Weighting or selecting sensory inputs when memorizing body-turns: What is actually being stored?

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Introduction

Many previous studies focused on how humans integrate inputs provided by different modalities for the same physical property. Some claim that these are merged into a single amodal percept, others propose that we select the most relevant sensory input. For instance, when exposed to vertical rotations of the visual field, after a while people feel their body moving, which is called circular vection (*Yardley 1990*). The CNS deals with conflicting sensory inputs about the rotation, and after the vection onset, the vestibular modality is inhibited in order to protect self-motion perception from misinterpretations of body kinesthesia (*Brandt et al. 1998; Cheung et al. 1989*). In another study, visual perception could be modulated or suppressed according to the activation of the vestibular system (*Mergner et al. 2000*).

After traveling a virtual path where turning the body was driving the visual displacement, participants could reproduce either visual or body rotations separately, depending on the task context (*Lambrey et al. 2002*).

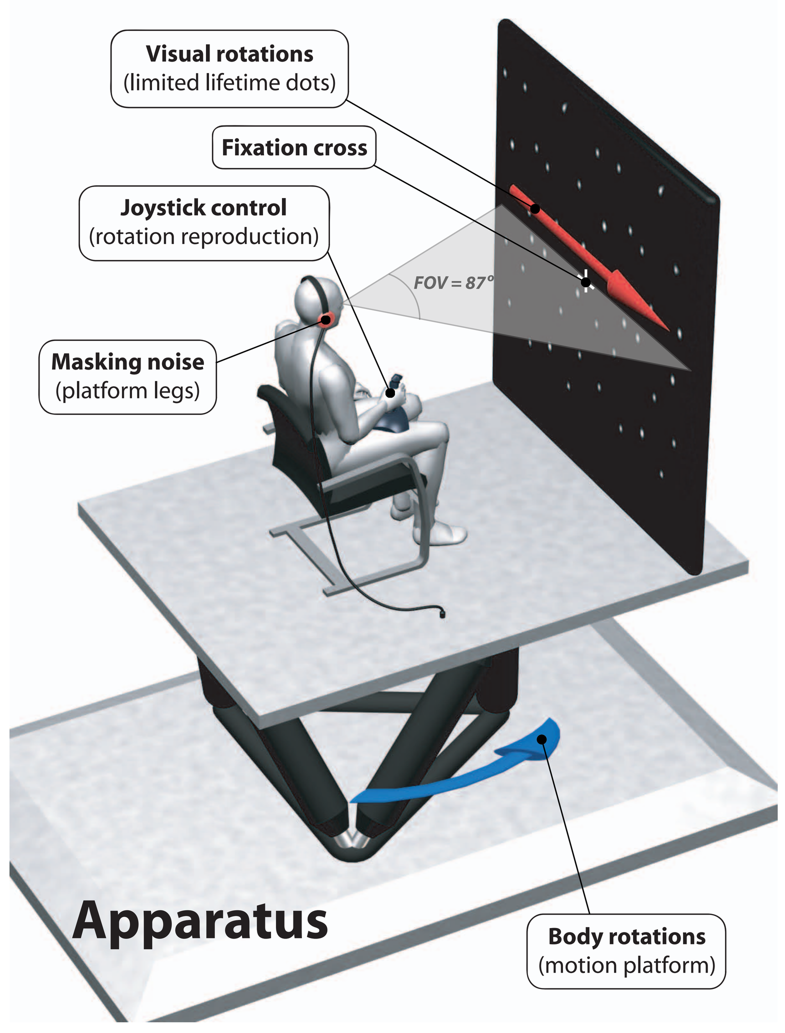
What is actually being stored during self-motion?

We investigated on which sensory base humans can perceive and memorize upright visual and body turns. We designed an experiment to clarify whether we select or merge the stimulated modalities (vision and body senses), in order to reproduce a particular rotation.

Material and methods

14 naïve participants (11 males and 3 females, aged from 20 to 28)

Participants experienced passive whole-body yaw rotations with a corresponding rotation of the visual scene turning 1.5 times faster. Then they were asked to reproduce the rotation in different conditions.



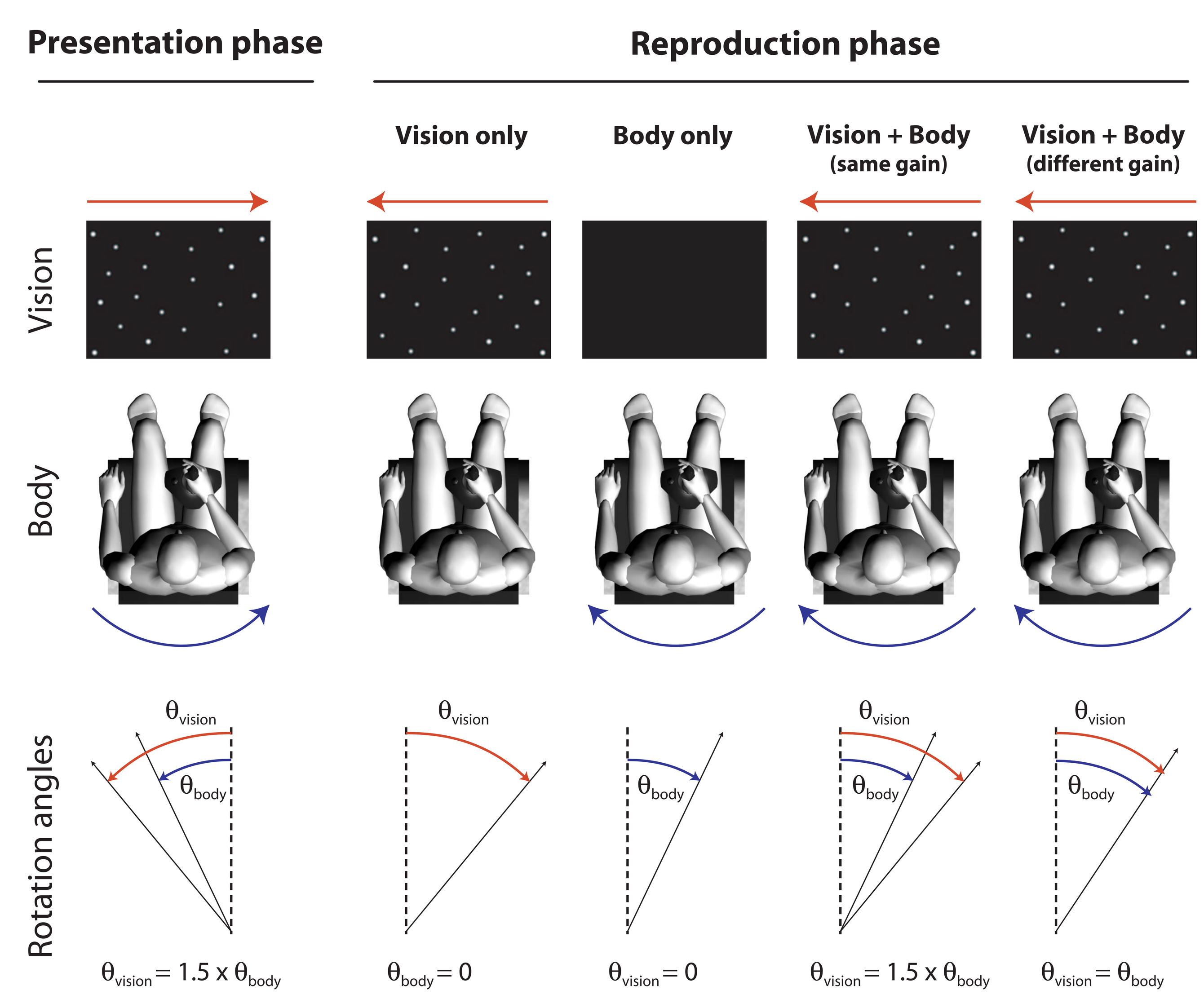
Apparatus and trial characteristics:

- Visual stimuli: limited lifetime (2s) rotating star field
- Body stimuli: motion base rotation
- Unnoticeable conflict: visual/body gain during rotations
- Velocity of presented rotations followed a Gaussian profile (peak velocity & total duration varying)
- Average presented rotations duration: 5.5s
- Backward reproduction with joystick (speed control)
- Fixation cross during all rotations (eye-tracker)
- Masking noise and active sound cancellation

Protocol: trials performed in random order

- 3 rotation angles: 45°/30°, 60/40°, 75°/50° (visual/body)
- 2 turn directions: leftward, rightward
- 4 reproduction conditions: Vision only, Body only, Vision+Body (same and different gain)
- 6 repetitions

144 trials



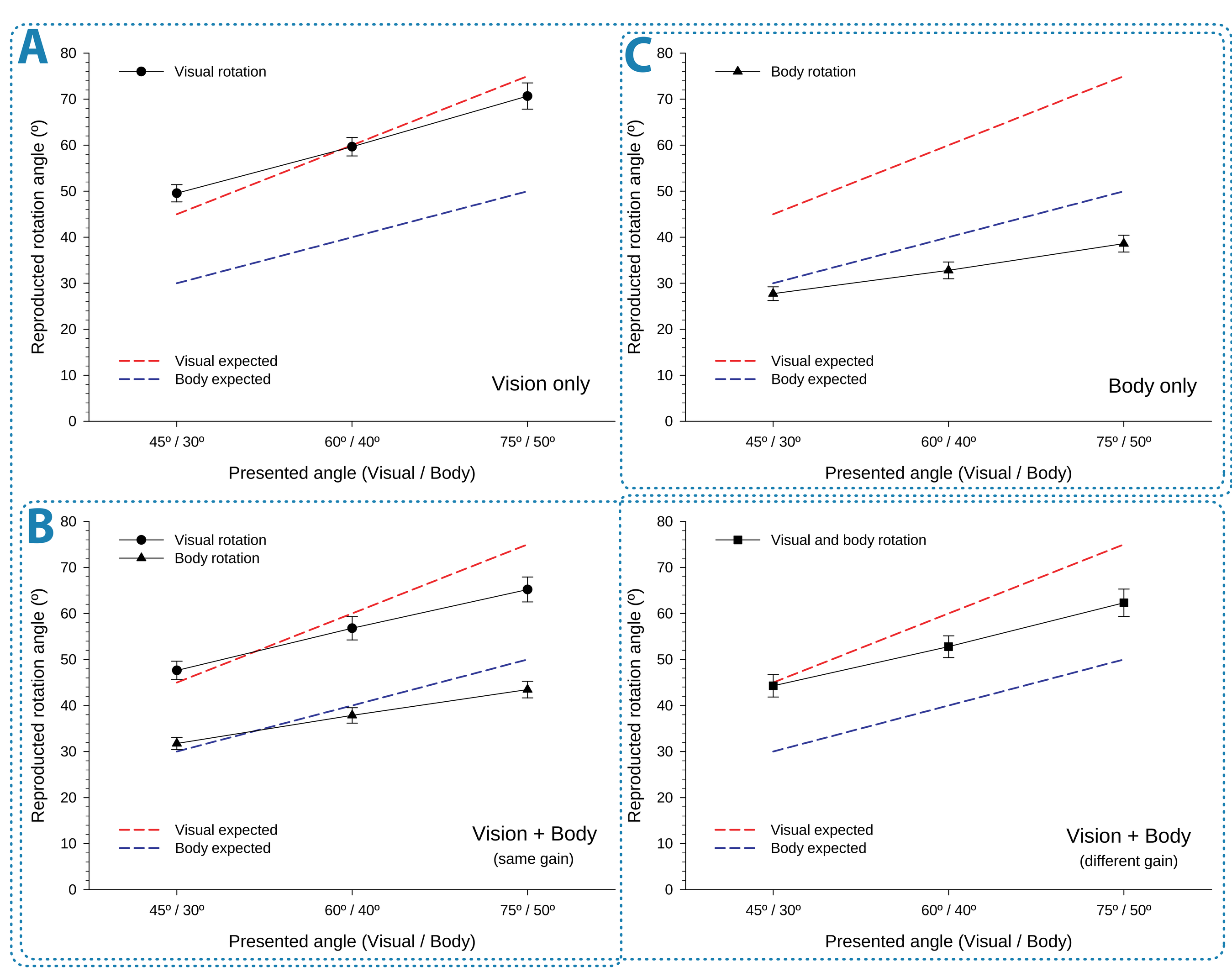
Results and discussion

Raw data: Reproduced rotation angles

No turn direction effect ⇒ leftward and rightward rotations were averaged.

Global tendency to underestimation (range effect), similar for body and visual rotations.

Reproductions with **Vision only** and **Body only** follow the expected rotations, which suggests an independent storage of each stimulated modality (like in *Lambrey et al. 2002*).

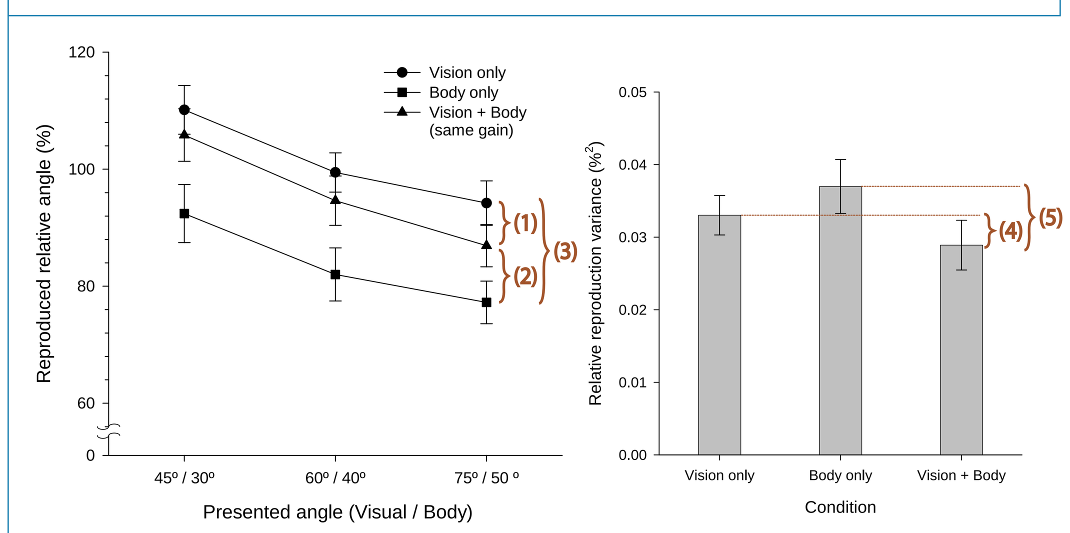


Statistical results:

Repeated measures ANOVAs

- **(1)** $F(1,13) = 13.00 ; p<0.004$
- **(2)** $F(1,13) = 5.83 ; p<0.04$
- **(3)** $F(1,13) = 12.21 ; p<0.004$
- **(4)** $F(1,13) = 3.39 ; p<0.05$
- **(5)** $F(1,13) = 17.38 ; p<0.002$
- **(6)** $F(1,13) = 158.77 ; p<0.001$

A) Multisensory fusion: Optimal fashion?

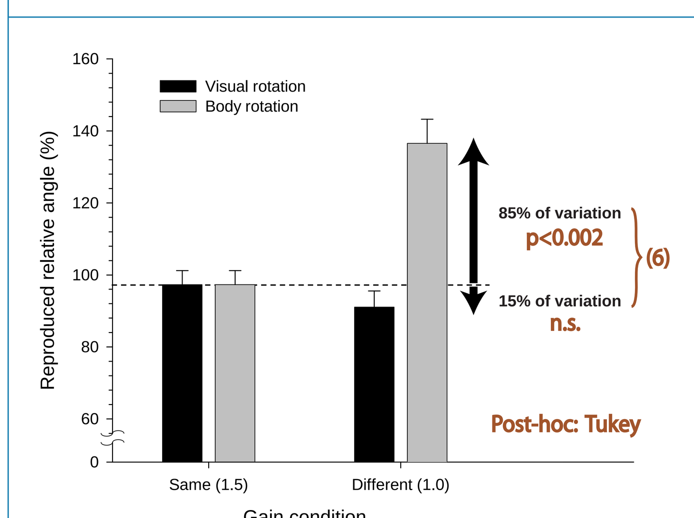


Relative angles calculated (reproduced/expected ratio)

Average estimations in the **Vision+Body (same)** condition lie in between that of the **Vision only** and **Body only**. The multimodal variance was smaller than for unimodal reproductions.

These properties suggest an optimal integration, although results were not consistent with the **MLE model**'s predictions (*Ernst & Banks 2002*)

B) Matching problem: Visual capture

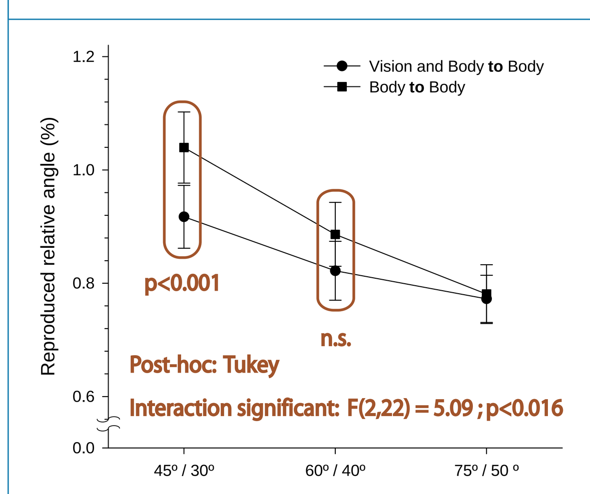


When the conflict changed, it became impossible to match both visual and body rotations. In this situation, participants disregarded the body rotation, and rather matched the visual rotation.

This indicates that when there is a noticeable matching problem, a selection mechanism between modalities occurs, which corresponds to the visual capture. Returning to the initial orientation is then performed on the basis of the visual rotation alone (protection of visual interpretation, like in *Brandt et al. 1998*).

C) Visual vs. Body: Masking of body senses

Comparison with 12 of the previous participants



Reproductions of body rotations with the body were higher than for visual and body rotations, despite the 1.5 times larger visual rotation. This suggests that when vision is available, there is some kind of masking effect of body sensory inputs (vestibular or proprioceptive), resulting in an underestimation of body rotations (mostly for small turn angles). Body turns can be correctly stored (which is consistent with *Siegler et al. 2002*), although vision may disturb this process.

No significant difference between V+B → V and V → V

Future work...

Determine...

- Performance in baseline conditions: **vision to vision** *and* **body to body** } done
- Performance in transfer conditions: **vision to body** *and* **body to vision**
- Effect of redundant sensory information (eventually conflicting) during reproduction: **vision to vision+body** *and* **body to vision+body**

...in order to define a complete model for the multimodal encoding/recalling process.