Evaluating the Subjective Straight Ahead Before and After Spaceflight

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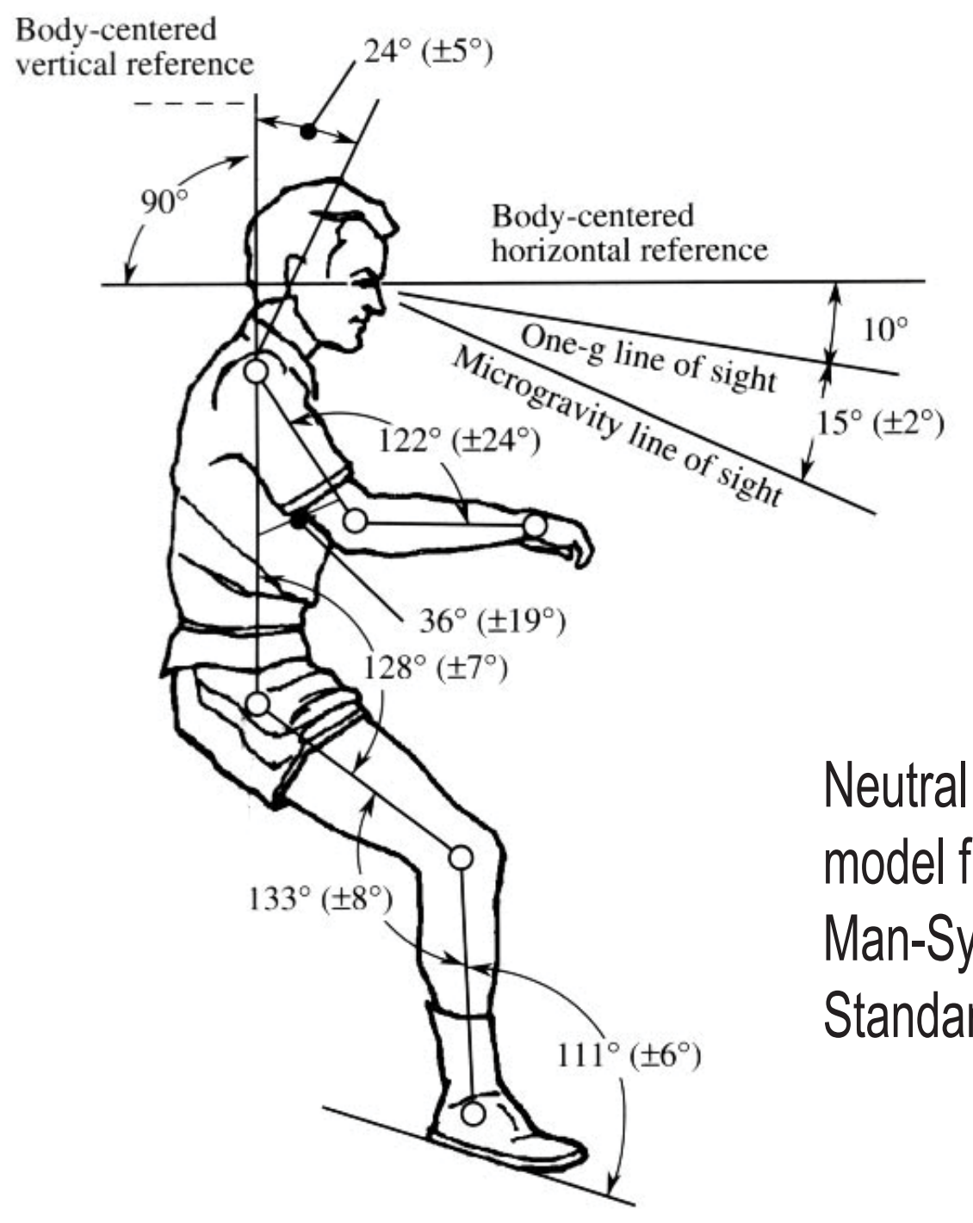
Introduction

This joint European Space Agency (ESA) – NASA study will address adaptive changes in spatial orientation related to the subjective straight ahead and the use of a vibrotactile sensory aid to reduce perceptual errors. The study will be conducted before and after long-duration expeditions to the International Space Station (ISS) to examine how spatial processing of target location is altered following exposure to microgravity. This study addresses the sensorimotor research gap to "determine the changes in sensorimotor function over the course of a mission and during recovery after landing."

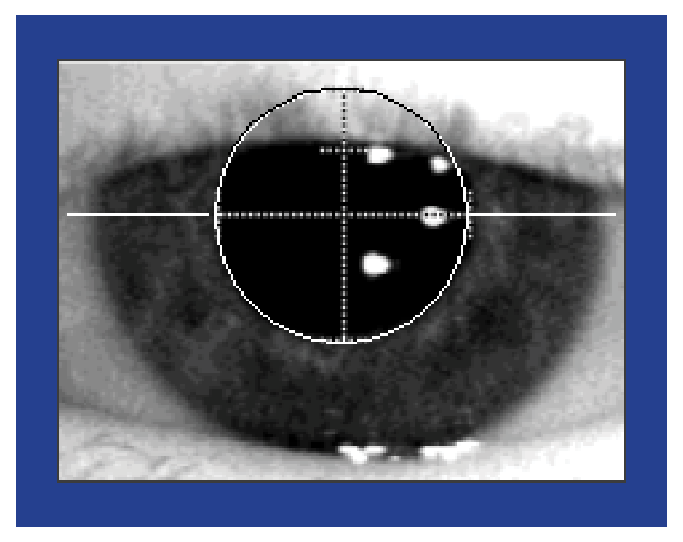
Progress-Mir collision, 1997



Neutral Body Posture model from NASA Man-Systems Integration Standards, 1995

Methods

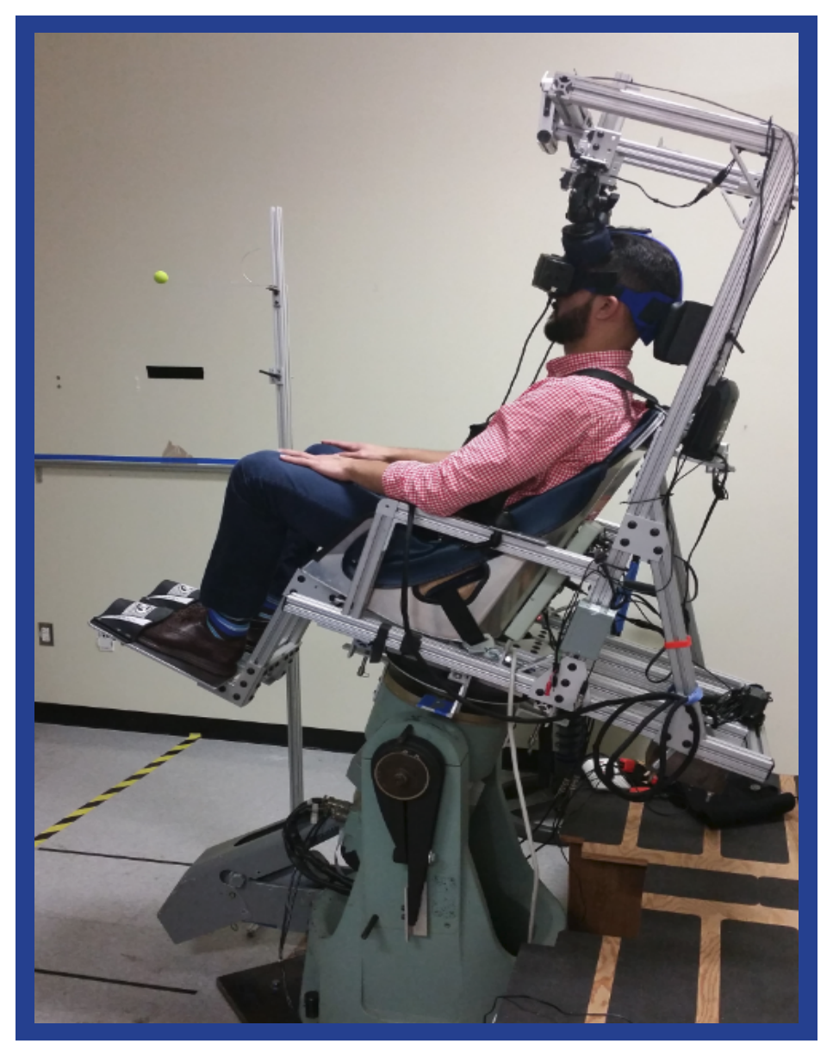
Eight ISS crewmembers will be recruited to participate in three preflight sessions (between 120 and 60 days before launch) and then three postflight sessions on R+0/1 day, R+4 (±2) days, and R+8 (±2) days. The three specific aims include examination of adaptive changes in: (1) fixation of actual and imagined target locations at different distances during pitch tilt, (2) directed eye and arm movements along different spatial reference frames during roll tilt, and (3) measurements of the vestibulo-ocular reflex (VOR) during vertical translation motion with fixation targets at different distances.

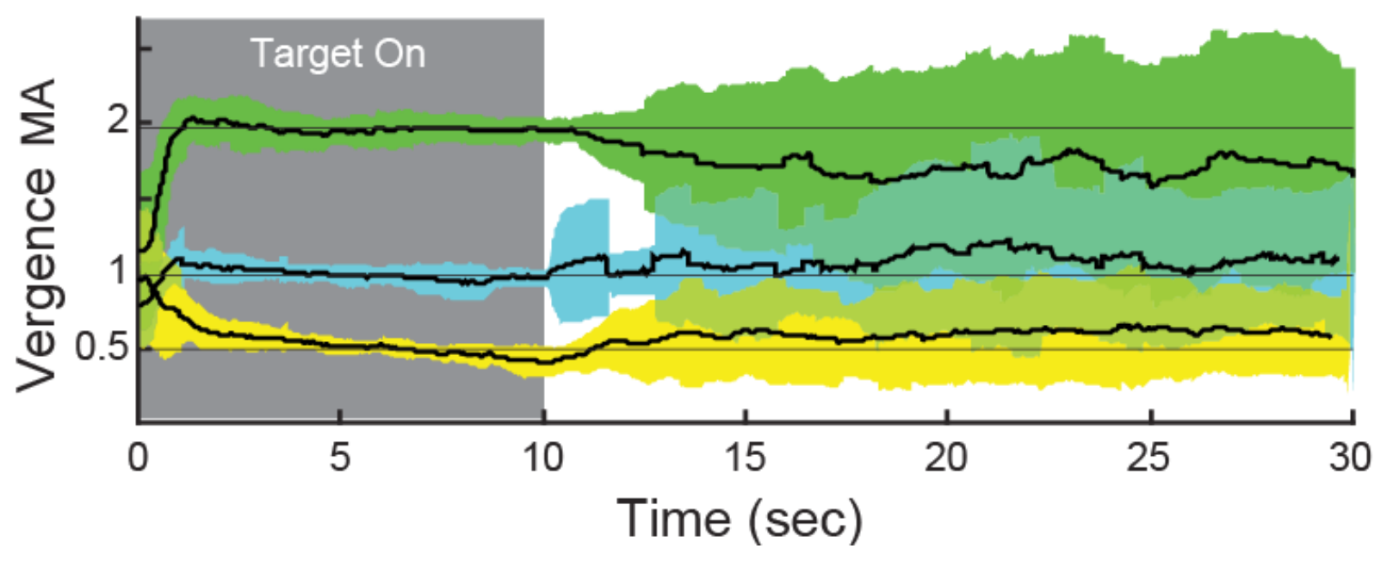


Horizontal and vertical eye movements will be recorded using binocular video-oculography to construct both conjugate (average) eye position and vergence (fixation distance). Head, arm, and trunk movements will be measured with inertial sensors and video tracking of a hand-held laser pointer. Electro-mechanical tactors spaced around a belt will provide vibrotactile feedback of direction and magnitude of tilt.

Near & Far Fixation

The subject will be asked to look at actual targets (normal vision) and then to imagine these same targets (occluded vision) in the straight-ahead direction. Targets will be located at near distance (arm's length, 0.5m), and far distance (>3 m). This task will be performed at 0º (upright) and counterbalanced pitch tilt orientations of ±15º, and the subject will be asked to report their perceived tilt angle and head translation from vertical. The subject will then be asked to fixate exclusively on the far target while moving through pseudo-random pitch tilt orientations of 0º, ±5º, ±10º, and ±15º with and without vibrotactile feedback.



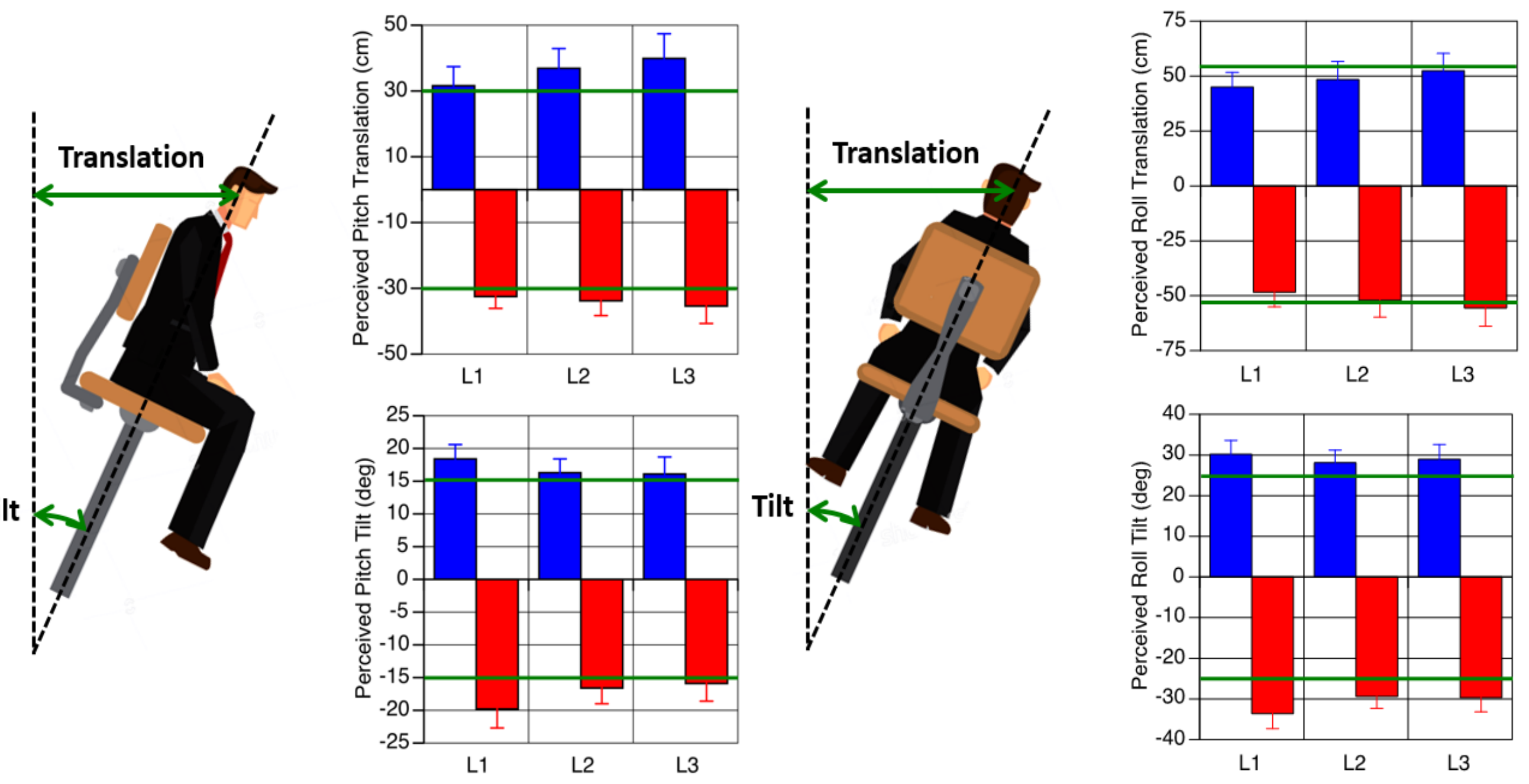


The coupling of vertical gaze during pitch tilt with vergence eye movements is expected to be altered following adaptation to microgravity.

Eye and Arm Movements

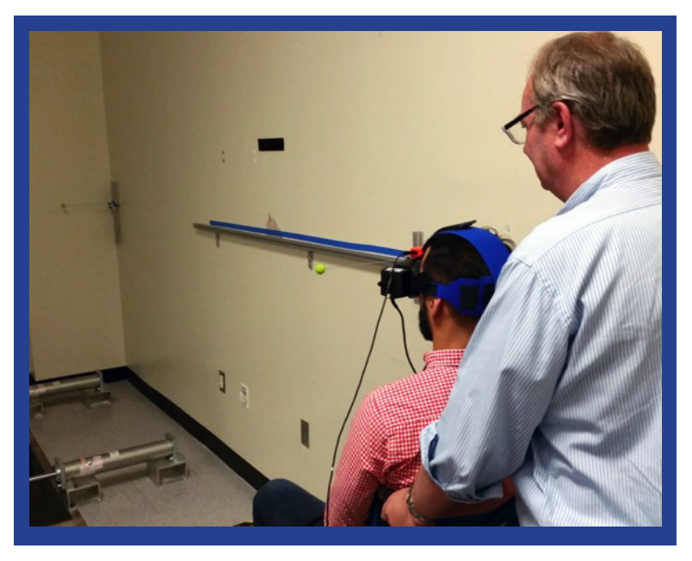
The subject will be asked to make directed horizontal and vertical eye and arm movements, first relative to Earth horizon and vertical, and then relative to the subject's head reference system. This task will be performed with subject's body aligned with upright, and then with subject's body tilted in roll (±30°) relative to this upright orientation. The subject will be asked to report their perceived tilt angle and head translation from vertical.

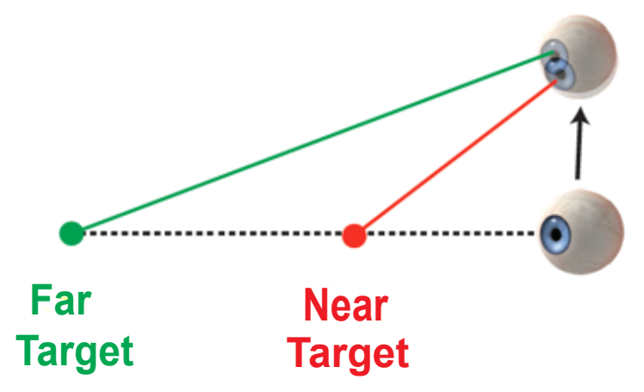
Directed eye and arm movements made in darkness along perceived axes are expected to be more closely aligned with the body's longitudinal axis following adaptation to microgravity, as the reference system for spatial orientation moves from an allocentric (gravitational) to an egocentric (idiotropic) vector.

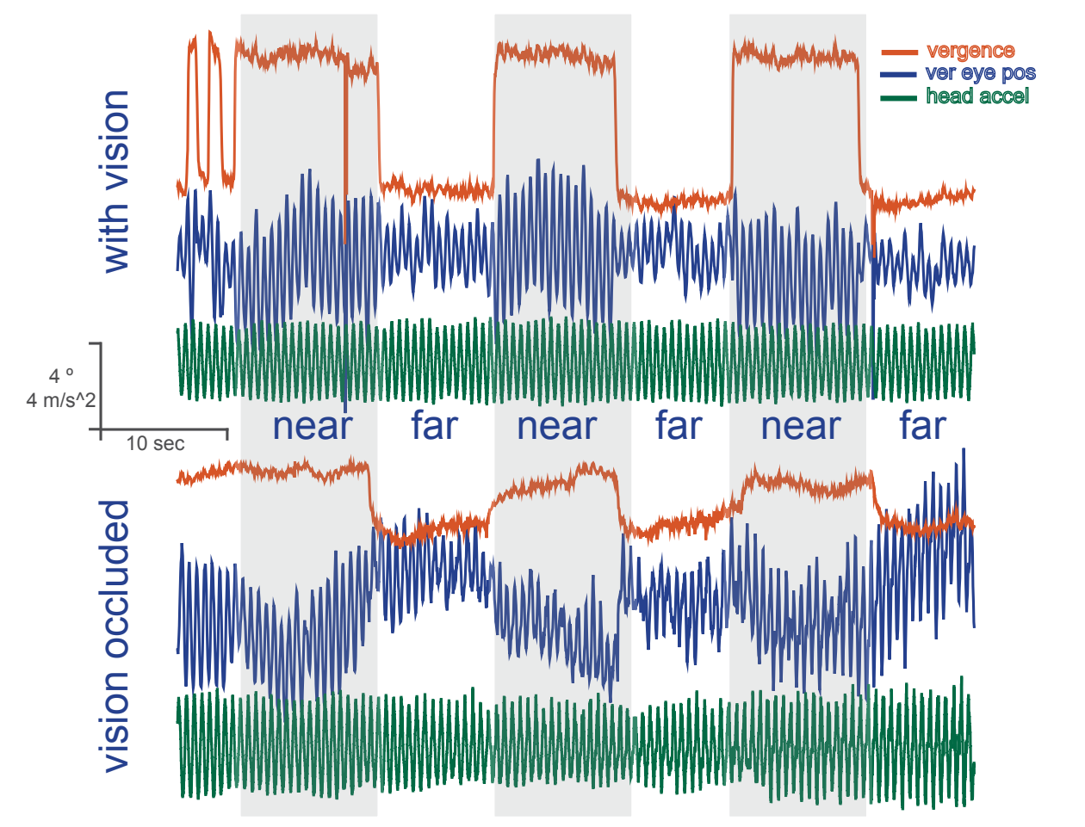


Near & Far VOR

The subject will be asked to fixate on visual targets (normal vision) at various distances (near and far) in the straight-ahead direction and estimate the distances from their eyes. The subject will then be passively translated up and down on a spring-loaded vertical linear accelerator, alternating focus between targets. Vision will be occluded and the VOR will be recorded as the subject continues to fixate at the same target locations during translation. An operator will oscillate subjects at ~2 Hz with ± 2 cm displacement to approximate the vertical motion typically observed during natural locomotion. Changes in the VOR will reflect adaptive changes in otolith-ocular reflex contributions to the perceived straight-ahead.







Status and Applications

During this past year, three ISS crewmembers completed the study and one has completed preflight data collection. Sixteen ground subjects completed three test sessions as part of a normative study.

Adaptive changes in an individual's egocentric reference might have negative consequences on evaluating the direction of an approaching object or on the accuracy of reaching movements or locomotion. Consequently, investigating how microgravity affects spatial target location will have theoretical, operational, and even clinical implications for future space exploration missions. The use of vibrotactile feedback as a sensorimotor countermeasure is applicable to balance therapy applications for vestibular loss patients and the elderly to mitigate risks due to loss of spatial orientation.

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