Reduced Ocular Torsion and Tilt Perception in Hypo-Gravity

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Abstract

The influence of gravity on human physiology has been at the center of bioastronautics since well before the space age. Early emphasis on high G acceleration evolved to hyper-gravity studies on centrifuges, and later to research on weightlessness in orbit. There is, however, nothing magic about “1 G” other than the fact that it was the condition for evolution of our species on Earth. Sub-orbital flight affords the opportunity to measure human spatial orientation and vestibular reflexes at a variety of G-levels during its extended return phase.

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Human spatial orientation and balance reflexes, including eye movements, depend on the magnitude as well as the direction of the gravito-inertial vector (G). Most early research was conducted at Earth’s gravity (1 G) and produced well known spatial orientation illusions, including the Aubert and Müller illusions of perceived tilt. Ocular torsion, the rotation of the eye about its primary axis, also is dependent on the lateral component of G, as detected by the otolith organs. Hyper-gravity, as produced on a centrifuge, accordingly increases both roll tilt estimation and ocular torsion (Young, Lichtenberg, Arrott, Cries, Oman and Edelman, 1981; Arrott, Young and Merfeld, 1990). A gravito-inertial vector less than 1 G (hypo-gravity) is much more difficult to obtain, and experimental results are few and far between. One technique is to align the supine subject’s longitudinal (Z) axis with a centrifuge’s centripetal acceleration below 1 G (Karmli F., Diaz A., Galvan-Garza R.C., Clark T.K., Sherwood D., Young L.R.**,** 2016**).** A 0.5 Gz environment (i.e., hypo-gravity) causes humans to significantly underestimate their own whole-body roll tilt as compared to their tilt perception in 1 Gz. We performed a pilot study (N=1) in parabolic flight at 0.16 and 0.38 G and similarly found underestimation of roll tilt in hypo-gravity (Clark and Young, 2017).

Conclusions

On-orbit measurements using a space sled only allow for variations from 0 g to less than 0.1 g. Parabolic flight measurements of ocular torsion and of perceived body tilt, over the full range of hypo-gravity, last only a fraction of a minute. The few brief hypo-gravity experiments agree with mathematical models of spatial orientation, but they need to be extended in duration and in number of subjects. Sub-orbital flight, by its very nature, assures a range of G from zero to one and above, lasting over periods of many minutes during entry, and will permit examination of human spatial orientation and eye movements in the important region of hypo-gravity.

References

1) Young, L. R., B. K. Lichtenberg, A. P. Arrott, T. A. Crites, C. M. Oman and E. R. Edelman (1981). "Ocular Torsion on Earth and in Weightlessness." Annals of the New York Academy of Sciences 374(Nov): 80-92.
2) Arrott, A. P., L. R. Young and D. M. Merfeld (1990). "Perception of Linear Acceleration in Weightlessness." Aviation Space and Environmental Medicine **61**(4): 319-326.
3) Karmali, F., A. Diaz, R. C. Galvan-Garza, T. K. Clark, D. P. Sherwood and L. R. Young (2016). Development of a Countermeasure to Enhance Sensorimotor Adaptation to Altered Gravity Levels. IEEE Aerospace Conference. Big Sky, MT.
4) Clark, T. K. and L. R. Young (2017). "A Case Study of Human Roll Tilt Perception in Hypogravity." Aerospace Medicine and Human Performance 88(7): 682-687(686).