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Effect of hyper-gravity on human perception of vehicle roll tilt

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Astronauts experience several altered gravity environments during space missions. In each novel gravity environment, astronauts need to maintain accurate perceptions of orientation for tasks such as planetary landing, vehicle docking, and extra-vehicular activities. Altered gravity forces during re-entry, accompanied by head tilt, can produce a version of the well-known "G-Excess" illusion. We aim to further understand human perception in altered gravity by studying dynamic and static roll tilts in hyper-gravity.

A long-radius (7.6 m) centrifuge (NASTAR Center's ATFS-400) was utilized to produce hyper-gravity environments. During each experimental session a subject (N=8) experienced passive whole-body roll tilts in the dark at different gravity levels (1, 1.5, and 2 Earth G's). A range of roll angle (10, 20, 40, or -20 degrees) and roll rate (4, 8, or 16 seconds per rotation or 0.25, 0.125, or 0.0625 Hz) combinations were studied. Perception of roll tilt was assayed using a "somatosensory indicator" which consisted of a bar that subjects attempted to keep aligned with their perceived gravitational horizontal. We hypothesize that hyper-gravity will cause overestimation in roll tilt perception during both the dynamic and static portions of the tilt profile.

When statically upright (zero roll tilt) subjects accurately perceived their orientation, even in hyper-gravity. However, when statically tilted, roll angle was significantly overestimated in hyper-gravity with more overestimation at higher G-levels and larger angles. The overestimations observed were much less than predicted by previous models such as the uticular shear [1] (sine model) or tangent model [2]. We propose a modified version of the utricular shear model which fits current and previous tilt perception data well. Significant overestimation was also seen during dynamic rotations in hyper-gravity across all angles and frequencies tested. However, at higher roll tilt angular velocities the amount of overestimation was slightly reduced.

Astronaut misperceptions of orientation due to altered gravity may impact safety and mission performance. In particular, perceptual errors during dynamic rotations may reduce piloting performance for vehicle control tasks in altered gravity. The quantification of the effect of hyper-gravity on orientation perception may lead to the development of more effective training and countermeasures.

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[2] Correia, M.J. et al (1968) Acta Otolaryn 230, 1-20.