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Research Article,

Motion Perception with Tilt and Translation and Its Consequences

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Abstract:

Investigating the effects of stimulus frequency on tilt and translation motion perception during constant velocity off-vertical axis rotation (OVAR), the findings were compared to those of stimulus frequency's effects on eye movements. Dynamic linear acceleration alters the amount of both self-motion perception and eye movements in the absence of any sensory data (from the canal or vision). Contrary to eye movements, the phase of perceived tilt and translation motion is unaffected by stimulus frequency. The finding that distinguishing tilt and translation linear acceleration stimuli requires distinct brain processing from eye motions and motion perception.

Keywords: Otolith, Vertical Axis, Acceleration, Eye Movements, Space Medicine, Orientation.

Spaceflight & Ovar

The otolith organs of the vestibular system convert translational motion and head tilt with respect to gravity into linear acceleration. The ambiguity between these two types of linear acceleration has to be resolved for the production of compensatory eye movements during different types of head movement as well as for the correct perception of motion (Mayne 1974). The Off-Vertical Axis Rotation (OVAR), which entails rotating the head and torso at a constant speed around an axis that is inclined with respect to gravity, is one technique for providing a dynamic linear acceleration stimulus. While the rotational velocity determines the frequency content, the tilt angle determines the magnitude of the linear acceleration stimulus during OVAR. The linear acceleration that is experienced during OVAR in the dark, which is sinusoidally oscillating, modulates the eye motions in the horizontal, torsional, and vertical directions (Guedry 1965; Benson and Bodin 1966; Darlot et al. 1988; Haslwanter et al. 2000; Yagi et al. 2000). Recent studies conducted in the study lab have demonstrated that during OVAR, lower frequency responses (0.3 Hz) are primarily characterised by the modulation of tilt- position dependent ocular reflexes (for example, torsion), whereas the modulation of translational ocular reflexes (for example, horizontal) are predominant at higher frequencies (Wood 2002).

The perception of motion during OVAR has been studied before (Guedry 1965; Graybiel and Miller 1970; Denise et al. 1988), but the stimuli utilised in these research were typically at frequencies lower than 0.3 Hz. Denise et al. (1988) found that during OVAR at these low frequencies, the motion perception frequently proceeds down the circumferential edge of a cone with a downward orientation. The angle of the imagined conical body route increases with the actual tilt angle of the rotation axis, indicating that the perception process is dependent on inputs signalling head and body position with respect to gravity. Studies that have employed OVAR stimuli louder than 0.3 Hz are few and far between. According to one study by Miller and Graybiel (1973), participants felt "at or near upright" when spinning at 0.66 Hz (240°/s). Unfortunately, Miller and Graybiel's study did not address whether the transition from tilt to translation ocular reflexes was followed by an improvement in perception of translation at higher frequencies, as was the case with the lowered tilt motion perception at higher frequencies (Wood 2002). Determining how stimulus frequency influenced how motion looked to be seen during OVAR was the review's main goal as a result. We particularly assessed the perception of whole body translation vs. tilt at frequencies above and below the crossover region of the tilt and translation ocular responses (0.3 Hz, Wood 2002). It is essential to emphasise whole-body motion in order to shed light on how the central nervous system is handling the ambiguity between tilt and translation. Prior study (Denise et al. 1988) described the impression of a downward-oriented cone as containing movement along the cone's edge, even though it is evident that this results from the feeling that one is tilting at an axis below the head. The impression of full body translation must be distinguished from head translation brought on by tilt about an eccentric axis. It is essential to emphasise whole-body motion in order to shed light on how the central nervous system is handling the ambiguity between tilt and translation. Prior study (Denise et al. 1988) described the impression of a downward-oriented cone as containing movement along the cone's edge, even though it is evident that this results from the feeling that one is tilting at an axis below the head. The impression of full body translation must be distinguished from head translation brought on by tilt about an eccentric axis.

Vertical axis rotation nd its effect:

One of the major achievements of this study is the demonstration that the amplitude of tilt and translation motion perception during OVAR changes as a function of linear acceleration frequency in the absence of visual and sensory cues. In contrast to eye movements, the phase of motion perception does not alter with stimulus frequency. We deduce that for eye motions and motion perception, different brain processing is needed to differentiate between tilt and translation (Merfeld et al. 2005). Even though the tilt and translation ocular reflexes appear to function more independently, the times at which they are seen have an impact on one another. Increased stimulus frequency causes a discernible decrease in tilt amplitude (Glasauer 1995; Merfeld et al. 2005), while the corresponding increase in feeling of translation maintains the perceived motion's phase in regard to the stimulus. However, one would need to tilt the head along a CCW motion route to obtain the same set of orientations without rotating on a longitudinal axis. This explains why the felt direction of rotation during OVAR at low velocities frequently differs from the actual direction of rotation (Graybiel and Miller 1970; Denise et al. 1988). It is not apparent whether translation or tilt is to blame for the sinusoidally varying linear acceleration observed during constant velocity OVAR. For instance, the highest leftward interaural acceleration brought on by gravity occurs in the right-ear-down (RED) position. Depending on the study's point of view, this can suggest a roll tilt to the right or a leftward acceleration of translation. Due to the fact that acceleration is 180 degrees out of phase with position, the highest leftward acceleration during sinusoidal translation occurs while one is in the extreme right position. If one understands the linear acceleration during OVAR as tilt, the motion route is described as moving around the edge of a cone while always facing the same way. If one reads linear acceleration during OVAR as translation, the motion path proceeds along the edge of an upright cylinder, once more in the opposite direction of true rotation. According to study results, the vestibular system resolves ambiguous linear acceleration information from otolith afferent input depending on the frequency content of head motion, at least in part (Paige 1996). However, frequency segmentation provides some space for doubt (Wood 2002). First, the observed motion's phase does not change with frequency, as one might anticipate from high- and low-pass filtering alone. It will soon be possible to switch between low- and high-pass information, which makes it more challenging to resolve tilt and translation information by frequency content. Several investigations have shown that the central nervous system uses other sensory modalities, such vision and semicircular canals, to resolve the ambiguity of tilt and translational linear acceleration inputs (Angelaki et al. 2004; Merfeld et al. 2005). Neurophysiological evidence for this is provided by the finding that neurons in the vestibular nuclei that respond to tilt or translation typically receive canal input (Angelaki and Dickman 2003). The majority of early studies on human OVAR were limited to frequencies under 0.3 Hz. These studies have demonstrated that there is a conical motion path, with the amplitude dependent on the degree of tilt (Graybiel and Miller 1970; Denise et al. 1988). The results of the study showed that as the tilt angle rose from 10° to 20°, the amplitude of tilt perception nearly quadrupled. With the exception of a few limited recordings made by Graybiel and Miller (1970) using a goggle device, previous study has exclusively employed verbal accounts. Miller and Graybiel (1973) found that during OVAR, respondents frequently felt "at or near upright." However, there was no proof that anybody had ever had a sense of translation. It is remarkable in the current study that at the high frequency, improved translation is felt together with a sense of reduced tilt. Even though OVAR is not the only motion paradigm that uses linear acceleration in the absence of visual and canal inputs, the effects of stimulus frequency on perceived tilt amplitude should be noticeable across a variety of motion paradigms. For instance, translations along a linear track and/or variable radius centrifugation have both been found to produce similar results (Glasauer 1995; Merfeld et al. 2005). Numerous studies (Guedry 1965; Benson and Bodin 1966; Correia and Money 1970; Young and Henn 1975; Raphan et al. 1981; Cohen et al. 1983; Hain 1986; Wall and Furman 1989; Furman et al. 1992; Clément et al. 1995; Angelaki and Hess 1996) have noted the modulation of horizontal SPV during OVAR, despite the fact that perception of translation has never been reported in earlier studies. It is well recognised that this shift in horizontal SPV is a translational response of the otolithocular system to the alteration in interaural acceleration brought on by OVAR (Angelaki and Hess 1996). Therefore, an increase in translational ocular reflex amplitude is consistent with a rise in translation perception amplitude with stimulus frequency. In order to diagnose vestibular disorders or astronauts returning from space flight, it may be helpful to test the otolith responses to low- and high-frequency linear accelerations (Furman et al. 1992; Clément et al. 1995). OVAR differs from previous linear acceleration paradigms in its ability to accurately sustain the linear acceleration's amplitude throughout a broad frequency range, particularly low frequencies. As a function of frequency, similar effects on the phase of the visual vertical under dynamic linear stimuli would be predicted. Similar distortions in felt translation measurements will result from high-pass filtering of horizontal eye movements, especially at frequencies below 0.3 Hz where there are considerable phase leads (Wood 2002; Merfeld et al. 2005).

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