Dependence of the subjective visual horizontal on pitch and roll tilt

M. de Vrijer¹,², W.P. Medendorp², J.A.M. Van Gisbergen¹

¹Biophysics, ²Institute for Cognition and Information, Radboud University Nijmegen, The Netherlands

Introduction

Human subjects, tilted laterally to large angles make systematic errors when aligning a visual line to the direction of gravity, as if roll tilt is underestimated (A-effect). At small roll tilts, performance is almost veridical, but some subjects show slight tilt overcompensation (E-effect). In most experiments so far, roll tilt effects have been studied with the head in zero pitch position. Considering the pitched-up orientation of the otoliths in the head, we wondered how the pattern of A- and E-effects would be modulated at pitch angles that would place the otoliths in a more or in a less pitched-up position with respect to gravity.

Methods

Subjects (n=8), initially seated upright, were first adjusted to the pitch angle chosen for the experiment: 45º forward, upright, or 45º backward, and then roll-tilted to various angles between +90º and -90º.

1. Chair in the three pitch orientations and zero roll angle

2. Subjective visual horizontal task (SVH)

Subjects adjusted the orientation of a polarized luminous line (12") to the perceived direction of the earth horizontal in otherwise total darkness.

Results

3. Pitch angle has striking effect on error pattern

Errors of undercompensation (A-effects) become larger in backward pitch for all subjects. Forward pitch has two effects: A-effects always become smaller for all subjects and clear E-effects emerge in several subjects (e.g. subject PM).

4. Pitch effect is not simply scaling of errors

Mittelstaedt’s idiotropic model was fitted to pooled data and to individual data, with two free parameters (S and M) per subject. The model accurately fits the three error patterns: R² values range between 0.41 and 0.96. Subjects with E-effects in forward pitch have a weak idiotropic vector.

Conclusions

- Pitch tilt affects the percept of the subjective visual horizontal during roll tilt: A-effects are larger in backward pitch. During forward pitch, A-effects become smaller and clear E-effects emerge in several subjects.
- Mittelstaedt’s idiotropic model can fit the error patterns at all pitch angles without additional parameters. According to this model, subjects with E-effects in forward pitch have weaker idiotropic vectors than subjects lacking E-effects.
- Recently, we showed that an alternative Bayesian model was able to account for A-effects in a zero pitch condition. We are currently exploring whether the model can be extended to explain E-effects as well.

Modeling aspects

In Mittelstaedt’s spatial perception model (1983), errors arise due to unequal numbers of hair cells in the otolith organs: utricle (coding Fy) and saccule (coding Fz). An idiotropic vector (M) compensates for these errors at the expense of errors at large roll tilts.

Can Mittelstaedt’s model fit the error patterns in forward and backward pitch?

Influence of pitch angle

Backward pitch: effect of idiotropic vector is too large, resulting in errors of undercompensation. Forward pitch: effect of idiotropic vector is insufficient, resulting in errors of overcompensation.

6. Idiotropic model accurately fits error patterns at all three pitch angles