

Temporal and Spectral Signatures of Graded Nociceptive Stimulation Across S1, PFC, and ACC in a Large-Animal Intracranial Model

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INTRODUCTION

Gamma-band power has been linked to reported pain intensity and to nociception^{1,2}. However, cortical power mixes a repeatable phase-locked response with non-phase-locked activity, and the two can behave differently³. S1, PFC and ACC take part in overlapping sensory, affective and control processes⁴, but which component of power follows stimulation intensity in each is unclear.

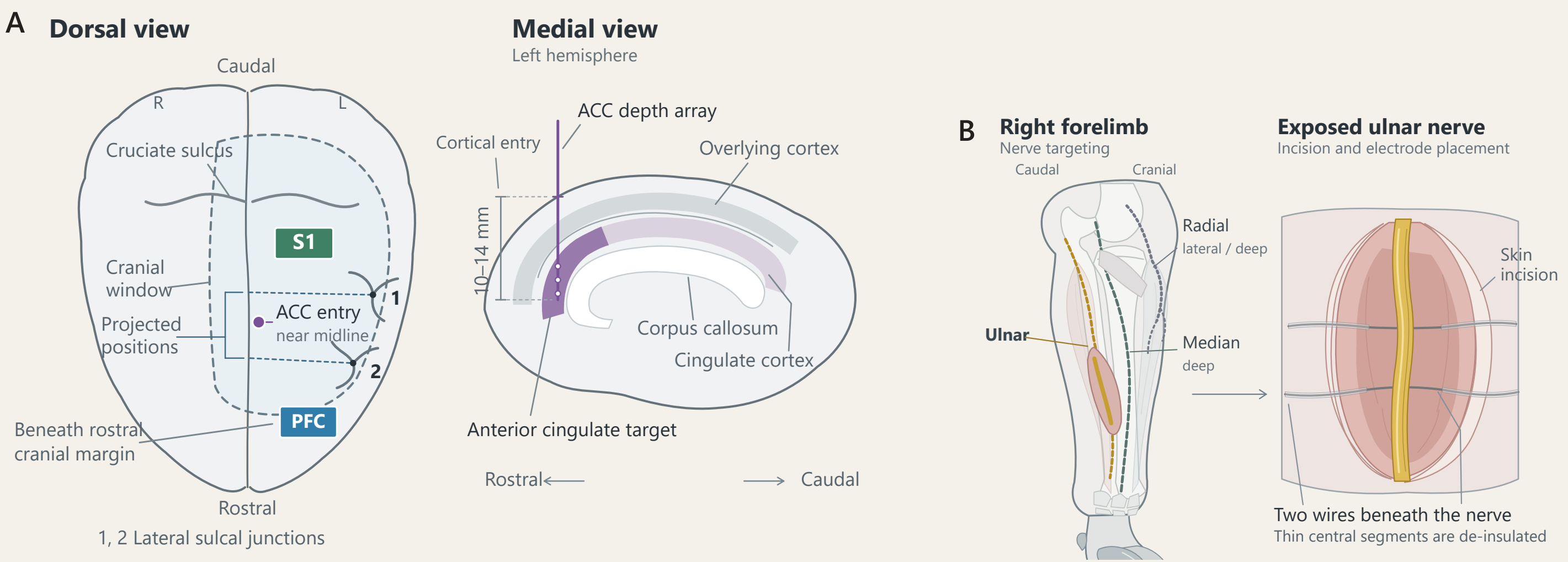
RESEARCH QUESTIONS

1. Does cortical power increase with stimulation intensity in S1, PFC and ACC?
2. Is the increase phase-locked or non-phase-locked?
3. When and at which frequencies does it occur?

METHODS

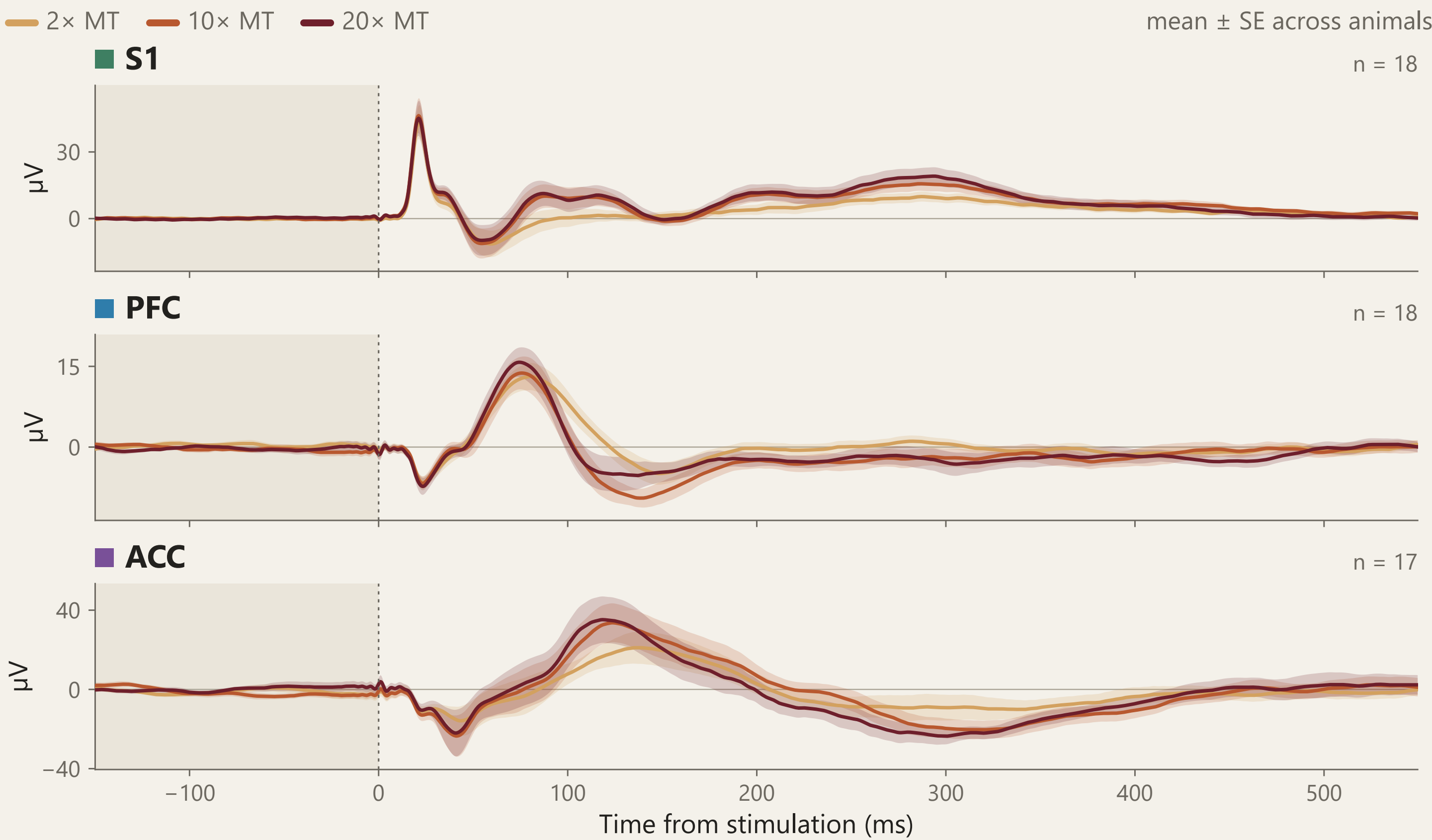
Simultaneous S1, PFC and ACC recordings during electrical nerve stimulation

Eighteen female Danish Landrace pigs were anaesthetised with propofol and fentanyl. Micro-ECoG arrays were placed on S1 and PFC, and a depth array was introduced towards the ACC (A; ACC: 17 animals after QC). The right ulnar nerve was stimulated with biphasic pulses at 2×, 10× and 20× motor threshold (MT)⁵ in ascending order to avoid carry-over from stronger stimulation, with stimulus onsets jittered by ±250 ms (B; 154 sequences). Power at 35–120 Hz over 0–400 ms was compared between intensities with mixed models (animal random effects, Holm correction), and 20–200 Hz time–frequency maps with TFCE⁶.



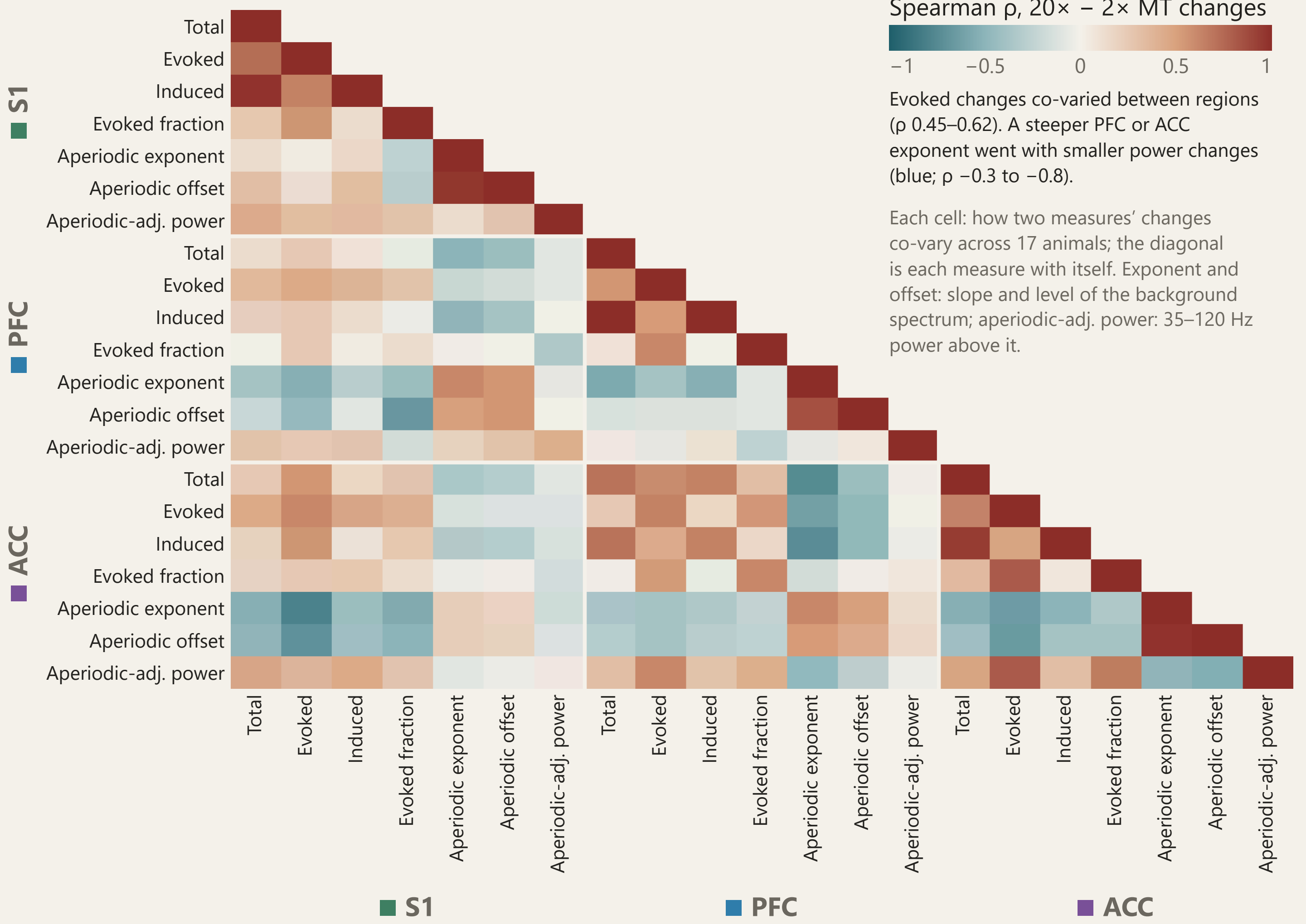
RESULTS · WAVEFORMS

All three regions showed a stimulation-locked response



RESULTS · CORRELATIONS

Total and induced power changed together within each region



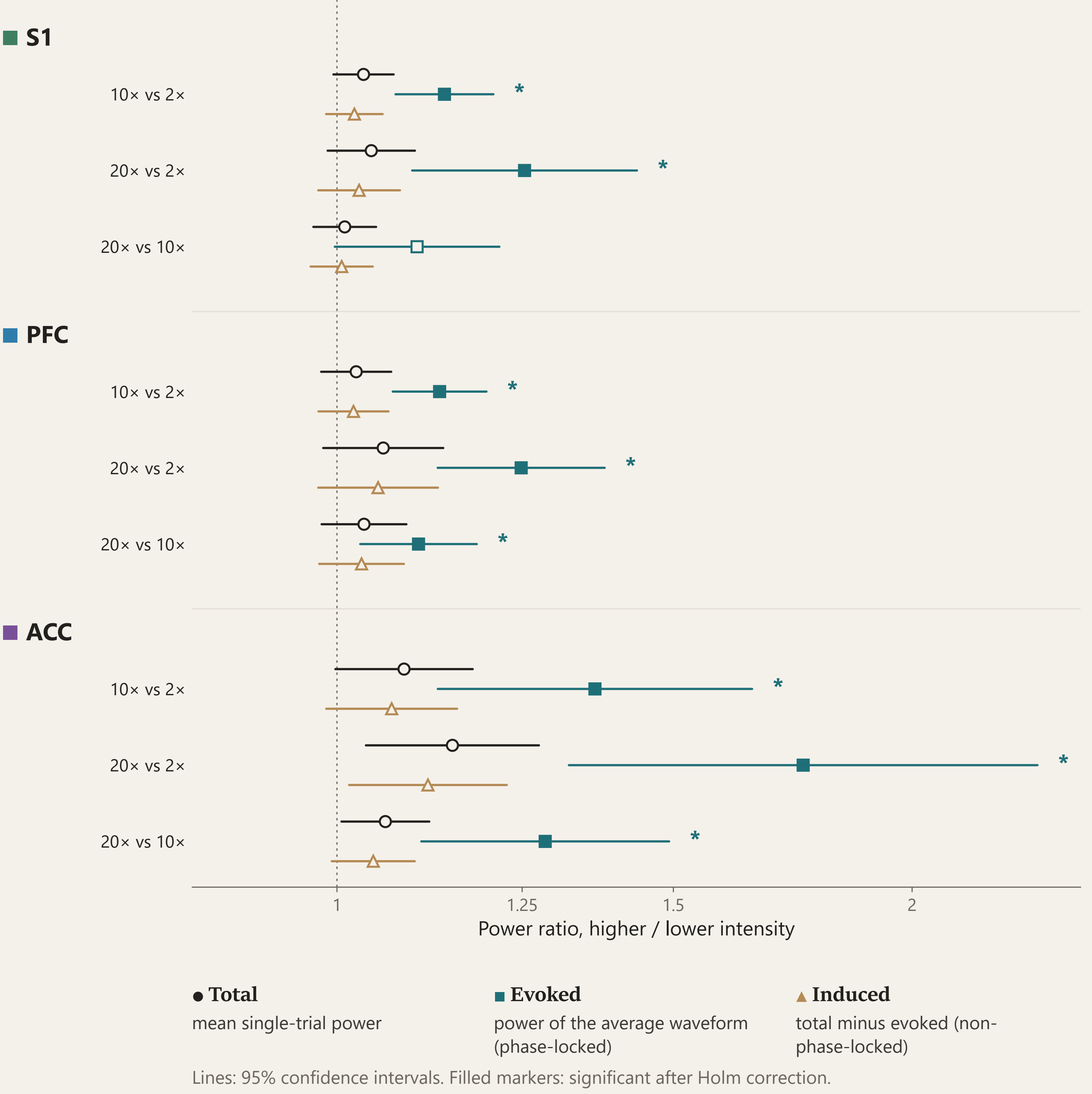
DISCLAIMERS

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RESULTS · POWER COMPONENTS

Evoked (phase-locked) power was higher at 10× and 20× than at 2× MT in all three regions

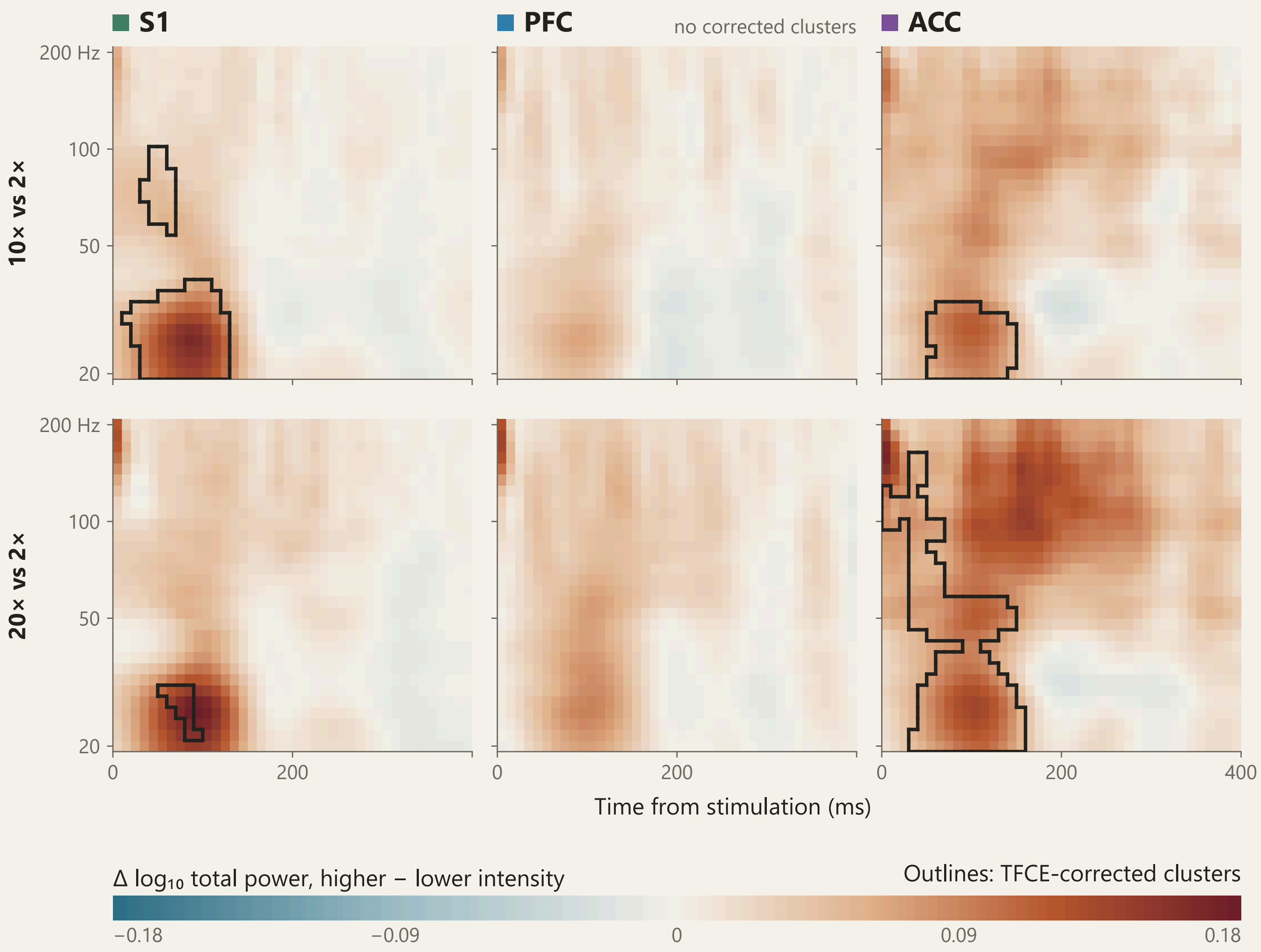
At 20× MT, evoked power was 1.25 times the 2× MT value in S1 and PFC and 1.75 times in ACC; all six 10× and 20× vs 2× contrasts had Holm $P \leq 0.005$. Evoked power was also higher at 20× than at 10× MT in PFC and ACC. No total- or induced-power contrast survived correction.



RESULTS · TIME-FREQUENCY MAPS

Corrected total-power differences appeared within ~160 ms in S1 and ACC

Four of the nine total-power maps survived correction: 10× and 20× vs 2× MT in S1 and ACC. Differences were largest at 20–30 Hz, 85–105 ms after stimulation; at 20× vs 2× MT the ACC cluster extended to ~160 Hz. No map survived in PFC or for 20× vs 10× MT.



Conclusions

Graded ulnar-nerve stimulation increased phase-locked (evoked) power in S1, PFC and ACC, and corrected time–frequency maps localised early total-power differences in S1 and ACC. Separating the response components revealed intensity effects that a broad power average did not, so cortical measures of nociception should state their response component and recording site. Recorded under general anaesthesia, these responses capture cortical nociceptive processing⁷.

Limitations: electrical nerve stimulation bypasses peripheral receptors, so responses to natural noxious stimuli may differ; all animals were female, so sex differences could not be assessed.

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