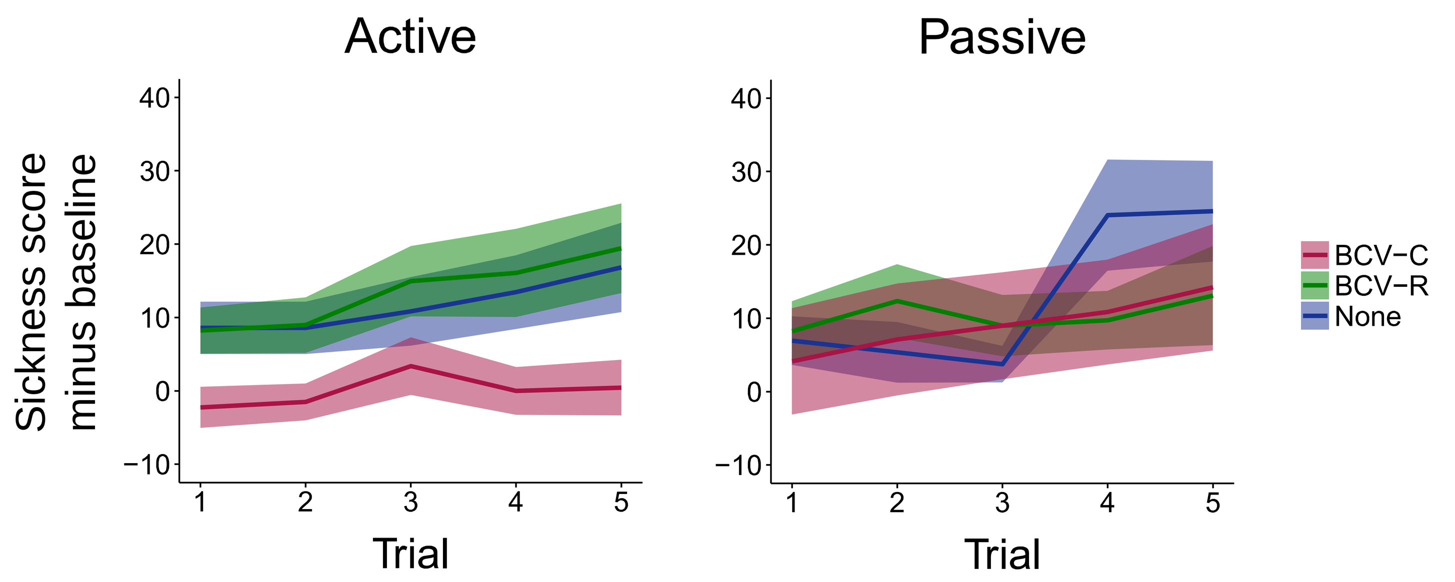
1) BCV concurrent with large angular accelerations of camera: **BCV-C**
2) BCV at random intervals ~0.5 Hz: **BCV-R**
3) No stimulation (control): **None**

Two types of trial:

1) Active (participant used motion-controller to navigate)
2) Passive (participant moved automatically using pre-recorded motion)

Measure: Post-trial simulator sickness questionnaire (Kennedy et al., 1993)

Results 2



Sickness increase was lowest in active trials for BCV-C (*ps* < .05, *N* = 30)

Interpretation

BCV helped to prevent sickness when it was concurrent with visual motion, but only when that visual motion was self-initiated in the active, BCV-C trials.

Conclusions

Vection is enhanced by noisy GVS and BCV.
BCV offers a low-invasive method for reducing simulator sickness.

References

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Kennedy, Lane, Berbaum, & Lilienthal (1993). *Int. J. Aviat. Psychol.*, *3*(3), 203-220.

Contact: Séamas Weech | seamas.weech@queensu.ca | **Funding:** Supported by NSERC CREATE-IRTG: The Brain in Action | **16th Annual Meeting of the Vision Sciences Society,** May 13-18, 2016, St. Pete Beach, FL