Integration of Visual-Vestibular Self Motion: Comparison of Landmark and Optic Flow Information

Markus von der Heyde & Heinrich H. Bülthoff

Max Planck Institute for Biological Cybernetics - Cognitive and Computational Psychophysics Department - Tübingen, Germany
Markus.von der Heyde@tuebingen.mpg.de - www.kyb.tuebingen.mpg.de

Introduction

Turns in VR are frequently misperceived.

We investigated two sources of information: optic flow and landmarks.

Methods

We presented visual and vestibular turns in VR.

Task:

Memorize a starting point and a turn pattern. We compared the effects of optic flow information and reliable landmark information (see Fig. 1) on angles, each in combination with vestibular information.

Snaps of the visual scenes

Fig. 1: The textured ground plane (a) provides optic flow information. The town scene (b) provides additional landmark information and absolute size cues. Subjects never saw a bird’s eye view (c) of the scene.

Fig. 2: The Motion-Lab setup (a) integrates a six degree of freedom motion platform (b: Stewart platform) and a high resolution (1024x768, 40x30 deg. FOV) head mounted display (c: Kaiser ProView 60 HMD).

The subjects’ task was to learn and memorize a trajectory with constant velocity of 1 m/s. The motion platform performed initial acceleration and final deceleration phases. The trials were between 40 and 60 seconds long. During a reproduction phase, the gain between the joystick control and the resulting visual and vestibular turns was independently varied by a factor of 1/sqrt(2), 1 or sqrt(2).

Results I - varied angles, gain: visual = vestibular

Three angles were reproduced qualitatively correctly.

Fig. 3: Turn angles were in general overestimated. Only the conditions with identical gain factor are plotted here.

Results II - varied gain factors, average turn angle

Optic flow:

Dominant effect for bigger gain factor.

Scene:

Landmarks lead to visually dominated responses.

Visual-vestibular interaction

optic flow

landmarks

Fig. 4: Motor response (turned angle using a joystick) control for optic flow and landmark condition plotted against the varied visual gain factor. The vestibular gain factor is plotted in different colors. The error bars correspond to the standard error of the mean.

Schematic visual and vestibular effects

visual effect

vestibular effect

Fig. 5: Here we schematically show both main effects (visual and vestibular) each plotted by means of motor response. For a small gain factor one has to turn further and for a large gain factor one has to stop earlier.

We propose three simple models for the combination of visual and vestibular information: Additive, multiplicative, and the “max-rule” model.

Model predictions

Three simple models are proposed to fit the data pattern.

Fig. 6: For the additive model the difference between the graphs is consistent across visual gain. The multiplicative model on the other hand leads to different slopes and offsets. The max-rule model predicts for the bigger gain factor an exclusive effect, e.g., turns are executed until one modality reaches the memorized turn angle. Therefore, the responses are constant for maximal gain factors.

Data fit for simple models

Only the max-rule explains the quite similar responses for maximal gain factors.

The additive model fits the scene data perfectly.

Fig. 7: Data fit for the optic flow (top row) and landmark (bottom row) condition. The average of the fits for the individual subjects is superimposed onto the actual data. The fit quality is the average quadratic difference between model and data.

Conclusions

A combined additive and multiplicative model fits the data, but the coefficients may not be meaningful.

The integration of visual and vestibular cues may use two strategies depending on the information available.

Data fit for combined model

Fig. 8: A combined model with an additive and multiplicative component is used for a final data fit. The fit quality is far better in comparison to the other models, but the coefficients can no longer be interpreted in a meaningful way due to instability problems; small changes in the data result in large differences in the weighting given to the additive or multiplicative component.

Landmark information is very robust and changes the cue integration to a visual only strategy.

Does the max-rule still apply? Yes, if visual landmarks result in a very high gain or weighting.

Landmark information is very robust and changes the cue integration to a visual only strategy.

Does the max-rule still apply? Yes, if visual landmarks result in a very high gain or weighting.