

PERCEPTION AND EYE MOVEMENTS DURING LOW FREQUENCY SINUSOIDAL TRANSLATIONAL MOTION IN THE ABSENCE OF NON-OTOLITH CUES

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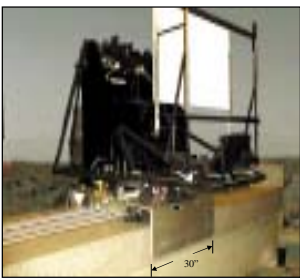
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INTRODUCTION

The otolith organs transduce linear accelerations of the head, thus serving the dual purpose of conveying head tilt with respect to gravity and linear accelerations arising during translational motion. These two types of acceleration are transduced ambiguously by the otoliths; a constant tilt of the head is indistinguishable from a constant translational acceleration. This inherent ambiguity must be resolved in order to support normal spatial behavior and postural stability, because processing necessary to maintain orientation and equilibrium is different for tilt and translation. The observation that we successfully maintain balance, clear vision, and accurate orientation throughout our normal activities indicates that this ambiguity is resolved sufficiently for natural behavior.

This tilt/translation ambiguity is thought to be partially resolved through a central frequency-parsing mechanism in which high frequency otolith activity is interpreted as translation, and low frequency as tilt. There is experimental evidence from a variety of otolith-mediated behaviors in support of the existence of a frequency-parsing mechanism. The ocular motor response to head translation (the Translational Linear VOR) is high-pass in nature, attenuating as stimulus frequency declines. The otolith-mediated ocular motor response to tilt of the head (the tilt LVOR) is most robust at low frequency. Tilt perception also undergoes frequency parsing, with low-frequency translational or centripetal accelerations resulting in a compelling perception of tilt. The perception of translation has not been found to be consistent with a frequency-parsing mechanism. Subjects have typically been able to report fairly accurate descriptions of their translational motion even during long periods of constant-velocity (i.e., zero acceleration) translation, in direct conflict to a frequency-parsing mechanism. However, because of the great difficulty in eliminating non-vestibular cues, such as vibration and noise, during translational motion, it is possible that otolith-mediated perception still undergoes frequency parsing, but higher order perceptual systems use any available extra-vestibular information to supplement the response at low frequency. In this study, we investigate otolith driven perception and eye movement during translational motion in the near absence of extra-vestibular cues.

Air-Bearing 30-ft Sled
Vestibular Research Facility, NASA-Ames



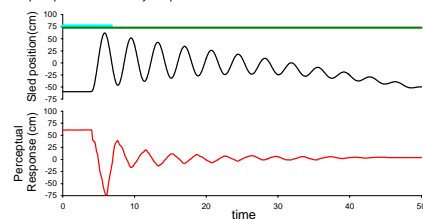
Background retouched for clarity

METHODS

Subjects: Normal human subjects (N=8, with 4 naïve), age range 24-45
Stimuli: All experiments were performed at the Vestibular Research Facility (NASA-Ames) on a sled with an overall excursion of approximately 8.2m. The sled carriage rode on air-bearings, enabling translational motion in the near absence of noise and vibration typically encountered during translation experiments. A bungee mechanism provided damped sinusoidal motion at three frequencies of approximately 0.1Hz (±90cm, 0.04G peak), 0.2Hz (±60cm, 0.1G peak), and 0.25 Hz (±60cm, 0.15G peak). Subjects were secured in a chair on the sled carriage, oriented with the interaural (IA) axis aligned with the motion of the sled. Subjects' heads were comfortably restrained with a custom-fit bitebar molded from dental impression compound.

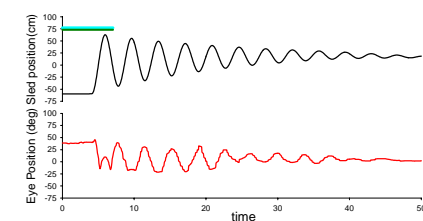
PERCEPTION Trials

•Subjects used a target stabilization task to report their perception of interaural translational motion.
•Subjects viewed a galvanometer-controlled laser spot (dark green line) projected at a screen approximately 80cm in front of the subjects, as well as an additional earth-fixed laser spot (reference spot, cyan line).
•After one cycle of sinusoidal motion, the reference spot was extinguished
•Subjects used a non-detented joystick to control the position of the remaining target, attempting to keep its position stationary in space.



EYE MOVEMENT Trials

•**Eye Movement Measurement:** Low noise horizontal eye-position records were obtained in four subjects using the Microguide infra-red oculography system.
•Trials were similar to the perception trials, with the exception that both the reference target and the controllable target were both extinguished after approximately one cycle of sinusoidal motion.
•Subjects were instructed to continue to carry out the task as if the controllable target were still present by imagining the controllable target and adjusting its imagined position with the non-detented joystick.

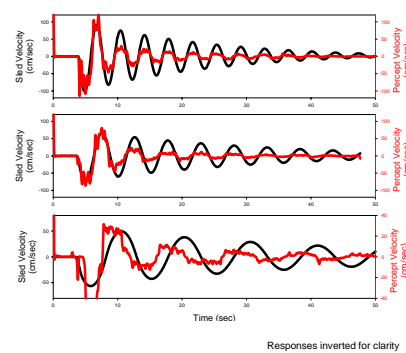


Analysis

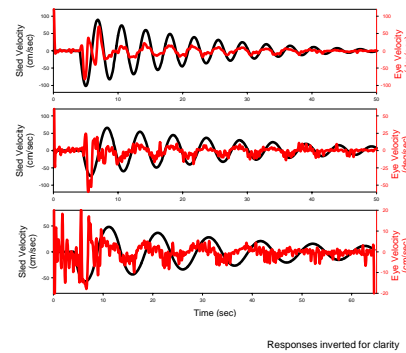
The gain and phase of the perception responses and the sensitivity and phase of desaccaded eye velocity responses at the first harmonic of the sinusoidal motion were calculated with the Welch Periodogram technique.

RESULTS

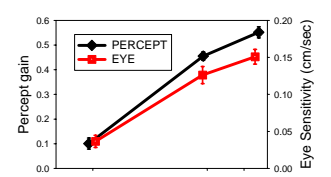
PERCEPTION Trials



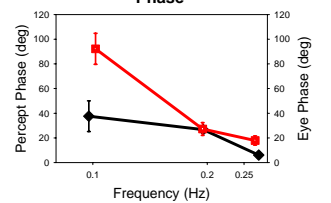
EYE MOVEMENT Trials



Gain and Sensitivity



Phase



SUMMARY AND CONCLUSIONS

- All subjects showed high-pass characteristics in their perception and eye movements elicited by these low-frequency damped sinusoids.
- Responses were closest to compensatory at 0.25Hz, with response magnitude decreasing and phase lead increasing as frequency fell. Phase leads were substantial at 0.1 Hz.
- Perceptual and slow-phase eye movement responses exhibited similar spectral characteristics, though low frequency phase lead was larger for the lowest frequency.
- Data are consistent with the use of a frequency-parsing mechanism to distinguish translation from tilt for both eye movement and perceptual pathways. The corner frequency for the high-pass translation filter is between 0.1 and 0.2 Hz, assuming first-order high-pass behavior.
- The integration of otolith signals to yield linear velocity estimates is leaky at best, suggesting that "path integration" of otolith input during natural navigation is weak.