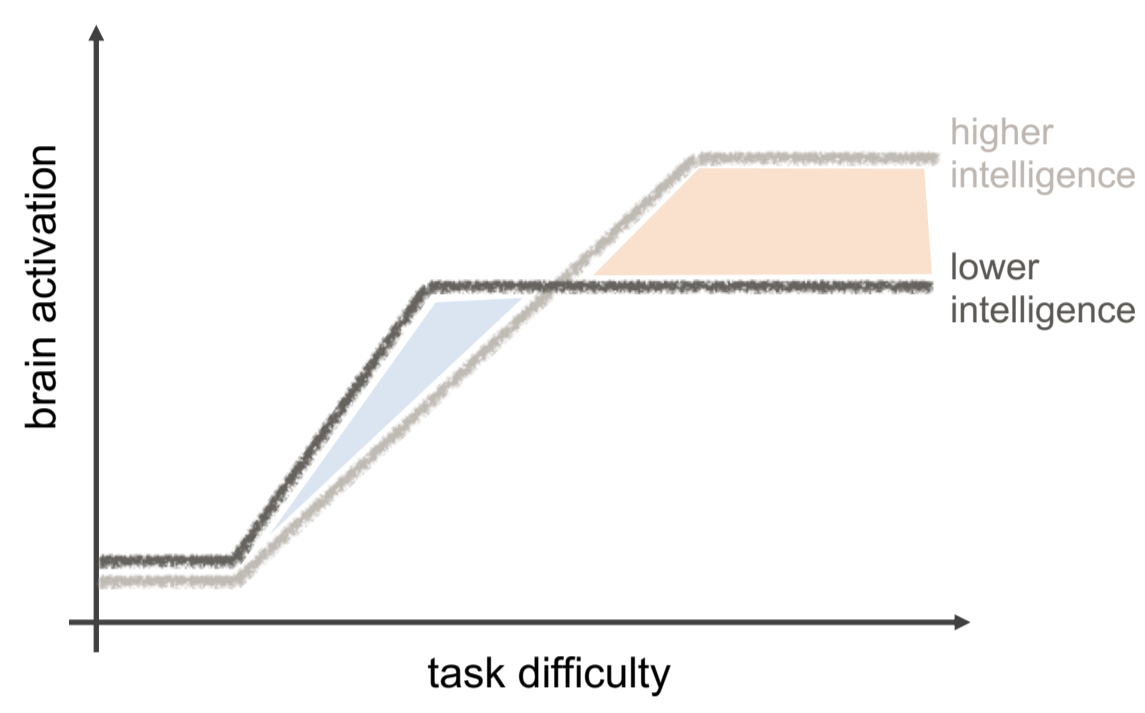


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1 Introduction

- Individual differences in **intelligence** have been associated with differences in **brain activation**.
- The **neural efficiency hypothesis** states that individuals with higher intelligence need less brain activation to solve a given cognitive task. (Haier et al., 1988)
- Task difficulty** was proposed to moderate the association between intelligence and brain activation. (Neubauer & Fink, 2009)

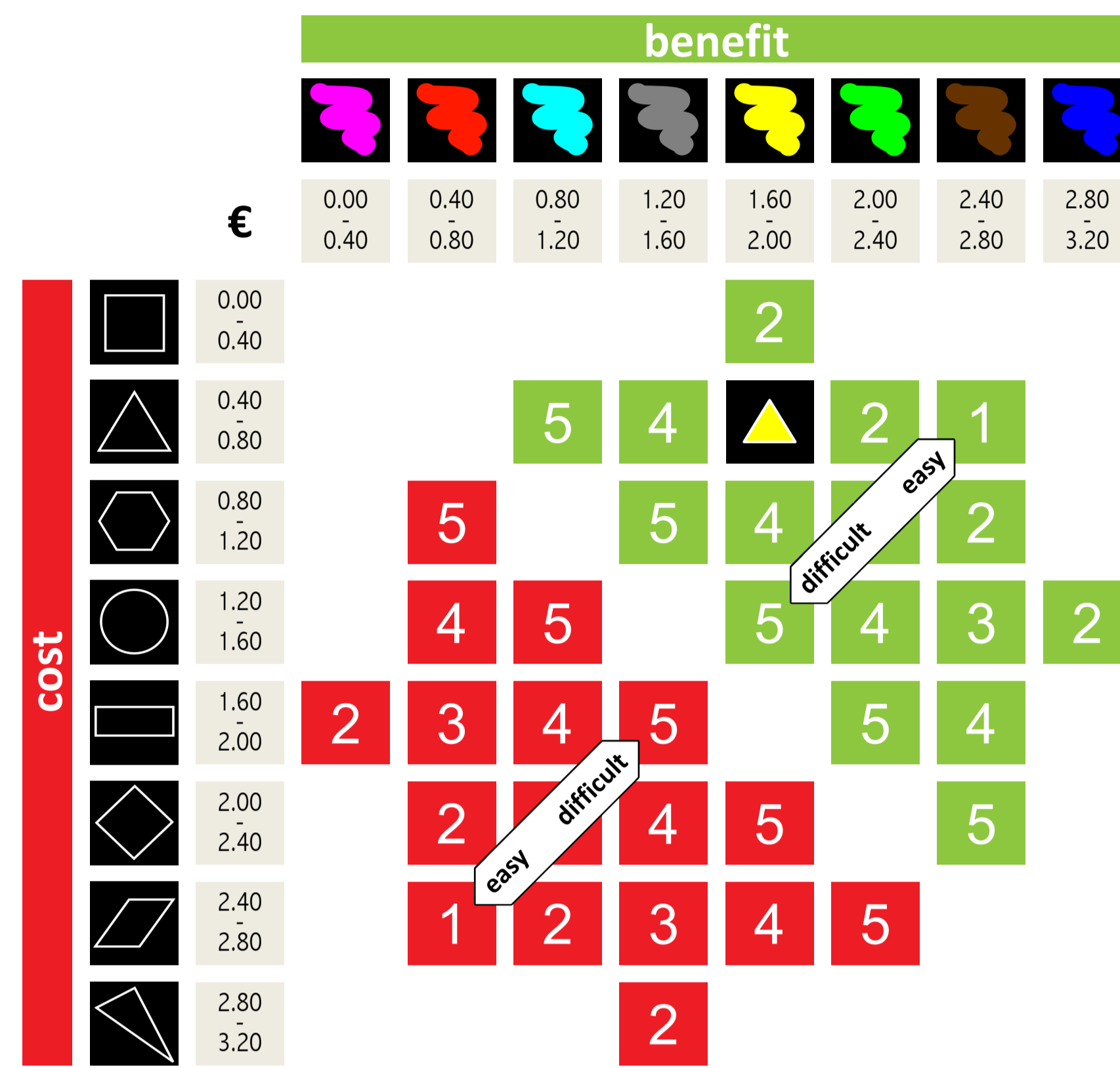


- We employed a demanding **cognitive task** with **five levels of difficulty** to investigate the interaction effect of intelligence and task difficulty on brain activation.

Are intelligence-related differences in brain activation moderated by the difficulty of the task?

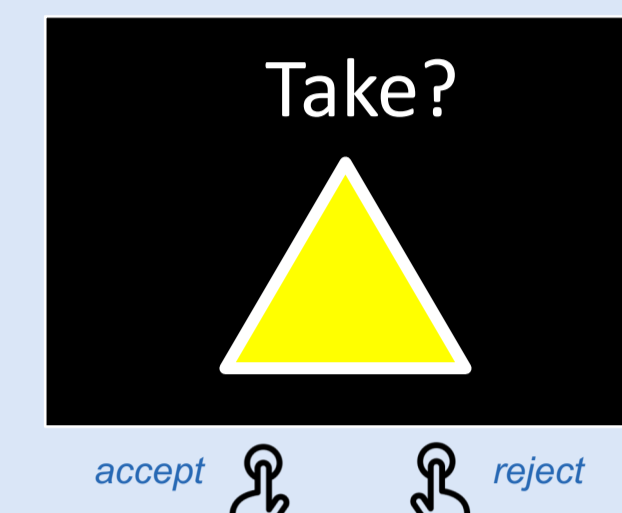
2 Methods

Cognitive Task Cost-Benefit Integration Task (Basten et al., 2010)

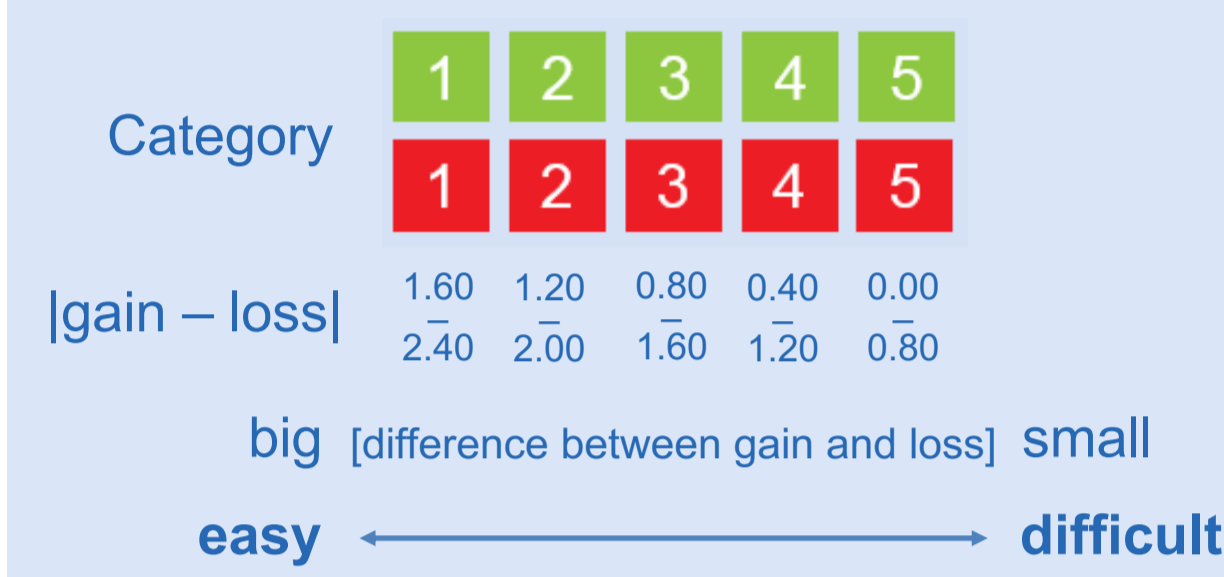


Main task

- fixation: 0.5 s
- stimulus: 1.25 s
- ITI: 4.25 – 24 s
- 4 blocks à 68 trials
- 12 minutes



Task difficulty: 5 levels



Training

- Day before task
- Rank order and value ranges
- Colours and shapes, separately
- Criterion: 95% correct

Measure of intelligence

- Bochumer Matrizenest (BOMAT) (Hossiep, Turck, & Hasella, 2001)

Participants

- N = 72 (38 males, 34 females)
- Age: 18 - 38 years (M = 22.94; SD = 3.95)

Behavioural analysis

Linear Mixed Effect Models

(R package lme4; Douglas et al., 2015)

- Response times** (log-transformed) ~ difficulty * intelligence * sex + (1 | subject) + (1 | trial) [lmer]
- Accuracy** ~ difficulty * intelligence * sex + (1 | subject) + (1 | trial) [glmer, binomial]

FMRI analysis

Full factorial model (SPM 12)

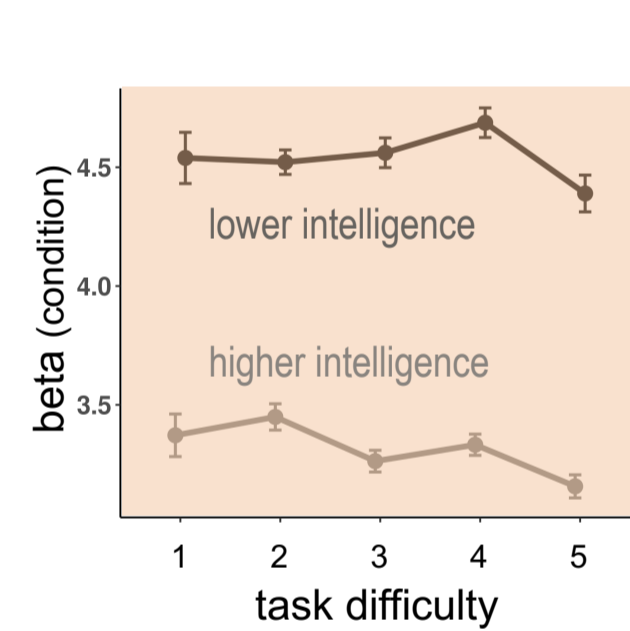
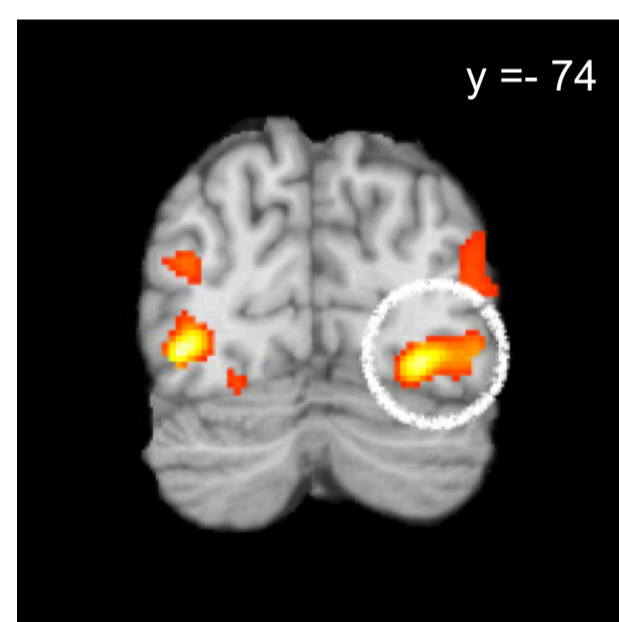


3 Results

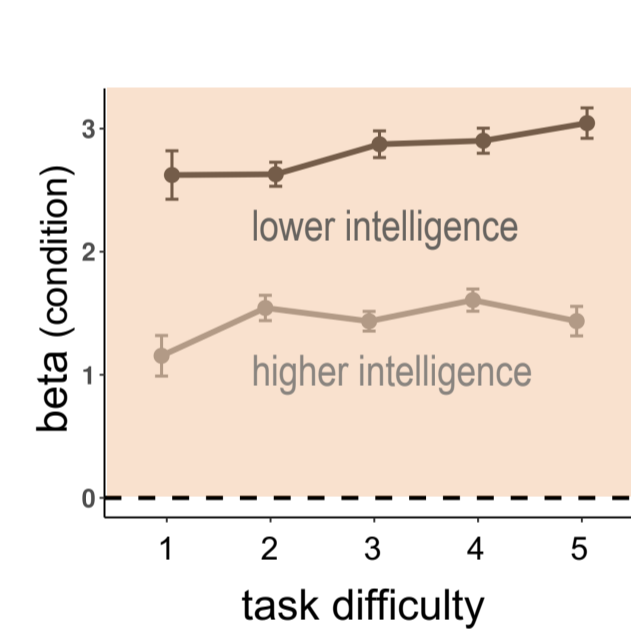
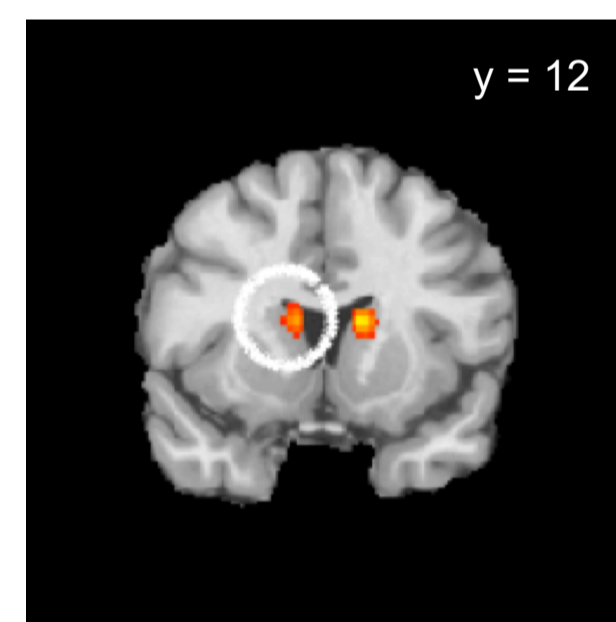
Main effect of intelligence

N = 72, voxel $p < .001$ (uncorrected), cluster $p < .05$ (FWE)

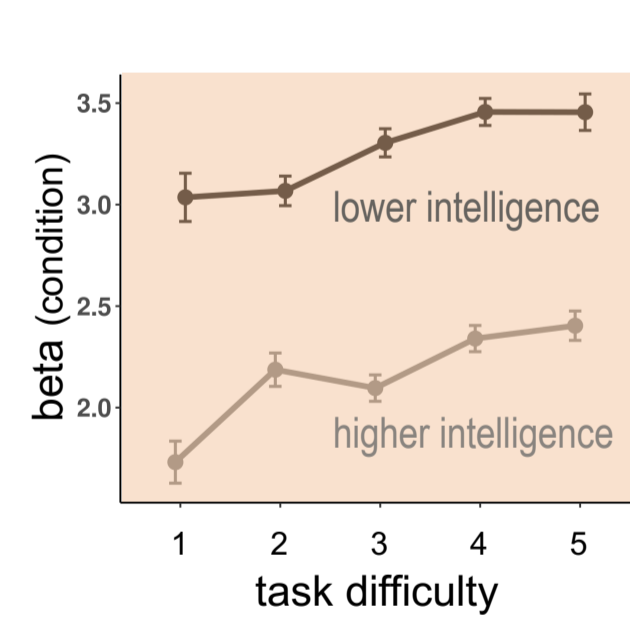
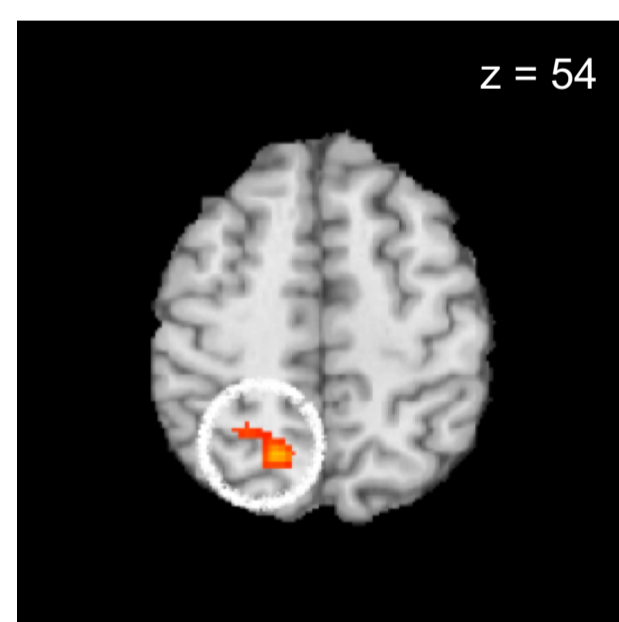
Occipital + Temporal



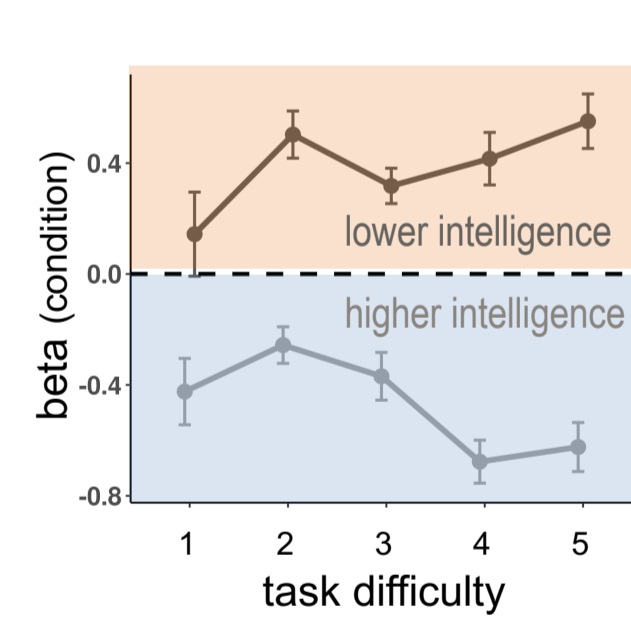
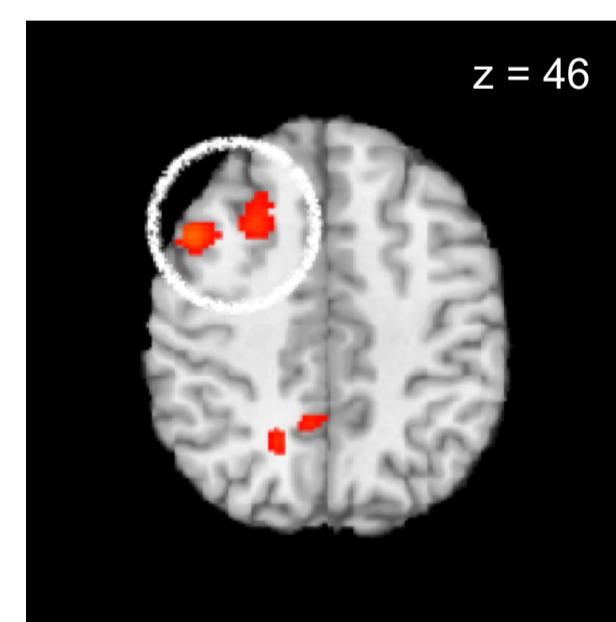
Caudate



Parietal



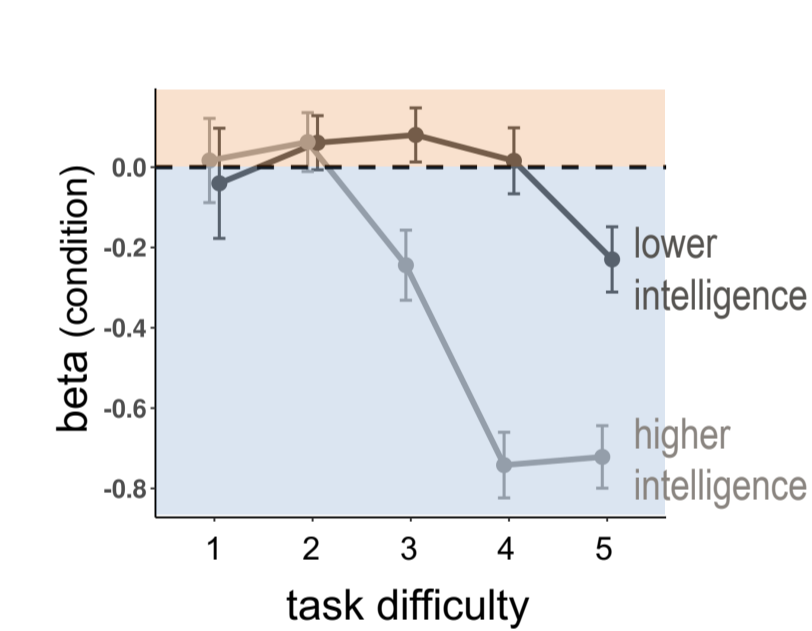
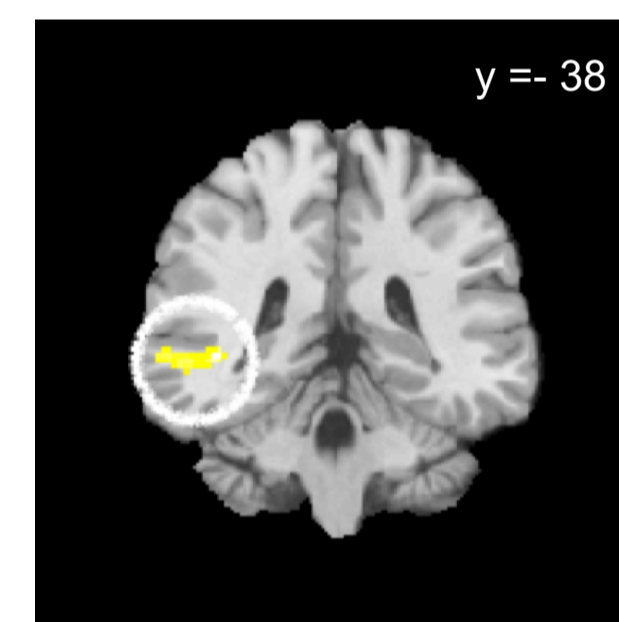
Middle and superior frontal gyrus



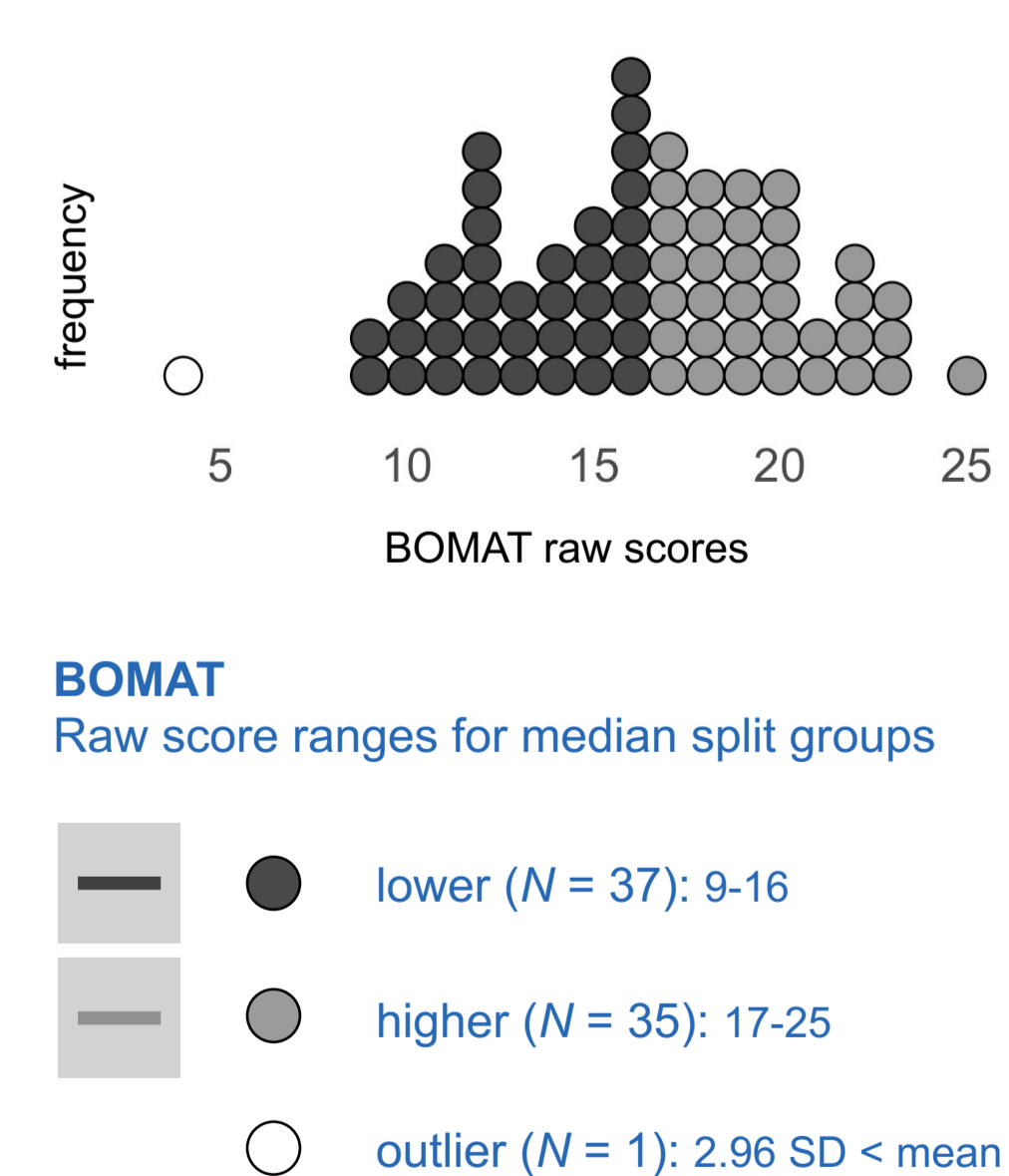
Interaction of intelligence and task difficulty

N = 72, voxel $p < .001$ (uncorrected), cluster $p < .05$ (FWE)

Left middle temporal gyrus (MTG)



Intelligence (N = 72)



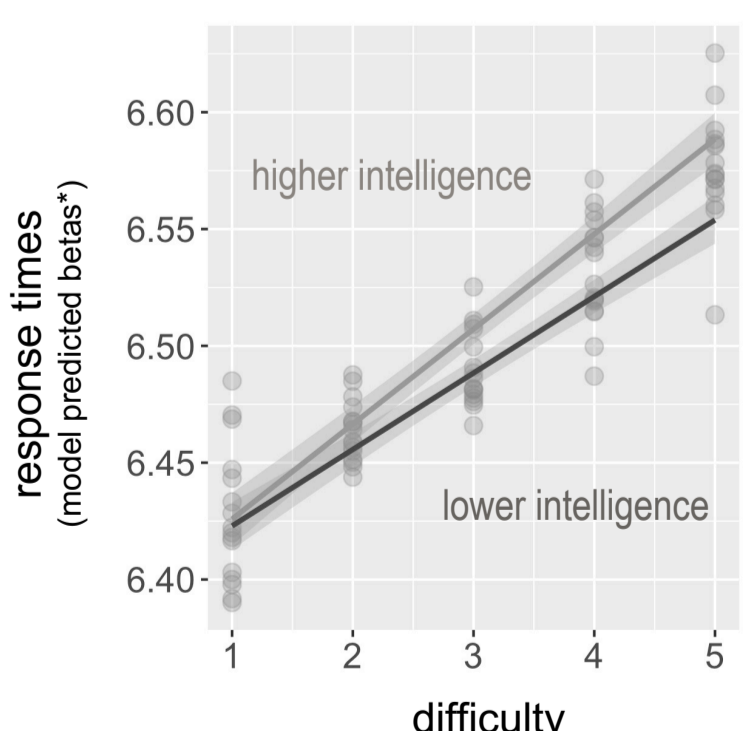
Cognitive task performance

Response times

LME t-scores

diff: -3.28 intell: 0.96 diff*intell: -1.66

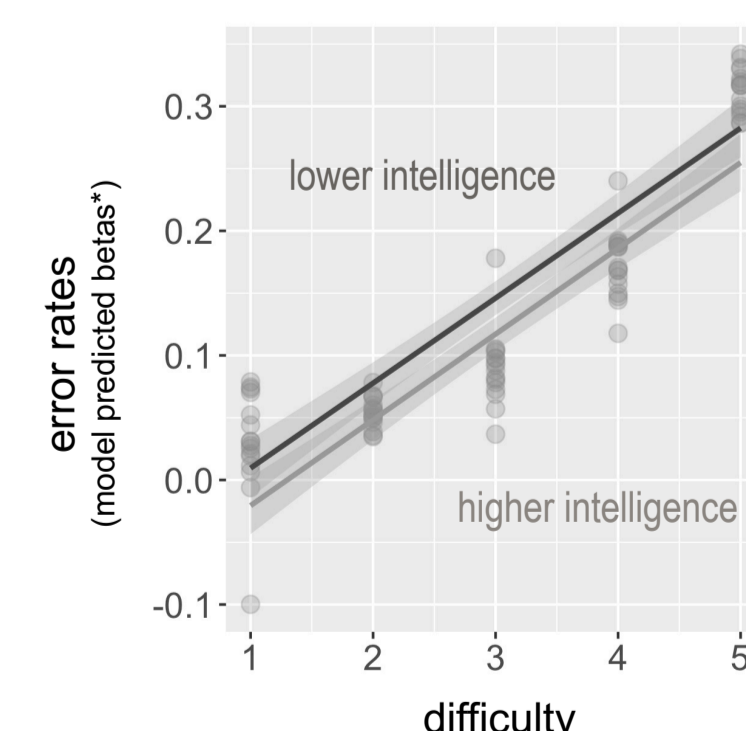
Reliable effects with $t \geq 2$ are highlighted in bold font



Error rates

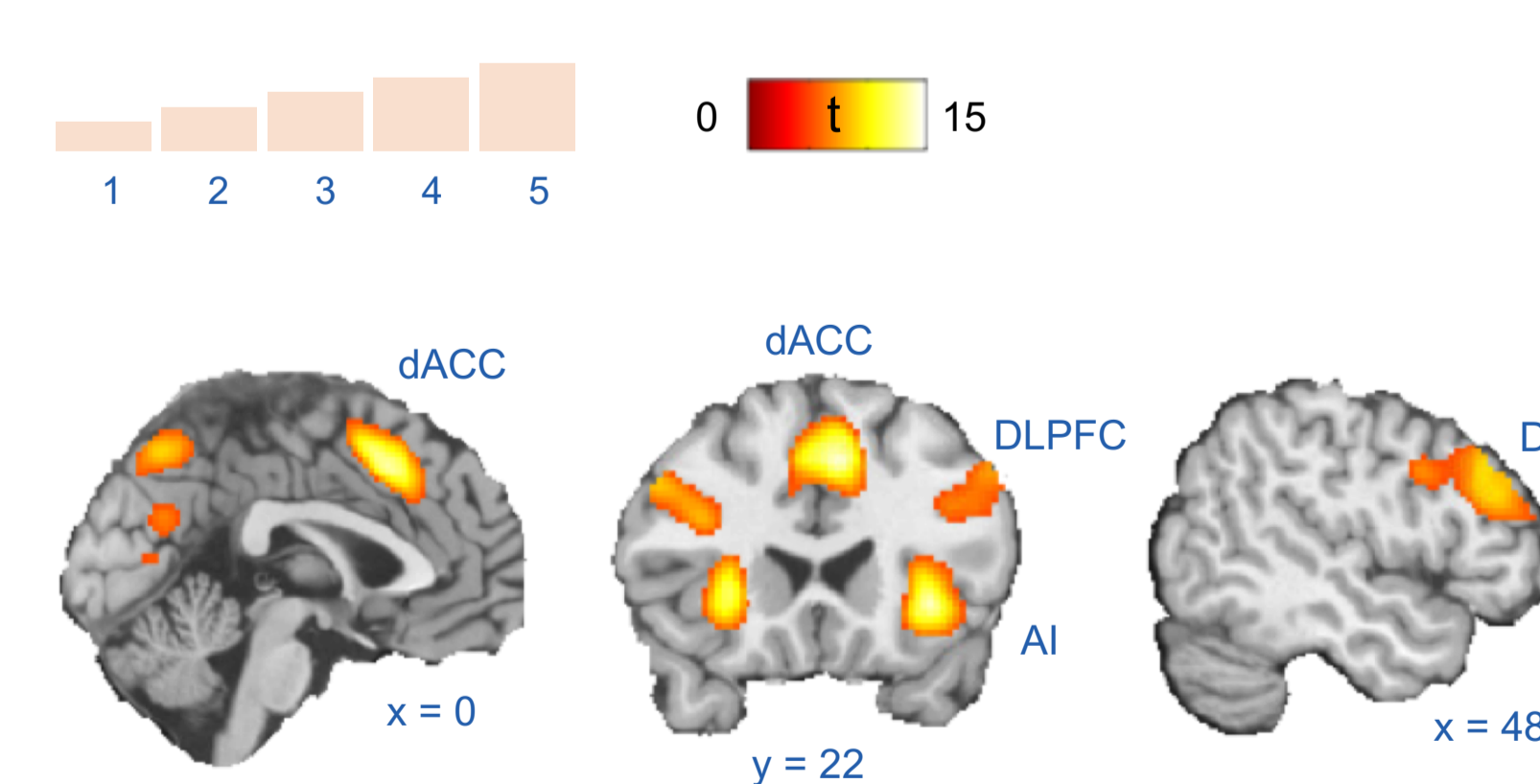
LME t-scores

diff: -7.51 intell: -1.41 diff*intell: 0.38

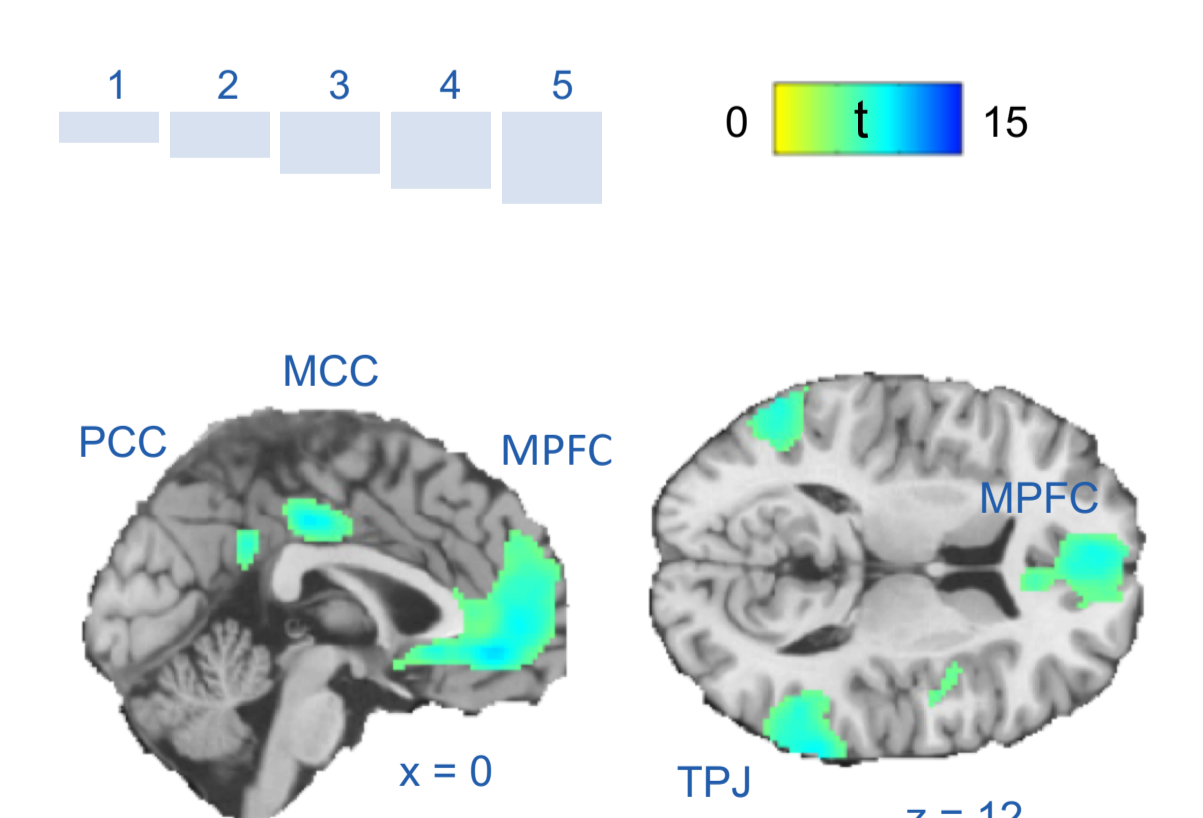


Task activation across participants (parametric modulation by task difficulty)

Increased activation in the task-positive network (TPN, cognitive control)

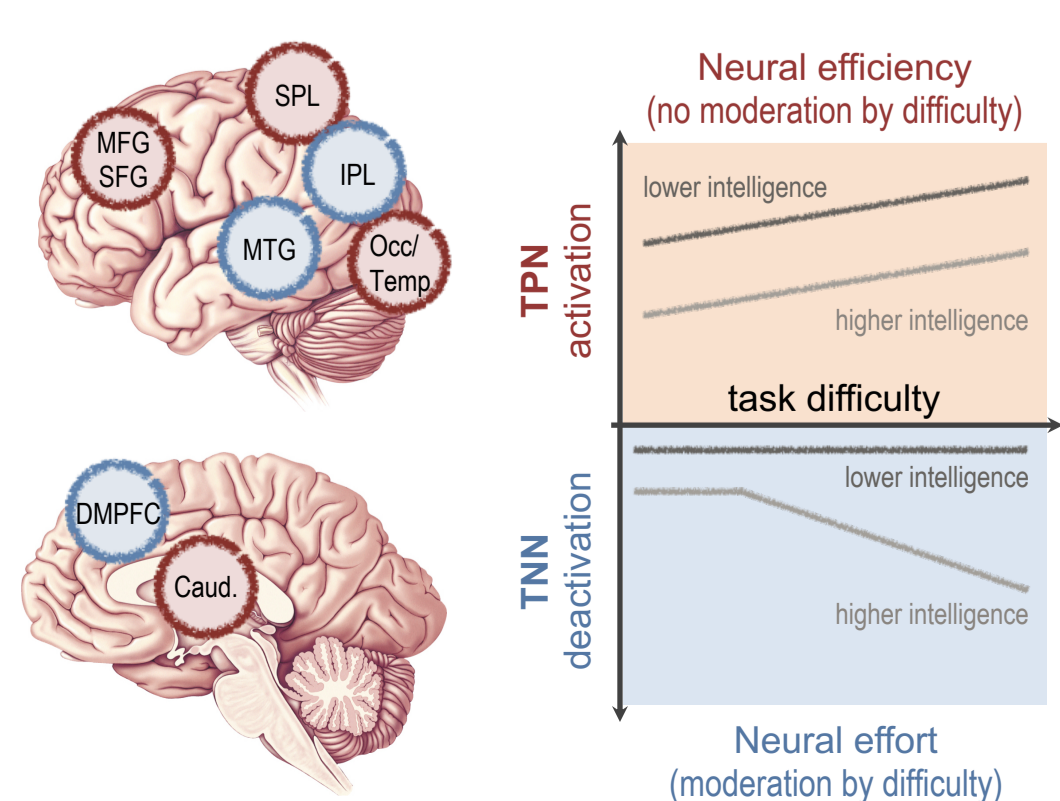


Decreased activation in the task-negative network (TNN, default mode)



4 Summary & Conclusion

Schematic summary of findings



Intelligence and Neural Efficiency

- Brains of more intelligent people are not generally more or less efficient. Associations depend on: → Brain network (TPN / TNN) and → Task difficulty

- Regions in **TPN** (red circles in schematic summary): Weaker activation in more intelligent subjects → Higher 'neural efficiency'

- Regions in **TNN** (blue circles in schematic summary): Stronger deactivation in more intelligent subjects (for higher task difficulty) → Higher 'neural effort'

- Opposite pattern observed for working memory task (Basten et al., 2013) due to different task demands?

Intelligence and adaptation to task demands

- Interaction effect in TNN regions (in parietal, temporal, and medial frontal cortex): Higher intelligence associated with stronger activation decrease for higher task difficulty
- Interpretation: **More intelligent people more effectively adapt brain activity to increasing task demands** by down-regulating default activity presumably associated with task-unrelated processing.
- Performance advantages not observed in this study, may occur for even higher task demands.

5 References

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Acknowledgement

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