Interaction of auditory and biomechanical cues for the perception of rotational locomotion

Bernhard E. Riecke, Daniel Feuereissen, & John J. Rieser

VANDERBILT

MPI FOR BIOLOGICAL CYBERNETICS

bernhard.riecke@tuebingen.mpg.de • http://www.kyb.mpg.de/~bernie

• Introduction & Motivation

Vection = "illusion of self-motion"

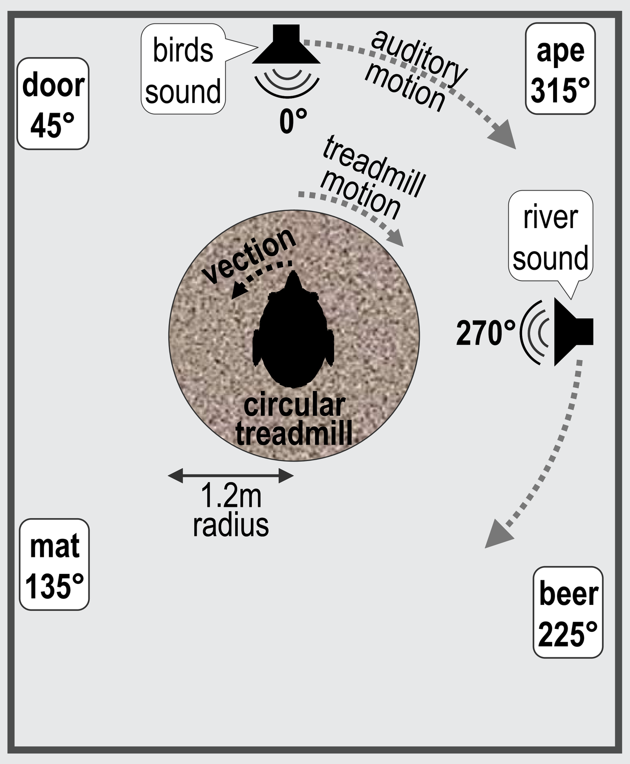
How do auditory and biomechanical cues interact for circular vection?

Can rotating auditory cues enhance biomechanical vection?

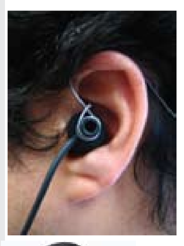
While both biomechanical and moving auditory cues have been shown to elicit self-motion illusions ("circular vection"), their combined influence and respective weightings have not been investigated.

Here, we tested the influence of biomechanical vection (blindfolded participants were seated stationary above a platform rotating at 60°/s and stepped along) and auditory vection (binaural recordings of two sound sources rotating at 60°/s) both in isolation and together.

• Methods

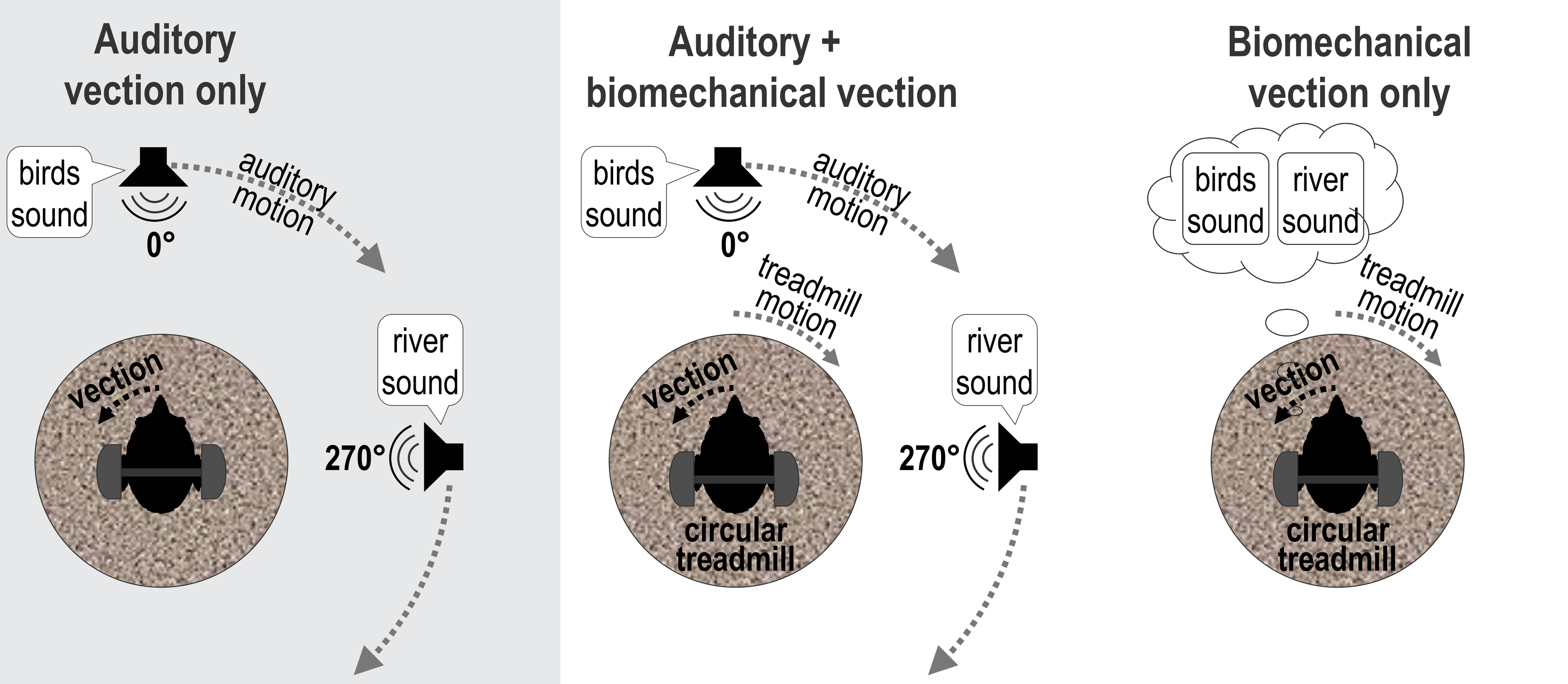


Auditory vection stimulus: Participants were listening to individualized binaural recordings of what it sounded like for that particular participant to turn in place at 60°/s, with two stationary sound sources spaced 90° apart.

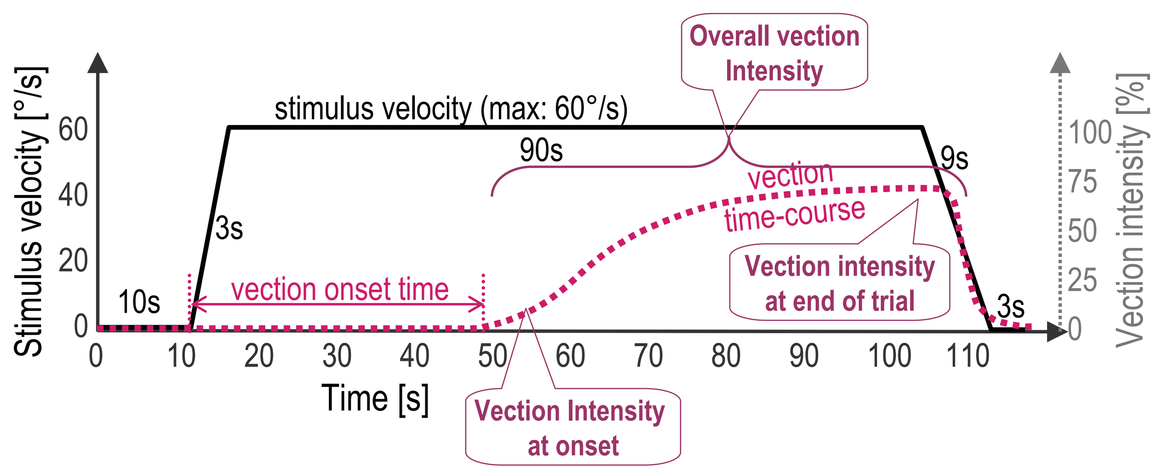


Biomechanical vection stimulus: Blindfolded participants were sitting on a stationary hammock chair mounted above a circular treadmill that rotated at 60°/s, and were stepping to compensate for the floor's rotation.

Experimental conditions:

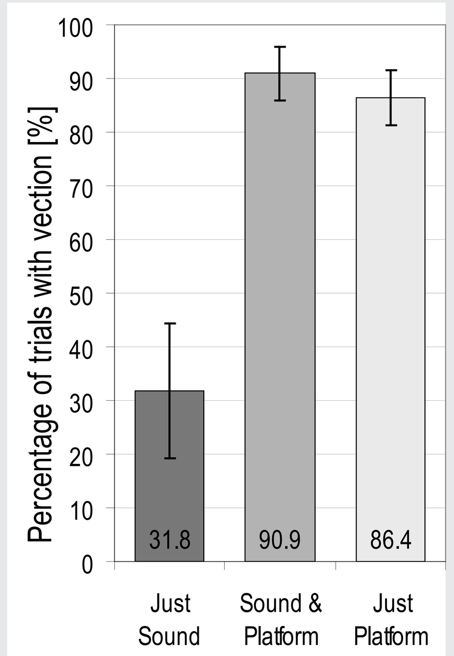


Experimental design: 3 stimulus combinations x 2 directions (L/R) x 2 repetitions = 12 trials; N=11.



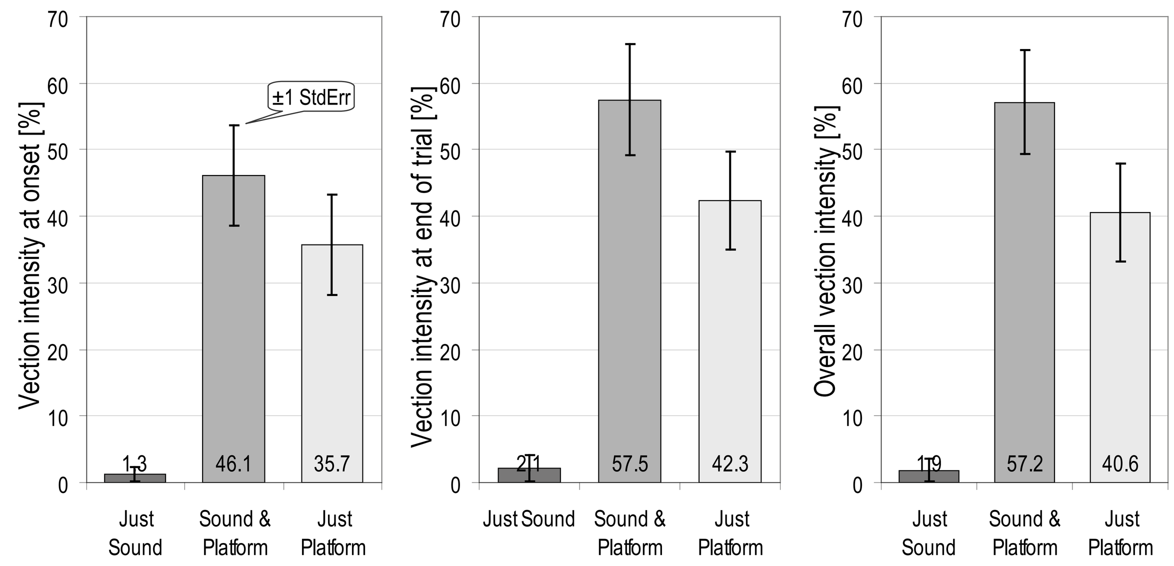
• Results

Biomechanical vection was significantly stronger than auditory vection



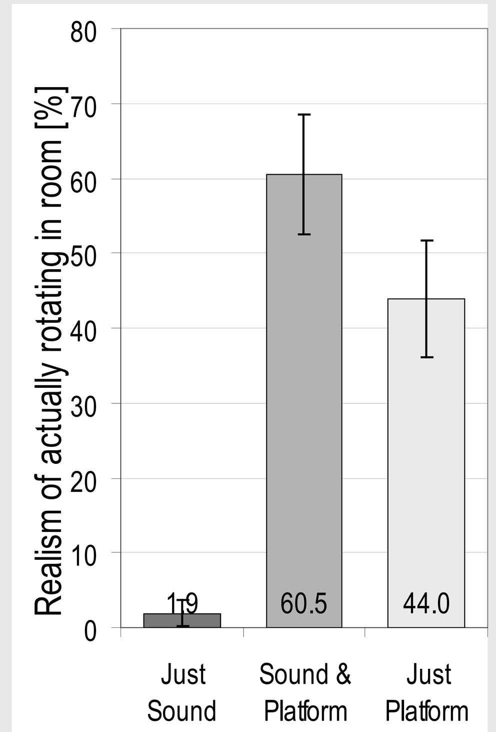
The auditory stimulus alone was not very effective at inducing vection, which was reported in only some of the trials of only 5 of the 11 participants.

The biomechanical vection stimulus was effective at inducing vection - all participants reported vection. Vection onset latencies averaged 24s, similar to the 22s observed for biomechanical vection in standing observers (Bruggeman et al., submitted).



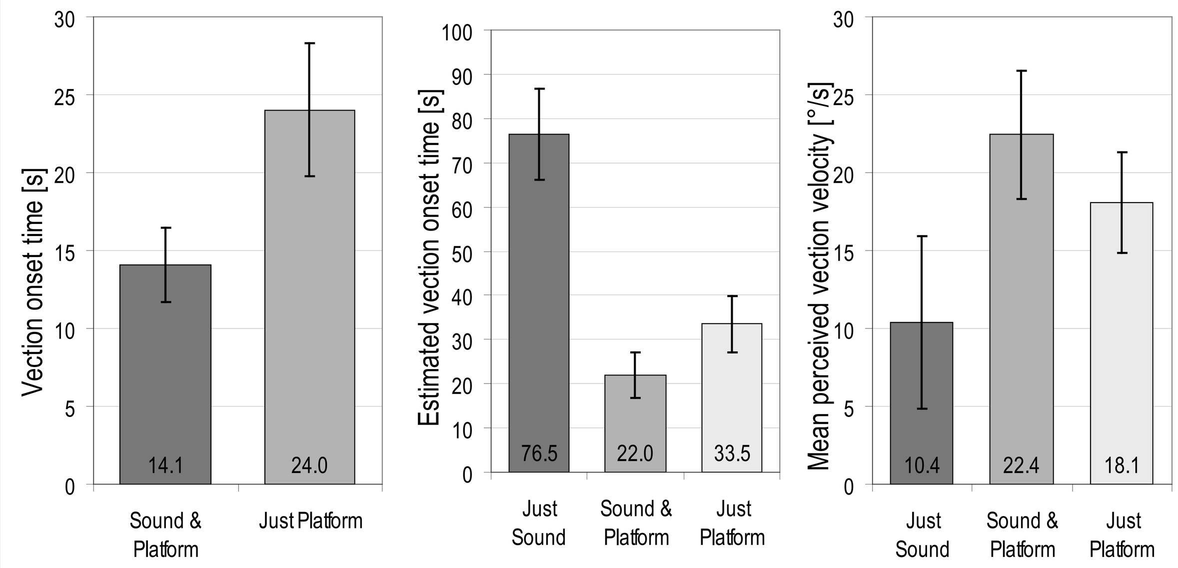
Nevertheless, biomechanical vection was enhanced by adding rotating sound fields

Vection induced/facilitated updating of the real room



Despite the low vection-inducing potential of the auditory stimulus, adding rotating sounds significantly enhanced biomechanical vection in most dependent measures: Vection intensity was increased by >40%, and participants had a stronger sensation of really rotating in the actual lab (37% increase).

In fact, participants were able to update their orientation in the lab in all but the pure auditory condition, suggesting that their mental representation was directly affected by the biomechanical and auditory cues – although perceived self-rotation velocities were typically below the stimulus velocities.



	ANOVA main effect			Contrast auditory vection vs. biomechanical vection			Contrast biomech. vection vs. auditory+biom. vection		
	$F(1,10)$	p	η_p^2	$F(1,10)$	p	η_p^2	$F(1,10)$	p	η_p^2
Percentage of trials with vection	15.06	.002**	60.1%	17.67	.002**	63.9%	.65	.441	6.1%
Estimated vection onset time	15.50	<.001***	60.8%	16.15	.002**	61.8%	3.14	.107	23.9%
Realism of actually rotating in room	33.86	<.001***	77.2%	26.38	<.001***	72.5%	9.40	.012*	48.5%
Vection intensity at onset	25.54	<.001***	71.9%	19.87	.001***	66.5%	8.38	.016*	45.6%
Vection intensity at end of trial	32.82	<.001***	76.6%	27.21	<.001***	73.1%	9.91	.010**	49.8%
Overall vection intensity	34.15	<.001***	77.3%	25.08	.001***	71.5%	12.75	.005**	56.0%
Estimated perceived vection velocity	4.49	.025*	31.0%	3.45	.093m	25.6%	2.67	.133	21.1%

Analysis of variance results for the different dependent variables. The asterisks indicate the significance level (α = 5%, 1%, or 0.1%), marginally significant effects ($\alpha \leq 10\%$) are indicate by an 'm'. The effect strengths partial η_p^2 indicates the percentage of variance explained by a given factor.

• Discussion & Conclusions

Auditory cues can facilitate biomechanical & visual cues for vection

Despite weak at inducing vection by themselves, auditory cues can support other modalities

Auditory information is a highly effective and cost-effective means of increasing circular vection

Auditory stimulation is affordable yet effective and can have higher fidelity than visual simulation

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 induce compelling self-motion illusions, it can clearly support and facilitate biomechanical vection and has earlier been shown to also facilitate visually induced circular vection (Riecke et al., 2008) and thus support information from other modalities.

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

Bruggeman, H., Pick Jr., H.L. & Rieser, J.J. Biomechanical Capture in Rotational Locomotion without Vision. Journal of Experimental Psychology: Human Perception and Performance (resubmitted).

Riecke, B. E., Väljamäe, A., & Schulte-Pelkum, J. 2008. Moving Sounds Enhance the Visually-Induced Self-Motion Illusion (Circular Vection) in Virtual Reality. ACM Transactions on Applied Perception (accepted).

Support: NIMH Grant 2-R01-MH57868, NSF Grant 0705863, Vanderbilt University, & Max Planck Society.
Poster presented at the Cyberwalk meeting 2008 in Tübingen, Germany.