

Modulating verbal fluency performance in healthy adults with tDCS over the left prefrontal cortex

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Introduction

Previous studies reported conflicting results about the efficacy of left prefrontal tDCS to modulate verbal fluency performance.

Potential procedural caveats

- Low power (small sample sizes)
- Single-blind application of tDCS
- Suboptimal electrode montage
- For offline fluency: no task during stimulation

Present study

- Double-blind within-participant crossover design
- Improved electrode montage
- Picture naming task during stimulation to enhance stimulation effect on neuronal level

Hypothesis

If tDCS effectively modulates neuronal activity underlying language production performance, verbal fluency scores should be higher following anodal compared to sham tDCS.

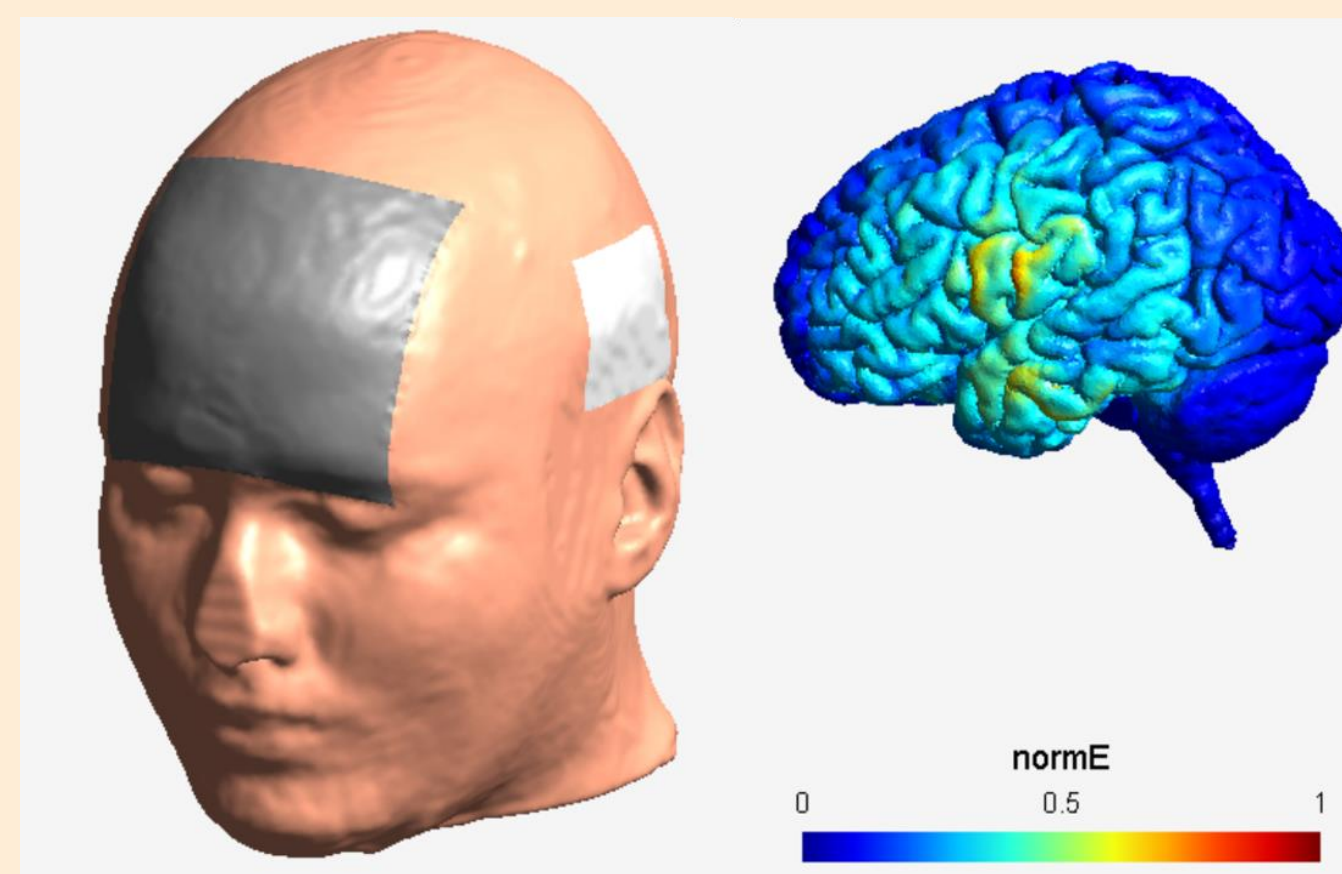
Methods

Participants

- 48 healthy native German speakers (26 female, mean age: 27.1 years, $SD = 3.8$); right-handed; tDCS-eligible

tDCS

- 20 min of 2 mA, anodal vs. sham tested within participants, double-blinded
- Active electrode: 5x5 cm (current density 0.08 mA/cm²); reference electrode: 10x10 cm (current density: 0.02 mA/cm²)
- Stimulation order counterbalanced across participants



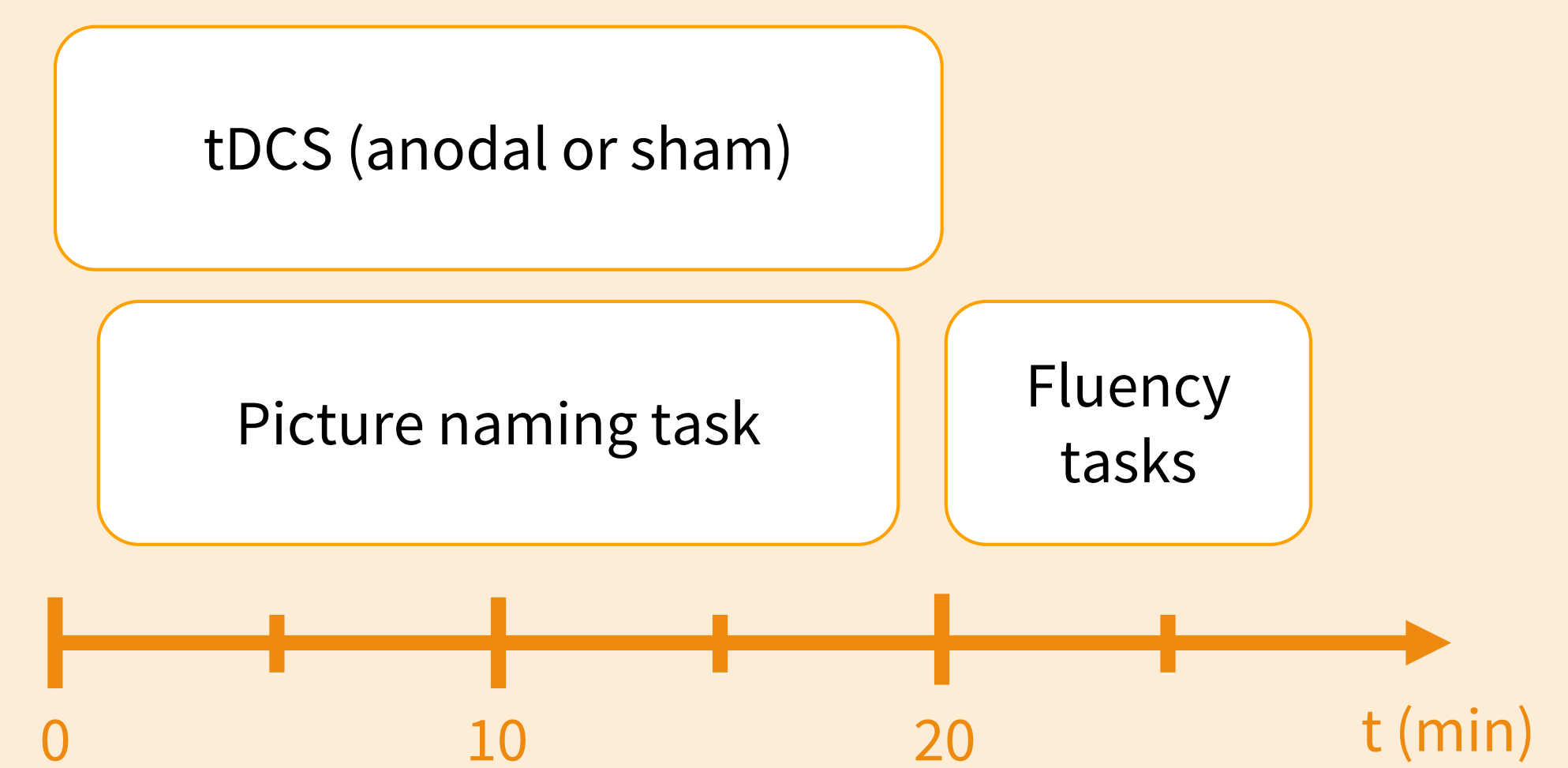
Verbal fluency (offline)

- Semantic: means of transportation, buildings, office supplies, metals, clothes/flowers, sports/fruit
- Phonemic: S, B, K, M, G/R, H/T
- Produce as many words as possible within 1 minute

Picture naming task (online)

- 496 coloured line drawings of concrete objects split in two lists, matched for frequency and visual complexity

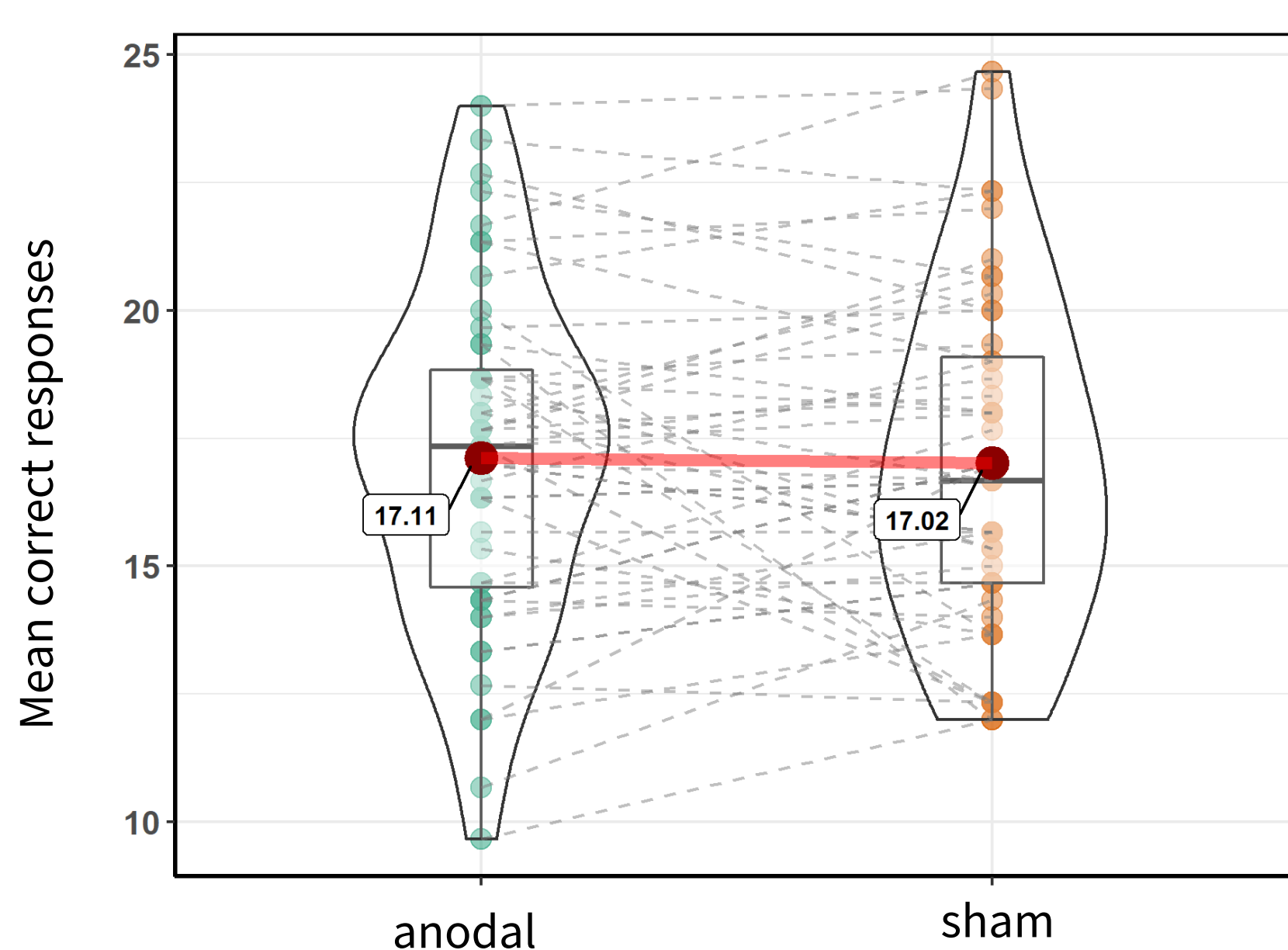
Procedure



Results

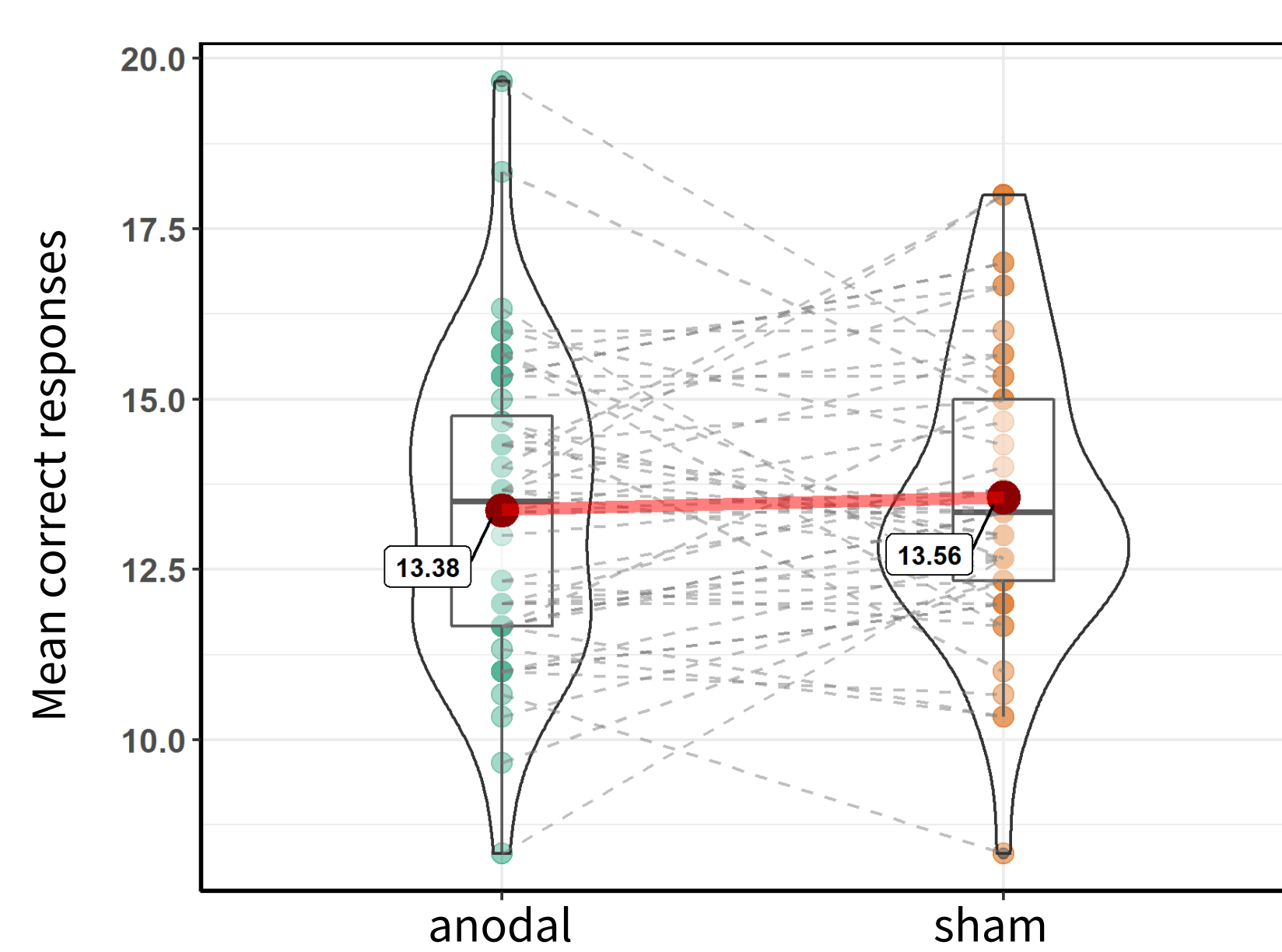
Verbal fluency

Phonemic task

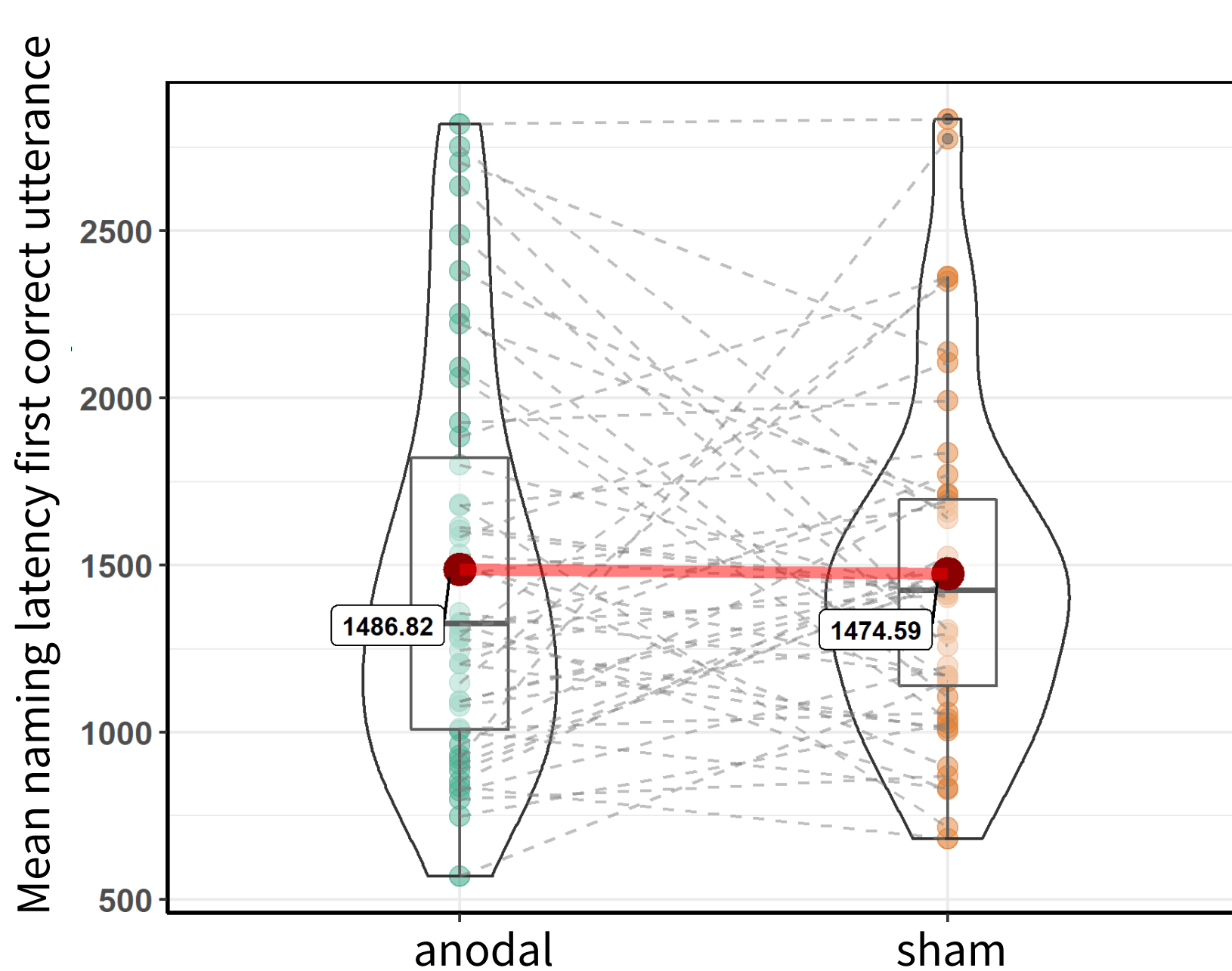


No significant difference between anodal and sham, $t(47) = 0.23, p = .818, CI_{95\%} [-0.25, 0.32]$.

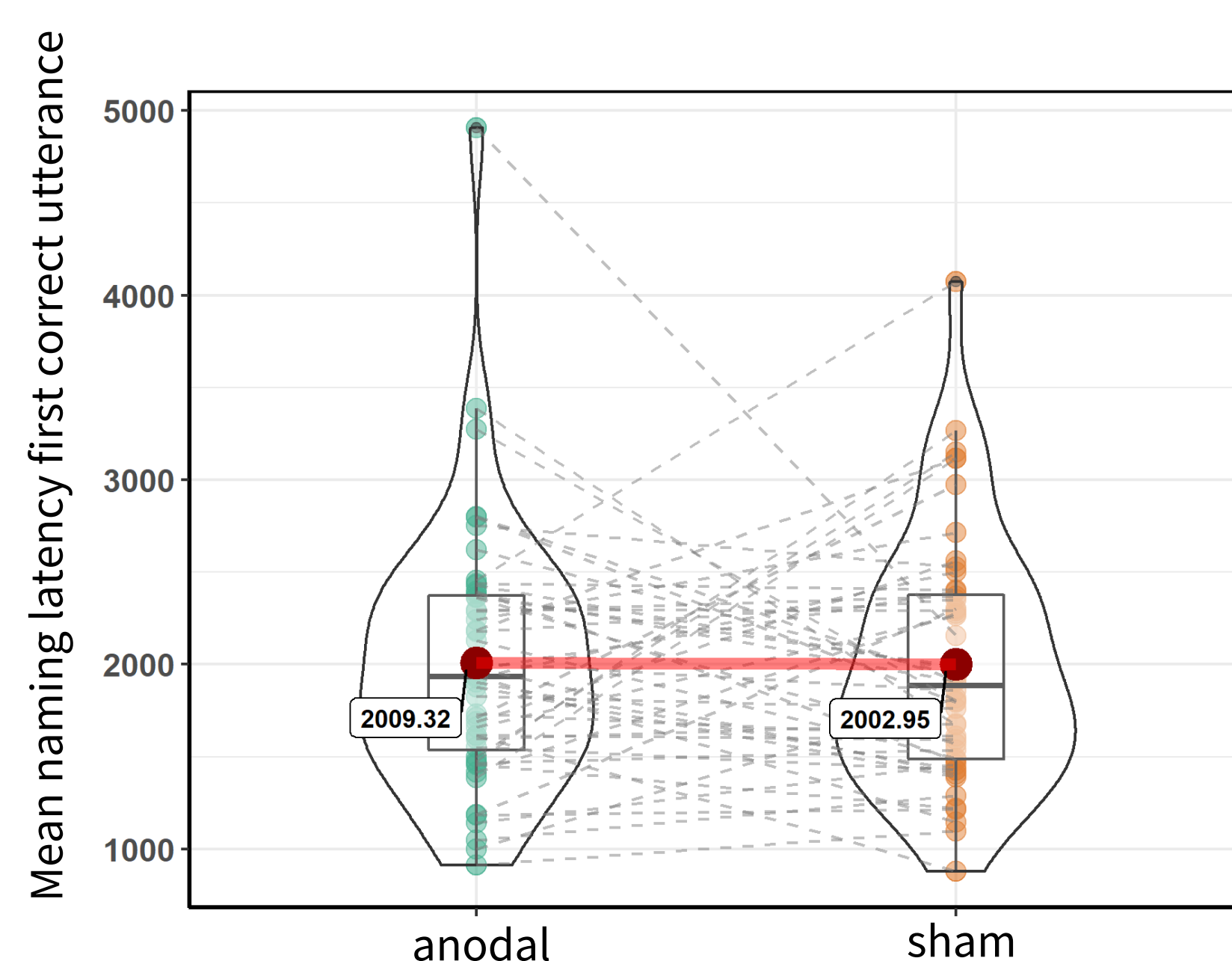
Semantic task



No significant difference between anodal and sham ($t(47) = -0.60, p = .550, CI_{95\%} [-0.37, 0.20]$).

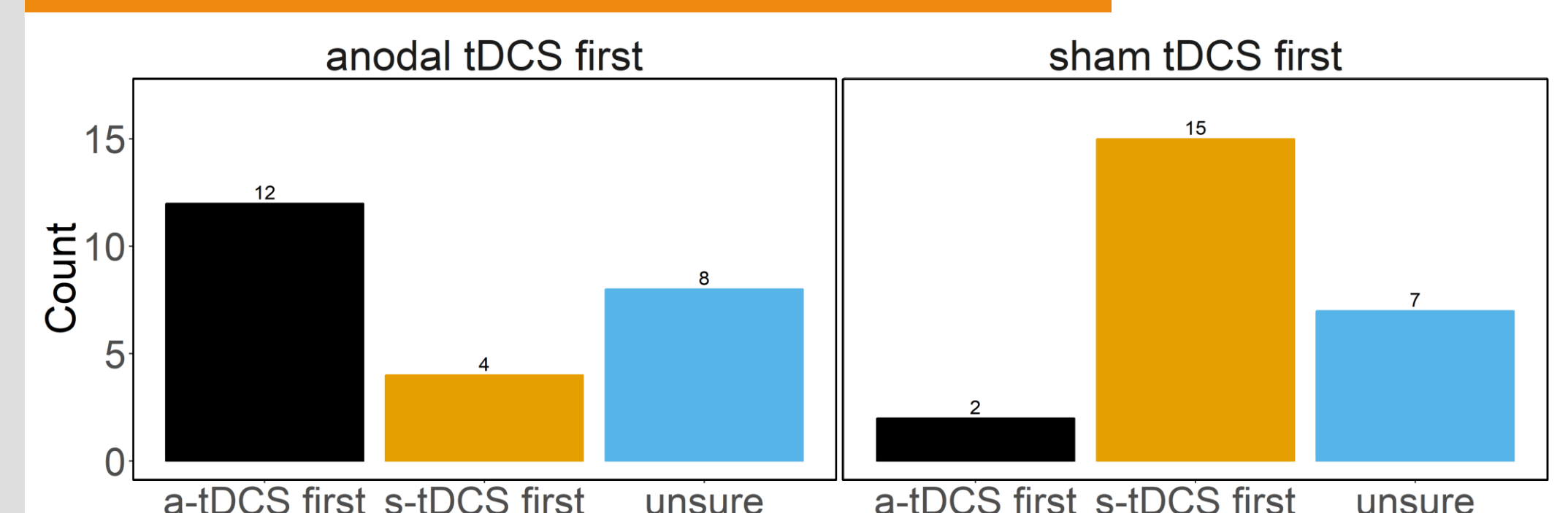


No significant difference between anodal and sham, $t(47) = 0.13, p = .899, CI_{95\%} [-0.27, 0.30]$.

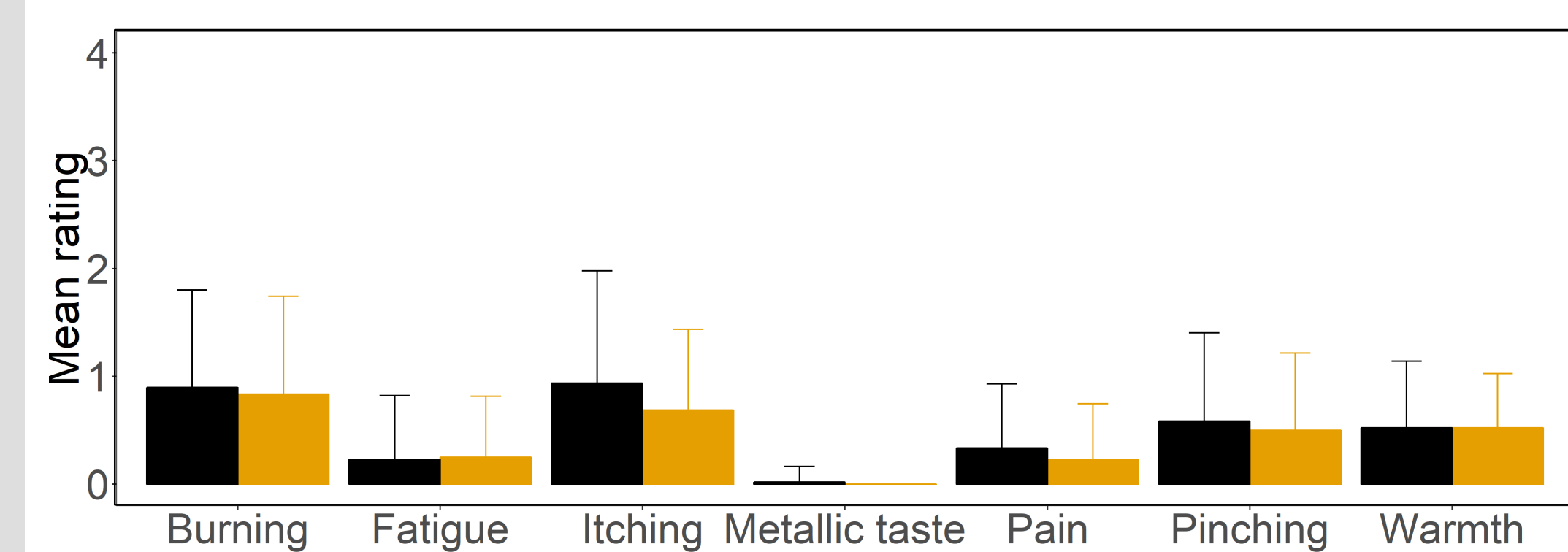


No significant difference between anodal and sham, $t(47) = 0.05, p = .961, CI_{95\%} [-0.28, 0.29]$.

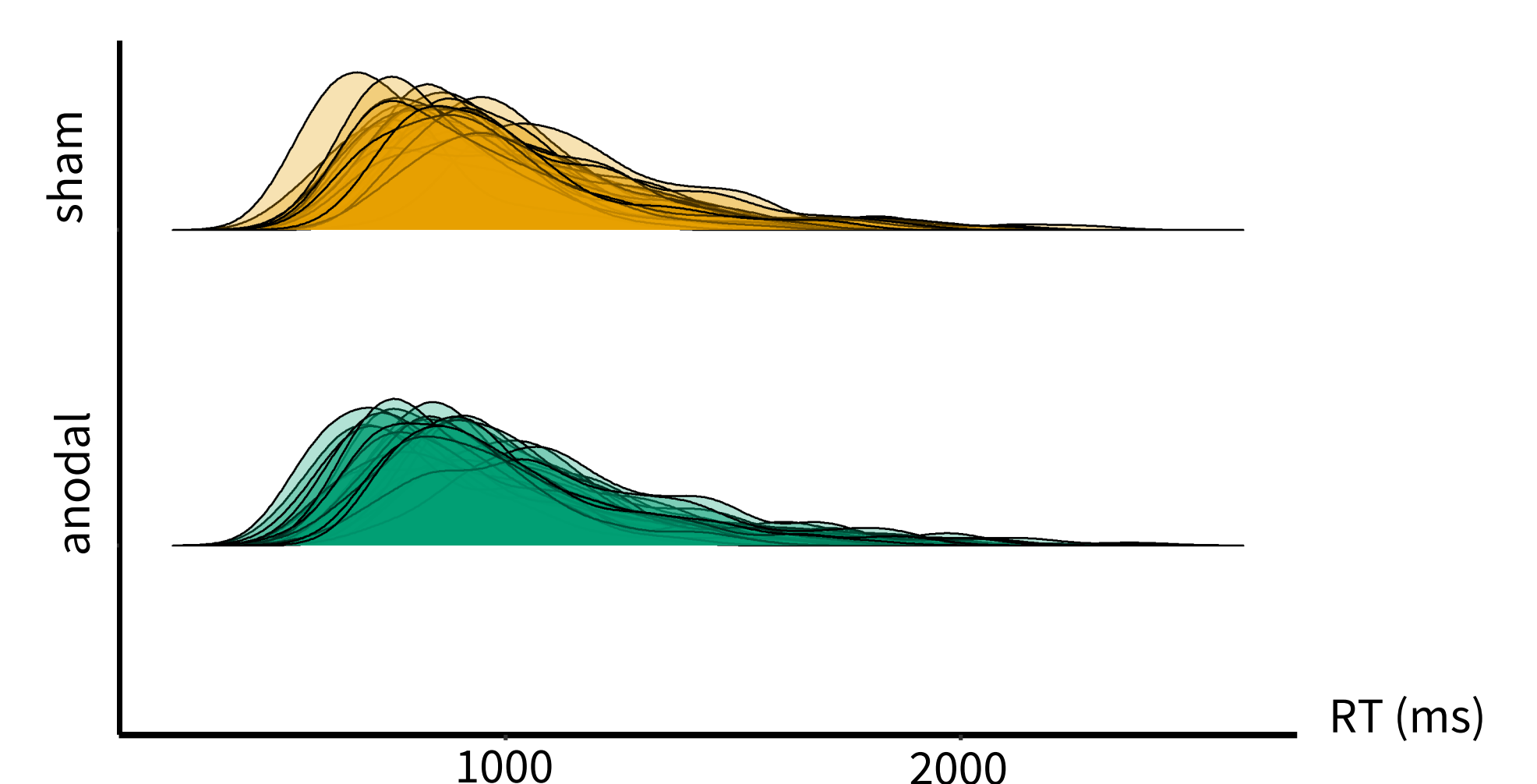
Participant blinding



After second session, participants guessed correct stimulation order above chance ($\chi^2(2) = 13.58, p = .001$)



Picture naming (preliminary - $N = 24$)



Naming latencies slower during anodal tDCS compared to sham, $\beta = 10.15, SE = 4.40, t = 2.31, p = .021$.

Discussion

- Our results add to the growing body of evidence disproving the efficacy of tDCS to modulate cognitive performance in healthy volunteers.
- Our study was preregistered on the Open Science Framework (<https://osf.io/4qmxs/>) and tested a comparably large number of participants in a within-participant design. These procedural improvements may reveal that previously observed positive effects could be false positives. Furthermore, preregistration increases rigour in data analysis and reporting.
- No evidence that verbal fluency performance is modulated by the application of anodal tDCS over the left prefrontal cortex
 - Number of correct words unaffected
 - Initiation naming latency unaffected
 - No systematic influence of task difficulty
 - No evidence that engaging participants in a related task during stimulation enhances the effect
- Participants perceived comparable sensations for both tDCS conditions but correctly guessed their sequence above chance; this further feeds the discussion of the efficacy of participant-blinding in tDCS studies.
- Preliminary analysis on half of the sample indicates slower naming latencies during anodal compared to sham tDCS; remaining annotation pending...