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GÖTTINGEN : UMG

How sensory anticipations in the human brain control motor action

ESCoP 2011

Roland Pfister, Tobias Melcher, Andrea Kiesel, & Oliver Gruber

Outline

- Dogma: Actions are controlled by sensory anticipations (ideomotor theory).

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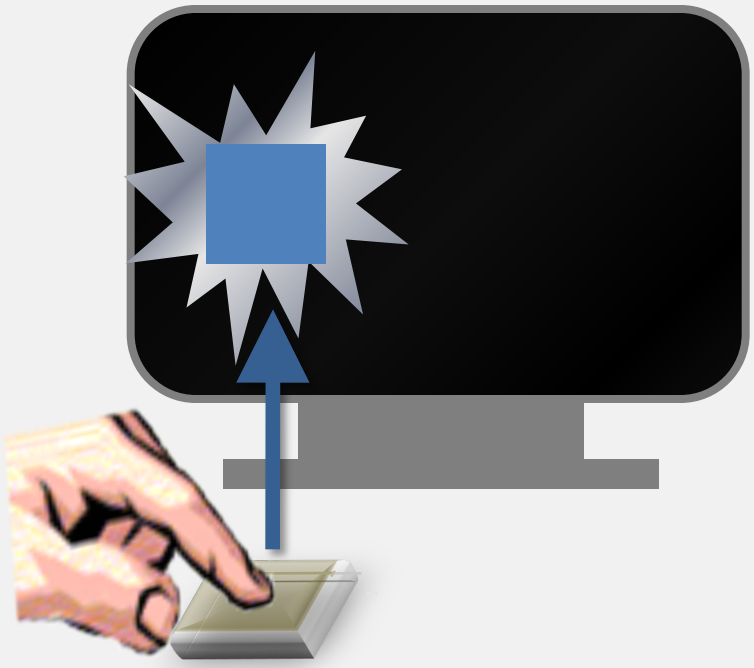
- Design: event-related fMRI…
- ...with (measureable) effect anticipations in some trials and no anticipations in other trials.

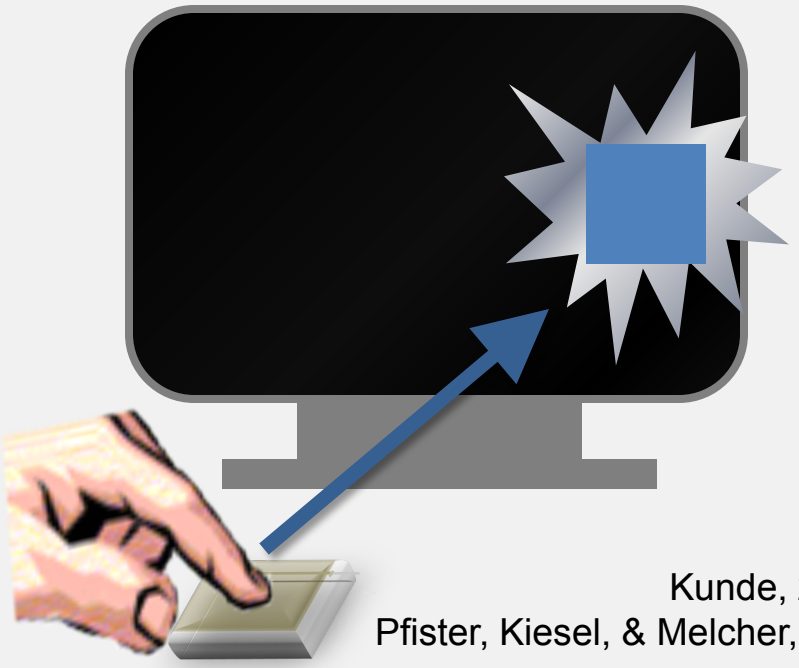
How to measure anticipations?

- Response-Effect Compatibility

R-E compatible



R-E incompatible

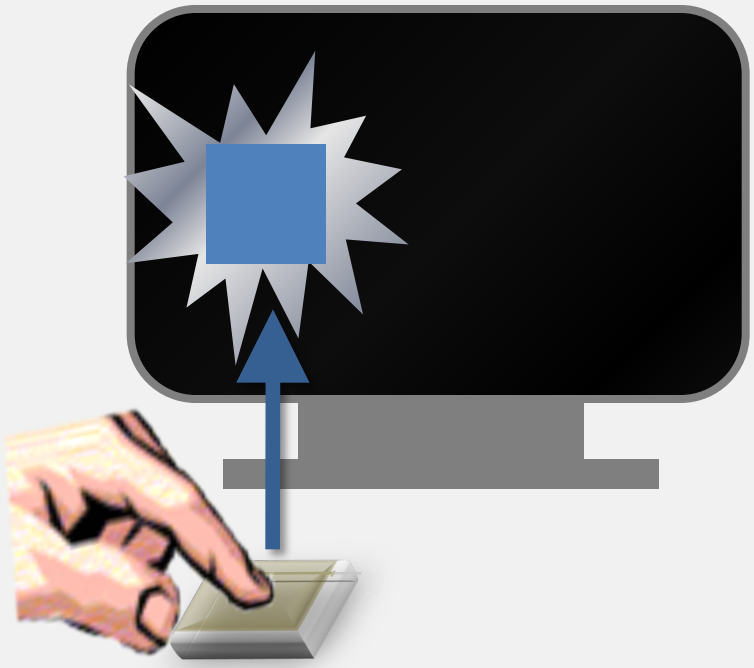


Kunde, 2001;
Pfister, Kiesel, & Melcher, 2010

How to measure anticipations?

- Response-Effect Compatibility
- Context-specific design (trial-by-trial)

R-E compatible



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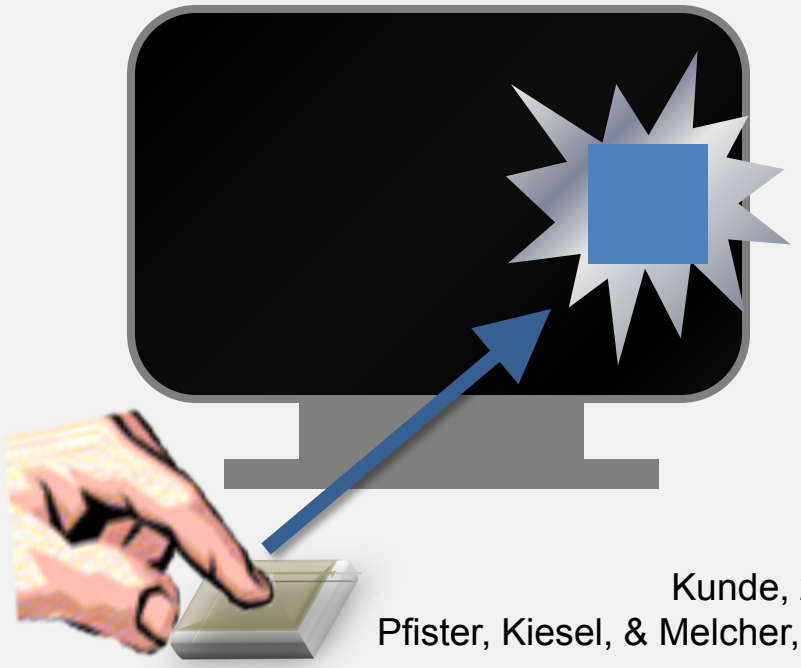
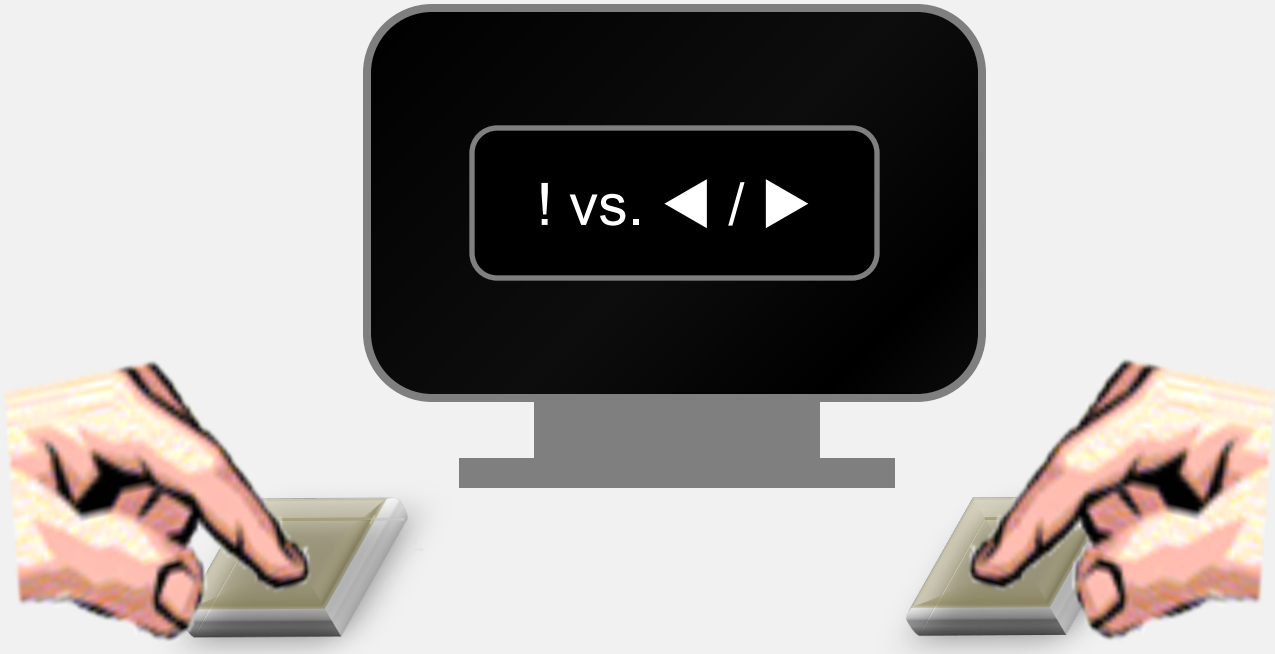


Kunde, 2001;
Pfister, Kiesel, & Melcher, 2010

Switching anticipations on and off

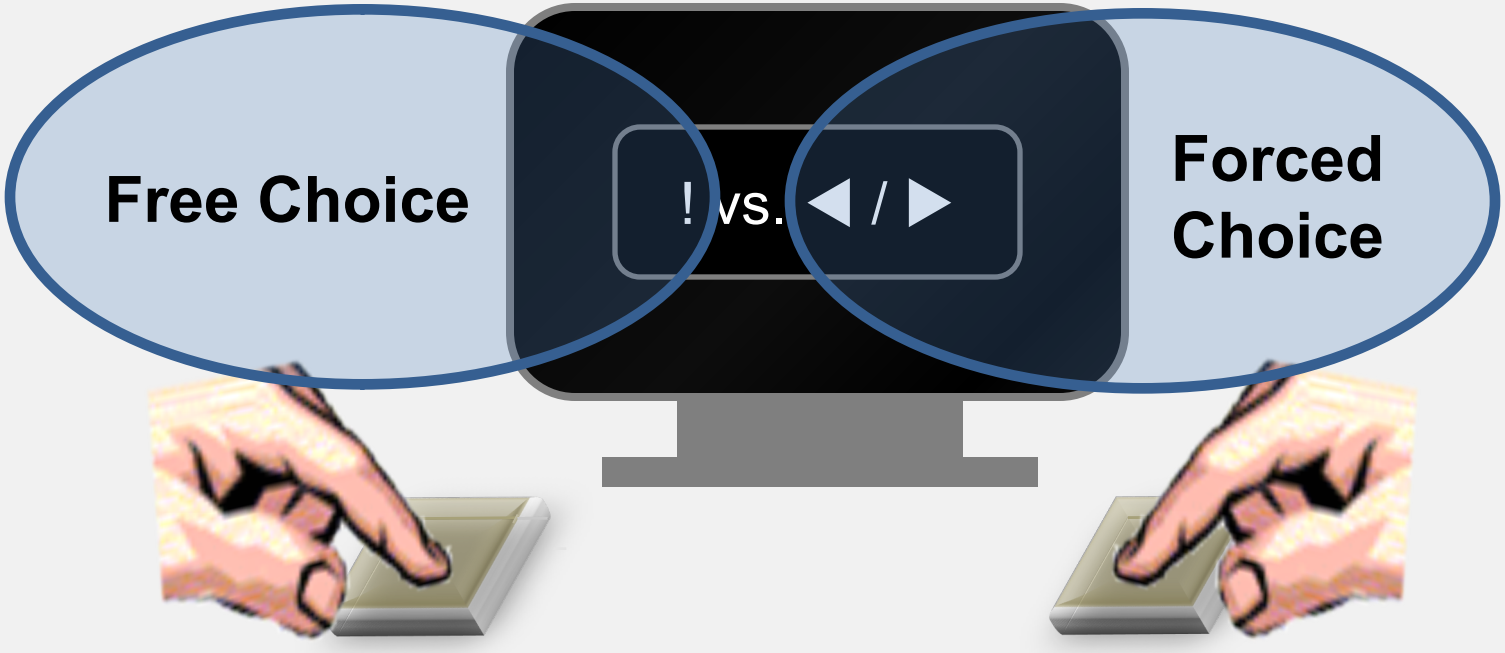
- Endogenously vs. exogenously selected actions



Pfister, Kiesel, & Melcher, 2010; cf. Ansorge, 2002

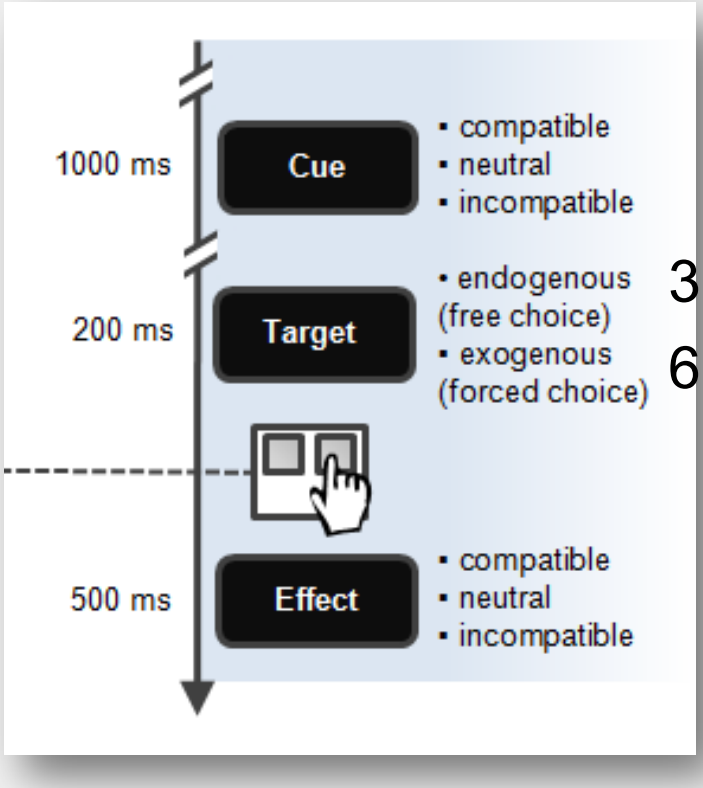
Switching anticipations on and off

- Endogenously vs. exogenously selected actions



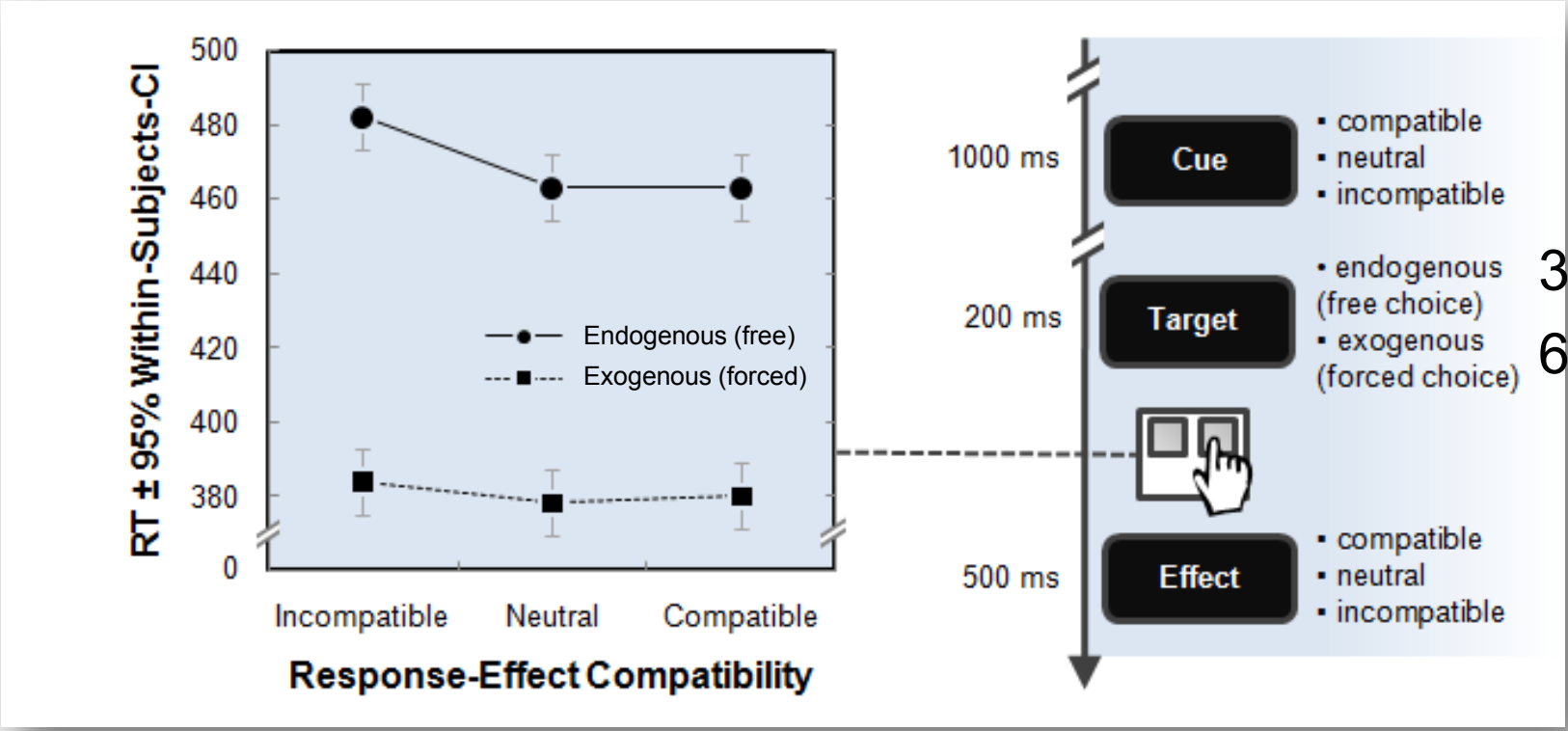
Pfister, Kiesel, & Melcher, 2010; cf. Ansorge, 2002

Design & behavioural results



N = 18

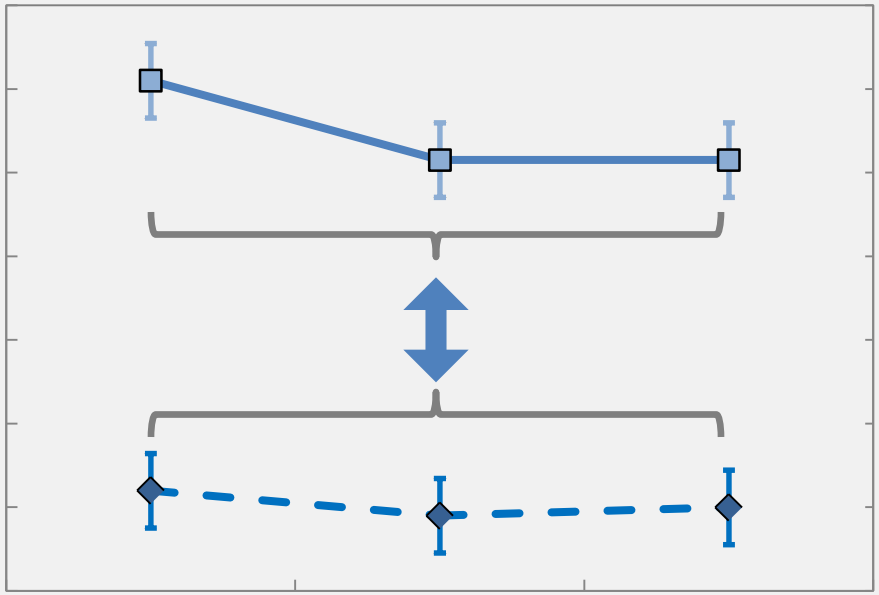
Design & behavioural results



N = 18

fMRI analysis I

1. Step: Contrasting endogenous (anticipations!) and exogenous actions (no anticipations!)



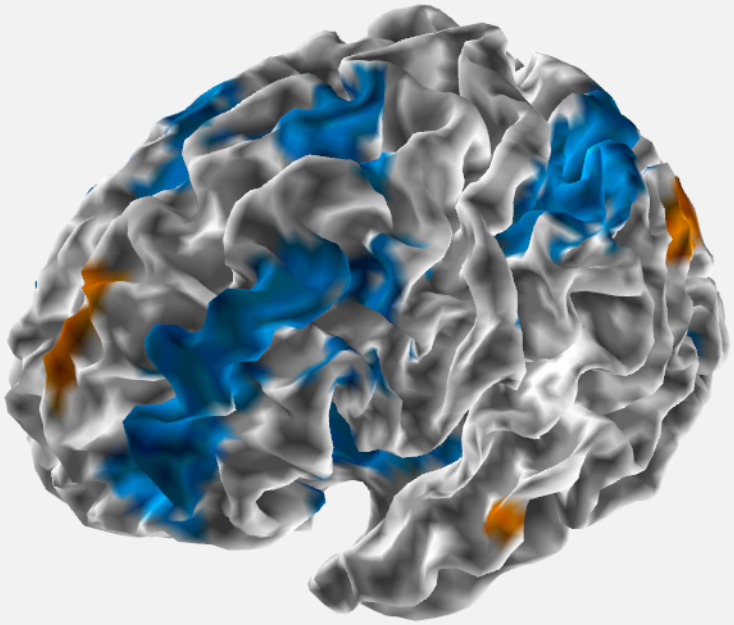
e.g., Jahanshahi et al., 1995; Rowe et al., 2010

1. Step: endogenous vs. exogenous

Endogenous > Exogenous

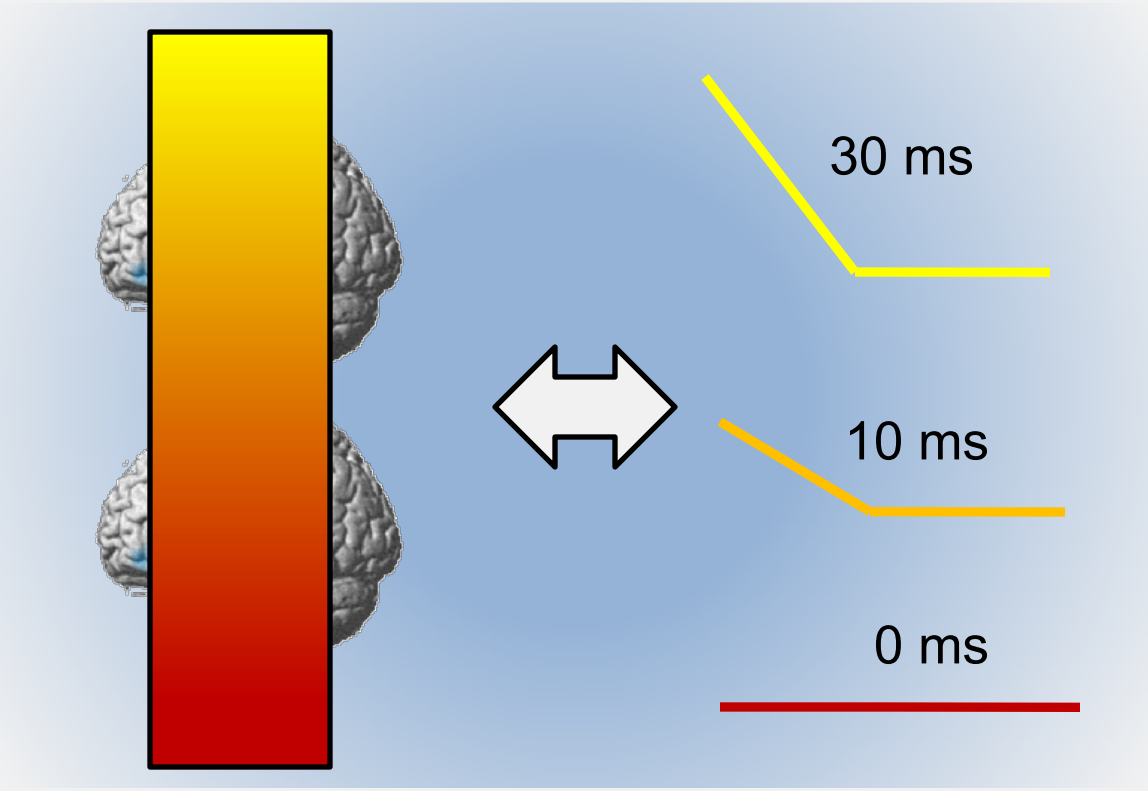
Exogenous > Endogenous

$p < .001$, uncorr., $k = 20$



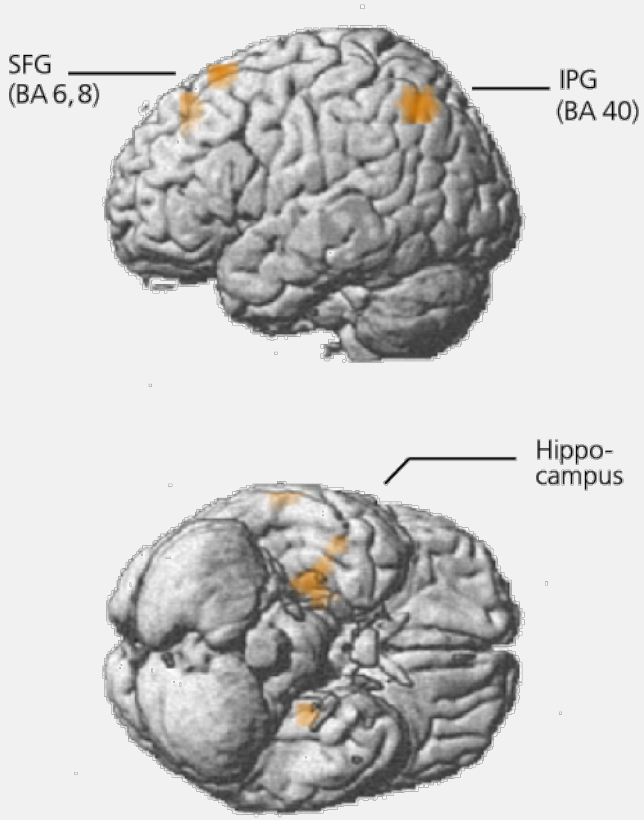
fMRI analysis II

2. Regression with individual R-E compatibility effects (i.e., the „strength“ of ideomotor effect anticipations)



2. Step: Regression analysis

$p < .005$, uncorr., $k = 20$ ($k = 15$ for left parahippocampal gyrus)



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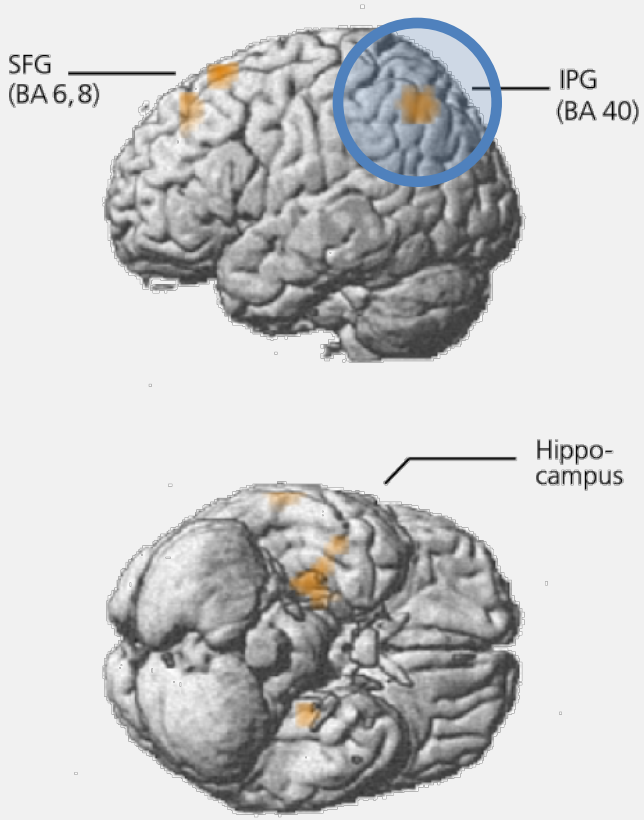
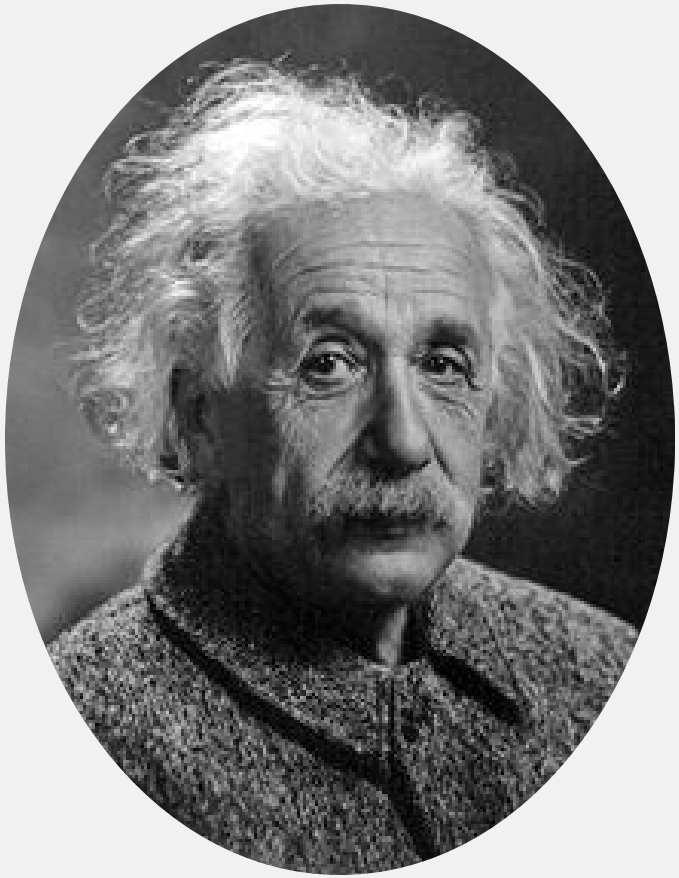


Inferior parietal



"[...] the inferior parietal lobe was 15 percent wider than normal."

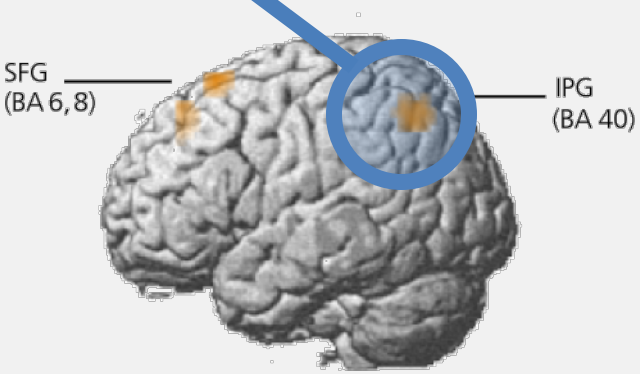
"Einstein's brain had more glial cells relative to neurons in all areas studied, but only in the left inferior parietal area was the difference statistically significant."

http://en.wikipedia.org/wiki/Albert_Einstein's_brain

Inferior parietal

Ideomotor Apraxia

Liepmann (1905), Daprati et al. (2010)



Inferior parietal

Ideomotor Apraxia
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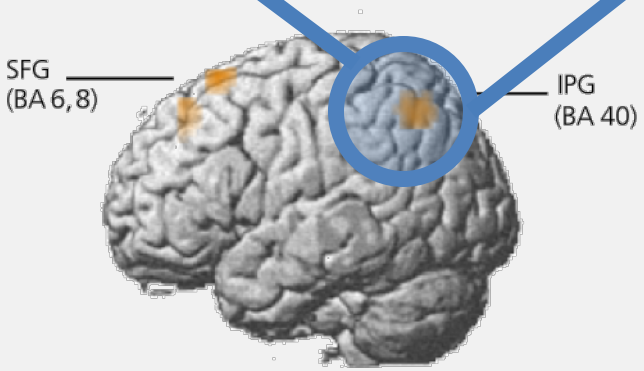
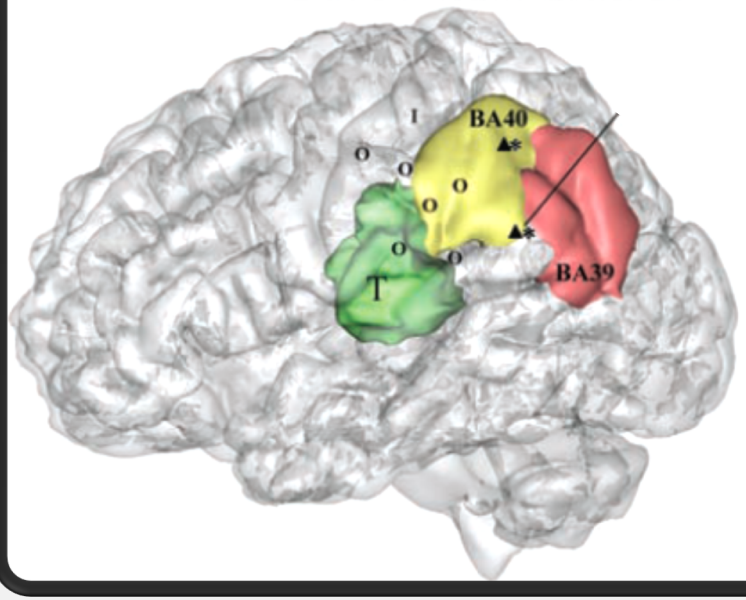
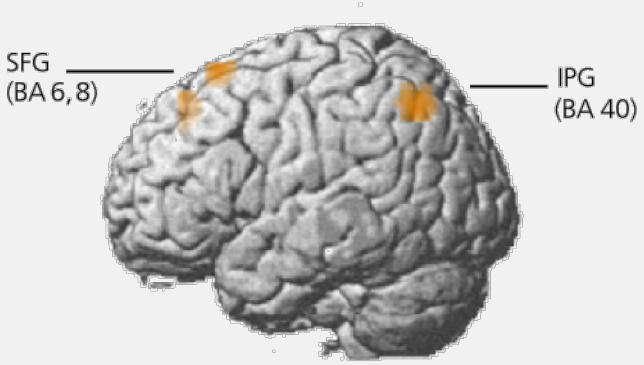


Direct Cortical Stimulation
(Desmurget et al., 2009):

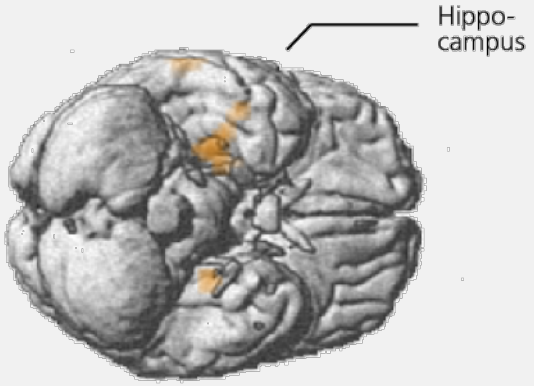


Conclusions

- The inferior parietal cortex (BA 40) is a central structure for action control via sensory anticipations.

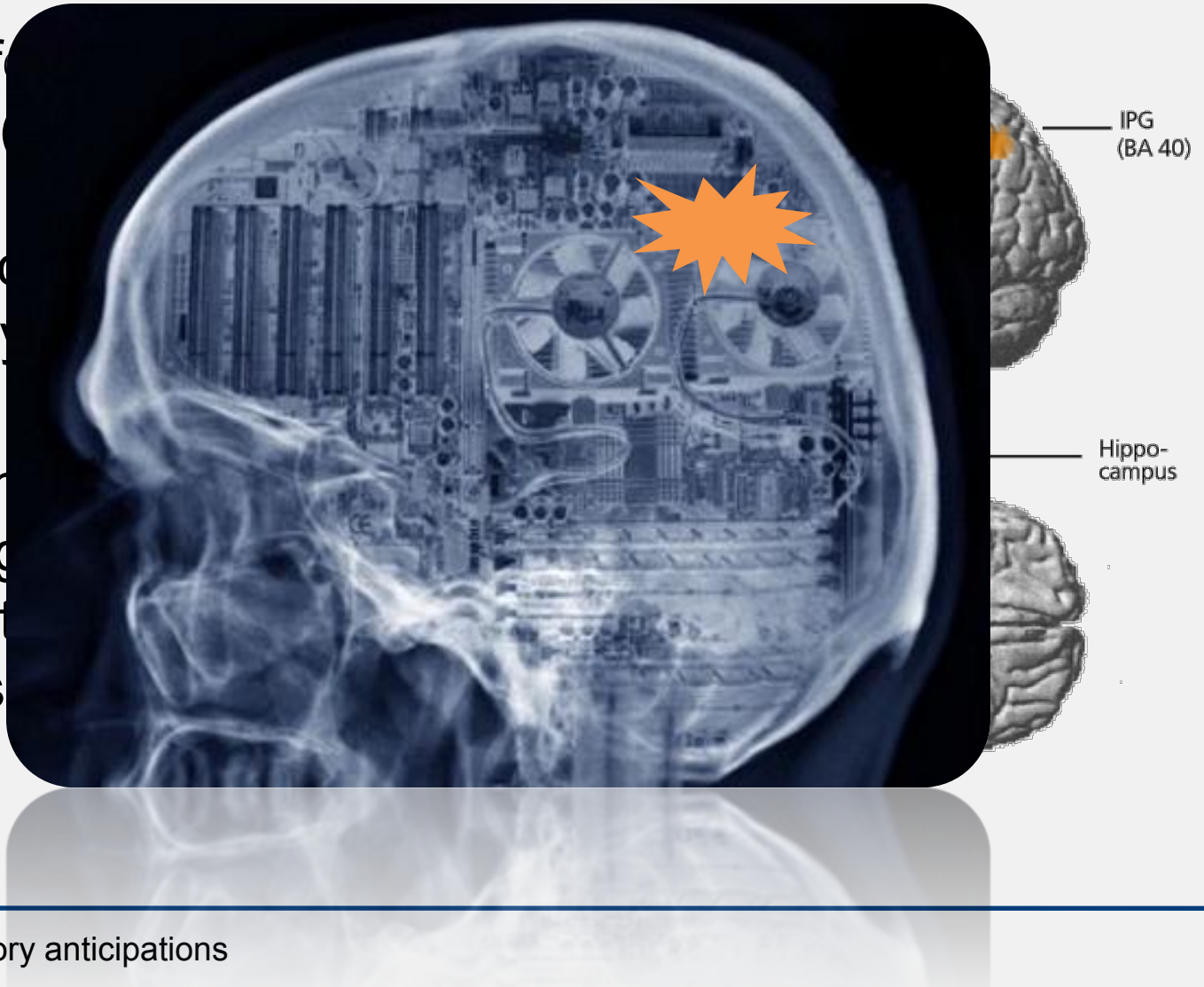


- Next challenge:
  Investigating the dynamics and interactions of parietal and frontal circuits in ideomotor action control.



Conclusions

- The inf
  cortex
  central
  action
  sensor
- Next ch
  Investig
  interact
  circuits



Conclusions

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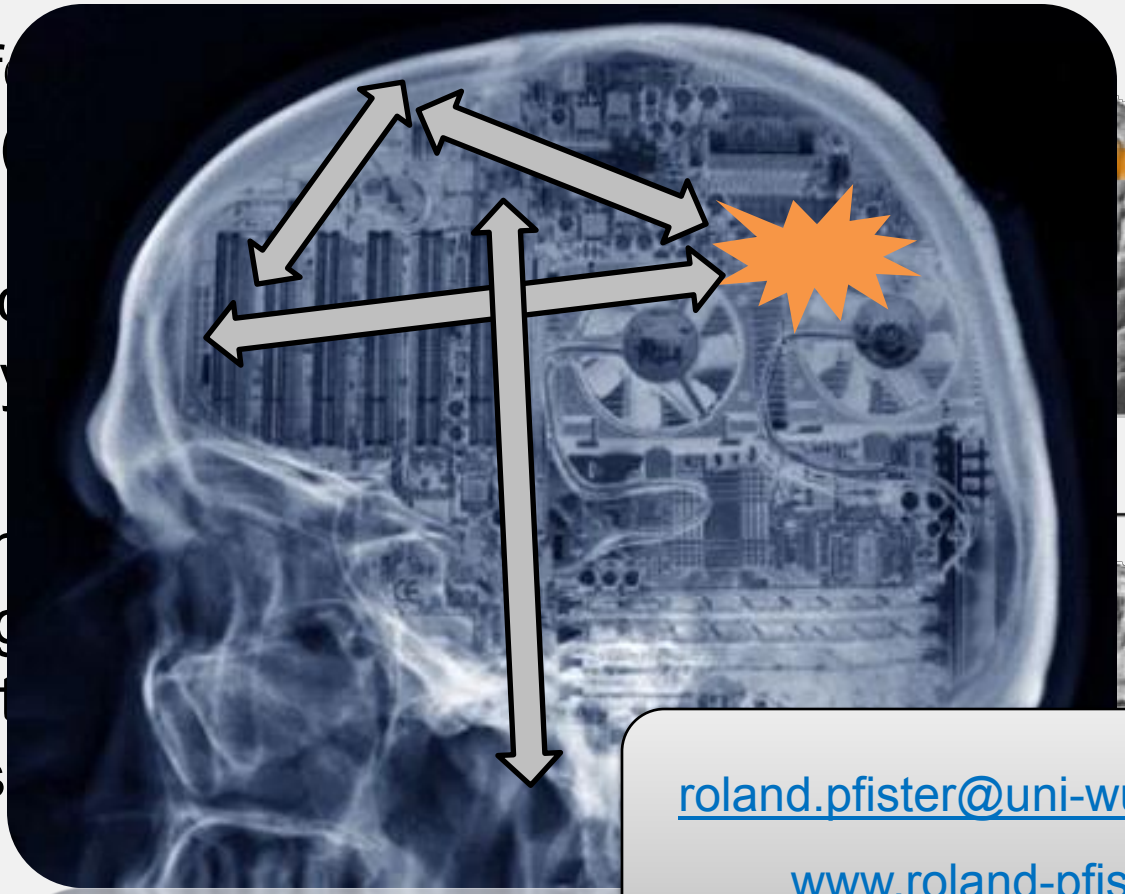

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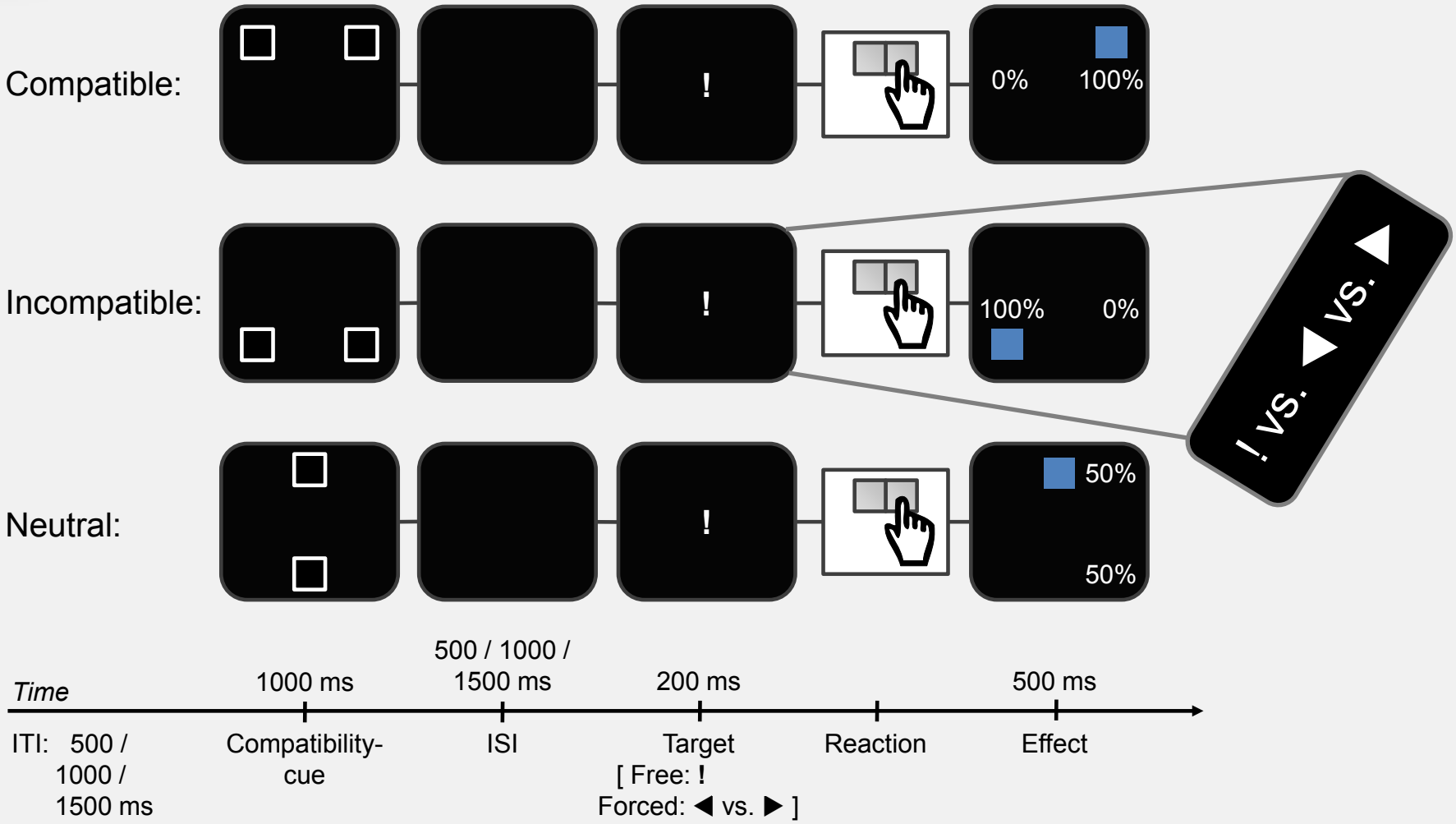
Apendix

- fMRI I: Voodoo, Interpretation
- fMRI II: Additional analyses

fMRT I

- More design
- Combined plot: Endo vs. Exo & regression analysis
- Hand effects
- Voodoo correlations: Group comparison
- Voodoo correlations: Outliers

Design I

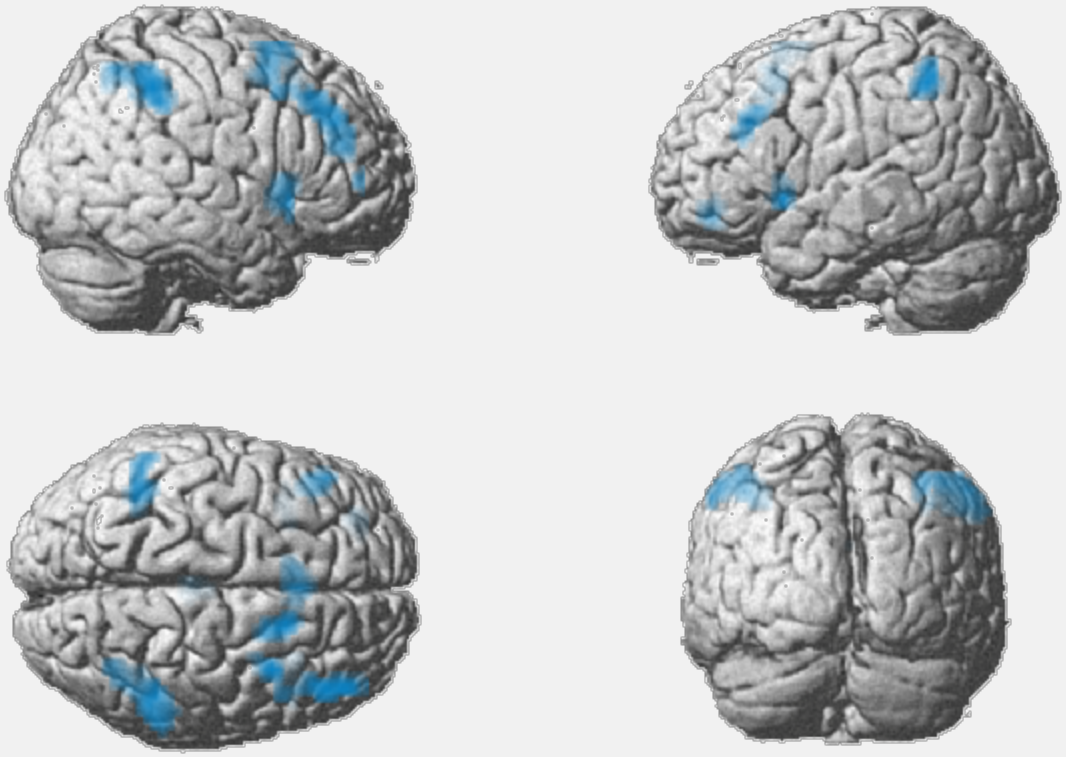

Compatible:
!
0%
100%
Incompatible:
!
100%
0%
Neutral:
!
50%
50%
! vs. ◀ vs. ▶
Time
1000 ms
500 / 1000 / 1500 ms
200 ms
500 ms
ITI: 500 / 1000 / 1500 ms
Compatibility-cue
ISI
Target
[Free: ! Forced: ◀ vs. ▶]
Reaction
Effect

Design II

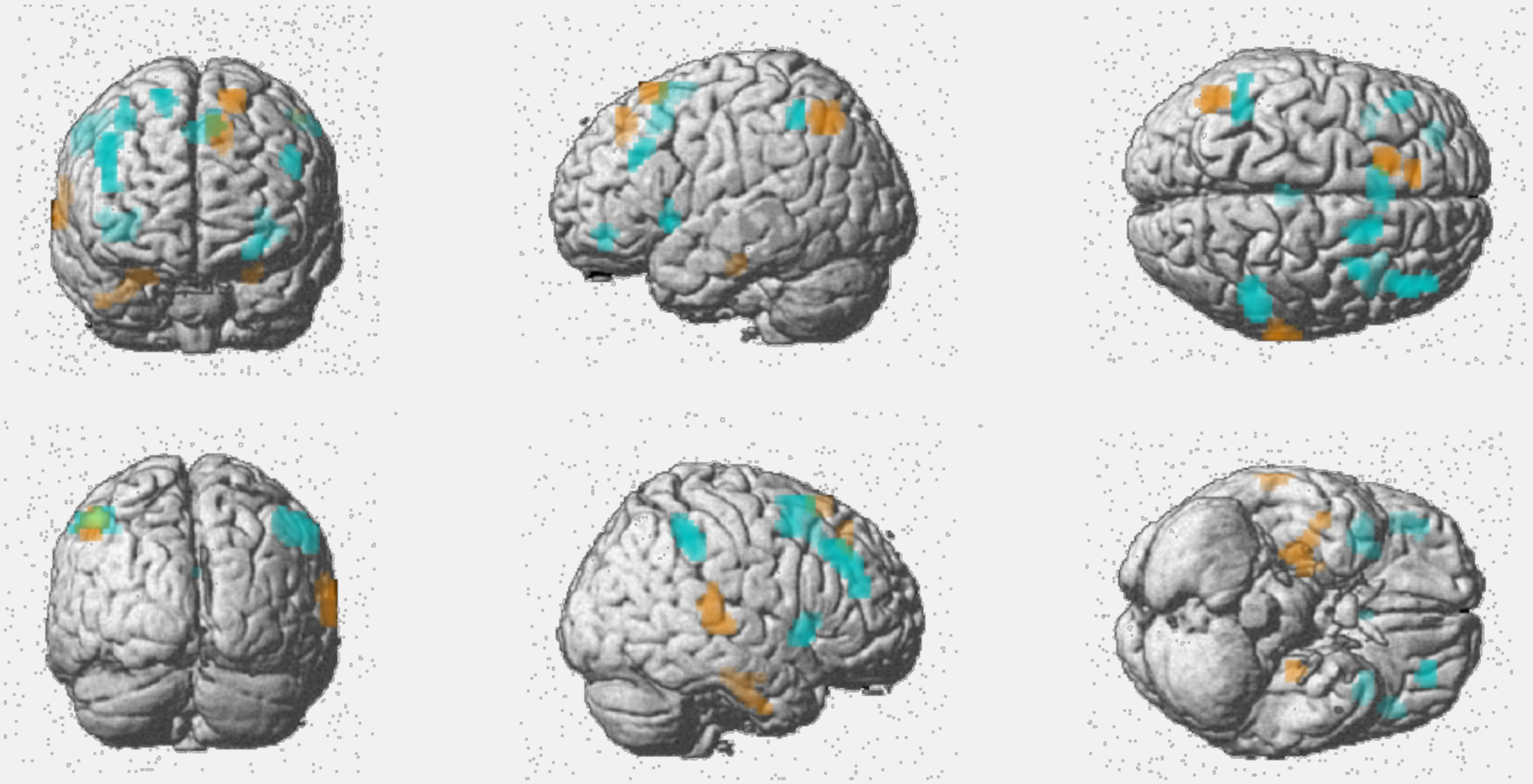
- 18 participants
- 3 runs with 126 trials each
- TR = 2000 ms, TE = 30 ms
- 33 slices (ascending)
- Voxel size: 3 x 3 x 3 mm^3

1. Step: endogenous vs. exogenous

p < .050, **FWE-corrected**, k = 20



Combined plot



More correlations

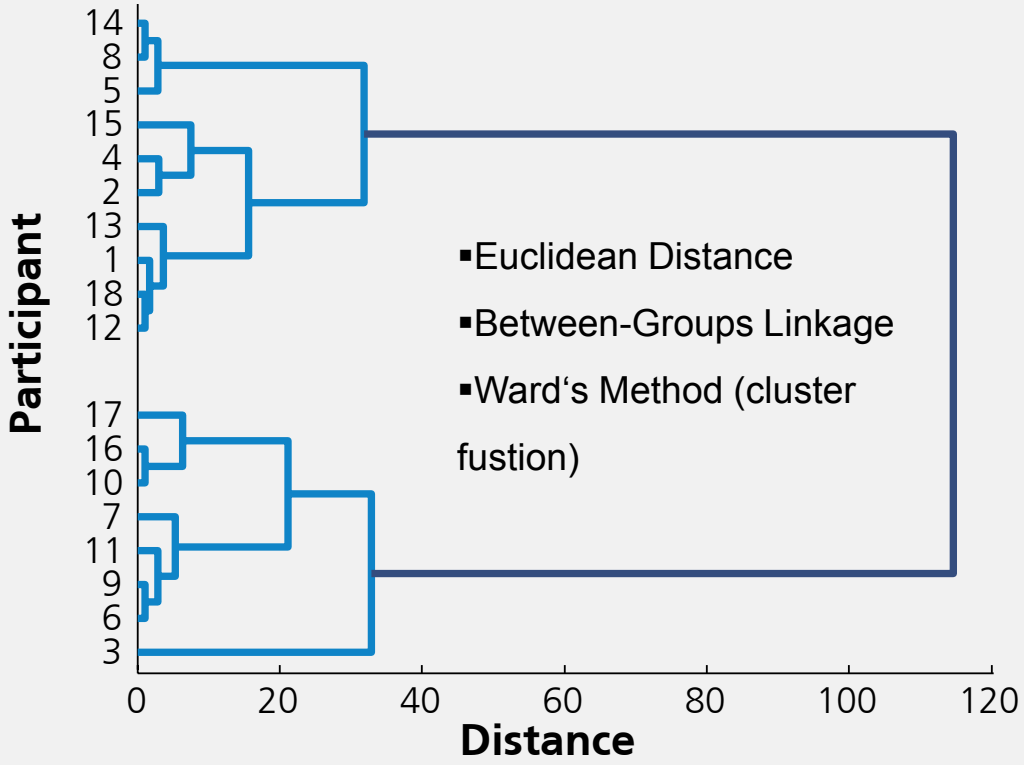
Region	BA	Hemi-sphere	k	x	y	z	t	z
SFG	6	L	35	-15	23	61	4.85	3.75
MFG	8	L	41	-9	35	46	4.26	3.43
IPG	40	L	50	-48	-64	46	4.42	3.52
Parahippoc.	36	L	15	-27	-22	-23	3.70	3.10
Parahippoc.	36	R	53	36	-13	-32	4.20	3.40
				30	-22	-23	4.11	3.35
				45	-7	-38	3.75	3.13
TPJ / STG	22	R	44	69	-28	4	3.90	3.22

And even more correlations (hand specificity)

Region	BA	Hemi-sphere	k	x	y	z	t	z	r_{left}	r_{right}
SFG	6	L	35	-15	23	61	4.85	3.75	0.72	0.47
MFG	8	L	41	-9	35	46	4.26	3.43	0.54	0.59
IPG	40	L	50	-48	-64	46	4.42	3.52	0.71	0.50
Parahippoc.	36	L	15	-27	-22	-23	3.70	3.10	0.53	0.39
Parahippoc.	36	R	53	36	-13	-32	4.20	3.40	0.48	0.43
				30	-22	-23	4.11	3.35	0.48	0.48
				45	-7	-38	3.75	3.13	0.34	0.26
TPJ / STG	22	R	44	69	-28	4	3.90	3.22	0.50	0.56

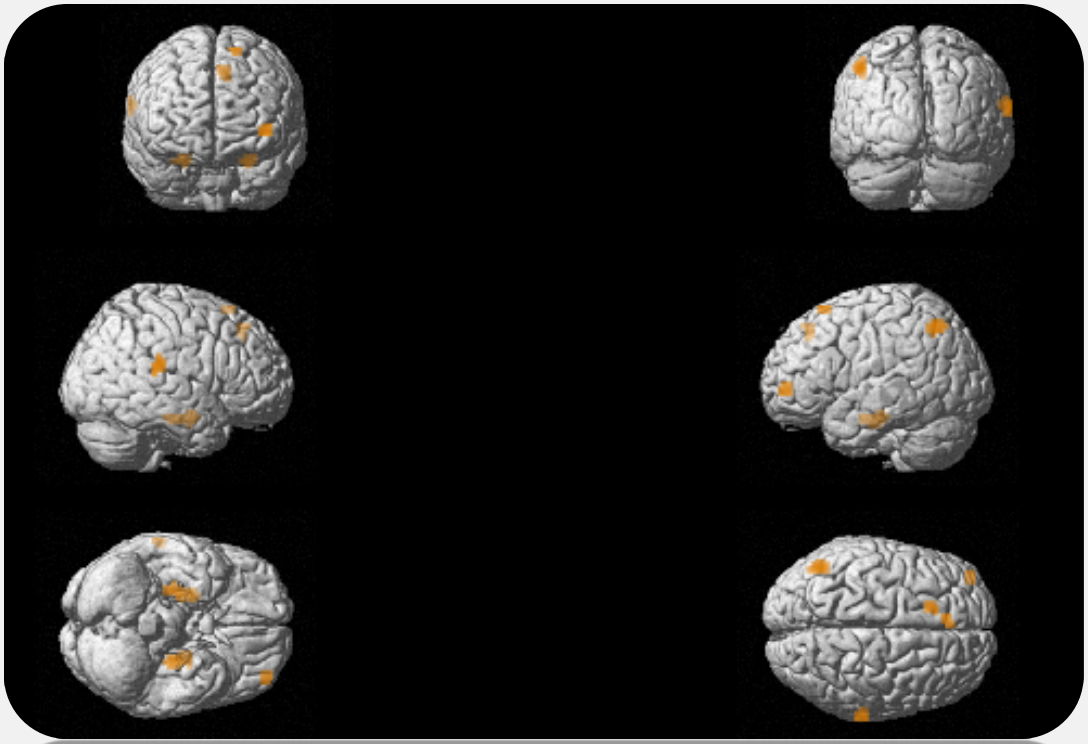
Black magic?

- Validation 1:Group comparison



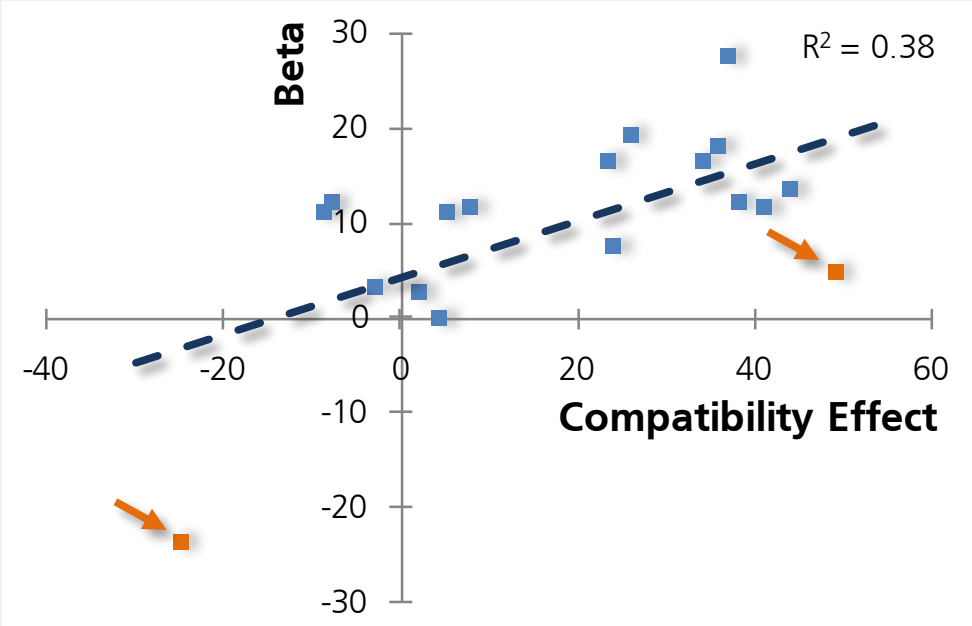
Correlation: Groups

- $p < .005$, $k = 20$ ($k = 10$ for frontal regions)



Black magic?

- Validation 2: Outlier correction for left inferior parietal cortex (BA 40; univariate & bivariate)



With outliers:

r = 0.61

Without outliers:

r = 0.57

Comparison:

z = 0.17,
p = .566

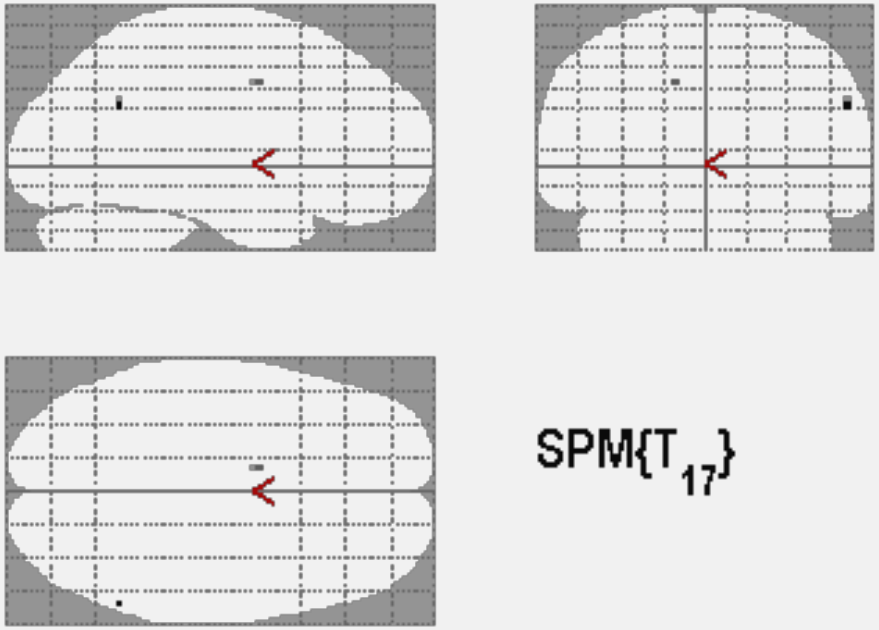
fMRT II

- Effect anticipations in neutral trials?
- Interaction contrast: Neutral/Compatible
- R-E compatibility: endo/incomp vs. endo/comp
- Correlations: R-E compatibility
- Effect size

Effect anticipation in neutral trials?

- Interaction contrast ($p < .005$, $k = 0$):

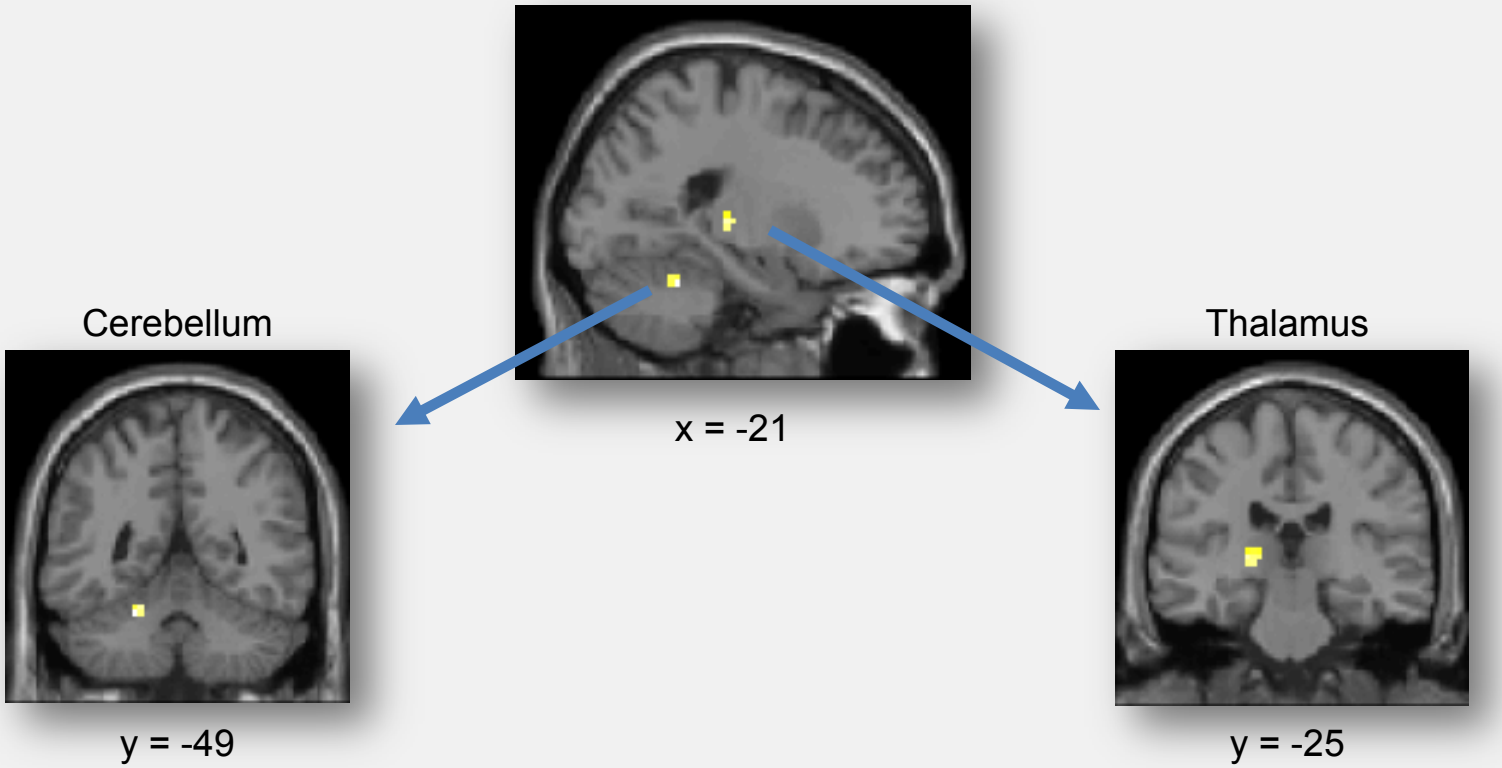
  $(Endo_{comp}$ vs. $Exo_{comp})$ vs. $(Endo_{neut}$ vs. $Exo_{neut})$



Random (neutral) Effects?

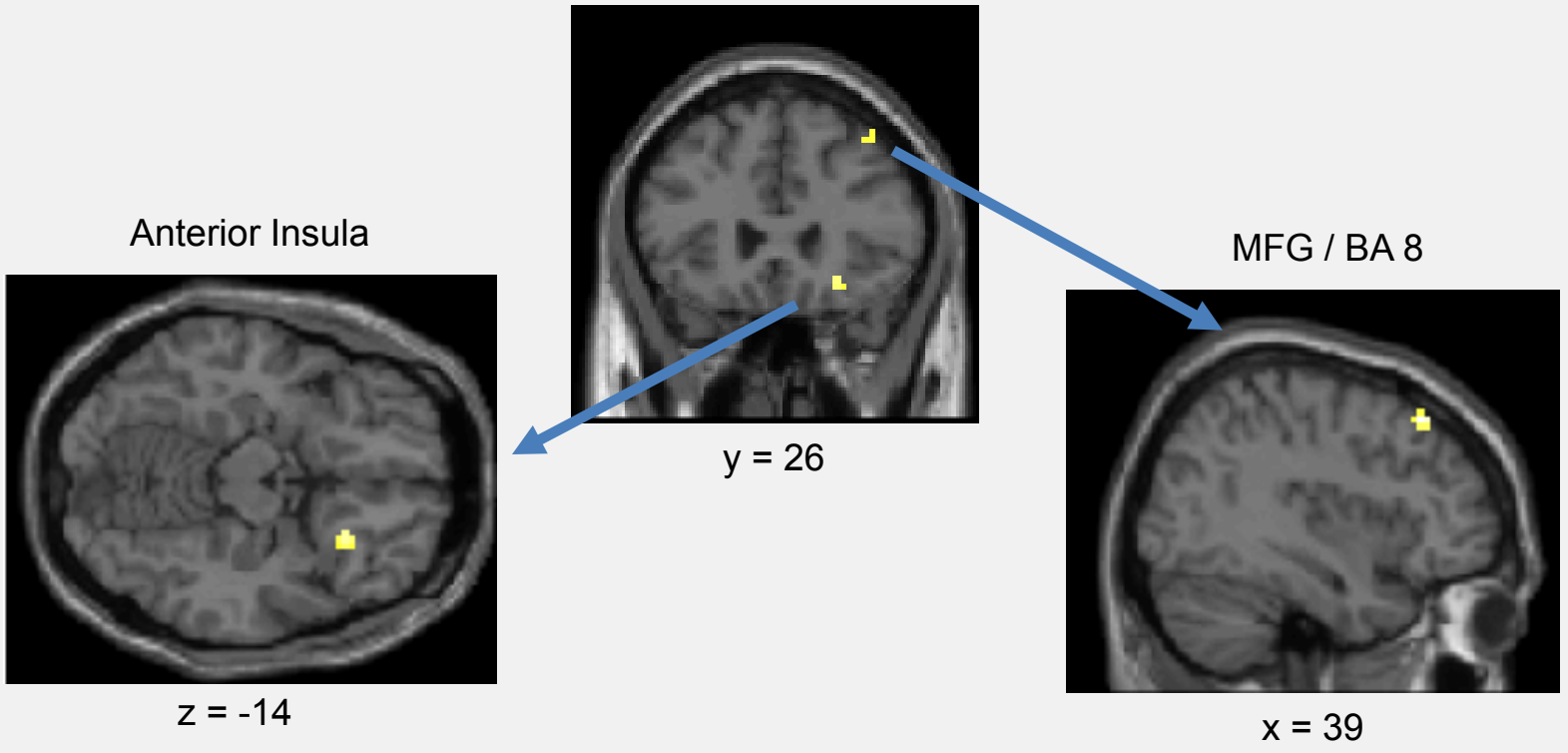
- Interaction contrast ($p < .001$, $k = 10$):

  $(Endo_{neutral}$ vs. $Exo_{neutral})$ vs. $(Endo_{comp}$ vs. $Exo_{comp})$



R-E compatibility

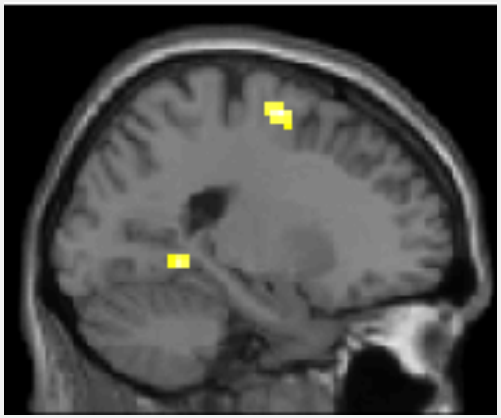
- Contrast: Endogenous/incomp vs. endogenous/comp ($p < .001$, $k = 10$; explosion at $p = .005$):



R-E compatibility

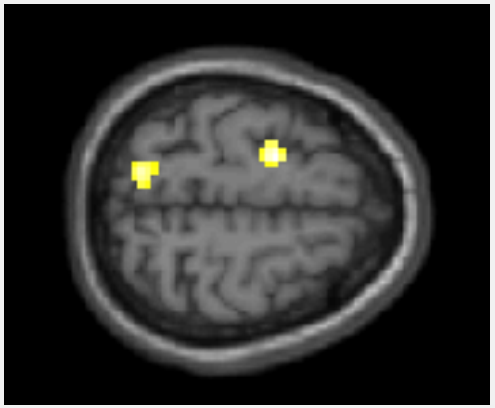
- Korrelation ($p < .005$, $k = 20$): Endogen/inkomp vs. Endogen/komp

Lingual gyrus & BA 6



x = -21

BA‘s 6 & 7



z = 61

Lingual gyrus

y = -49

Effect size

Contrast „left vs. right hand“ at…

- p < .001 (FWE), k = 0
- p < .05 (FWE), k = 0
- p < . 05 (FDR), k = 0