Reflex-like spatial updating of rotations can be adapted without any sensory conflict

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• Introduction

Spatial updating as a reflex-like process

In this study, we investigated the adaptation of reflex-like spatial updating. Spatial updating refers to the online updating of our egocentric spatial reference frame during self-motion. This process is typically reflex-like in the sense of being largely beyond conscious control.

Goal: Adapting spatial updating without any sensory conflict

GOAL: It is known that reflex-like processes can be adapted using concurrent sensory conflict. The goal of this study, however, was to test if adaptation can occur even *without* any concurrent sensory conflict. Here, we tried to adapt vestibularly-induced reflex-like spatial updating using a purely cognitive interpretation of the angle turned - that is, without any concurrent sensory conflict, just by presenting an image with a different orientation after physical turns in complete darkness.

• Methods

3 Phases: Pre-test, Adaptation phase, &post-test

EXPERIMENTAL PHASES: The experiments consisted of an identical pre- and post-test and an adaptation phase in between (see Fig. 1). In all three phases, spatial updating was quantified using behavioral measurements of the new post-rotation orientations (rapid pointing to invisible landmarks in a previously learned scene). In the adaptation phase, visual feedback was additionally provided after the turn and pointing task (display of an orientation that differed from the actual (physical) turning angle by a factor of 2).

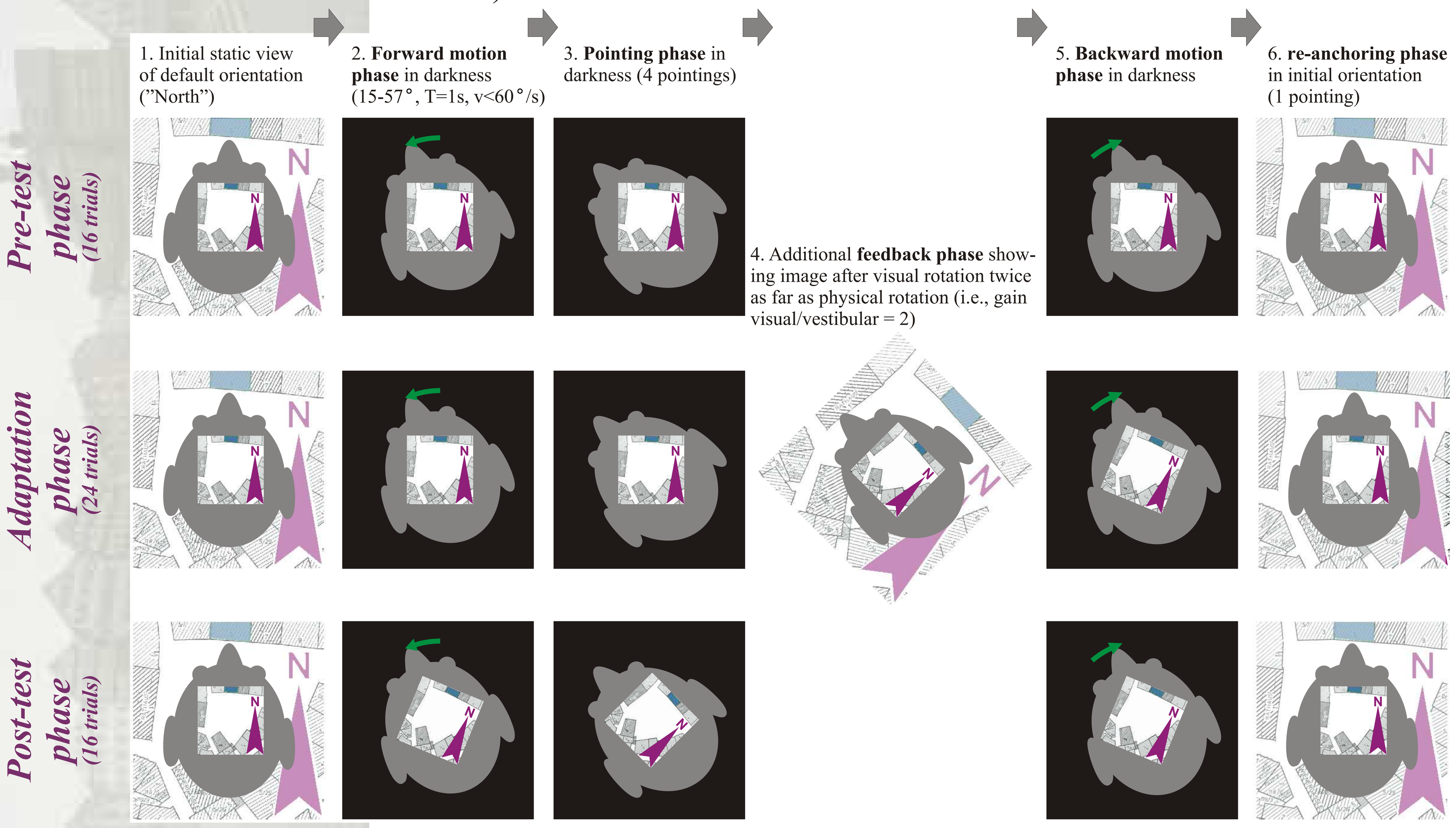

Fig. 1: Experimental design

Each trial consisted of a forward motion phase with four subsequent pointings (both in darkness) and a backward motion phase with one subsequent pointing

TRIAL: After being rotated to a new orientation in complete darkness **(forward motion phase**, see Fig. 1), participants were asked to point "as accurately and quickly as possible" to 4 out of 22 previously-learned targets (**pointing phase**, still in darkness). Targets were announced consecutively via headphones. Afterwards, participants were rotated back to the original orientation in complete darkness (**backward motion phase**). Here, they were re-anchored to the default orientation in the scenery by displaying a static image of this default orientation and by performing one additional pointing (**re-anchoring phase**).

Participants were rotated passively and saw a photorealistic scene

STIMULI: The visual stimulus consisted of a photo-realistic virtual replica (4096x1024 pixel roundshot) of the Tübingen market place presented on a curved projection screen (86°x64° FOV, see Fig. 2-8). All participants were familiar to the scene and trained on the pointing task. For vestibular stimulation, participants were seated on a 6 DOF motion platform.

• Results

Gain factor increased from 1.17 to almost 2

The natural, unadapted gain of perceived vs. real turn angle in the pre-test (gain=1.17) was increased by nearly a factor of 2 in the adaptation phase and remained at this level during the post-test (gain=1.97, see Fig. 9). The difference between the pre-test and post-test gain was significant ($t(3)=-6.34$, $p=.008$).

Even without any sensory conflict

We emphasize that at no point were simultaneous visual and vestibular stimulation provided, therefore, there exists no sensory conflict whatsoever.

Response times and configuration error (see Fig. 9) were comparable to earlier experiments where participants were presented with additional optic flow information about the turn (Riecke et al., 2003 & Riecke, 2003).

Spatial updating performance

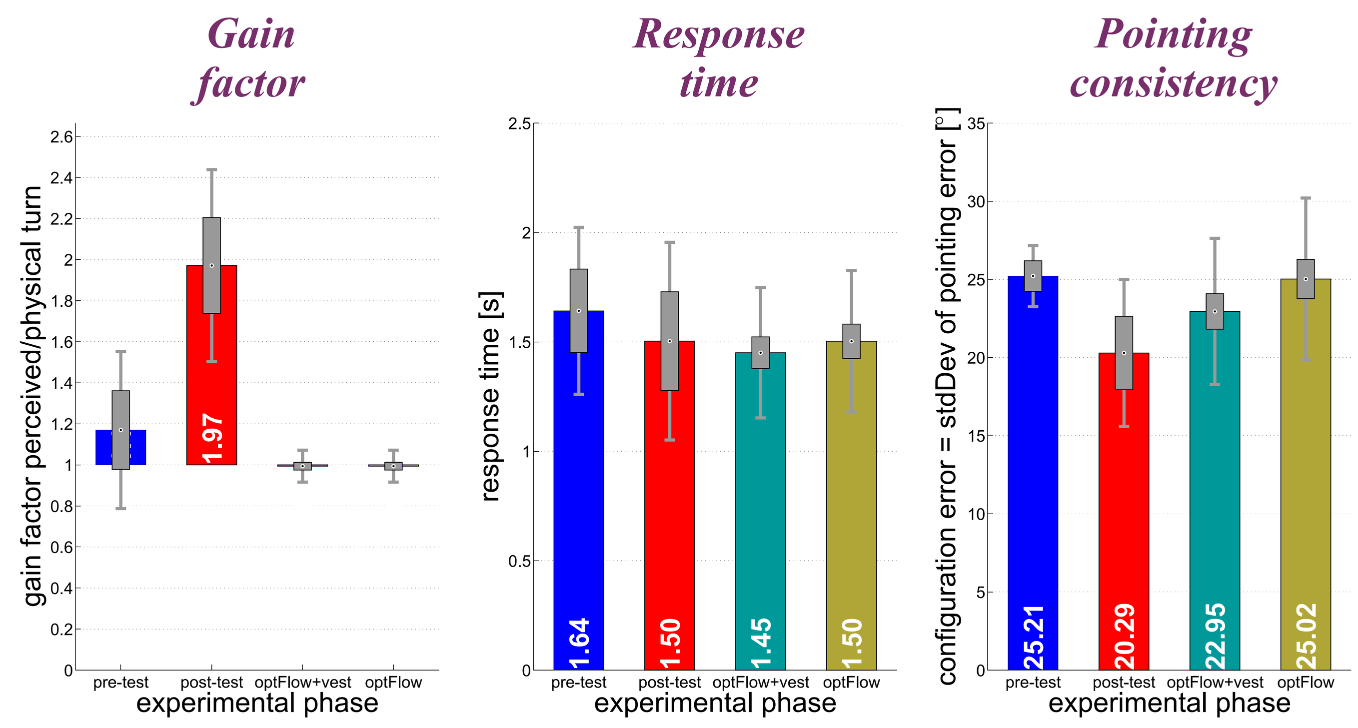

Fig. 9: Mean spatial updating performance. Note the gain factor of almost 2 in the post-test phase. The 'optFlow+vest' and 'optFlow' conditions are data from an earlier spatial updating experiment that used an optic flow stimulus with and without concurrent physical rotations, respectively (Riecke et al., 2003 & Riecke, 2003). Response time and configuration error were comparable between the two studies. Boxes and whiskers denote one standard error of the mean and on standard deviation, respectively.

• Conclusions

A cognitive conflict can recalibrate spatial updating and hence the interpretation of vestibularly perceived self-motions

CONCLUSIONS: Vestibularly-driven reflex-like spatial updating can be adapted without any concurrent sensory conflict, just by a pure cognitive conflict. That is, the cognitive discrepancy between the vestibularly updated reference frame (which served for the pointing) and the subsequently received static visual feedback were able to recalibrate the interpretation of self-motion.

Does that hold for other reflexes like the VOR, too?

OUTLOOK: Future experiments will investigate whether the adaptation of behavioral measures (spatial updating) also affects physiological measures (that is, more reflexive phenomena). The vestibulo-occular reflex (VOR) serves here as a prototypical testbed.

REFERENCES:

Riecke, B. E., von der Heyde, M., & Bülthoff, H. H. (2003). Spatial updating in virtual environments: What are vestibular cues good for? *Journal of Vision,* 2(7), 421a. http://journalofvision.org /2/7/421/

Riecke, B. E. (2003). *How far can we get with just visual information? Path integration and spatial updating studies in Virtual Reality*. PhD thesis, Eberhard-Karls-Universität Tübingen, Fakultät für Physik, http://www.kyb.tuebingen.mpg.de/publication.html?publ=2088.

SUPPORT:

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• Apparatus and material

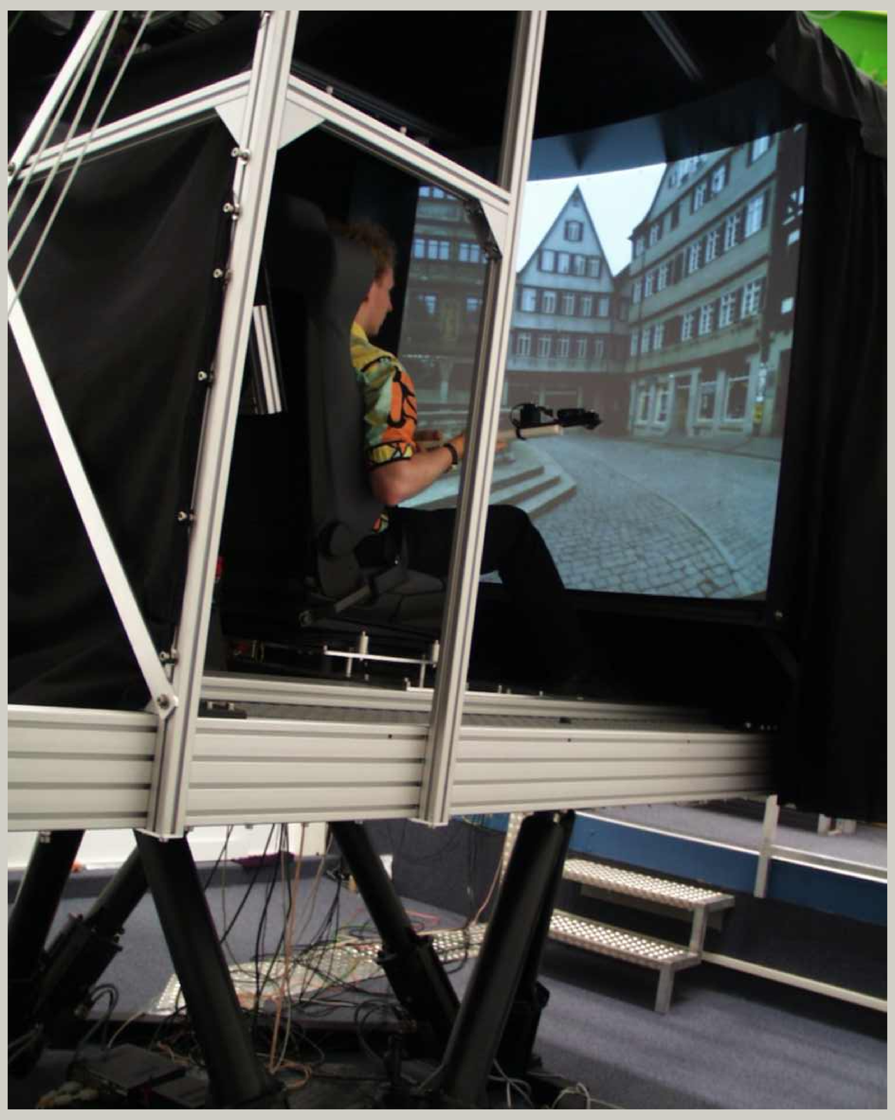

Fig. 2: Participant sitting on the motion platform and facing the curved projection screen. The physical field of view (FOV) is 86°x64° and matches the simulated FOV.

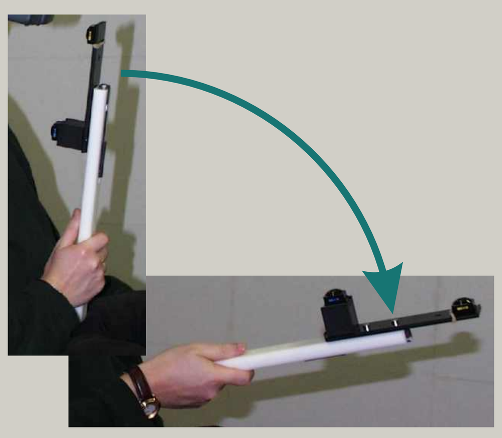

Fig. 3: Position-tracked pointer in the default position (upright) and pointing position.

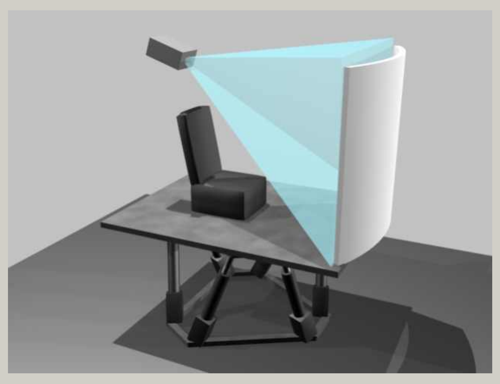

Fig. 4: Schematic experimental setup showing the 6 degree of freedom motion platform and the projection setup.

Fig. 5: The model was created by wrapping a 360° round shot photograph of the Tübingen market place (see Figure 8) onto a cylinder. This creates an undistorted view for the observer positioned in the center of the cylinder.

Fig. 6: 86°x64° view of the market place, displaying the landmarks "Lammhofpassage", "Briefkasten", "Kreissparkasse", "Marktschenke", "Bäckerei", and "Fotomarkt", indicated by little red dots.

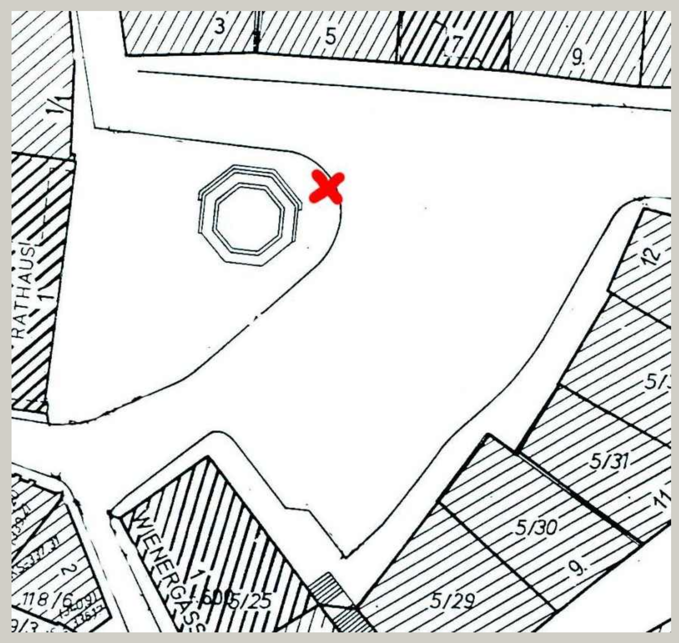

Fig. 7: Bird's eye view of the market place illustrating its irregular geometry. The viewpoint is indicated by the red cross.

Fig. 8: 360° round shot of the Tübingen market place.

Poster presented at ECVP 2003 in Paris.
Available: www.kyb.tuebingen.mpg.de/publication.html?publ=2127