



MAX-PLANCK-GESELLSCHAFT



MPI FOR BIOLOGICAL CYBERNETICS

Contribution and interaction of visual and vestibular cues for spatial updating in real and virtual environments

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- **Problem: Disorientation in Virtual Reality**
- **Why? What is missing? Vestibular cues?**
- **What did we find?**
 - Vestibular cues *not* required
 - Visual cues *can* be sufficient
- **What was missing? “Spatial updating”!**



“Automatic” vs. “Obligatory” Spatial Updating?



generalized spatial updating

= transformation of egocentric mental
spatial reference frame, e.g.,
during imagined ego-motions or perspective-taking

(automatic) spatial updating

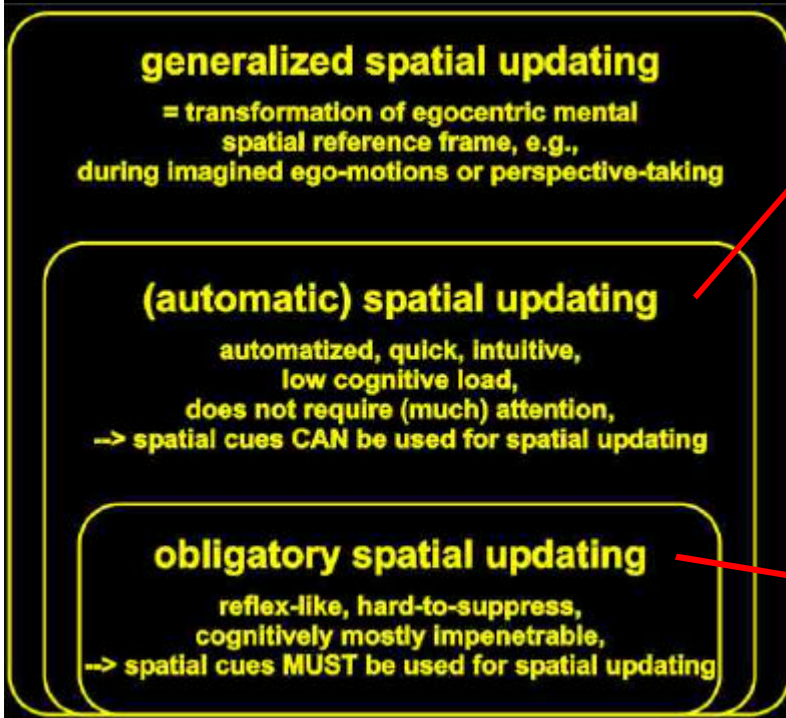
automatized, quick, intuitive,
low cognitive load,
does not require (much) attention,
--> spatial cues **CAN** be used for spatial updating

obligatory spatial updating

reflex-like, hard-to-suppress,
cognitively mostly impenetrable,
--> spatial cues **MUST** be used for spatial updating



Goals



Goal 1: What is needed for *automatic* spatial updating?

- 1 a) Can visual cues alone be sufficient?
- 1 b) When do vestibular motion cues become important?

– **Task: UPDATE vs. CONTROL**

Goal 2: How can we obtain *obligatory*, reflex-like spatial updating?

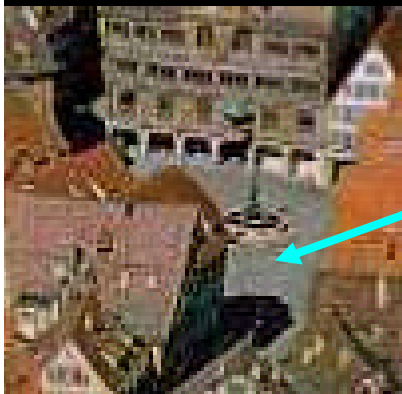
i.e., What spatial cues are powerful enough to transform the world inside our head even against our own conscious will

– **Task: IGNORE vs. UPDATE**

- Ultimate goal: Understanding**
- a) Spatial cognition: How is spatial information used in human brain
 - b) Human factors: How to cheat intelligently



Methods – Virtual Scenery



Targets: 22 landmarks





Methods - Setup



- **Vestibular stimuli: 6 dof Motion Platform**

- **Visual stimuli: LCD video projection setup**

- 86 x 63deg FOV

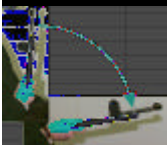
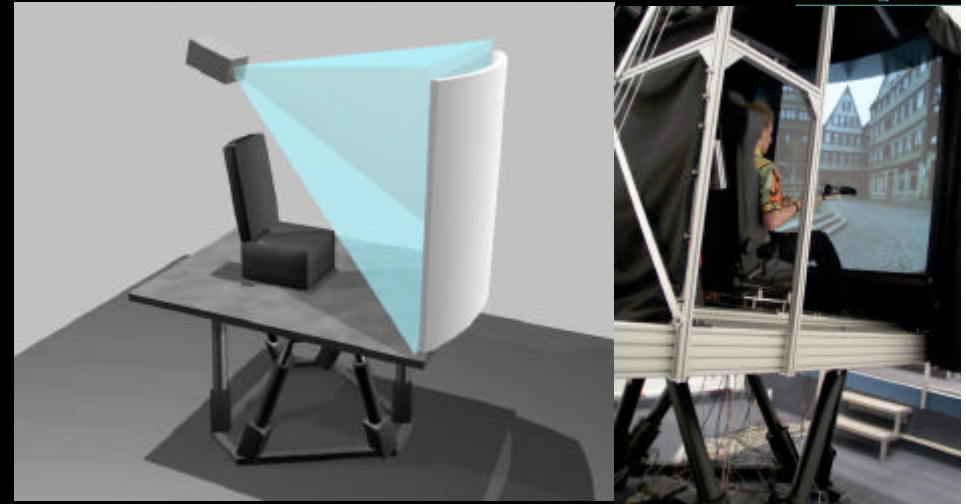
- **Task: Speeded pointing after consecutive rotations**

1. **Auditory announcement of next trial**

2. **Motion phase (turn)** 

3. **Pointing phase:**

- **Auditory target announcement**
- **Subsequent speeded pointing to currently invisible targets: Point “as accurately and quickly as possible!”**
- **Raising pointer to upright (default) position**
- **Repeat 4 times**





- **N=17 participants**
- **Within-subject design**
- **3 spatial updating conditions were alternated**
 - **CONTROL** (baseline for “optimal” performance)
 - **UPDATE** (can spatial cues be used for spatial updating? → test automatization, i.e., automatic spatial updating)
 - **IGNORE** (must spatial cues be used for spatial updating? → test reflex-like character, i.e., obligatory spatial updating)
- **3 independent variables were balanced:**
 - **3 spatial updating conditions (update, control, ignore)**
 - **2 visual conditions**
 - **2 vestibular conditions**

} 4 cue combinations

	landmarks	optic flow
platform ON		
platform OFF		



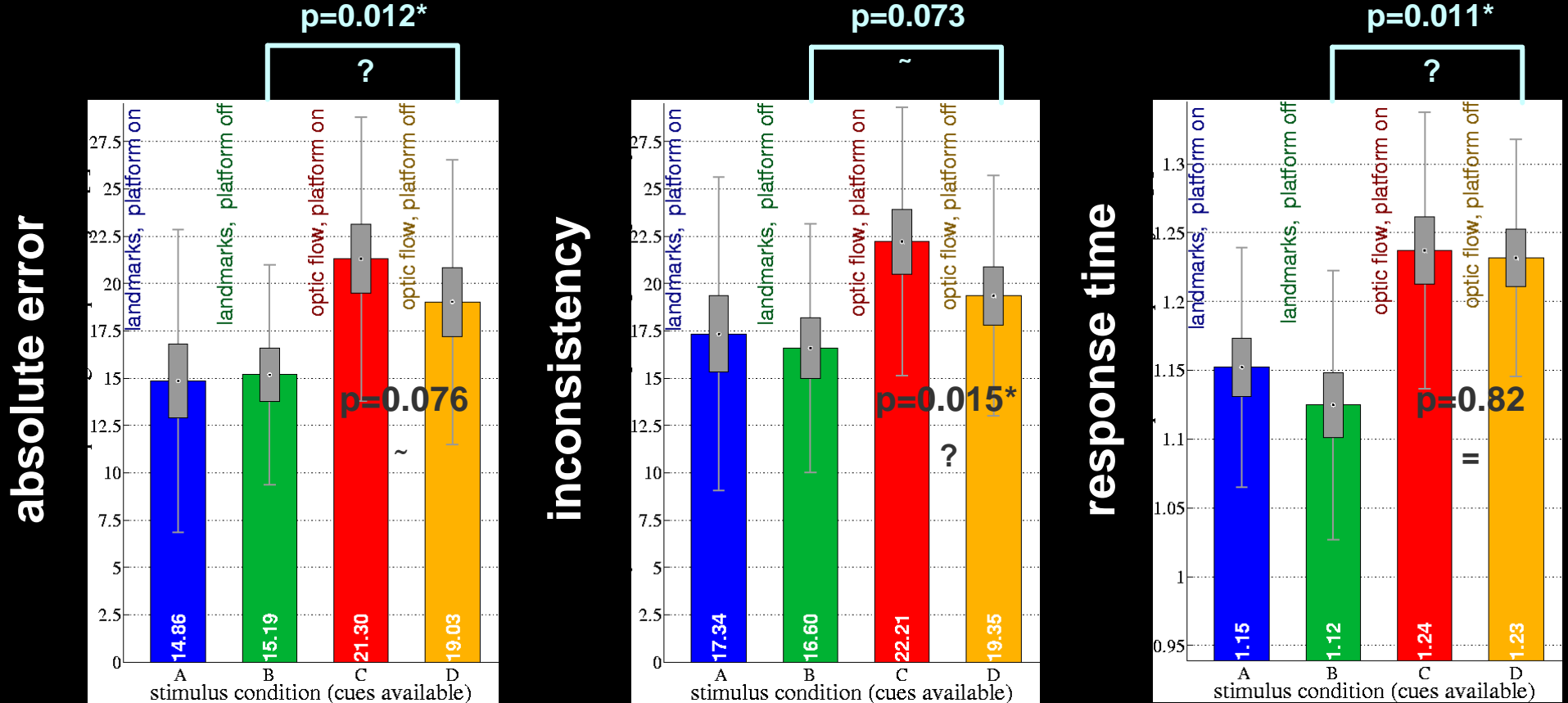
Results – Control Trials (baseline)



Goal: What is needed for good baseline (control) performance?

→ Landmarks are needed for optimal baseline performance (Optic flow is not quite insufficient)

→ Vestibular cues don't help





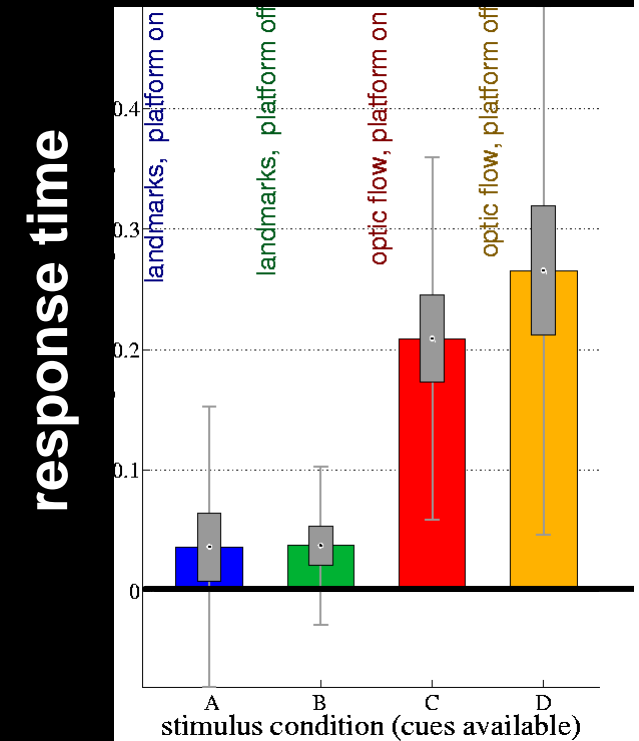
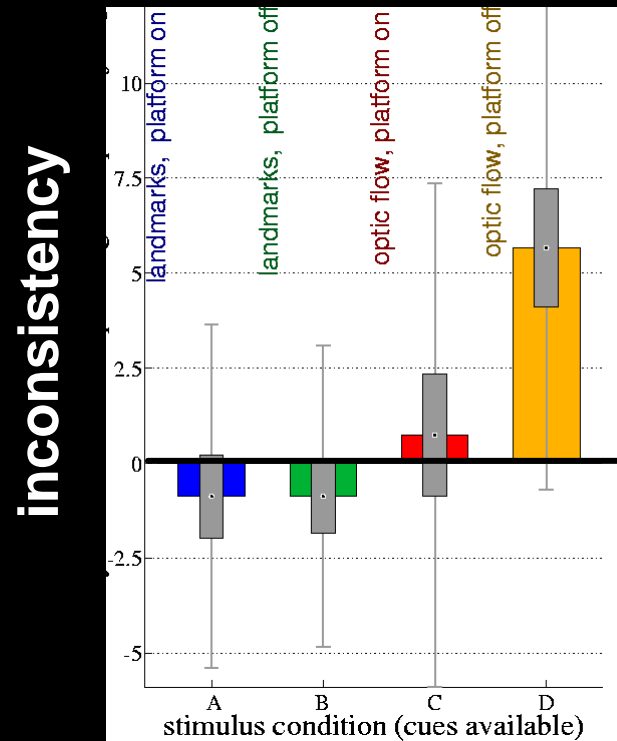
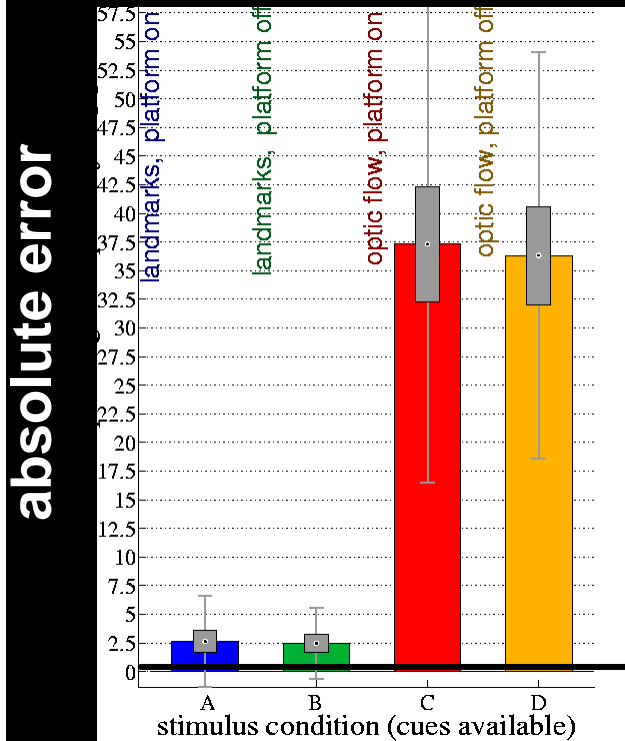
Results – What Cues enable Spatial Updating



Goal 1: What is needed for good spatial updating? (What spatial cues can be used?)



- Photo-realistic visual stimuli (landmarks) are sufficient for enabling good spatial updating (update ~ control), irrespective of vestibular cues
- Vestibular cues are only relevant when visual cues are insufficient (optic flow)





Results – Obligatory (reflex-like) Spatial Updating

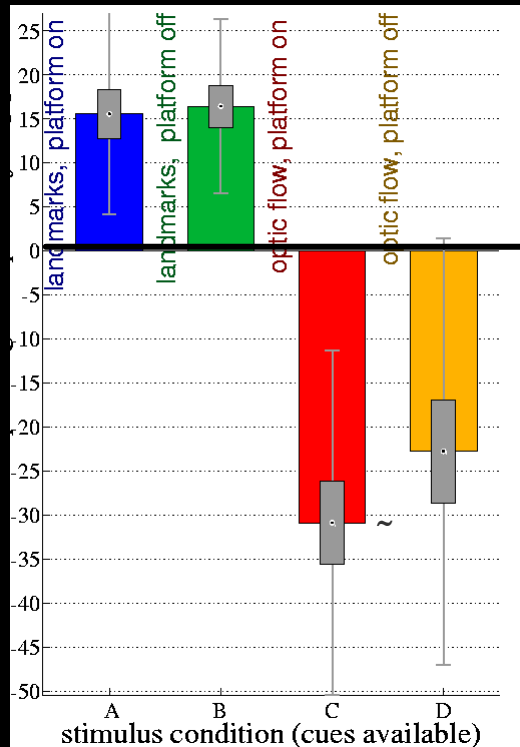


Goal 2: How can we obtain *obligatory*, reflex-like spatial updating?
(What spatial cues cannot be suppressed?)

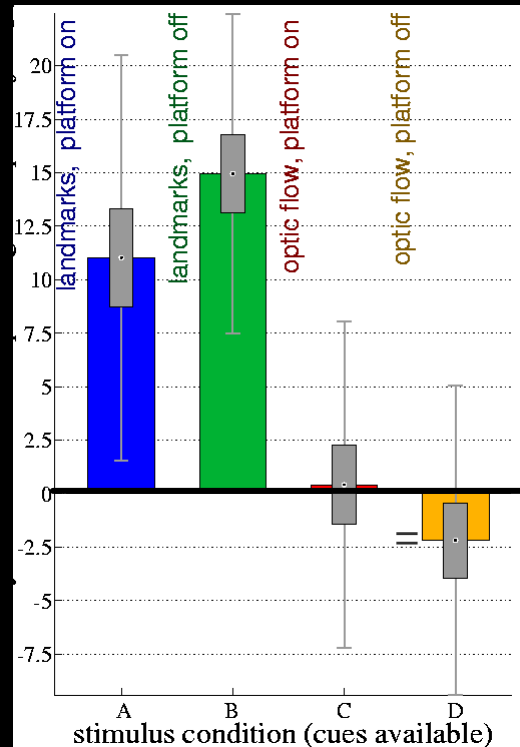


- Photo-realistic visual stimuli (landmarks) are sufficient for inducing obligatory, reflex-like spatial updating (ignore >> update),
- Optic flow is insufficient (ignore < ~ update)
- This is true irrespective of concurrent vestibular cues

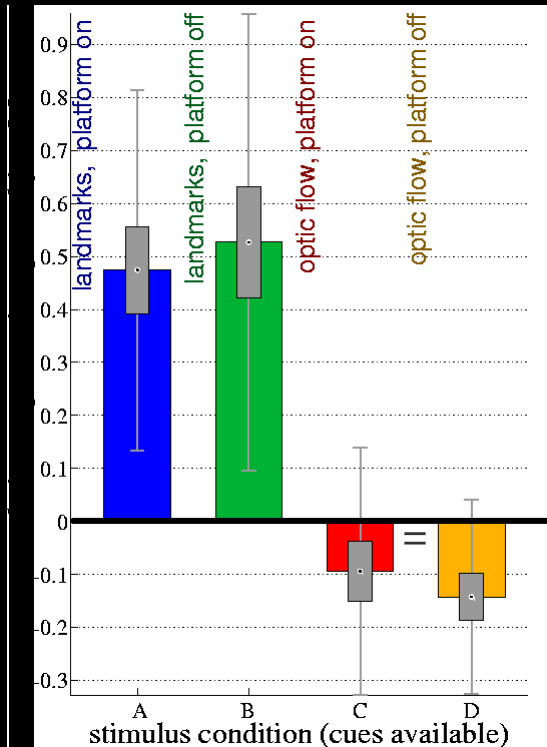
absolute error



inconsistency



response time





- **Landmarken:** Photorealistische visuelle Reize einer bekannten Szene ermöglichen *automatisches spatial updating* und können *obligatorisches spatial updating* auslösen, unabhängig von vestibulären Reizen. → **Dominanz visueller Landmarken**
- **Optischer Fluss:** reicht *nicht* aus für schnelles und genaues spatial updating (weder obligatorisches noch automatisches)
 - IGNORE einfacher als UPDATE, **aber** nicht so einfach wie CONTROL
 - → **Optischer Fluss beeinflusst die mentale Raumrepräsentation**
- **Vestibuläre Reize:** Helfen unzureichende visuelle Reize teils zu kompensieren → reduzierter Konfigurationsfehler (& Desorientierung?)
- Spatial updating wurde durch zusätzliche vestibuläre Reize jedoch nicht obligatorischer!
- **Fazit:** „Gute“ Landmarken, in eine konsistente, bekannte Umgebung eingebettet, können den visuo-vestibulären Konflikt und das Fehlen vestibulärer Drehreize überdecken und obligatorisches spatial updating auslösen

Weitere Info: <http://www.kyb.tuebingen.mpg.de/~bernie> or bernhard.riecke@tuebingen.mpg.de



- **Optic flow is insufficient for quick and accurate spatial updating**
 - IGNORE easier than UPDATE, but not as easy as CONTROL
 - → Optic flow did have effect on mental spatial representation
- **Photo-realistic visual stimuli from a well-known scene can enable automatic spatial updating as well as initiate obligatory spatial updating, irrespective of vestibular cues.**
 - Visual dominance for landmarks
- **Vestibular cues can be used to partially compensate for insufficient visual cues (→ configuration error decrease)**
- **However, vestibular cues do *not* render spatial updating more obligatory!**
- **This suggests that “good” landmarks imbedded in a consistent, well-known scene can overcome the visuo-vestibular cue conflict and lack of vestibular turn cues and initiate obligatory spatial updating.**

Further info: <http://www.kyb.tuebingen.mpg.de/~bernie> or bernhard.riecke@tuebingen.mpg.de



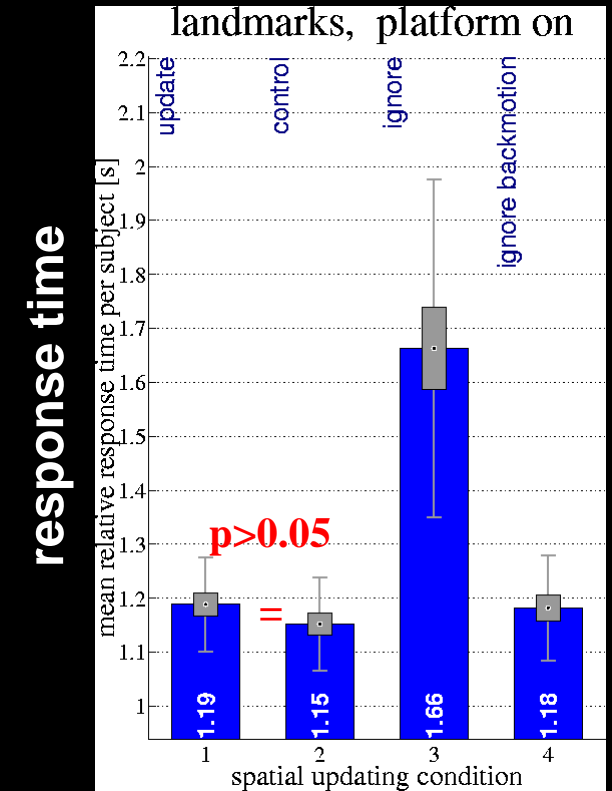
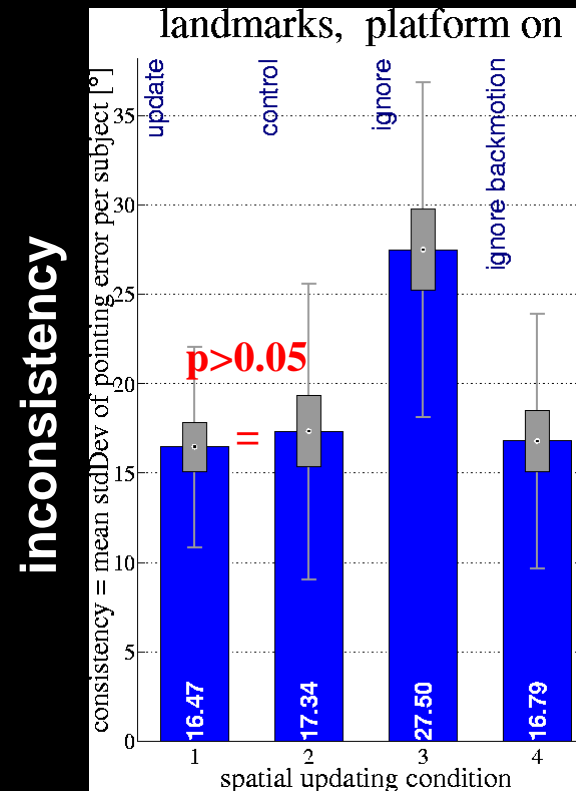
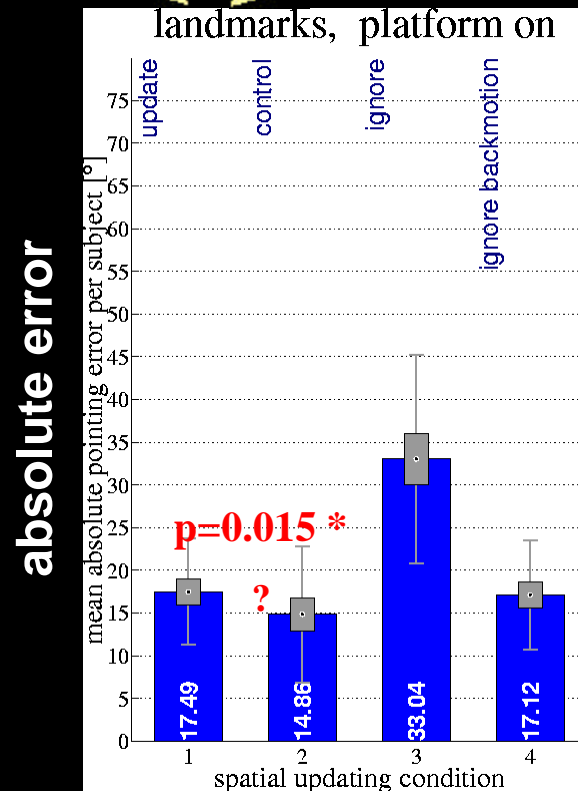
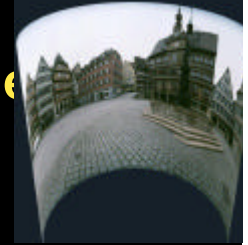
- (not used in the talk)



Results – Landmark Conditions, Platform On



- Can visual landmarks + vestibular cues be used for spatial updating?
 - Yes, update is almost as easy as control
- Must landmarks be used for spatial updating? I.e., are they capable of triggering *obligatory* spatial updating?
 - Yes, IGNORE >> UPDATE ($p > 0.0005$ ***)





Results – Landmark Conditions, Platform Off

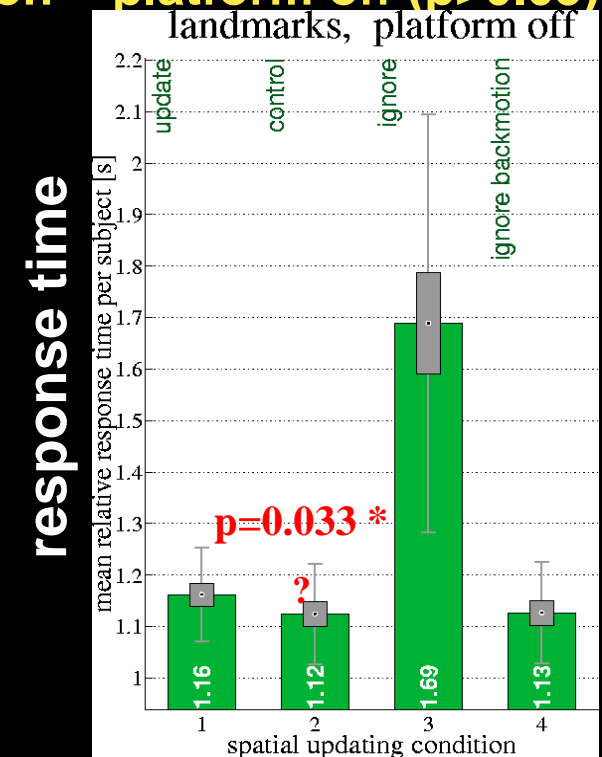
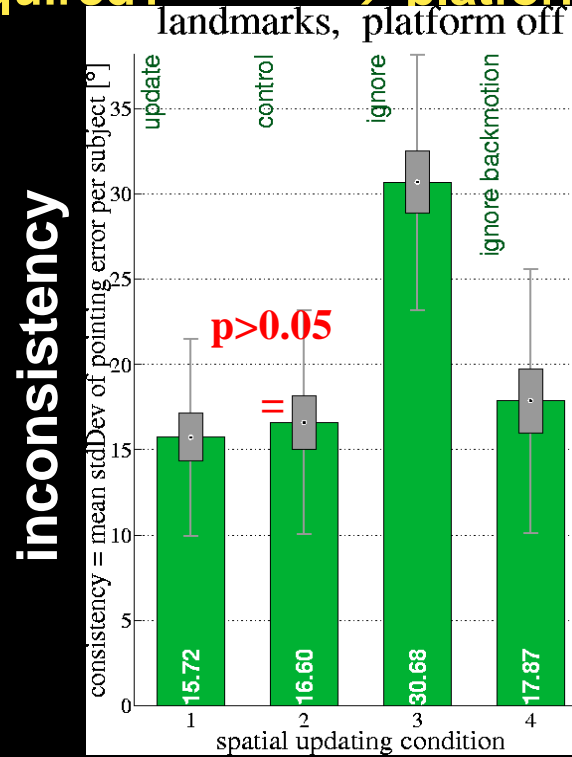
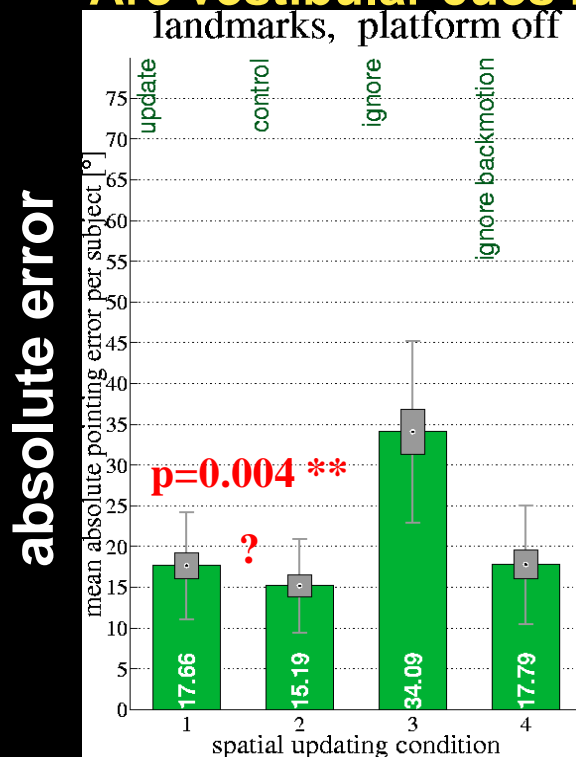


- Can visual landmarks without vestibular cues be used for spatial updating?
 - Yes, but performance without vestibular cues seems more impaired
- Must landmarks be used for spatial updating? I.e., are they capable of triggering *obligatory* spatial updating?



→ IGNORE >> UPDATE ($p > 0.0005$ ***) → Yes

- Are vestibular cues required? → platform on ~ platform off ($p > 0.05$)

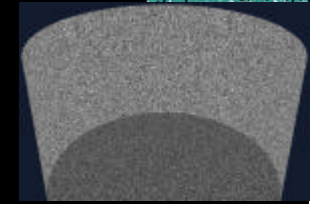




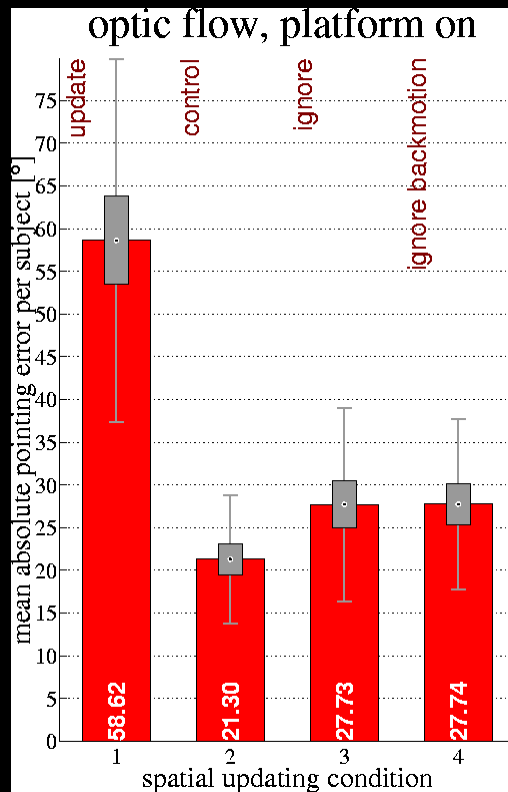
Results – Optic Flow, Platform On



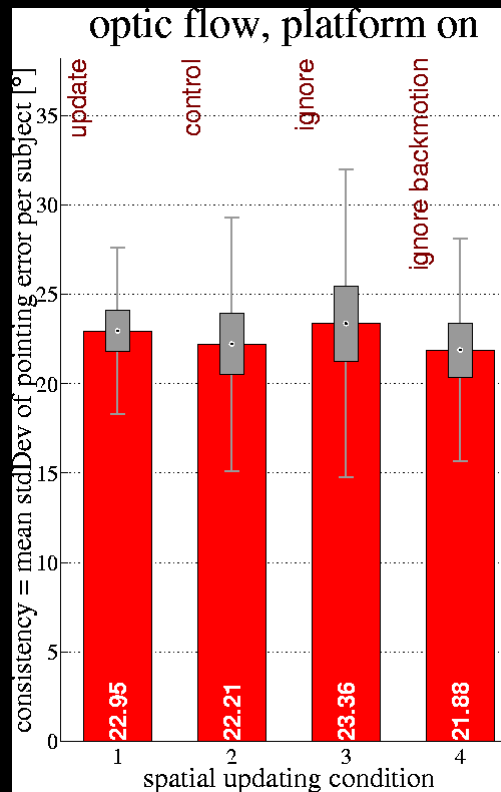
- Can optic flow + vestibular cues be used for spatial updating?
→ UPDATE >> CONTROL → No!
- Are optic flow + vestibular cues able of triggering *obligatory* spatial updating?
→ IGNORE < UPDATE → No!



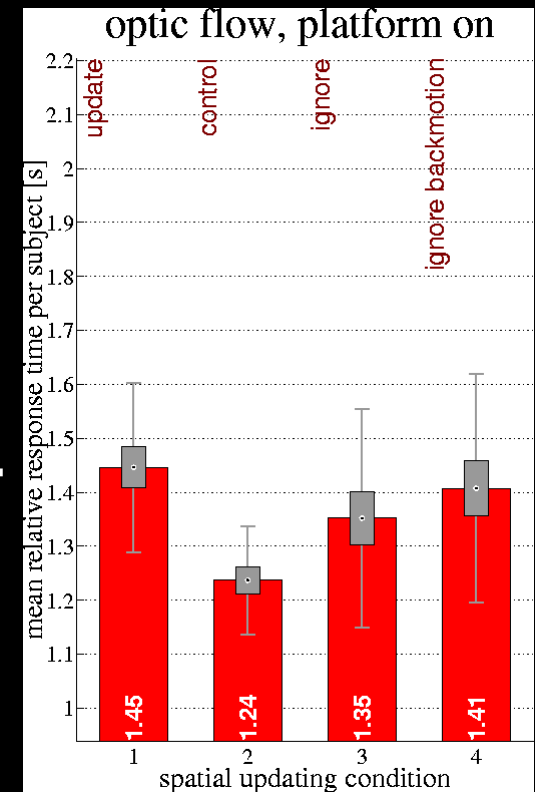
absolute error



inconsistency



response time

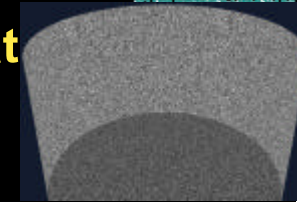




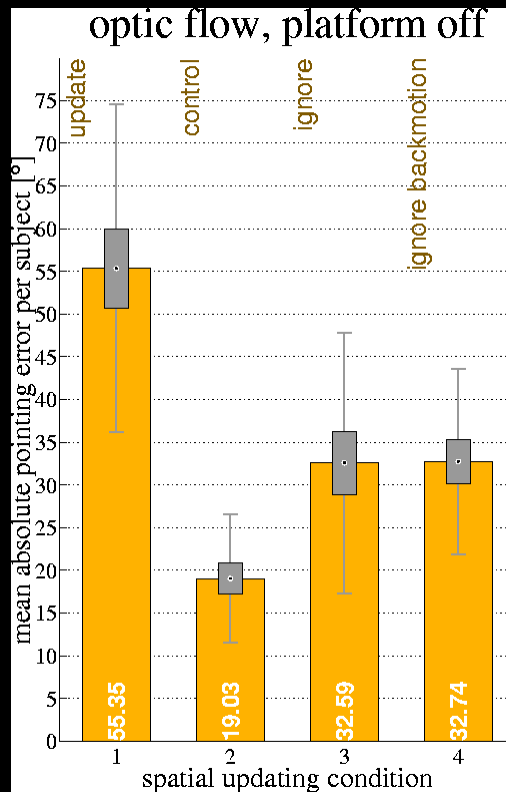
Results – Optic Flow, Platform Off



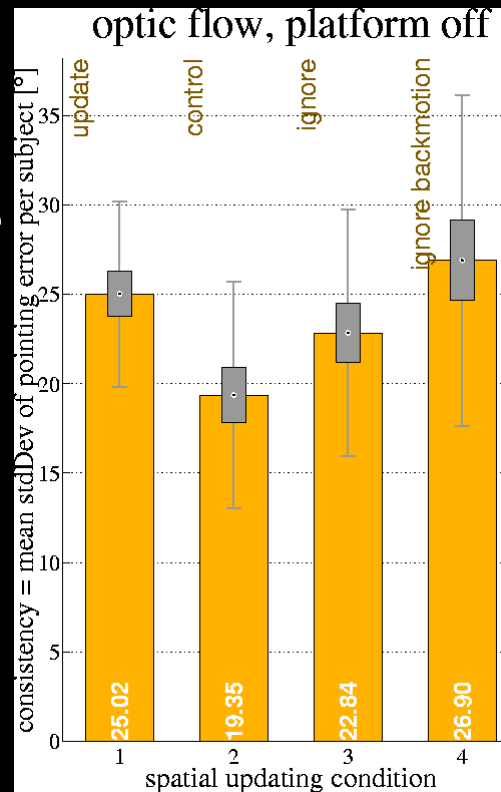
- Can optic flow without vestibular cues be used for spatial updating
→ UPDATE >> CONTROL → No!
- Is optic flow without vestibular cues able of triggering *obligatory* spatial updating?
→ IGNORE << UPDATE → No, even less than with vestibular cues



absolute error



inconsistency



response time

