Spatialized Sound Influences Biomechanical Self-Motion Illusion ("Vection")

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• Introduction & Motivation

Vection = "illusion of self-motion"

How do auditory and biomechanical cues interact for circular vection?

Can rotating auditory cues facilitate as well as interfere with biomechanical vection?

• Methods

Auditory vection stimulus: Participants were listening to individualized binaural recordings of what it sounded like for that particular participant to turn in place at 60°/s, with two stationary sound sources spaced 90° apart.

Biomechanical vection stimulus: Blindfolded participants were sitting on a stationary hammock chair mounted above a circular treadmill that rotated at 60°/s, and were stepping to compensate for the floor’s rotation.

Experimental design: 19 adults completed 16 trials, consisting of a factorial combination of 4 sound conditions (randomized) x 2 rotation directions (L/R, alternating) x 2 repetitions.

Experimental conditions and hypotheses:

- H1: Rotating sound fields can enhance biomechanical vection.
- H2: Conflicting (stationary spatialized) auditory cues can diminish biomechanical vection.
- H3: Simulated (binaural) stationary auditory cues did not interfere with biomechanical vection, whereas real-world sound did.

• Results

H1: Rotating sound fields enhanced vection, evidenced by increased perceived vection intensity, velocity, and marginally reduced vection onset times (see data plots below, H1). An analysis of effect sizes showed that listening to binaural recordings of a rotating sound field versus non-spatialized (mono) recordings of the same sound field accounts for η² = 46% (vection intensity), η² = 28% (vection velocity), and η² = 16% (vection onset time) of the variability in the data. This vection-facilitating effect of moving sound fields parallels findings from audio-visual vection experiments, where adding spatialized sound that moved in sync with a rotating visual stimulus increased visually induced circular vection [Riecke et al. 2009b].

H2: Although auditory cues by themselves are clearly less potent in inducing vection than biomechanical cues [Riecke et al. 2009a], our study provides first evidence that stationary (real-world) auditory cues can, in fact, significantly reduce the intensity of biomechanically induced vection compared to the baseline (mono) condition (see H2 in data plots above; effect size partial η² = 31%). To the best of our knowledge, such cross-modal interference of stationary auditory cues for vection has not been demonstrated before, neither for biomechanical nor for visually induced vection.

H3: When the static real world sound was replaced with individualized binaural recordings of the same stationary sound presented through headphones, the stationary sound no longer interfered with biomechanical vection, and vection intensity, velocity, and onset latencies were virtually identical to the mono recording condition (see data plots above, stationary recording vs. mono recording). Moreover, the stationary real world sounds yielded significantly impaired vection as compared to the stationary binaural recording (see data plots above, H3).

• Discussion & Conclusions

Apart from its theoretical relevance, the current findings have important implications for applications in, e.g., entertainment and motion simulation: While spatialized sound seems not by itself sufficient to reliably induce compelling self-motion illusions, it can clearly support and facilitate biomechanical vection and thus support information from other modalities. Moreover, conflicting (stationary) sound can interfere with biomechanical vection. Such cross-modal interference corroborates the importance of carefully reducing real-world sound cues in applications like virtual reality or gaming.

Furthermore, high-fidelity, headphone-based sound simulation is not only reliable and affordable, but also offers an amount of realism that is yet unachievable for visual simulations: While even the best existing visual display setups will hardly be confused with "seeing the real thing", headphone-based auralization can be virtually indistinguishable from listening to the real sound and thus can provide a true "virtual reality".


References