Power for detecting the presence of set size differences in the contralateral delay activity

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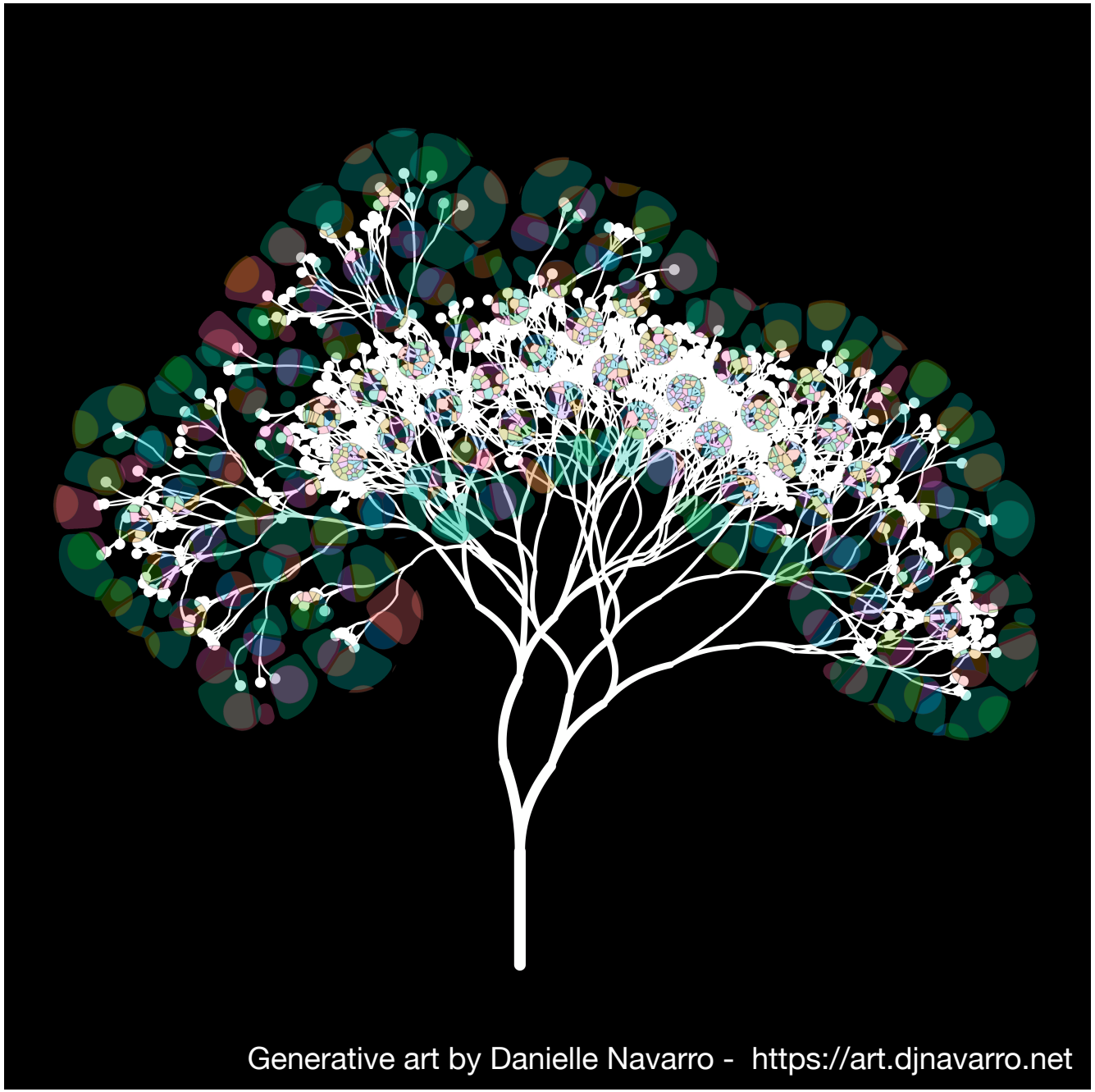
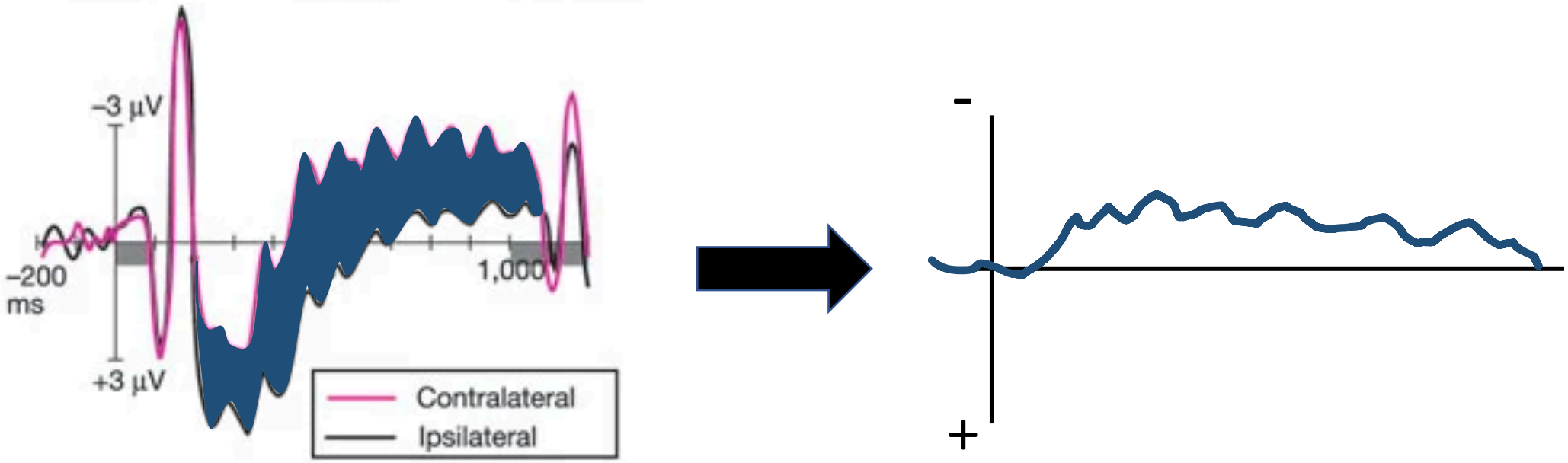


Contralateral Delay Activity (CDA)

- An event-related potential (ERP) measured during the retention period of a bilateral change-detection task
  - Sustained negativity over the contralateral hemisphere
  - Across posterior and occipital electrodes
  - Mean amplitude of difference wave between contralateral and ipsilateral electrodes



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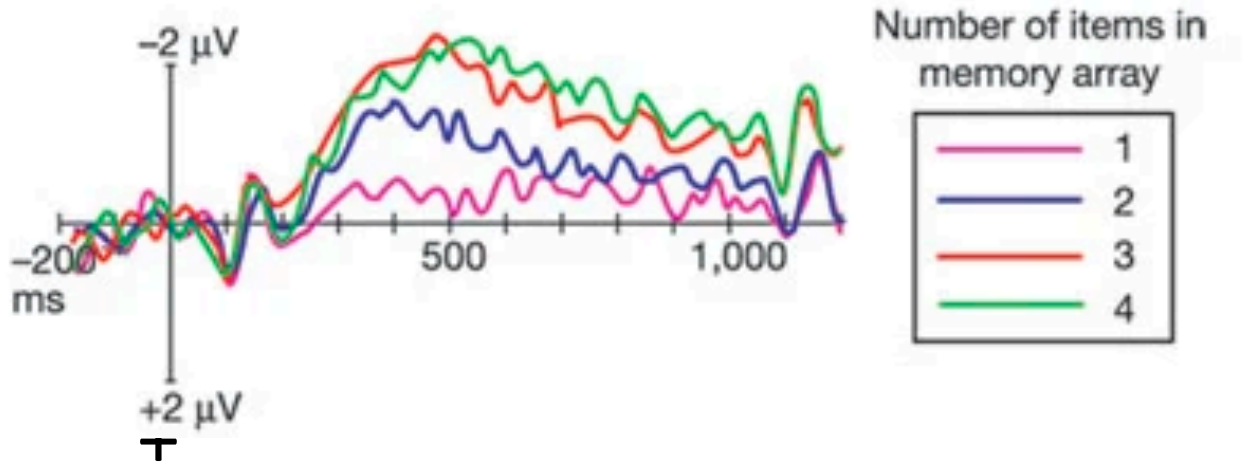
Vogel & Machizawa (2004). *Nature*, *428*(6984).

Contralateral Delay Activity (CDA)

- Closely tracks the memory load
  - Increases in amplitude with increasing set-size, plateauing at a typical VWM capacity of 3-4 items



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Vogel & Machizawa (2004). *Nature*, *428*(6984).

Contralateral Delay Activity (CDA)

- Useful tool in advancing research on visual working memory
  - Filtering efficiency and attention
  - Binding and grouping
  - Complexity and resolution
  - Visual search
  - Multiple object tracking
  - Rapid-serial visual presentation

- For a review: Luria, Balaban, Awh, & Vogel (2016). *Neuroscience & Biobehavioral Reviews*, 62, 100-108.

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What is power?

- The probability of detecting an effect given the effect exists
  - *p*(significant|effect)

- As scientists, we want to maximize the positive predictive value - the probability that a positive (significant) finding is due to a true effect and not a false positive
  - *p*(effect|significant)

- The positive predictive value is maximized by increasing our statistical power
  - A potential reproducibility crisis in science due to a high prevalence of false positives

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Ioannidis (2005). *PLos med*, *2*(8), e124.
Open Science Collaboration. (2015). *Science*, 349(6251), aac4716.

Why we need to care about power

- It's important that experimenters are sufficiently powered to detect the effect of interest
  - Researchers consume precious time and resources in conducting the experiment
  - A false negative (due to lack of power) can mean:
    - A slowing of scientific progress as the negative results cannot be reliably interpreted
    - Left in a file drawer as the result is a null effect
    - And we have missed out on knowing the effect exists!

- Increasing statistical power improves the reliability of the findings
  - Estimated median statistical power is between 8 and 31% due to typically small sample sizes in neuroscience (Button et al., 2013)

- Estimating the number of subjects and trials needed is useful!
  - Enables pre-registration of sample sizes and study design
  - Evaluate whether the experiment is feasible

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Button, Ioannidis, Mokrysz, Nosek, Flint, Robinson, & Munafò (2013). *Nature Reviews Neuroscience*, 14(5), 365-376.

Estimating power to measure the CDA

- What number of subjects and number of trials is required to be sufficiently powered to detect:
  - The presence/absence of the CDA
  - Set-size differences in the CDA

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Datasets

- Unsworth et al. (2015) *JoCN* dataset
  - Color working memory task with set size 2 and 6
  - 171 participants – very large EEG dataset
  - 139 participants had at least 170 clean trials in both set size conditions

- Hakim et al. (2019) *PsychSci* dataset
  - Color working memory task with set size 2 and 4
  - 31 participants with at least 220 clean trials in both set size conditions

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Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. K. (2015). *Journal of Cognitive Neuroscience*, 27(5), 853-865.
Hakim, N., Adam, K. C., Gunseli, E., Awh, E., & Vogel, E. K. (2019). *Psychological science*, 30(4), 526-540.

Subsampling analysis

- Randomly sampled a given number of trials from a given number of randomly sampled subjects
  - Conducted a statistical test on the subsampled data
  - 10,000 iterations of each combination of number of trials and subjects
  - Estimate power with the proportion of iterations that produced significant tests

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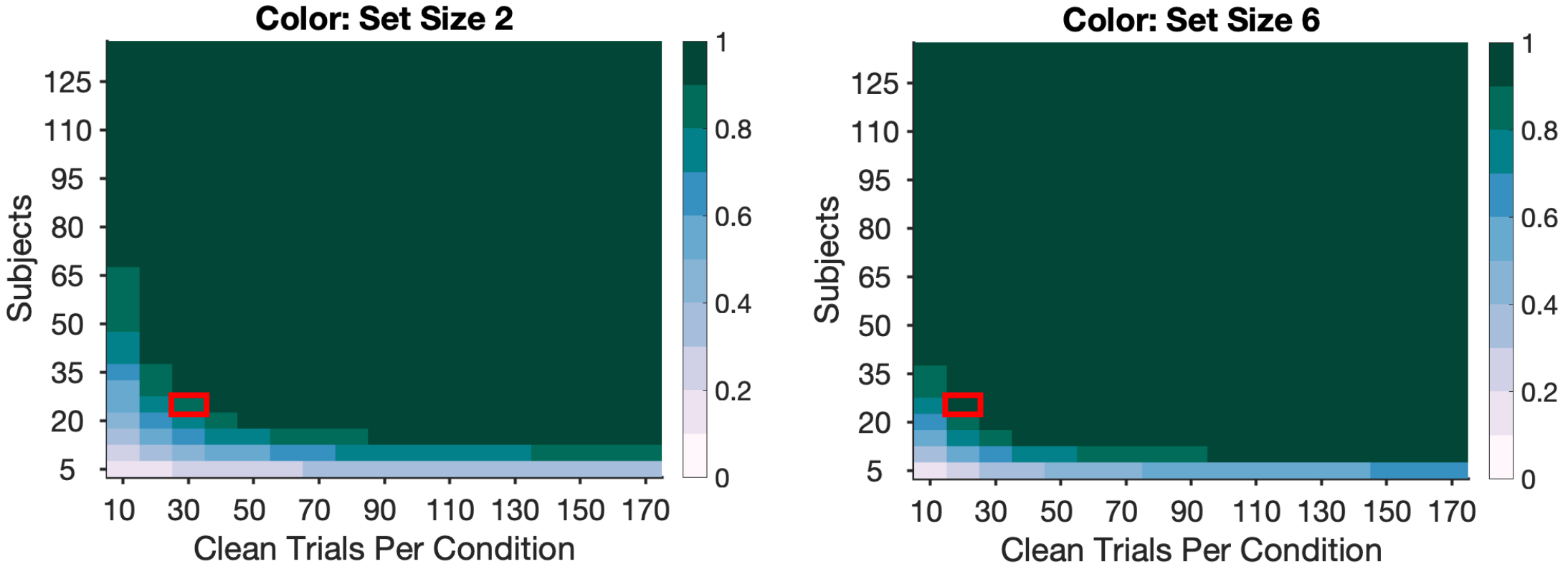
Power to detect the presence of CDA



- For $n = 25$
  - 30 trials required for at least 80% power in set size 2
  - 20 trials required for at least 80% power in set size 6

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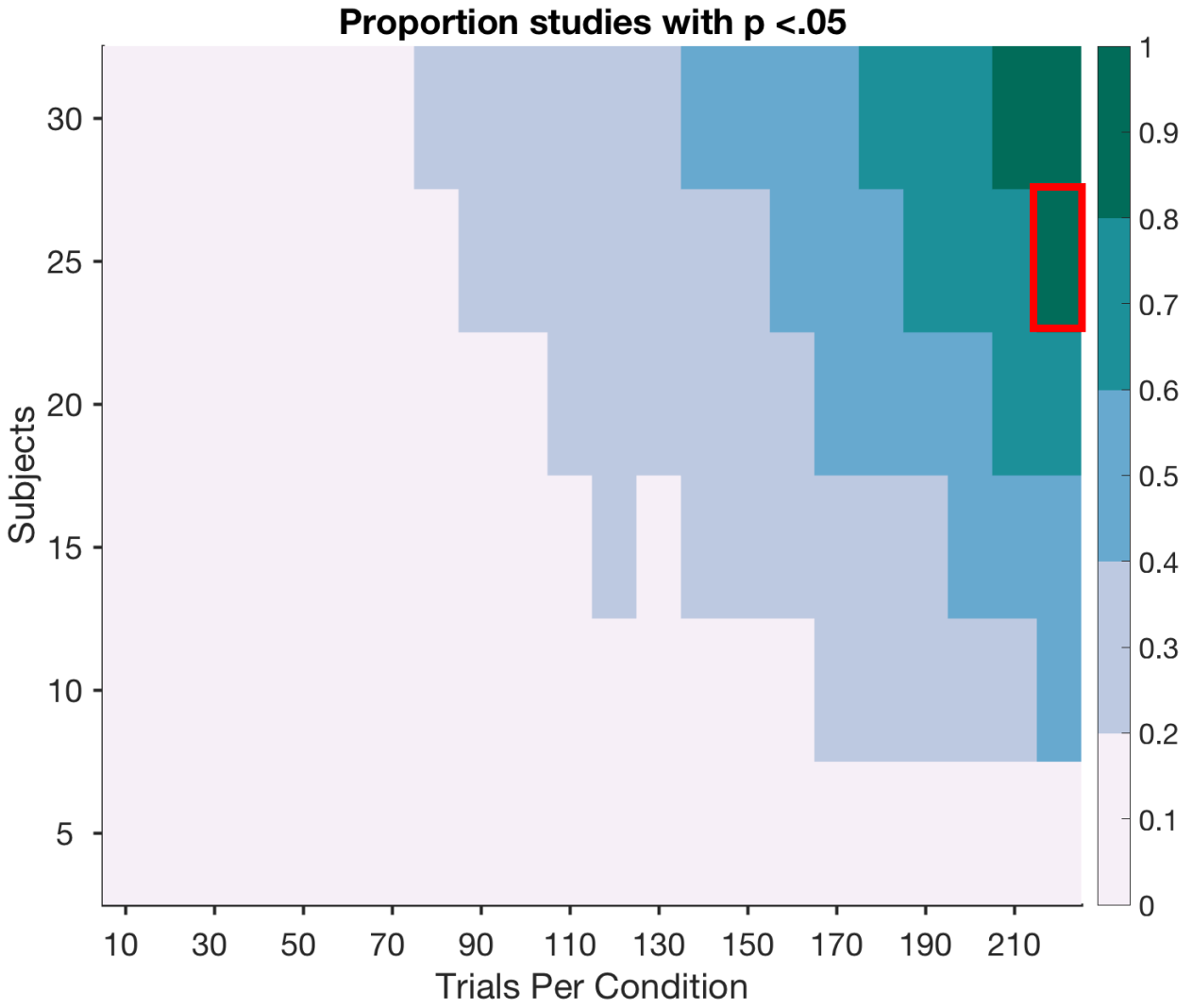
Power to detect set-size differences in CDA

- To detect a 2 vs 4 set-size difference in the CDA:
  - For *n* = 25, about 220 clean trials is needed to achieve 80% power



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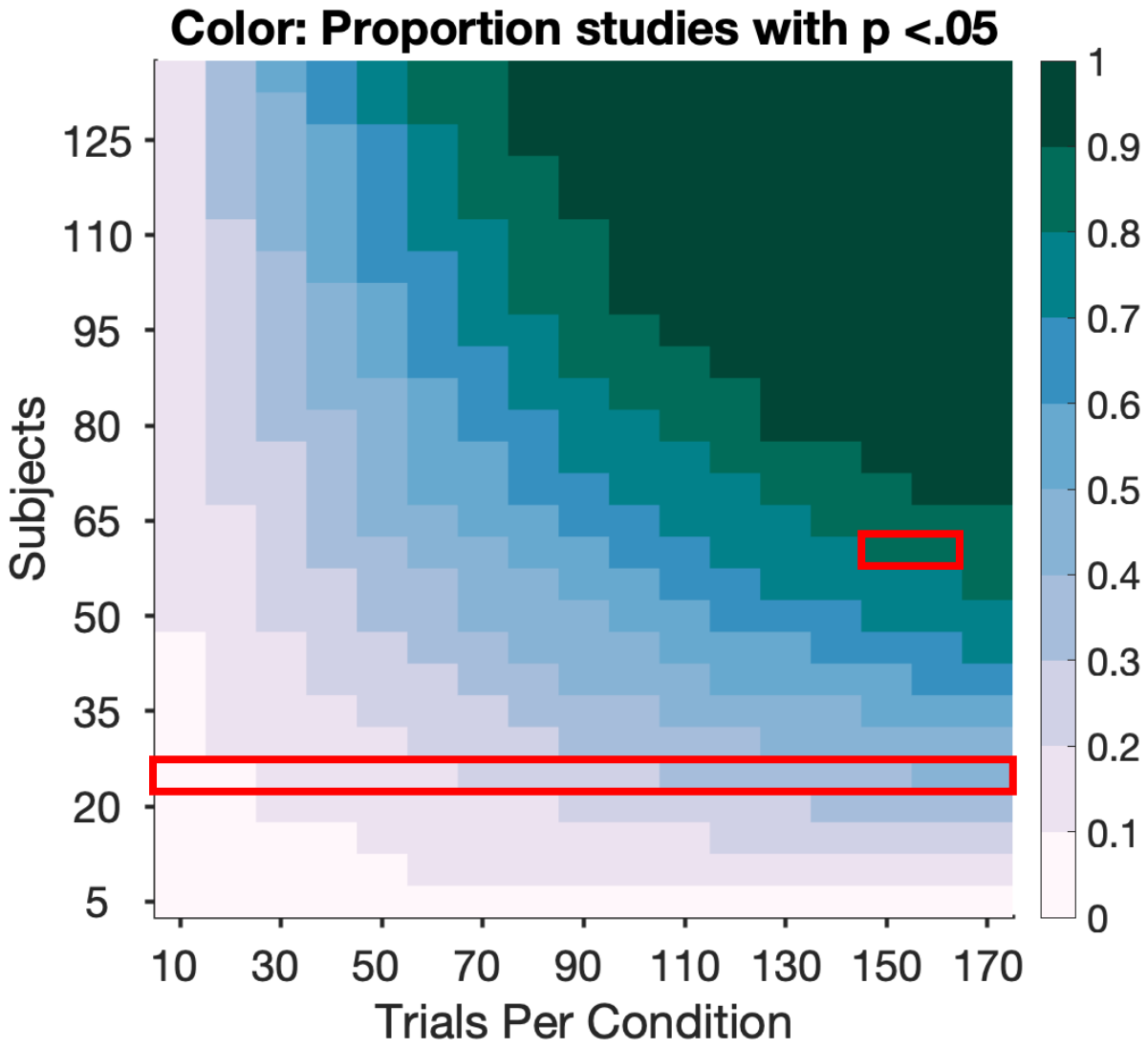
Power to detect set-size differences in CDA

- To detect a 2 vs 6 set-size difference in the CDA:
  - For *n* = 25, 80% power is not achieved with 170 clean trials
  - To achieve 80% power, you might need 60 subjects and 150 clean trials



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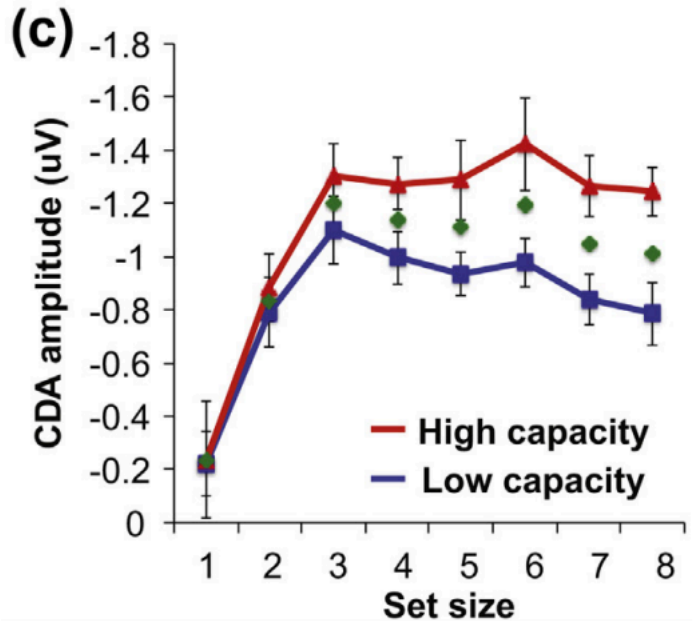
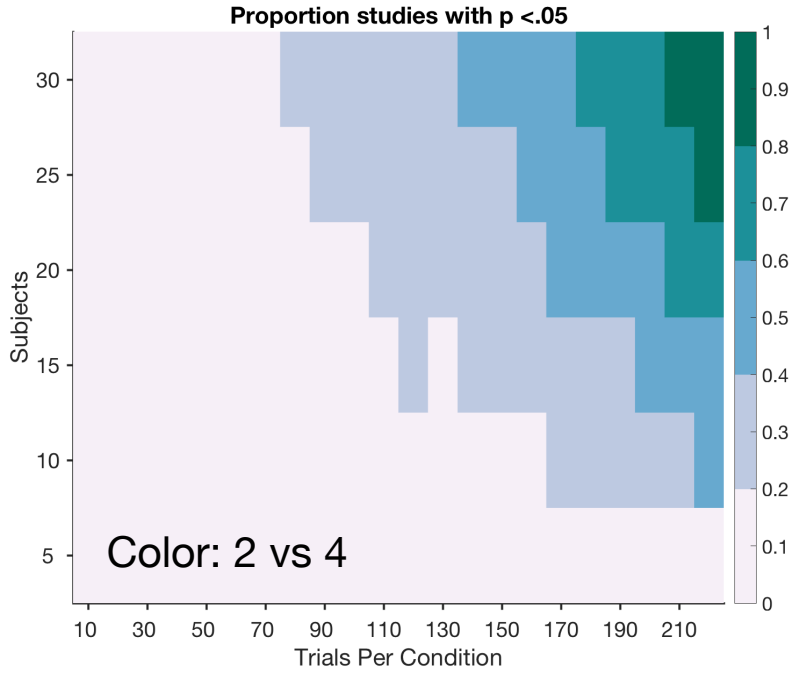
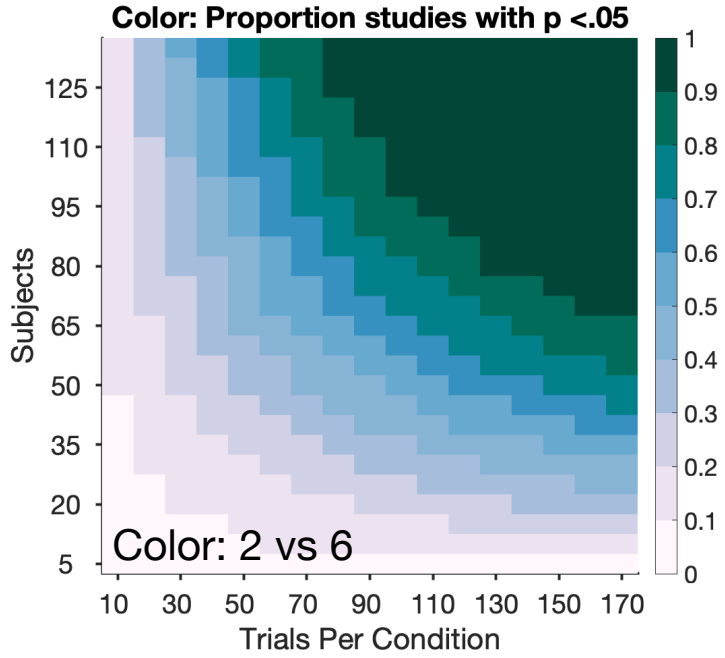
Power to detect set-size differences in CDA

- Set-size effects between 2 versus 6 appear to be harder to detect compared to 2 versus 4 (smaller effect size)
  - Set size 6 may overload the VWM system and recruit filtering processes

- Suggests experimental designs that target 1 versus 3 instead for example







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Fukuda, Woodman, & Vogel (2015). *Mechanisms of sensory working memory: attention and performance XXV.*

Limitations

- These analyses are restricted to a maximum of 200 clean trials
  - We have preliminary simulations predicting beyond these limits
- How well these analyses extrapolate relies on the generalizability of these datasets
  - Given these are larger than standard EEG datasets suggests it has more external validity
- Power can be improved with more precise measurement of the CDA (see Luck et al., 2020 for measure of ERP data quality)

Takeaways

- Typical numbers of subjects and trials for contralateral delay activity experiments may be underpowered when detecting set size differences

- The size of the effect is critical when planning numbers of subjects and trials in any experiment
  - Improve your experimental design to increase power

- We hope this subsampling analysis will enable principled estimates of power, ensuring better chances of detecting the effect
  - We have preliminary simulations beyond the number of subjects and trials

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Thank you!

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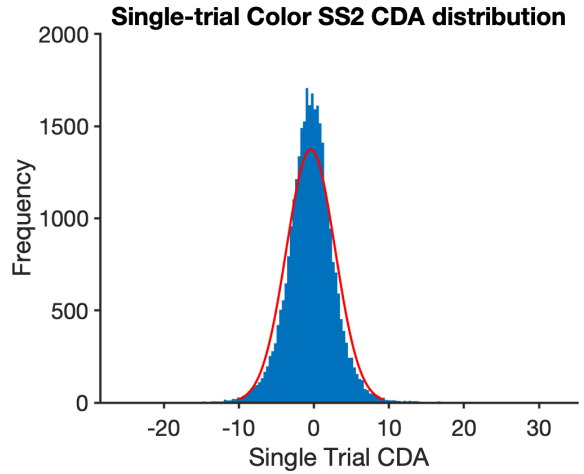
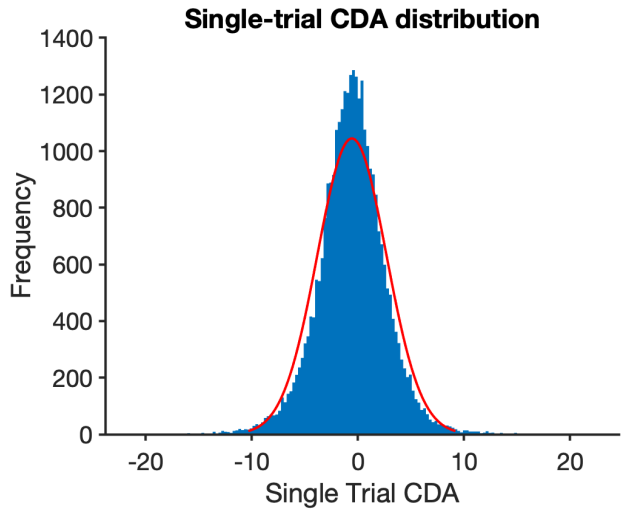
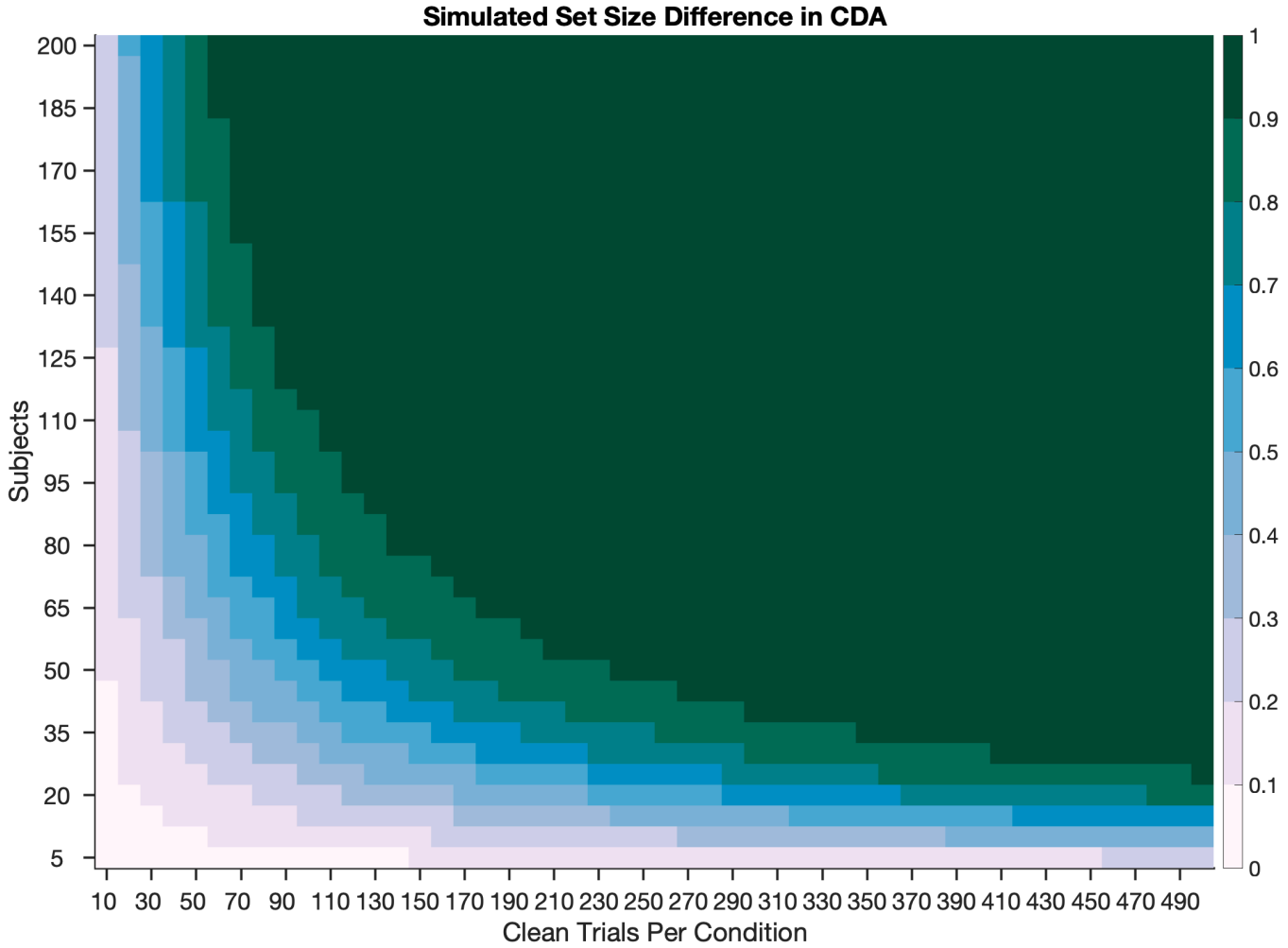
Simulations







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