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

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Introduction and Methods

Although moving auditory cues have long been known to induce self-motion illusions ("circular vection") in blindfolded participants, little is known about how spatial sound can facilitate or interfere with vection induced by other non-visual modalities like biomechanical cues. To address this issue, biomechanical circular vection was induced in seated, stationary participants by having them step sideways along a rotating floor ("circular treadmill") turning at 60°/s (see Fig. 1, top). Three research hypotheses were tested by comparing four different sound conditions in combination with the same biomechanical vection-inducing stimulus (see Fig. 1, bottom):

H1: Can rotating sound fields enhance biomechanical vection? To investigate this, individualized binaural recording of two sound sources rotating at 60°/s consistent with the circular treadmill ("rotating recording" condition) were compared to a non-spatial (mono) recording of the same sounds ("mono recording").

H2: Can conflicting (stationary spatialized) sound interfere with biomechanical vection? To address this, the mono recording was compared with participants listening to two static sound sources in the lab ("stationary real sound").

H3: Is binaural playback through headphones as effective as listening directly to real-world sounds? Here, the stationary real world sound condition was compared to an individualized binaural recording of the same stationary sound field ("stationary recording").
Experimental design: 19 adults completed 16 trials, consisting of a factorial combination of 4 sound conditions (randomized) × 2 rotation directions (L/R, alternating) × 2 repetitions.

Results and Discussion

H1: Rotating sound fields enhanced vection, evidenced by both increased perceived vection intensity and marginally reduced vection onset times (see Fig. 1 c & d, 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 $\eta^2 = 46\%$ (vection intensity) and $\eta^2 = 16\%$ (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 Fig. 1 c, H2; effect size $\eta^2 = 31\%$). 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.

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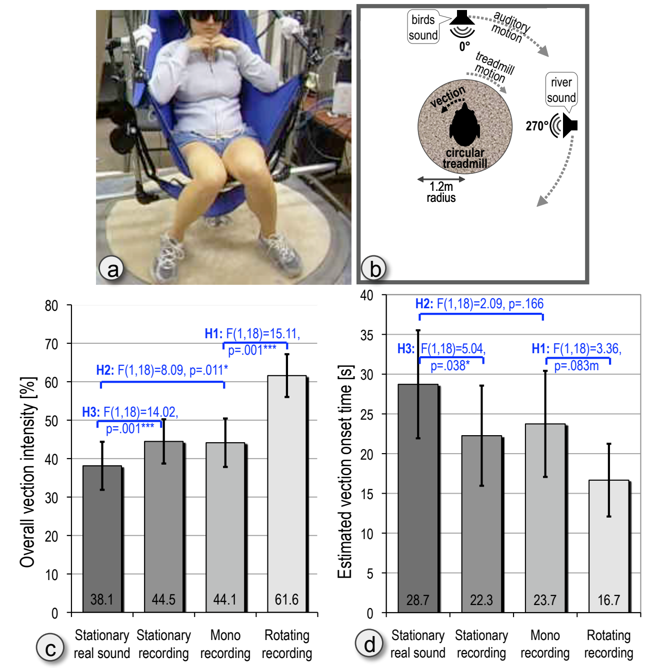

Figure 1: ***Top:*** *(a) Photograph and (b) top-down schematic view of a participant seated above the circular treadmill used to induce biomechanical vection.* ***Bottom:*** *Means ±1 SEM of verbal ratings of vection intensity (c) and onset time (d). The asterisks indicate the significance level (α = 5%, 1%, or .1%) of the planned pairwise contrasts for hypotheses H1 – H3.*

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 and onset latencies were virtually identical to the mono recording condition (see Fig. 1 c&d, stationary recording vs. mono recording). Moreover, the stationary real world sounds yielded significantly impaired vection as compared to the stationary binaural recording (see Fig. 1 c&d, H3).

In sum, spatial auditory cues can not only facilitate but also critically 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.

Acknowledgments Support: NIMH Grant 2-R01-MH57868, NSF Grant 0705863, Vanderbilt University, Max Planck Society, and Simon Fraser University

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The definitive version was published in Bernhard E. Riecke, Daniel Feuereissen, and John J. Rieser. 2010. Spatialized sound influences biomechanical self-motion illusion ("vection"). In Proceedings of the 7th Symposium on Applied Perception in Graphics and Visualization (APGV '10).ACM, New York, NY, USA, 158-158. http://doi.acm.org/10.1145/1836248.1836280