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Influence of gravito-inertial cues on the perception of looming auditory stimuli

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Introduction

Sustained linear acceleration induces an illusion of backward tilt and a modification of the perceived visual horizon in the direction of the illusion. Yet, it is not clear how sustained linear acceleration influences spatial auditory perception. As being supine modifies the perceived size of visual objects [1] and the size of defensive peripersonal space [2], we hypothesized that the perceived distance of auditory objects could be influenced by vestibular information during sustained linear acceleration.

Methods and Material

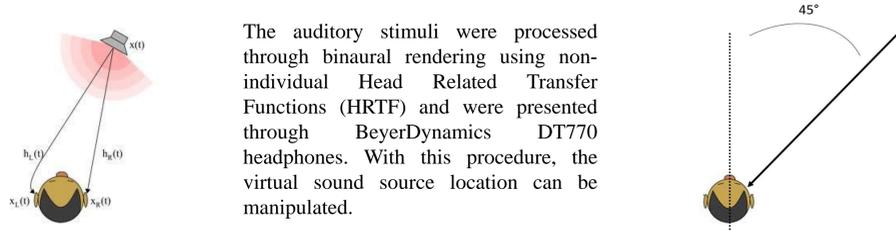
Participants

24 healthy right-handed participants
11 women; age: $M \pm SD = 32.0 \pm 9.3$, range 20-56

Auditory Time-To-Contact (TTC)

➤ **Looming auditory stimuli:** Burst trains of Gaussian white noise
2 levels of sound intensity: soft and loud

⇒ **3D sound**, auditory source looming for 2000 ms from the frontal right space



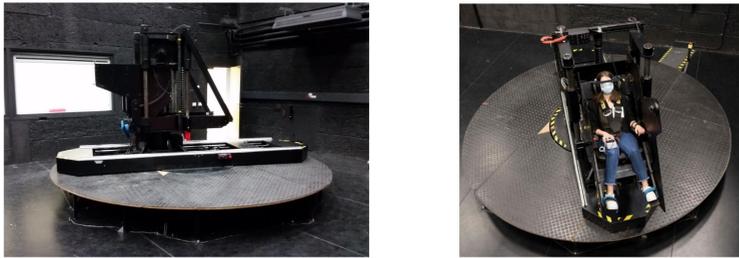
The auditory stimuli were processed through binaural rendering using non-individual Head Related Transfer Functions (HRTF) and were presented through BeyerDynamic DT770 headphones. With this procedure, the virtual sound source location can be manipulated.

Different approach speed conditions, thus different distances of the source at sound offset

TTC conditions	Theoretical TTC (ms)	Sound source distance at sound onset (m)	Sound source distance at sound offset (m)	velocity of sound source (m.s ⁻¹)
TTC_1	500	6,40	1,27	2,57
TTC_2	783	6,40	1,80	2,30
TTC_3	1316	6,40	2,54	1,93
TTC_4	2555	6,40	3,59	1,41

➤ **Task:** Blindfolded participants were instructed that they would hear an object approaching them from the frontal space, from the right hemisphere. At one point, the object would stop emitting sound. Their task was to imagine the auditory object continuing to approach them at the same and constant speed and to **press a button when they estimated that the object would have made contact with their body.**

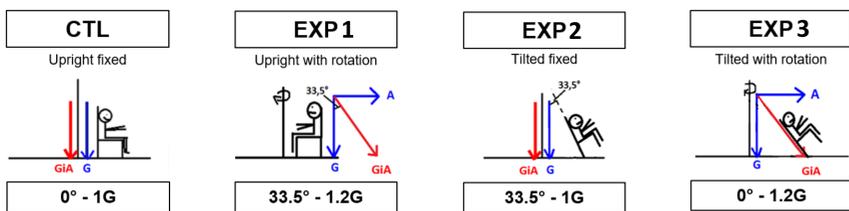
Vestibular stimulation



Armed forces Biomedical Research Institute's human centrifuge

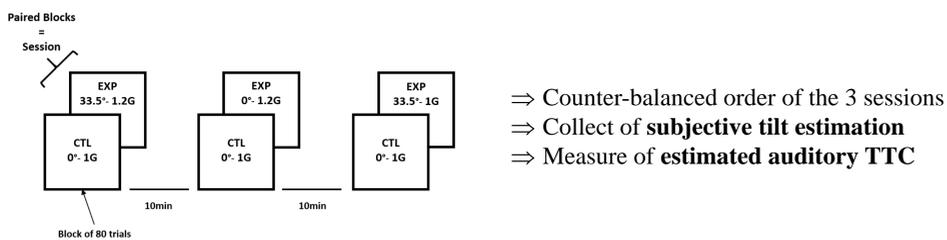
4 vestibular conditions varying in :

- GiA direction in relation to the long axis of participants' body (°)
- GiA intensity (G)



Recreating vestibular stimulation and potential illusion of tilt induced by horizontal linear acceleration

Protocol



Estimated TTC
48 Conditions, Factors:

- TTC (4 levels: 500 ms, 783 ms, 1316 ms, 2555 ms)
- SOUND INTENSITY (2 levels: soft/loud)
- SESSION (3 levels : 33.5°-1G, 33.5°-1.2G, 0-1.2G)
- BLOCK TYPE (2 levels: CTL/EXP)

References:

- [1] Kim, J. J., McManus, M. E., & Harris, L. R. (2022). Body Orientation Affects the Perceived Size of Objects. *Perception*, 51(1), 25-36.
[2] Bufacchi, R. J., & Lunetti, G. D. (2016). Gravitational cues modulate the shape of defensive peripersonal space. *Current Biology*, 26(21), R1133-R1134.
[3] DeLucia, P. R., Preddy, D., & Oberfeld, D. (2016). Audiovisual integration of time-to-contact information for approaching objects. *Multisensory Research*, 29(4-5), 365-395.
[4] Keshavarz, B., Campos, J. L., DeLucia, P. R., & Oberfeld, D. (2017). Estimating the relative weights of visual and auditory tau versus heuristic-based cues for time-to-contact judgments in realistic, familiar scenes by older and younger adults. *Attention, Perception, & Psychophysics*, 79(3), 929-944.

Results

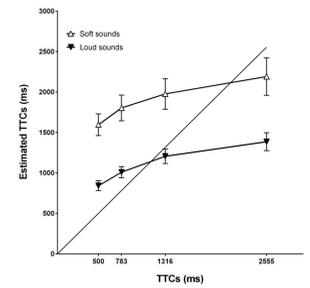
Estimated Time-To-contact (eTTC)

Mean estimated TTCs were calculated for each of the 48 conditions, for each participant

ANOVA on estimated TTCs (N=24):

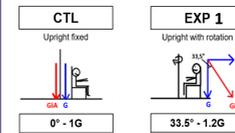
- TTC (4 levels: 500 ms, 783 ms, 1316 ms, 2555 ms)
- SOUND INTENSITY (2 levels: soft/loud)
- SESSION (3 levels : 33.5°-1G, 33.5°-1.2G, 0-1.2G)
- BLOCK TYPE (2 levels: CTL/EXP)

⇒ Main effect of TTC
($F_{(3, 69)} = 29.45, p < 0.001, \eta^2_p = 0.56$)
⇒ Main effect SOUND INTENSITY
($F_{(1, 23)} = 40.24, p < 0.001, \eta^2_p = 0.64$)
⇒ coherent with [3, 4] findings



⇒ Trend effect of the interaction SESSION * BLOCK TYPE ($F_{(2,46)} = 3.09, p = 0.055, \eta^2_p = 0.12$)

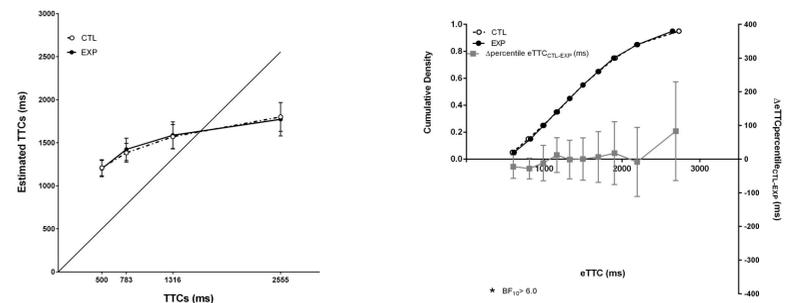
Session 33.5° - 1.2G



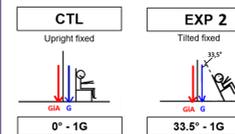
Subjective tilt estimation (°)

CTL: 0.0 ± 0.0 EXP: -55.2 ± 27.0

Estimated TTCs (ms)



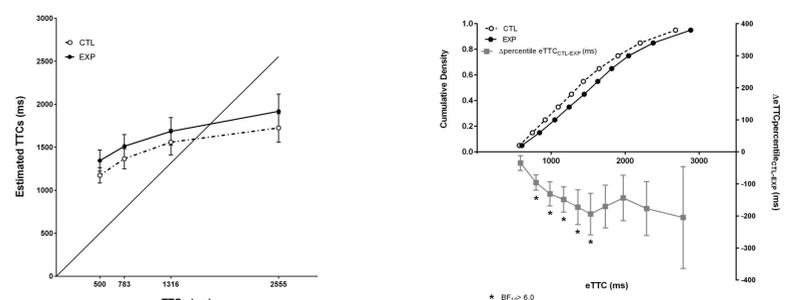
Session 33.5° - 1G



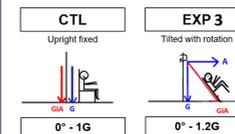
Subjective tilt estimation (°)

CTL: 0.6 ± 3.1 EXP: -73.3 ± 22.8

Estimated TTCs (ms)



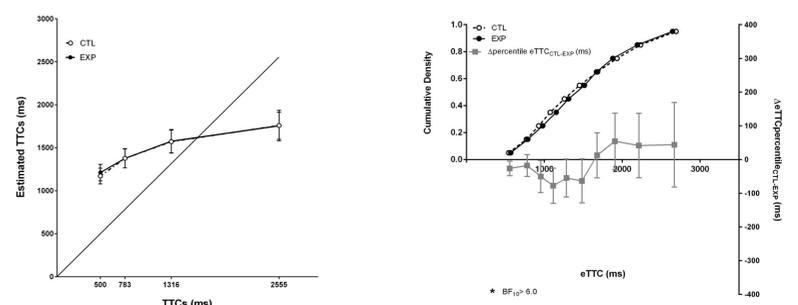
Session 0° - 1.2G



Subjective tilt estimation (°)

CTL: 0.6 ± 3.1 EXP: -11.4 ± 32.9

Estimated TTCs (ms)



Discussion/Conclusion

- ① Participants experienced illusory tilt when exposed to sustained acceleration
- ② Auditory TTCs estimation modified only when participants are tilted backwards in normogravity
- ③ No evidence of auditory TTCs modifications under sustained acceleration

⇒ Body posture as indicated by otolithic signals but also extra-vestibular graviceptors modulate auditory TTC in normogravity