The statistical significance filter leads to overoptimistic expectations of replicability

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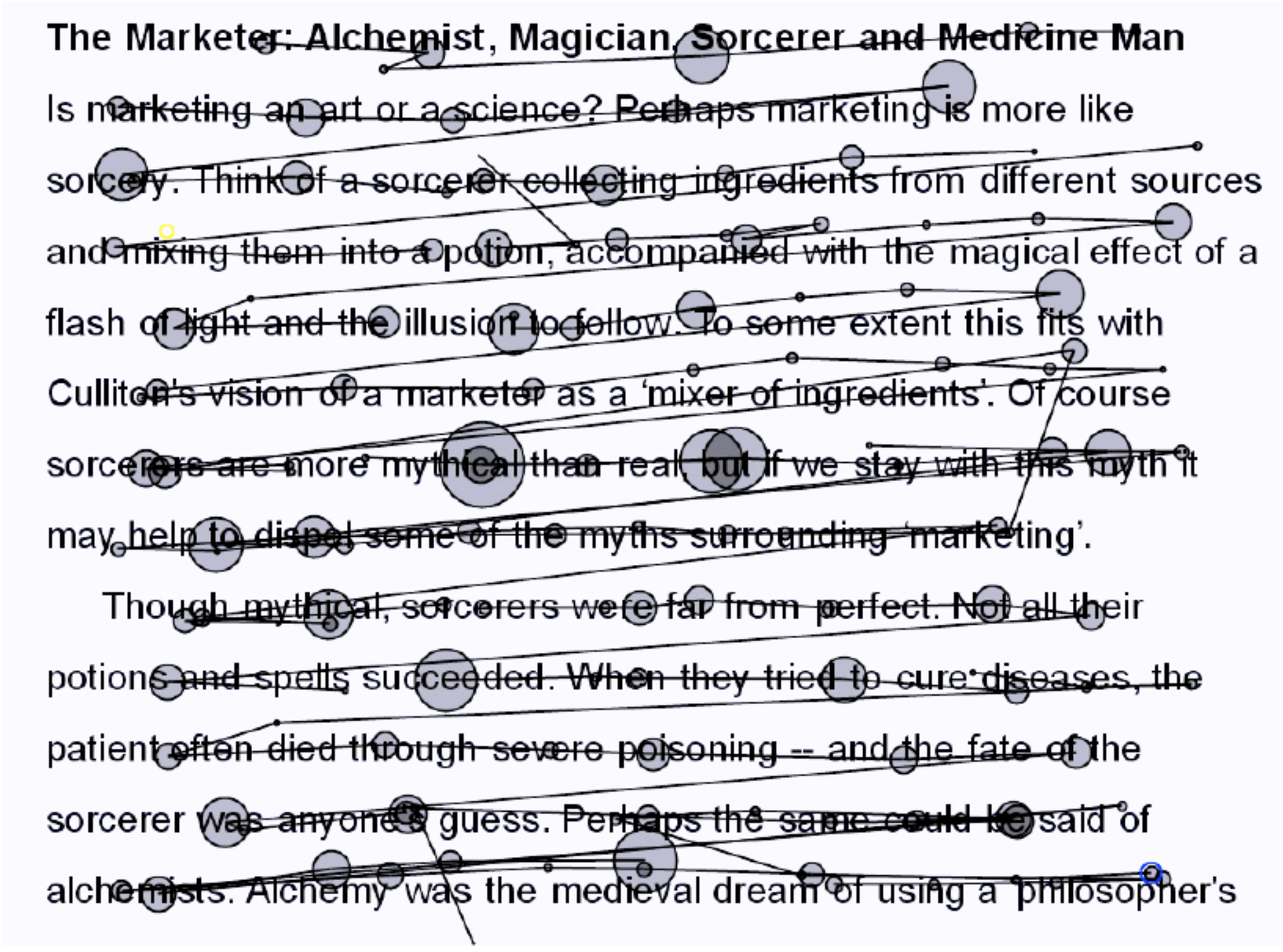
Columbia University

Research area: Reading processes in cognitive psychology



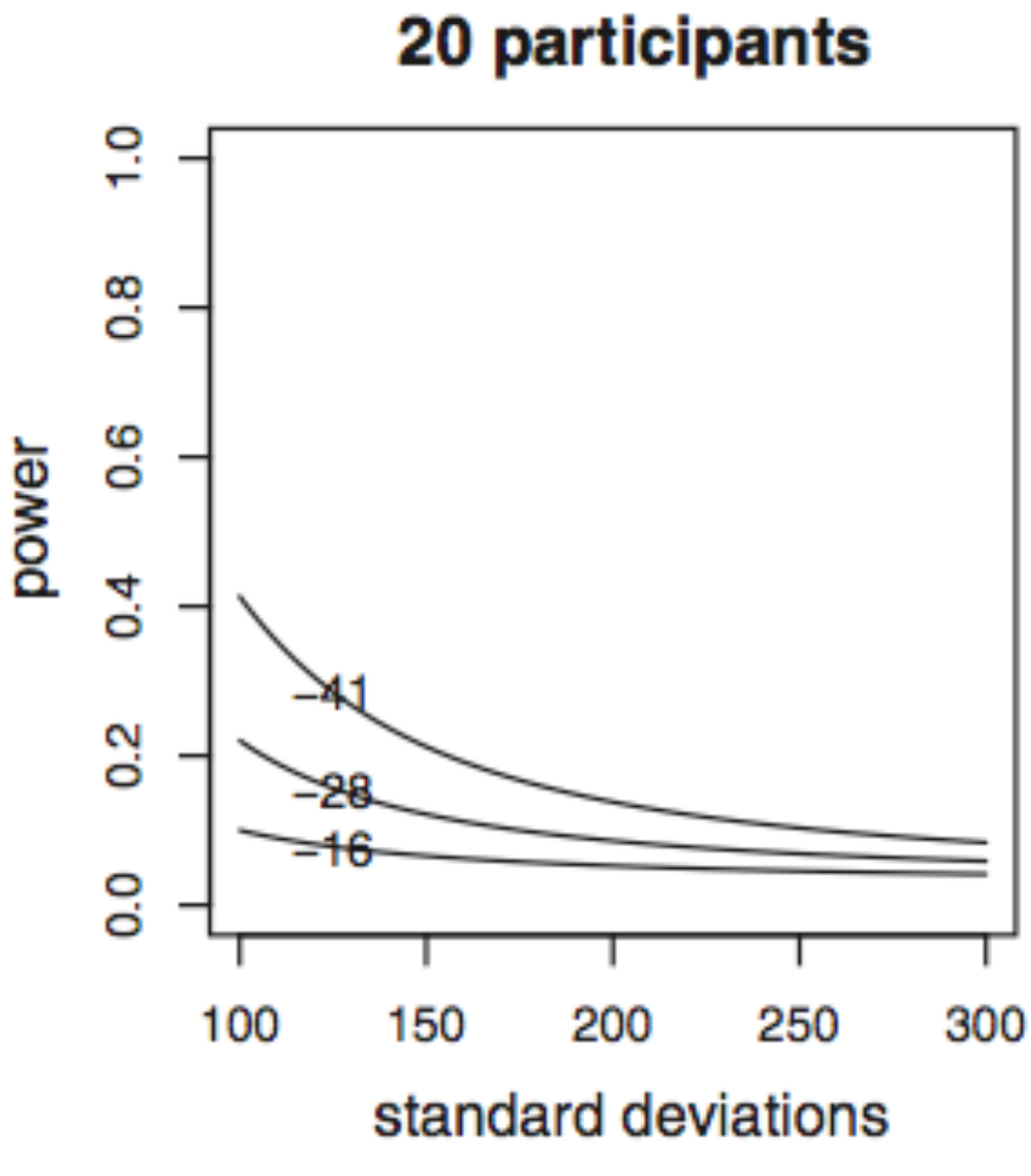
The Marketer: Alchemist, Magician, Sorcerer and Medicine Man

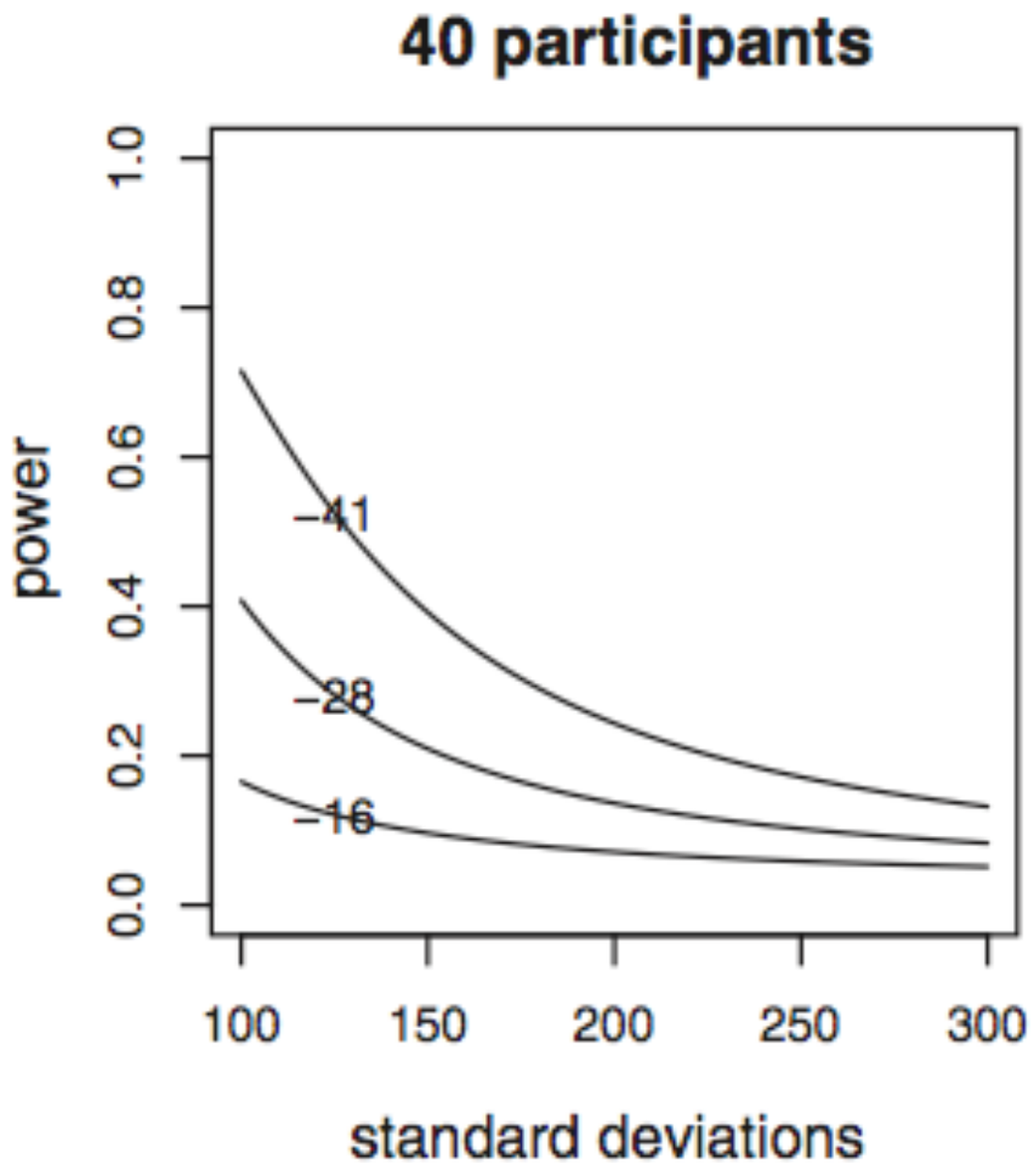
Is marketing an art or a science? Perhaps marketing is more like sorcery. Think of a sorcerer collecting ingredients from different sources and mixing them into a potion, accompanied with the magical effect of a flash of light and the illusion to follow. To some extent this fits with Cullitan's vision of a marketer as a 'mixer of ingredients'. Of course sorcerers are more mythical than real, but if we stay with this myth it may help to dispel some of the myths surrounding 'marketing'.

Though mythical, sorcerers were far from perfect. Not all their potions and spells succeeded. When they tried to cure diseases, the patient often died through severe poisoning -- and the fate of the sorcerer was anyone's guess. Perhaps the same could be said of alchemists. Alchemy was the medieval dream of using a 'philosopher's

1. Power is sometimes quite low in reading research
2. Low power leads to exaggerated estimates
3. Published claims will not be replicable
4. We demonstrate this with real data

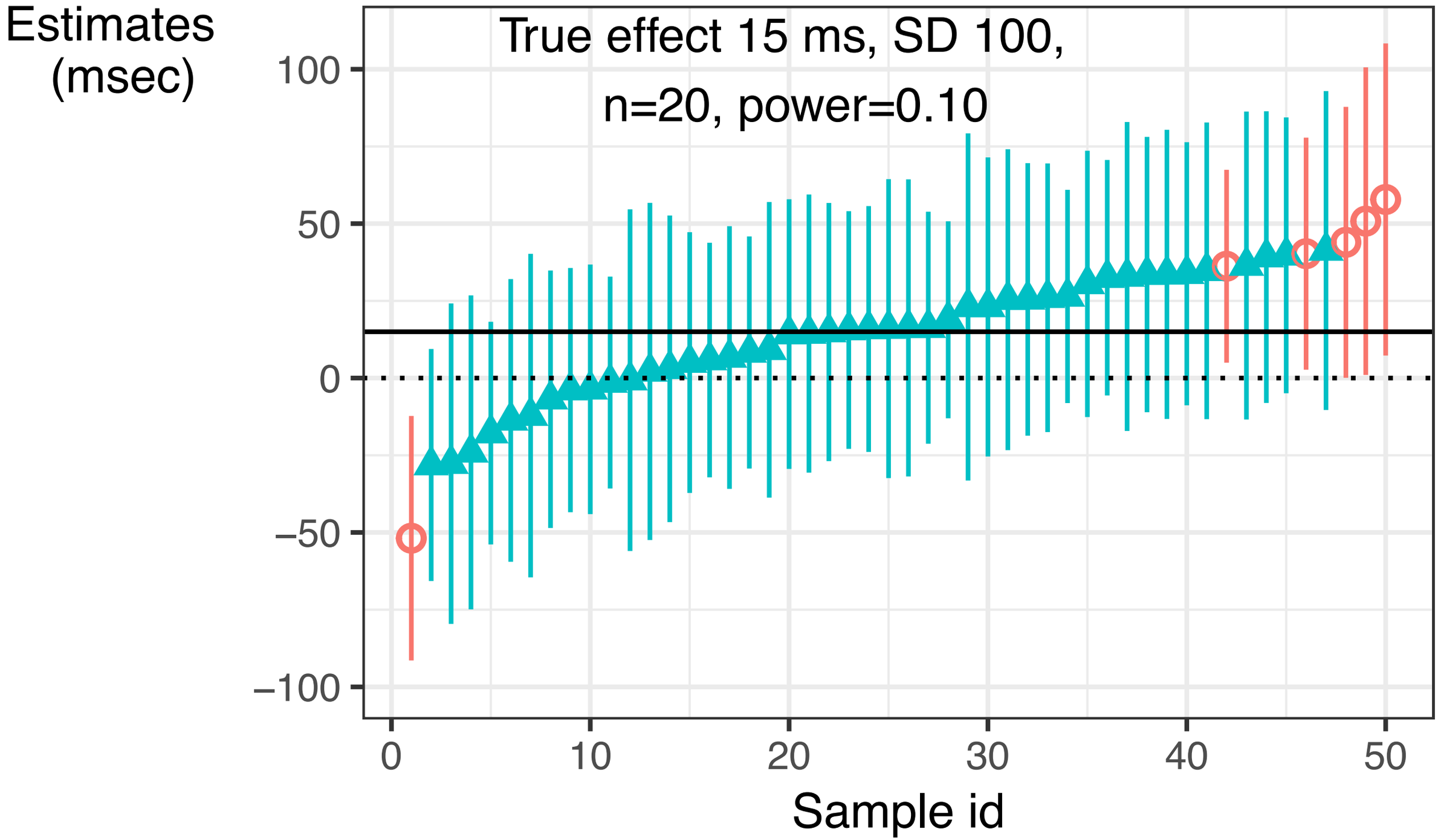
Power is generally quite low in sentence processing reading research





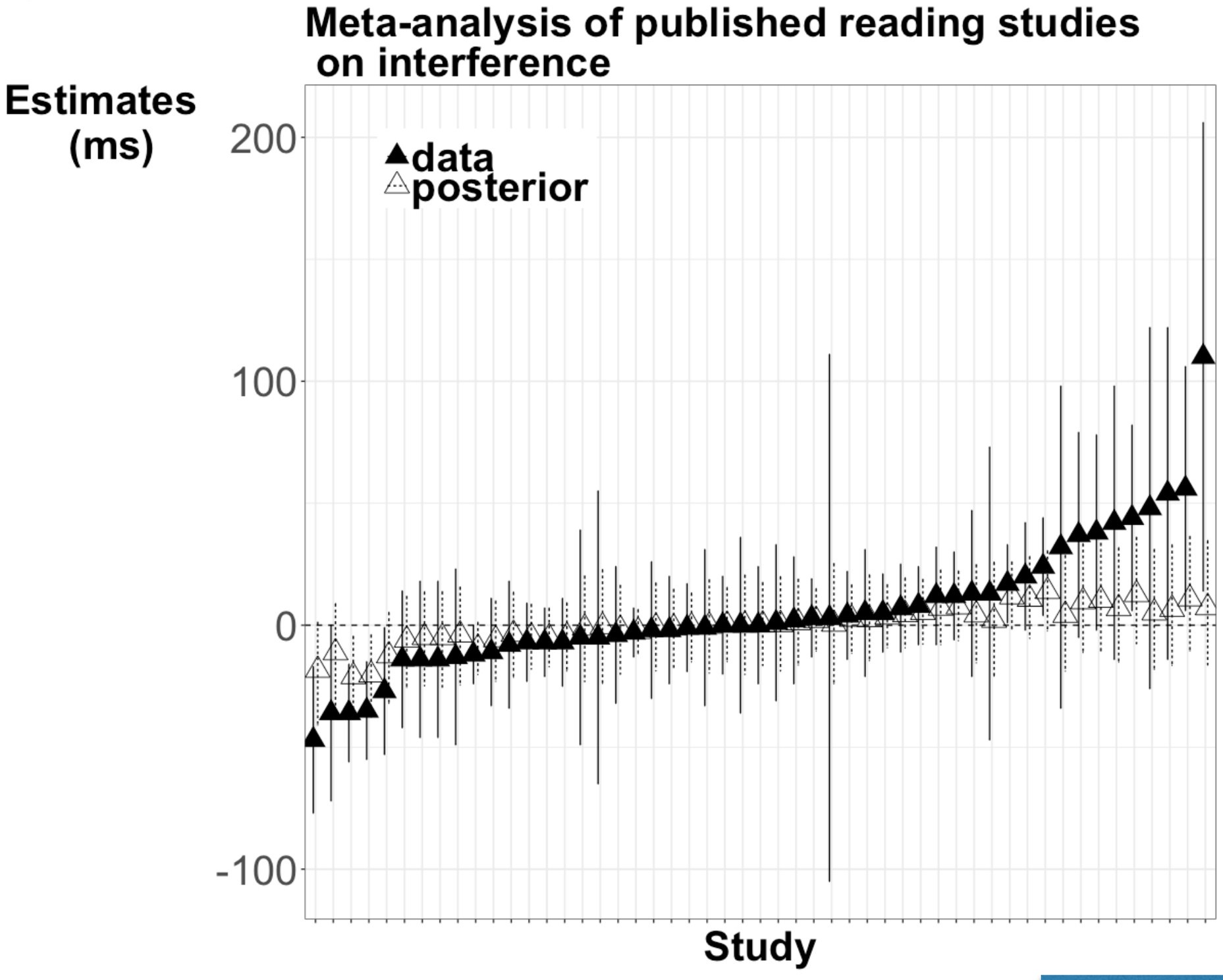
Jäger, Engelmann & Vasishth, JML, 2017

Low power leads to exaggerated estimates: Type M error (simulated data)



Gelman & Carlin, 2014

Low power leads to exaggerated estimates: Type M error (published data)



Jäger, Engelmann & Vasishth, JML, 2017

A puzzle: Most psychologists are aware of the replication crisis, but few think they are affected

Commonly heard reactions:

- "In *our* field, we *always* replicate our results."
- "My *own* sub-field doesn't have problems."
- "We replicate, we just don't *publish* the data."
- "You are just a stats fetishist."

Problem 1: Lack of statistical training

The replication crisis is just a side effect of the statistical ignorance crisis.

Problem 2: Unwillingness to ever be wrong

The first principle is that you must not fool yourself and you are the easiest person to fool.

Feynman

We demonstrate Type M error in published data

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Journal of Memory and Language

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Expectation and locality effects in German verb-final structures

Roger P. Levy [a,*], Frank Keller [b,1]

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[b] School of Informatics, University of Edinburgh, 10 Crichton Street, Edinburgh EH8 9AB, UK

We demonstrate Type M error in published data

The original eye tracking (reading) experiments:

- 2x2 repeated measures factorial design
  Two main effects and one interaction
- 28 subjects, 24 items, Latin square design
- Reading time in milliseconds

Seven replication attempts of Levy & Keller, 2013, using eyetracking and self-paced reading.

Self-paced reading

Self-paced reading

The _____ _____

Self-paced reading

boy

Four replication attempts

- Two self-paced reading studies, two eye tracking
- Prospective power for Levy and Keller experiments:

Effect (ms)	Power (percentage)
30	11
50	28
80	51

[Full details in paper: bit.ly/TypeMError]

Hierarchical linear models in Stan

i=1,…,I subjects
j=1,…,J items
n data points

$$\log rt = \underbrace{X\beta}_{\text{fixed effects}} + \underbrace{Z_u b_u}_{\text{subjects random effects}} + \underbrace{Z_w b_w}_{\text{items random effects}} + \varepsilon$$

$$X_{n\times p} = \begin{bmatrix} 1 & -1 & -1 & +1 \\ 1 & +1 & +1 & +1 \\ \vdots & \vdots & \vdots & \vdots \end{bmatrix} \qquad \beta_{p\times 1} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} \begin{matrix} \\ \text{Main Effect 1} \\ \text{Main Effect 2} \\ \text{Interaction} \end{matrix}$$

Hierarchical linear models in Stan

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Hierarchical linear models in Stan

$$\log rt = \underbrace{X\beta}_{\text{fixed effects}} + \underbrace{Z_u b_u}_{\text{subjects random effects}} + \underbrace{Z_w b_w}_{\text{items random effects}} + \varepsilon$$

Priors:

$$\beta_0 \sim Normal(0,10)$$

$$\beta_{1,2,3} \sim Normal(0,1)$$

$$\sigma \sim Normal_+(0,1)$$

$$\rho \sim LKJ(\nu = 2)$$

$$b_u \sim MVN_4(\mathbf{0}, \Sigma_u)$$

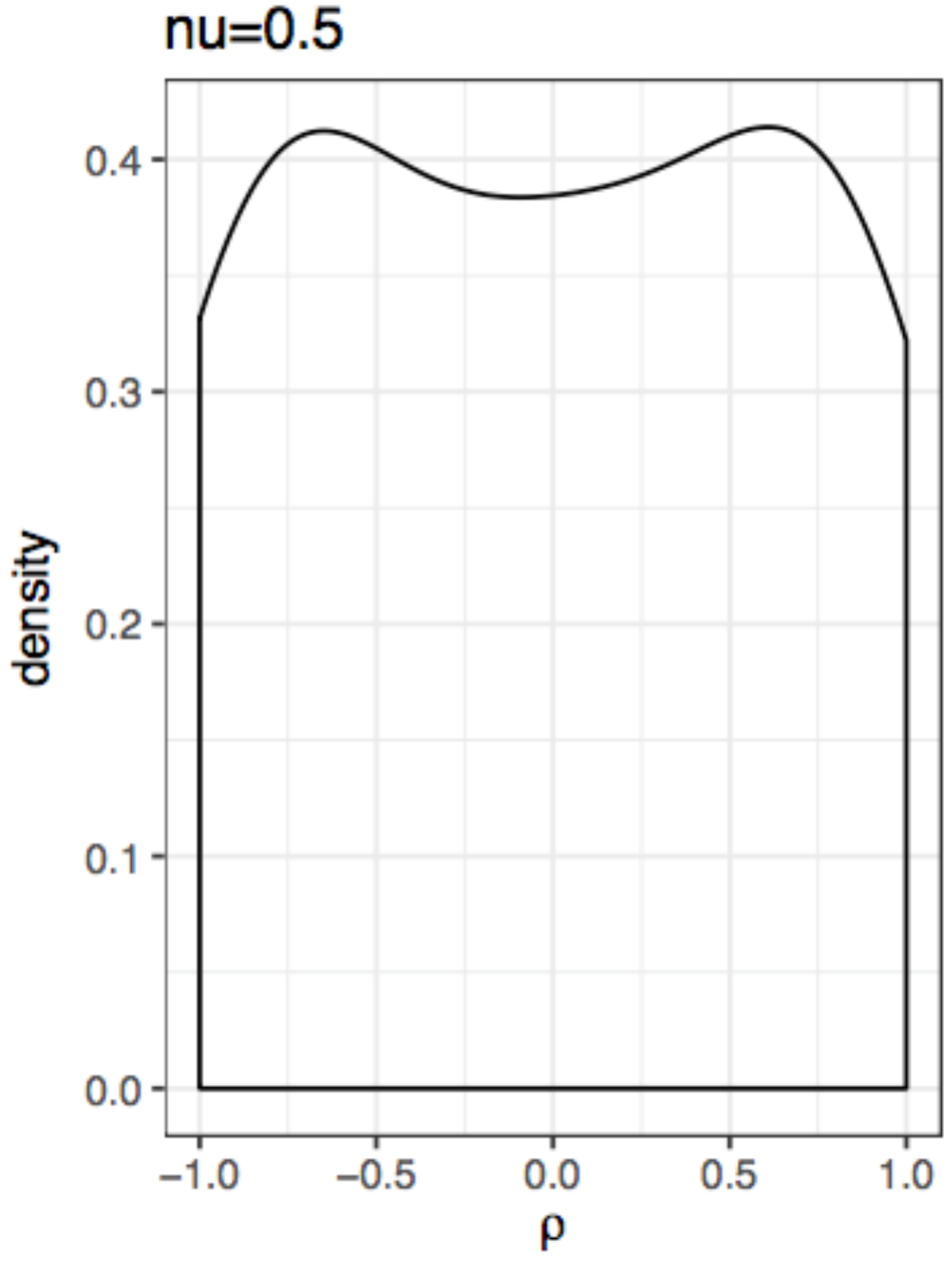
$$b_w \sim MVN_4(\mathbf{0}, \Sigma_w)$$

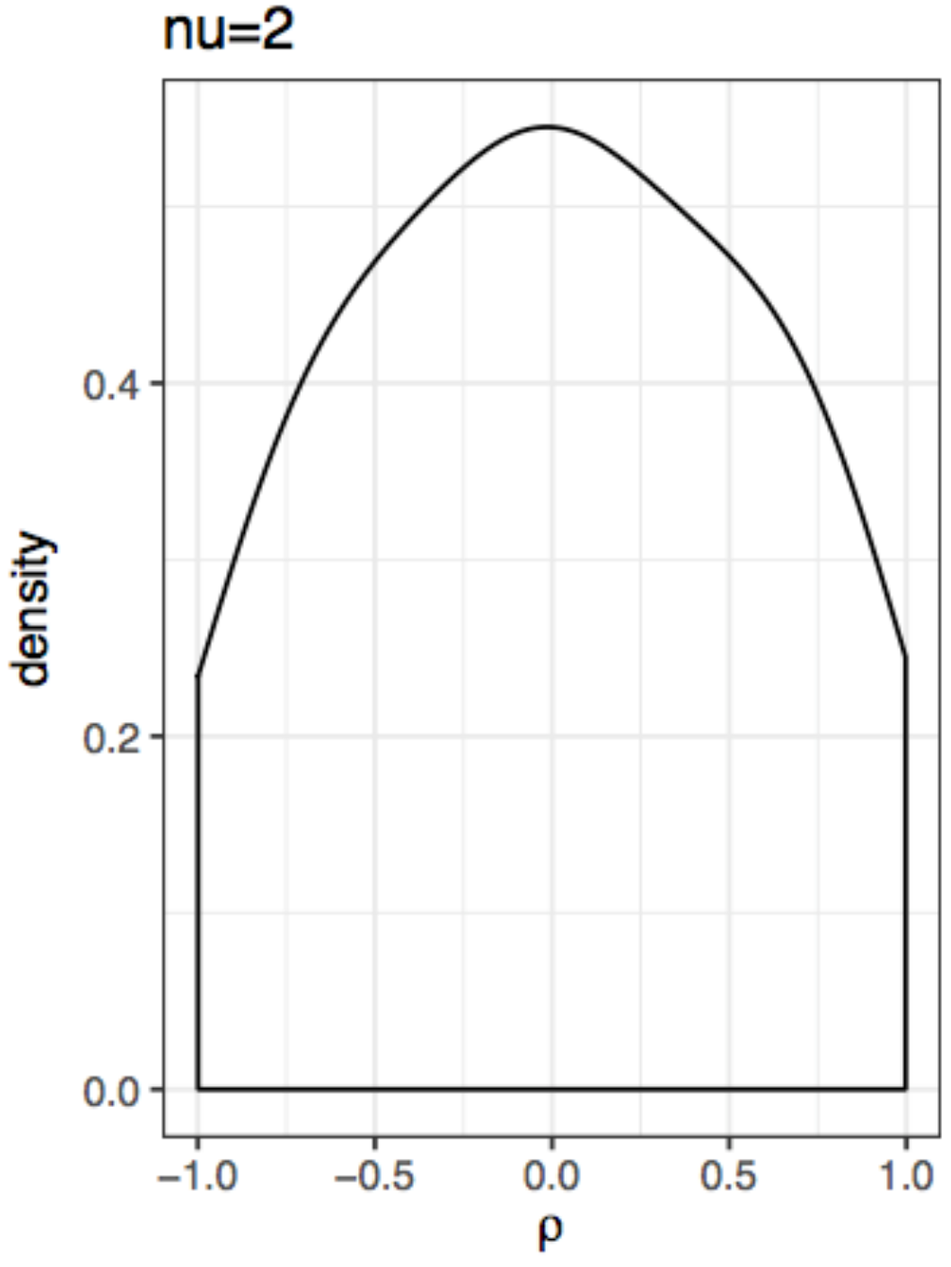
$$\varepsilon \sim Normal(0,\sigma)$$

Hierarchical linear models in Stan

Priors:

$\rho \sim LKJ(2)$





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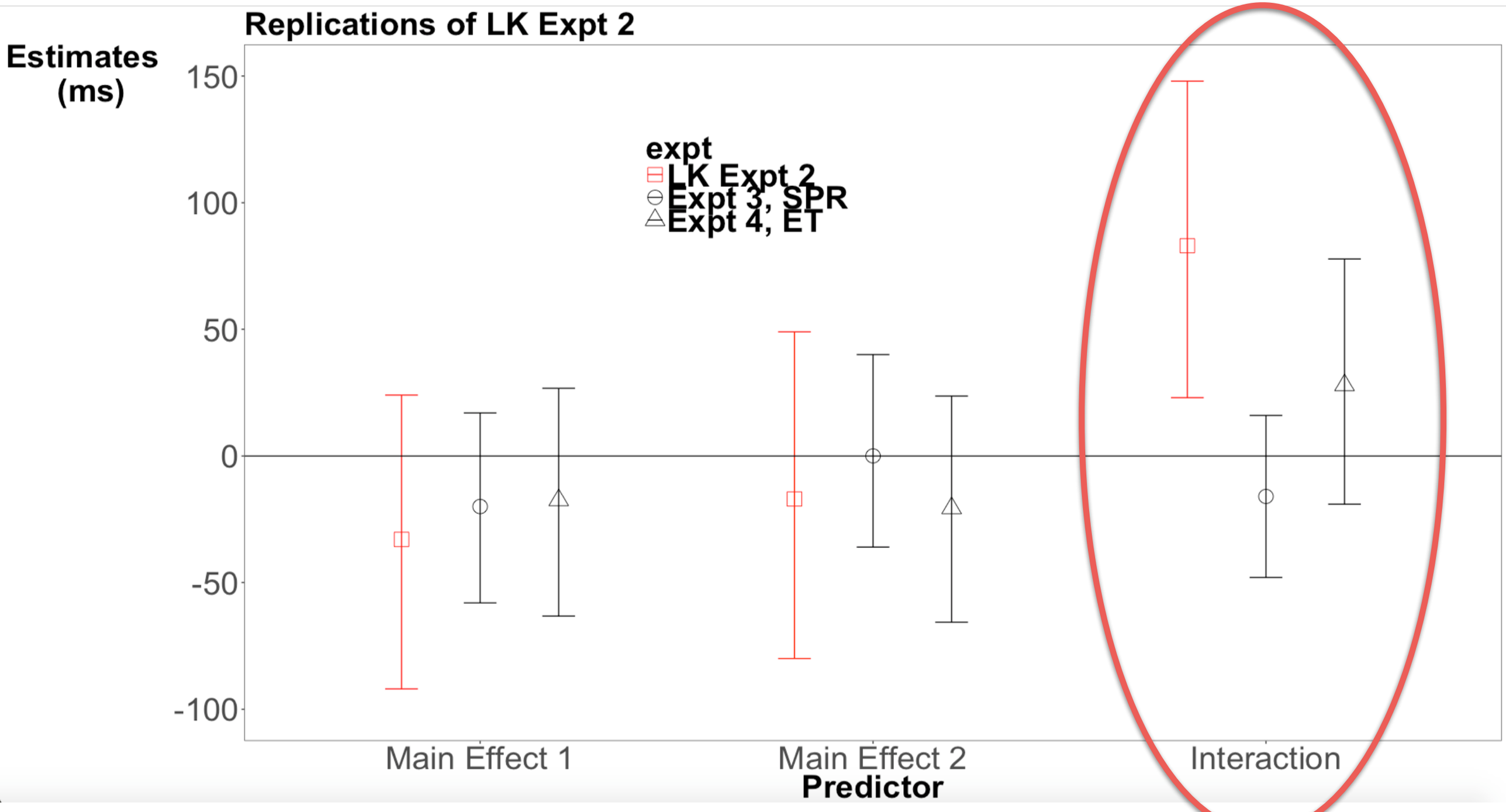
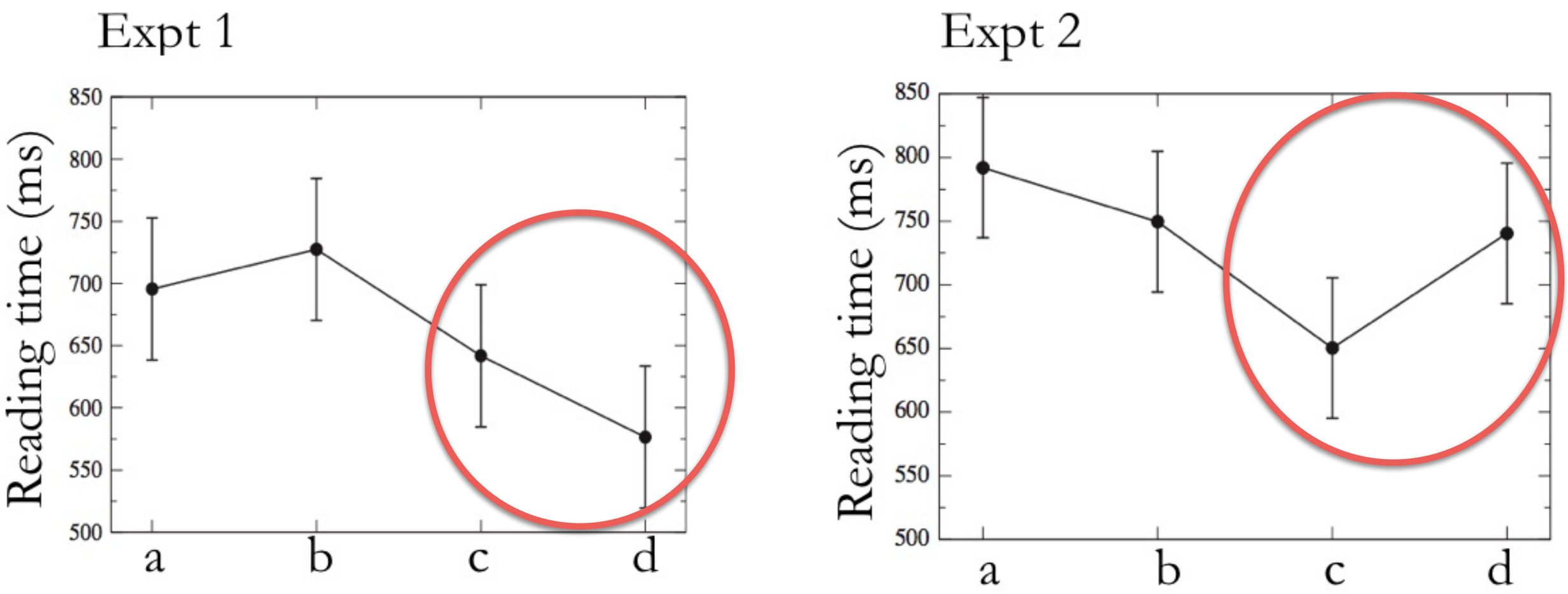
Levy & Keller's Expt 1 replication attempts

Levy & Keller's Expt 2 replication attempts



Levy & Keller 2013 claimed an interaction across the two experiments but never checked it statistically

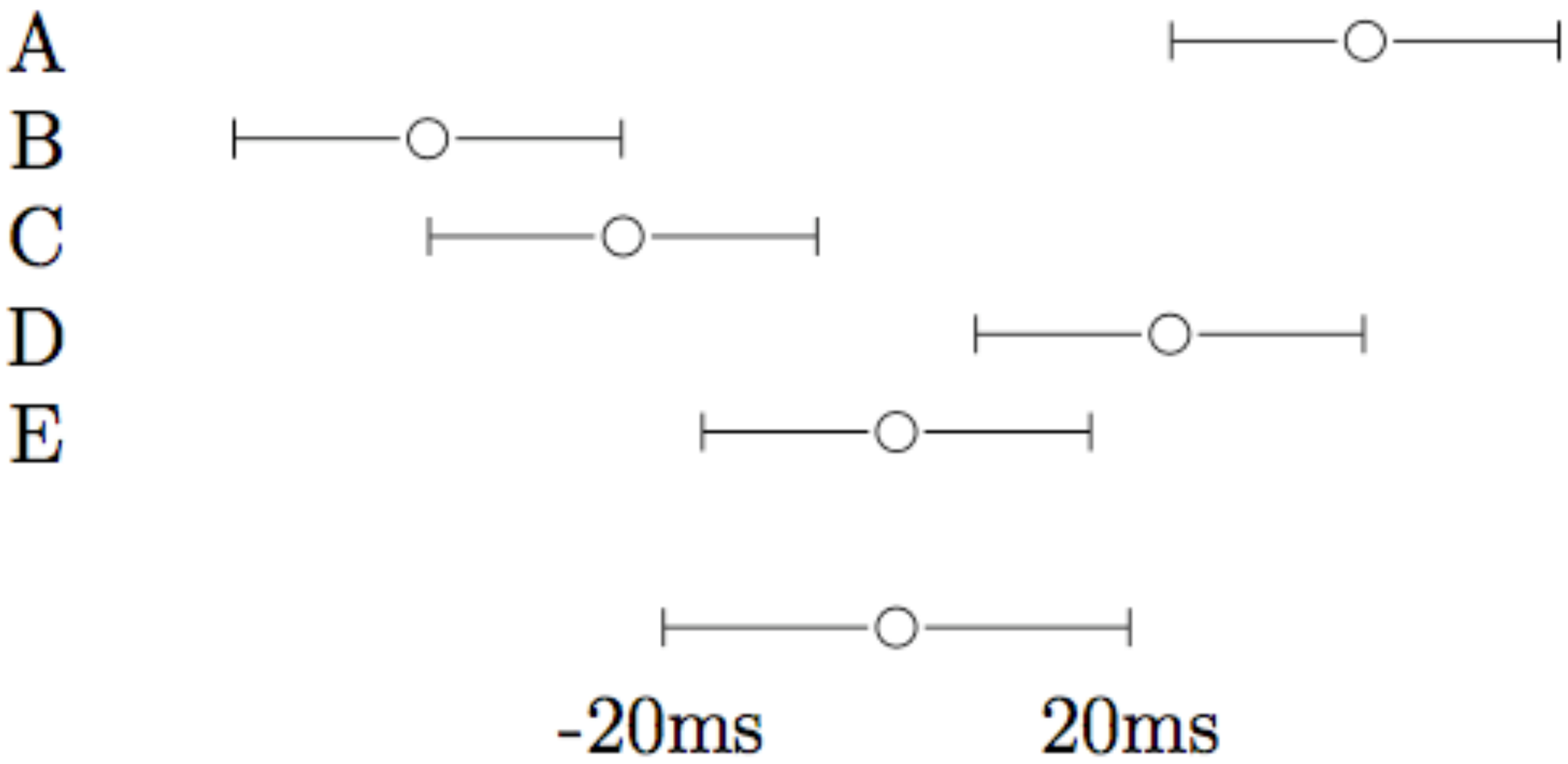


Nieuwenhuis et al, 2011, Nature Neuroscience

Three replication attempts of the claimed interaction

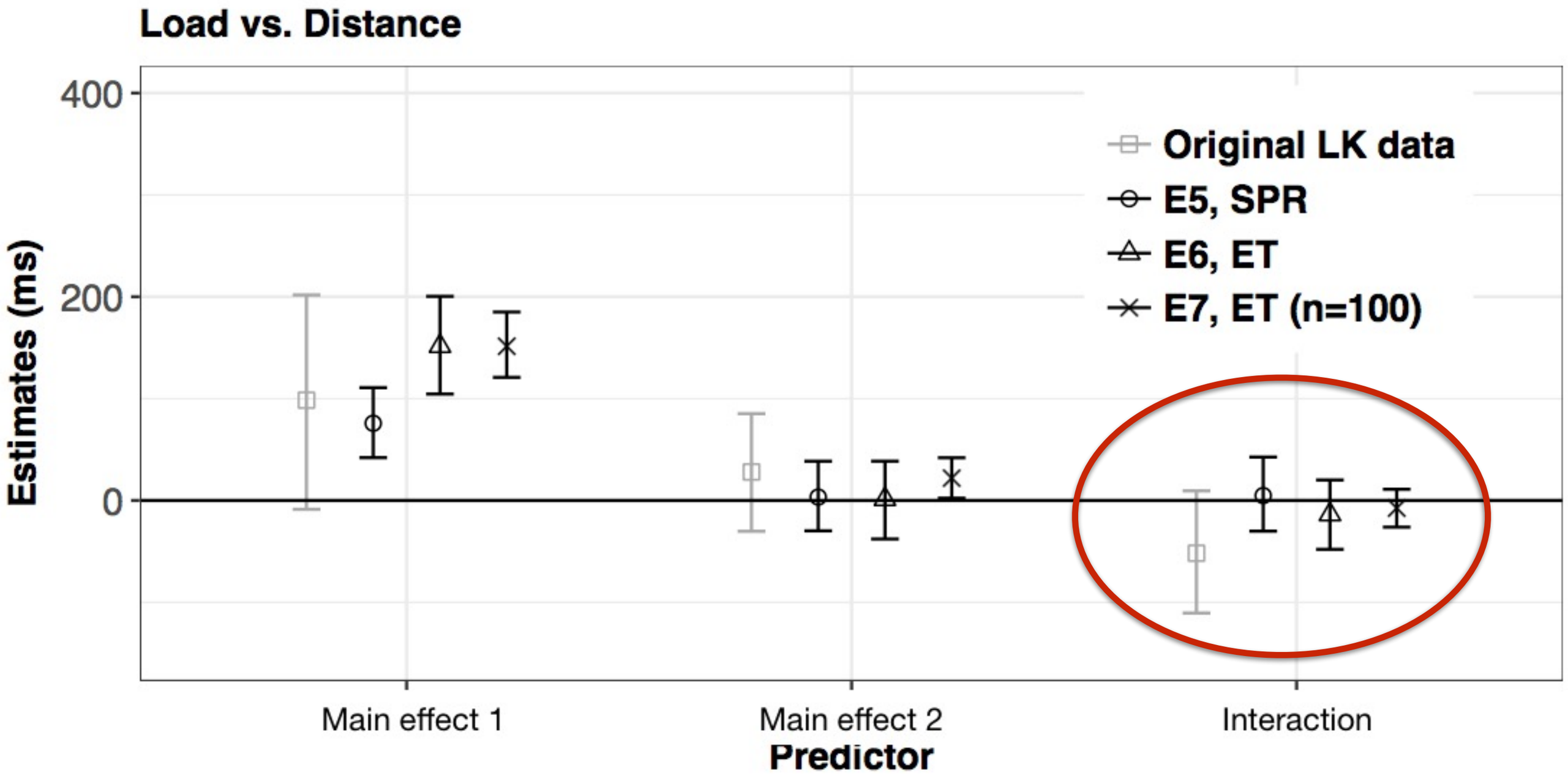
- Expt 5 (SPR): 28 participants, 24 items
- Expt 6 (ET): 28 participants, 24 items
- Expt 7 (ET): 100 participants, 24 items

Expt 7: Stopping rule determined by region of practical equivalence



Freedman, Lowe, Macaskill, 1984

Three replication attempts of the claimed interaction



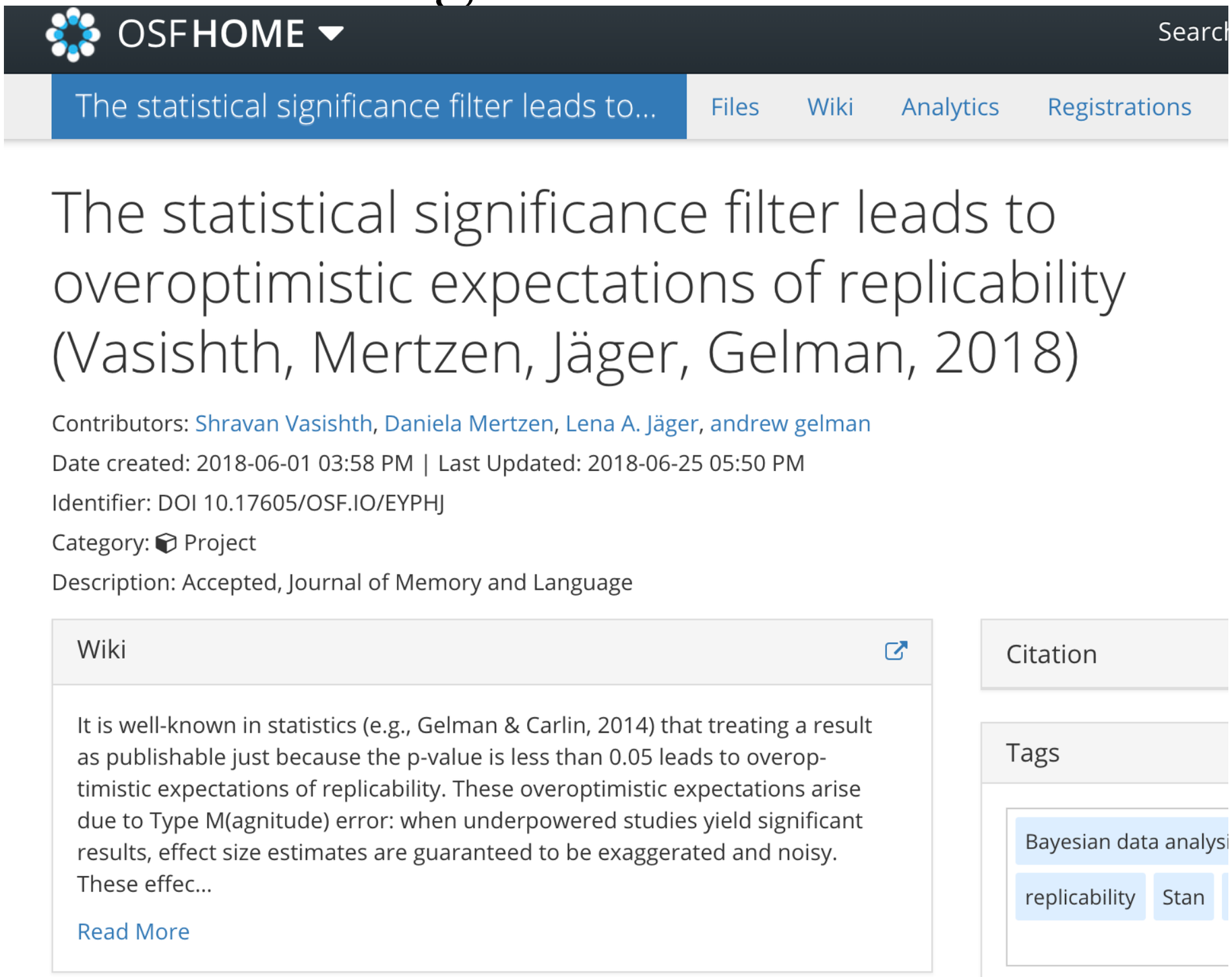
The statistical significance filter
Concluding remarks

1. Expts with 268 subjects show not a single effect
2. The published effects are Type M errors
3. Many researchers still don't understand this point

The statistical significance filter
Concluding remarks

1. Move focus away from significance
2. Focus instead on estimation
3. Run higher-precision studies
4. Pre-register experiments
5. Conduct direct replications

The statistical significance filter



bit.ly/TypeMError

The statistical significance filter

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ABSTRACT

It is well-known in statistics (e.g., Gelman & Carlin, 2014) that treating a result as publishable just because the p-value is less than 0.05 leads to overoptimistic expectations of replicability. These effects get published, leading to an overconfident belief in replicability. We demonstrate the adverse consequences of this statistical significance filter by conducting seven direct replication attempts (268 participants in total) of a recent paper (Levy & Keller, 2013). We show that the published claims are so noisy that even non-significant results are fully compatible with them. We also demonstrate the contrast between such small-sample studies and a larger-sample study; the latter generally yields a less noisy estimate but also a smaller effect magnitude, which looks less compelling but is more realistic. We reiterate several suggestions from the methodology literature for improving current practices.