Shared brain areas underlying imagined and perceived self-motion

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Mental changes of self location
Mental Simulations & Neural Correlates

Idea

(a) S₁ → s₁ → r₁ → R₁
S₂ → s₂ → r₂ → R₂

(b) S₁ → s₁ → r₁ → R₁
S₂ → s₂ → R₂

(c) S₁ → s₁ → r₁ → R₁
S₂ → s₂ → r₂ → R₂
S₃ → s₃ → r₃ → R₃

TRENDS in Cognitive Sciences
Hesslow, 2002

Neural Level

Kosslyn et al., 2001

Motor Imagery
Movement Execution

Hardwick et al., 2017, bioRxiv
Vestibular imagery?

Vestibular Recall & Imagery

No vestibular areas involved in recall

In contrast to the galvanic vestibular control experiment, we did not detect activations in the parietal operculum, the posterior insula (PIVC) or the superior temporal gyr. Other essential gateways within the cortical vestibular network like the hippocampus or the dorsolateral thalamus were also unresponsive during our vestibular recall task (Dieterich et al, 2005; Smith et al, 2010). All of which are well-known

Very difficult

cause the rating (Logie et al, 2011). Hence, we feel that the high degrees of difficulty in recalling a vestibular sensation and the missing activation of core regions within the vestibular network during the recall task suggest a hindered voluntary access to cortical vestibular areas.

Zu Eulenburg et al., 2013

Nigamatullina et al., 2015
Why is this relevant?

OBE in vestibular disorders

Phenomenology and pathophysiology of autoscopic phenomena

Falling (2.5-3.0 mA)
OBE (3.5 mA)

Blanke et al., 2002
Blanke et al., 2004
Lopez & Elzière, 2017
Mental self-rotation & Vestibular processing

Idea: Areas involved in self-motion are also involved in simulated self-motion

Microgravity
- Grabherr et al., 2007

GVS
- Lenggenhager et al., 2008
- Dilda et al., 2011

CVS
- Falconer & Mast, 2012

Passive self-motion
- Van Elk & Blanke, 2014
- Deroualle et al., 2015

→ Mental body transformations
(simulated change in self-location)

Inconclusive results: Conflicting stimulations, Individual strategies
Which cortical areas are involved in vestibular processing and simulated self-location changes?

Galvanic Vestibular Stimulation and Mental Rotation

GVS: Method & neural correlates

Mental Rotations

Area OP2

Tomasino et al., 2016

Eickhoff et al., 2006

Lopez et al., 2012

Smith et al., 2012
Current study: Two aims

1. Cortical overlap of simulated and perceived self-motion
   - Simulated = egocentric mental rotation
   - Perceived = GVS

2. Behavioral effects of GVS on simulated self-motion
Mental Rotation & Vestibular Stimulation

Egocentric Rotation

Object Rotation

No Rotation

Keehner et al., 2006

GVS Signal

Sensation

Gravity
fMRI Design

3 (Egocentric, Object, No Rotation) x 2 (GVS, Sham) Design
Main effect of GVS

GVS vs Sham over all rotation tasks

pFWE < 0.05
Conjunction analysis: Area OP2

Area OP2

Vestibular processing & egocentric mental rotation

A) Conjunction egocentric rotation & vestibular processing in OP2

B) Mean parameter estimates from conjunction in OP2

$pFWE-SVC = .039$
Current study: Two aims

1. Cortical overlap of *simulated* and *perceived* self-motion
   - Simulated = egocentric mental rotation
   - Perceived = GVS

2. Behavioral effects of GVS on simulated self-motion
Accuracy & Reaction Times

Proportion of correct responses

Reaction Times

Stimulation
- GVS
- Sham
Conclusion

> Vestibular brain areas are involved in egocentric mental rotation.

> First evidence that *vestibular processing* and *egocentric mental rotation* rely on shared area in the vestibular cortex (area OP2)

> No effect of GVS on egocentric mental rotation
  - Robustness to interference?
  - Task difficulty?
  - Difference to body rotation task?
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Thank you for the attention
Conjunction analysis: Area OP2 II

Post hoc correlations

Shared area involved in egocentric mental rotation and vestibular processing

Brain-Behavior relationship: The higher the difference, the faster the responses

C) Contrast estimates OP2 conjunction

D) Contrast estimates & Reaction Times – OP2 conjunction