Bayes Factors for time-resolved neuroimaging data

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Time-resolved neuroimaging

- M/EEG allows us to study regional and large-scale dynamics of brain activity

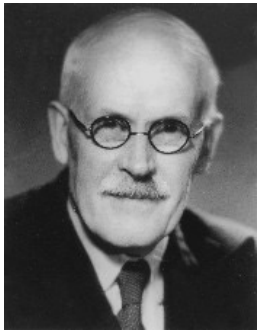
- Many different analysis techniques
  - Event-related analyses
    - Time-domain
    - Frequency-domain
  - Source analyses
  - Oscillations
  - Connectivity
  - ...

- **Statistics important to draw meaningful conclusions**

Using Bayes Factors for M/EEG results

- Based on Harold Jeffreys perspectives and philosophy of scientific learning (*cf. Ly et al., 2016*)
  - Relationship between probability & inference: How probable is one hypothesis in comparison to another when considering the data? *(Jeffreys, 1935, 1939)*

- Practical advantages for M/EEG analyses
  1. Allow us to directly compare two hypotheses
  2. Measure of strength that is interpretable
  3. Enables us to collect data iteratively

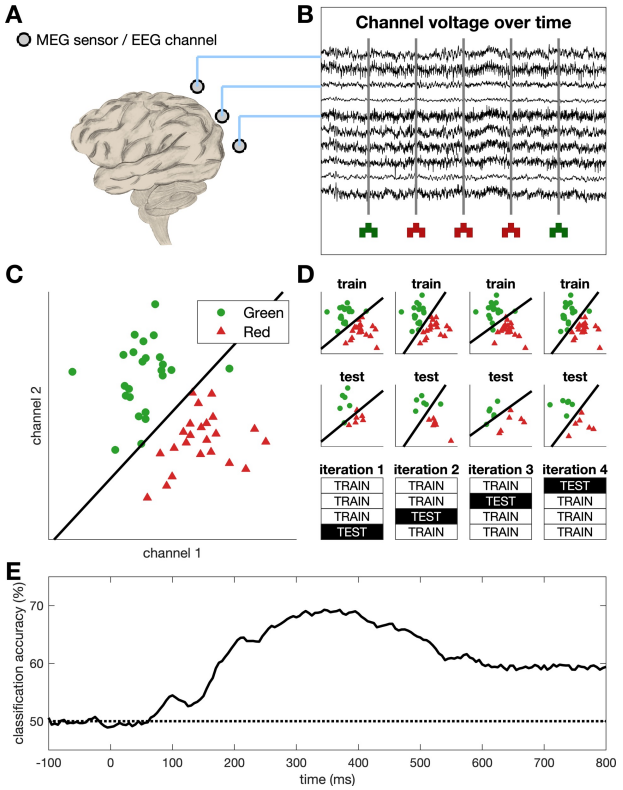


Sir Harold Jeffreys

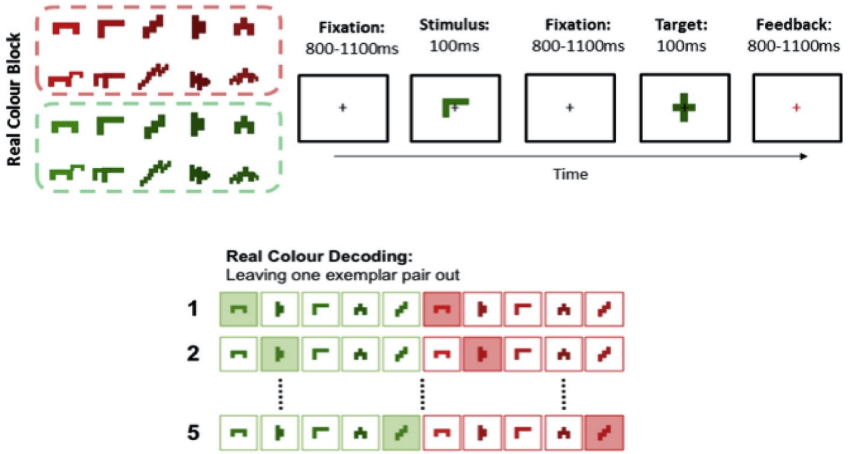
Time-resolved classification analysis

- Example: Colour processing

- Activation- vs information-based framework *(cf. Hebart & Baker, 2018)*
  - Activation: Does red evoke a stronger/weaker signal than green? (univariate)
  - Information: Is there information about green/red in the signal? (multivariate)
- Classification analysis hypotheses
  - Ho: mean decoding equals chance decoding
  - Ha: mean decoding is larger than chance decoding
- **Bayes Factors:** the probability of one hypothesis versus another given the data



Example dataset

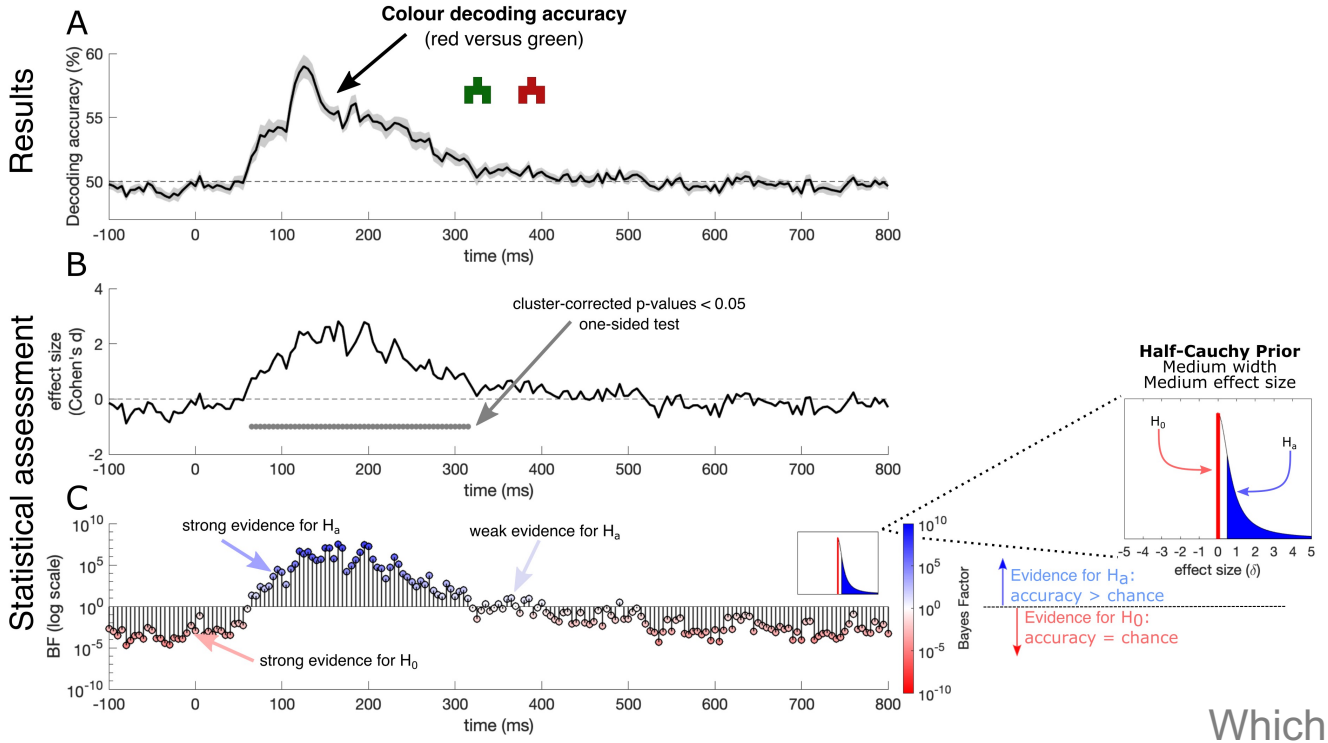


- 18 participants
- 1600 trials
- Epoched -100 to 800ms
- 200 Hz resolution
- Target-detection task (targets excluded from analysis)

- 5-fold cross-validation
- Originally, permutation tests and cluster-corrected p-values

Teichmann et al., 2019, NeuroImage

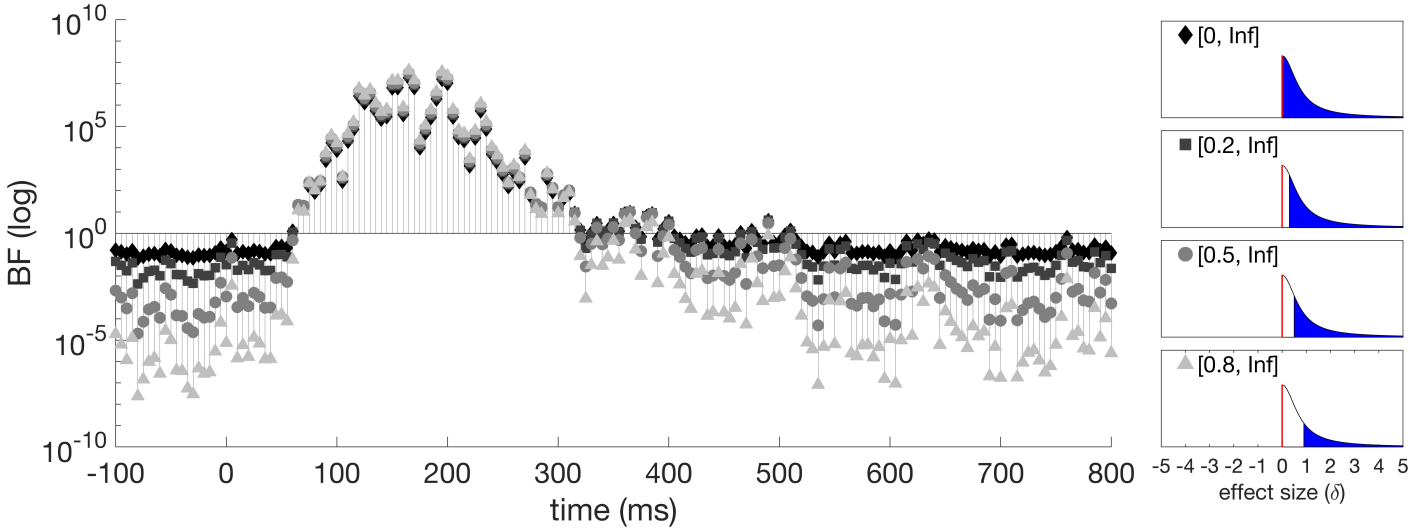
Example dataset results



Which parameters make the most sense?

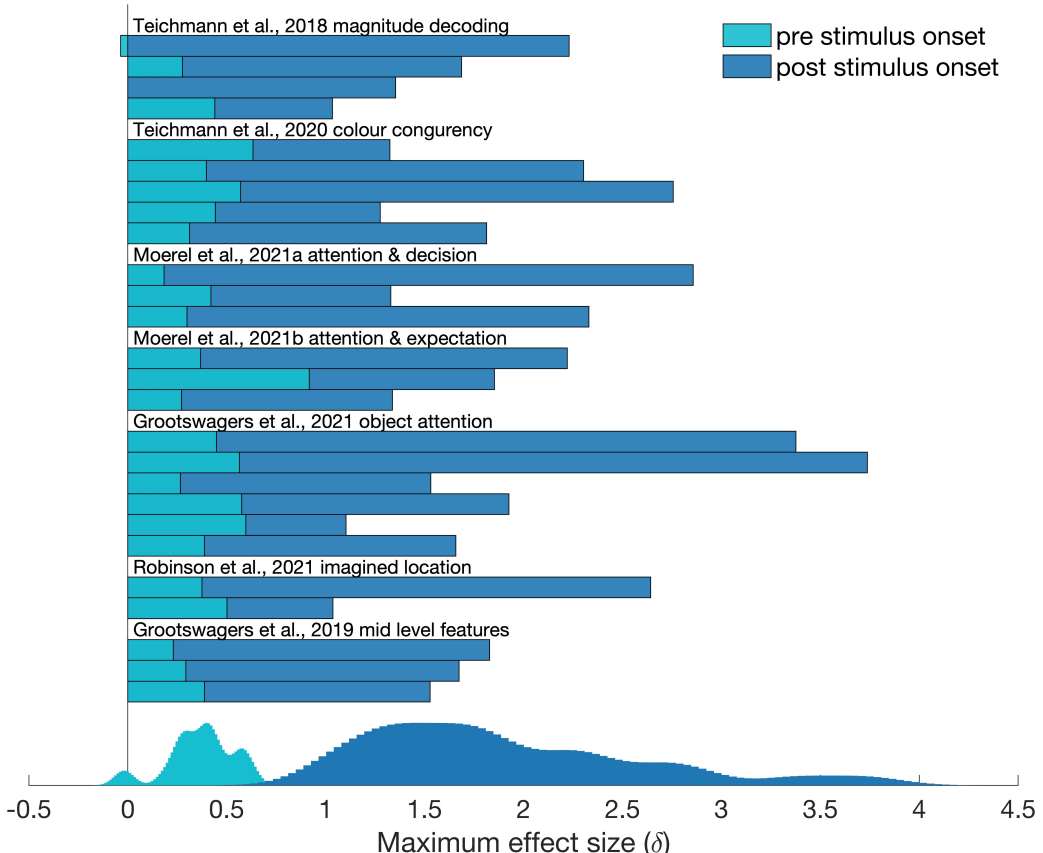
Adjustment of prior range (null interval)

- Increasing the lower bound means allowing small effects under Ho
- Observed chance is often different than theoretical chance



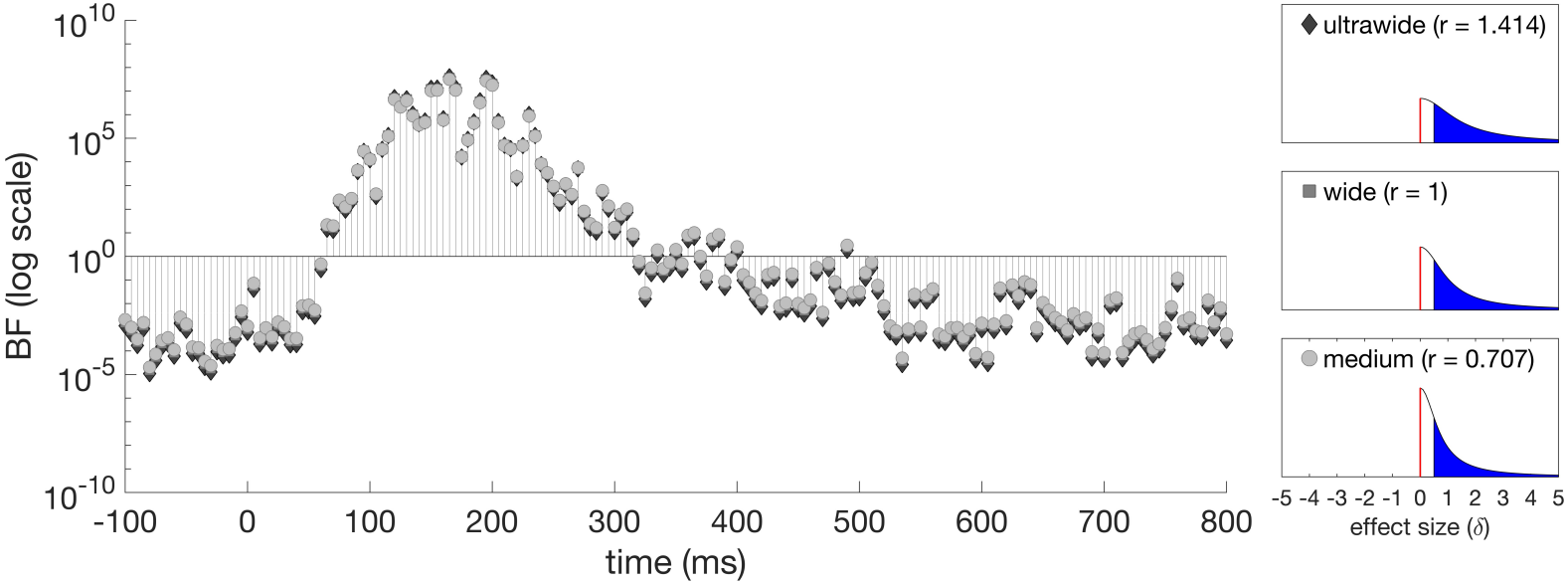
What lower bound makes sense?

- Baseline period: What values can be expected “by chance”



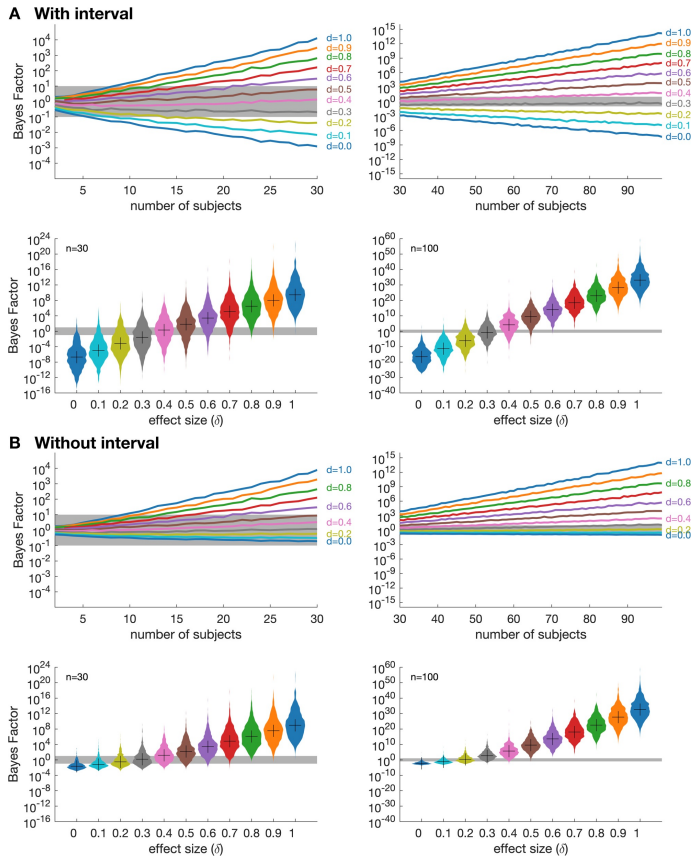
Variation of prior width

- Widths capture expected effect sizes
- Changing prior width has no influence on our data (effect sizes large)



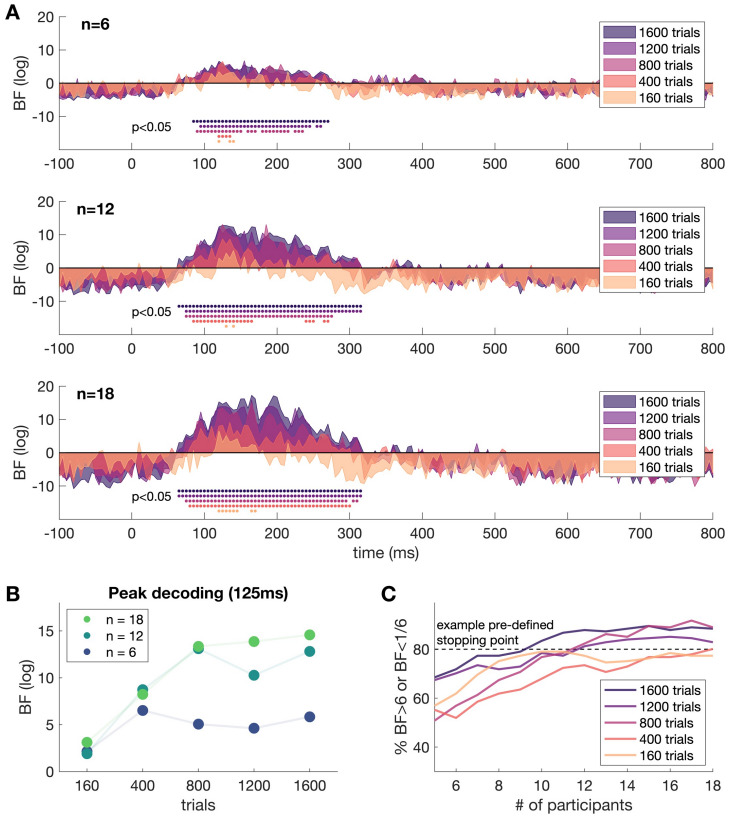
Sensitivity to small effects given parameters

- Simulated classification results for different sample sizes and varied the effect sizes
  - Even if effect is small (and lies within the pre-defined null interval) we find evidence for Ha after a while if the effect is consistently there
  - Large number of observations does not automatically lead to conclusive evidence (if the effect is truly in between the hypotheses)
  - Interval is critical to find evidence for the null



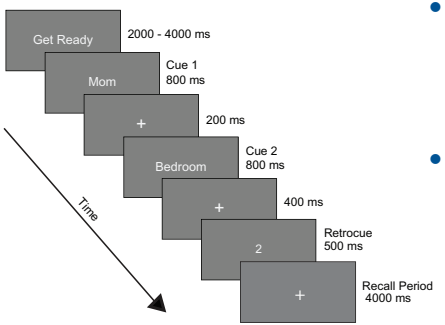
Flexible sampling plans

- Bayes Factors allow us to collect data iteratively
- More trials or more participants?
- Safer to overpower number of trials

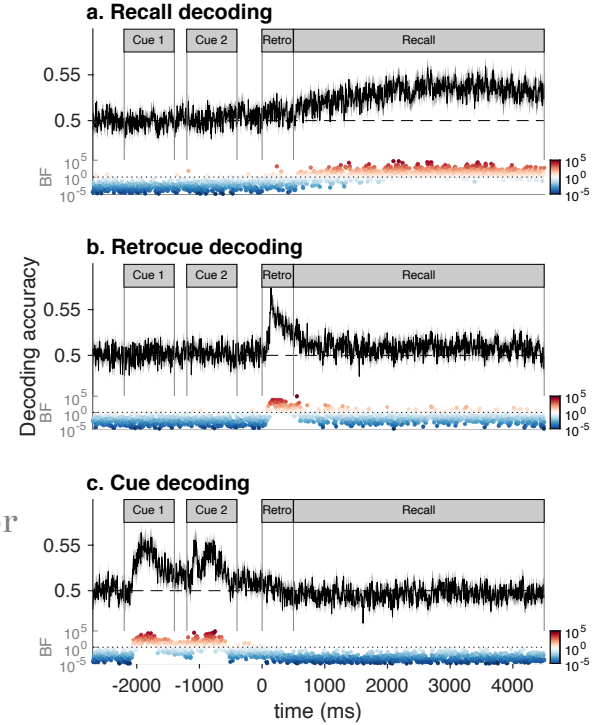


Example studies: making use of Bayes Factor advantages

Mental imagery: when do we have the strongest/weakest evidence?



- Stimuli: personally-relevant people and places
- Is there information about stimulus class during mental imagery?



- Long epochs / recall period
- Is there a time-window where we have strong evidence for accurate recall?

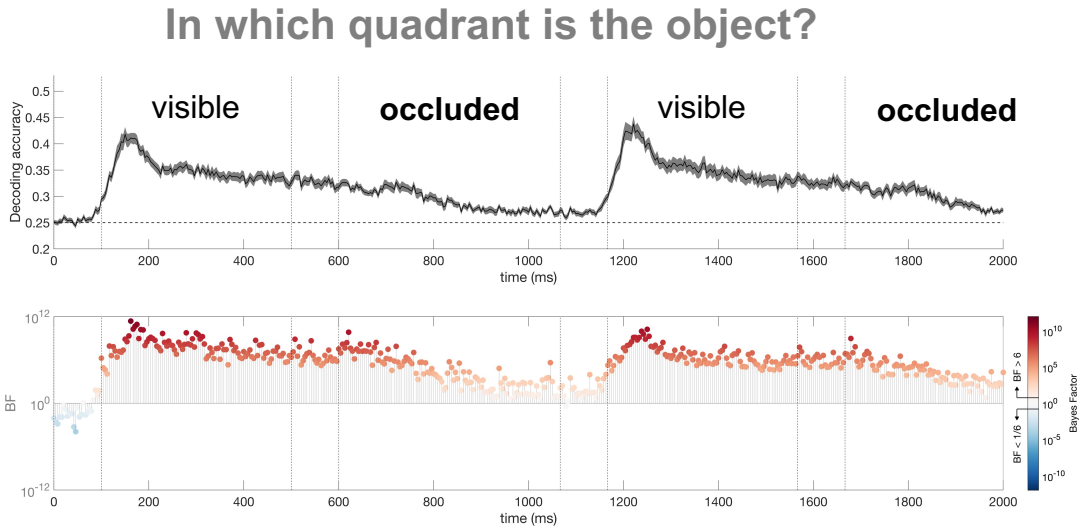
[Interpretability of Bayes Factors]

Kidder, Corriveau*, Teichmann, Wardle, Baker (under review)*

Occlusion: Are there timepoints with *no* information?

- How are object properties represented during occlusion?
- Possible that there is *no* information about the object during occlusion

[Contrasting Ho and Ha]



Teichmann, Moerel*, Rich & Baker, Cortex, in-principle acceptance*

Thank you ☺

Denise Moerel

Chris Baker

Tijl Grootswagers

Paper on bioRxiv: *An empirically-driven guide on using Bayes Factors for M/EEG decoding*

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