in Body Yaw-Rotation Perception

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• Motivation

- Using attention, humans can control to what extent which sensory information is granted access to higher brain areas.
- Since perception is often the result of a combination of different sensory cues, the question arises whether attention can also change the relative weights of the relevant cues in this sensor fusion process and thus influence the resulting percept.
- This question was studied on the example of body yaw rotations. The perception of the angle of body rotation is influenced by both visual and vestibular/proprioceptive cues. We measured how subjects reproduced rotations in a cue conflict situation.

• Methods

- Subjects were rotated on a Stewart platform with projection screen (see Fig. 1).
- Visual stimulus was a random-dot starfield providing optic flow information during rotation; stars had limited lifetime to prevent subjects from using them as reference.
- Active-noise-cancellation headphones were used to prevent uncontrolled influence of auditory cues.
- Each trial consisted of the following phases (see Fig. 2):
  - **Rotation presentation phase:** concurrent rotation (varied between 7.5° and 18°, in six steps) of the platform and the visual display (equal rotation angles).
  - **Active rotation reproduction phase:** Subjects were then instructed to either *return* (rotate back to the previous position) or *repeat* (turn again for the same angle) the presented rotation actively by using a joystick. During active reproduction of the turn, a gain factor between the visual and vestibular rotation was applied (rotation speeds of the visual movement relative to the platform movement varied between 0.71 and 1.42 in five steps).

- Using these gain factors allowed us to analyze the weights of the two cues in the subjects' responses, and to investigate the influence of the rotation angle, gain factors and attentional bias on the cue weights.
- In the first experiment (three subjects), no instruction was given to which modality subjects should attend. In the second and third experiment (six subjects each), the subjects were additionally instructed to pay attention specifically to the visual movement or to the platform movement.
- Data was analyzed using correlation analysis, and a 5-way ANOVA for experiments two and three (subject x visual or vestibular bias x training angle x gain factor x return or repeat).

• Results

- Subjects were able to reproduce the angles with standard deviations of 2.8° - 5.3°, increasing with the size of the training angle. The response angles were highly correlated with both visual and vestibular target angles ($p<0.00001$ in all three experiments).
- Subjects did not notice that conflicting rotation angles were used for visual and vestibular cues during the rotation reproduction phase.
- Subjects tended to over-estimate small rotation angles (7.5°) by about 1° and to under-estimate large rotation angles (18°) by about 2.5°.
- In all three experiments the correlation of responses with the visual target angles was higher than with the vestibular / proprioceptive target angles ($r_{vis}=0.63$, $r_{vest}=0.52$).
- In experiments 2 and 3 no significant influence of attention on the reproduction/perception of the rotations was found (see Fig. 4, $p=0.568$ between visual attention and vestibular attention condition).
- In the cue conflict situation, subjects could in principle alternate between visual and vestibular cues. However, looking at single responses we find an unimodal distribution (see Fig. 5), which shows that subjects mix the cues instead of alternating between visually and vestibularly guided rotations.
- Subjects made smaller rotations in the return task than in the repeat task (see Fig. 6). This might be an after-effect of the previous rotation.

• Conclusions

- Single response distributions are unimodal, which shows that subjects use both visual and vestibular cues for the estimation of their rotation instead of deciding alternatively.
- Correlation of responses with the visual cue is higher than with the vestibular cue ($r_{vis}=0.63$, $r_{vest}=0.52$).
- Apparently, in human body rotation perception, the weights in the sensor fusion process can not be voluntarily changed by attention.

• Outlook

- Experiments show that in visual/haptic sensor fusion, humans use a maximum-likelihood method to fuse different cues by giving more weight to the cue with the higher reliability. In further experiments we will test this hypothesis for the visual/vestibular cue integration.

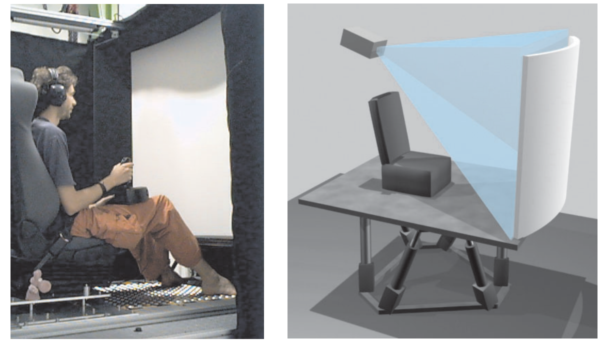

Figure 1: Motion platform and projection screen (86° x 63°)

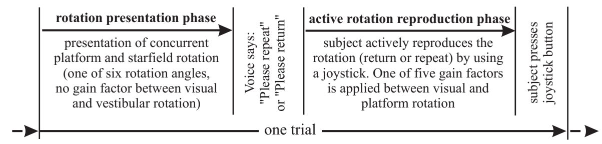

Figure 2: Experimental design

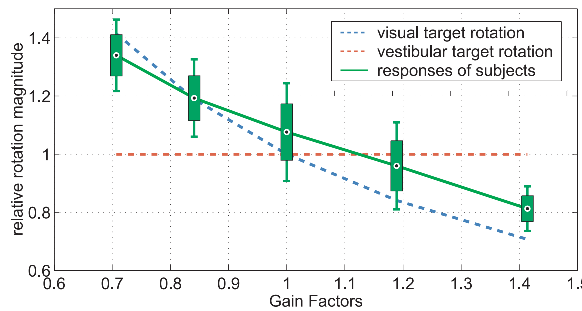

Figure 3: Results of experiment 1 (no attentional bias)

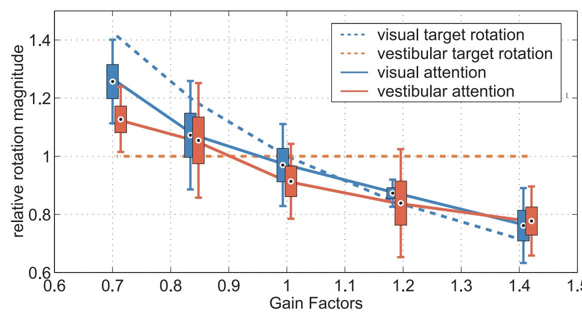

Figure 4: Normalized responses in experiments 2 and 3

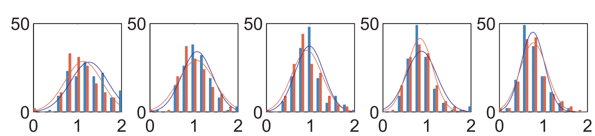

Figure 5: Distributions of normalized responses and best gaussian fits of the data shown in Figure 4

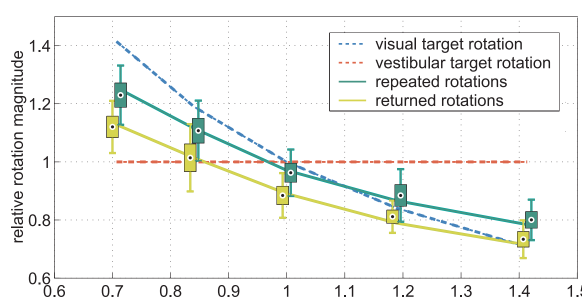

Figure 6: Subjects' normalized responses in return and repeat conditions (data from experiment 2 and 3)

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