

Cortical excitability shapes somatosensory perception with spatiotemporally structured dynamics

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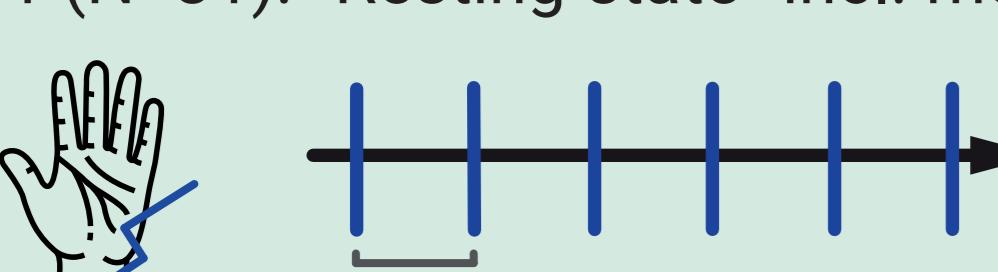
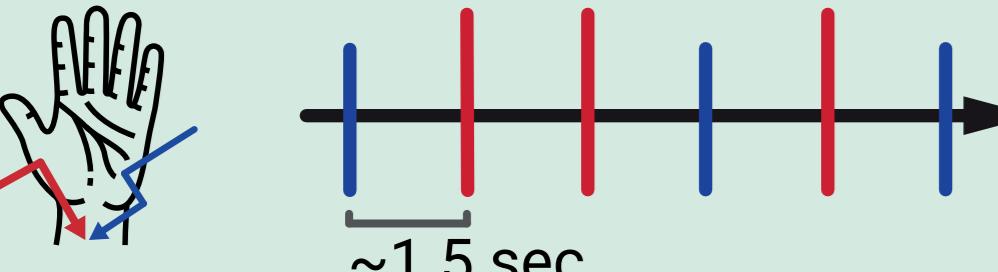
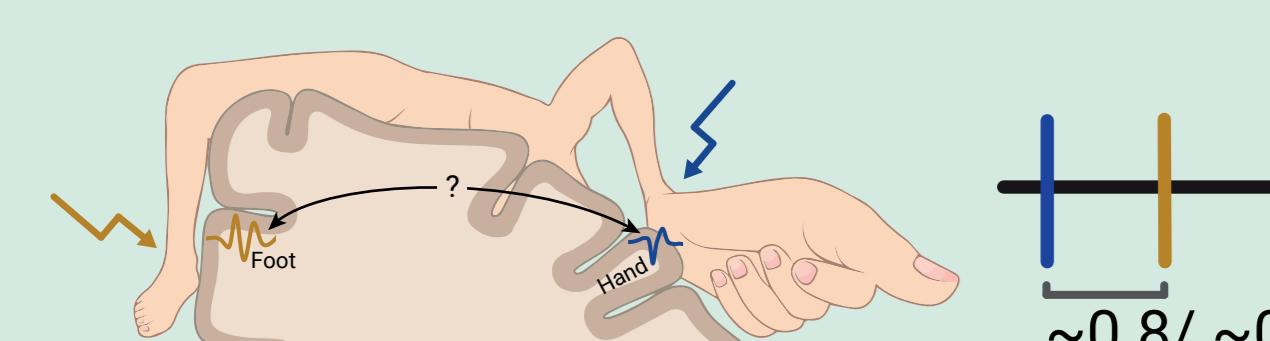


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Introduction

- Moment-to-moment variability of stimulus perception is associated with instantaneous changes of cortical excitability.^[1-4]
- Yet it is unclear how these dynamics are organized spatiotemporally and on which level the modulation of perception takes place.
- How to measure "cortical excitability"?
 - Pre-stimulus oscillatory activity in the alpha band (8-13 Hz) of the EEG^[4-7]
 - N20 component of the somatosensory evoked potential (SEP)
 - reflects initial excitatory post-synaptic potentials (EPSP) in Brodmann area 3b^[8-10]
 - direct measure of cortical excitability in response to median nerve stimulation
- Research questions:
 - What is the temporal structure of spontaneous fluctuations of cortical excitability?
 - How do excitability changes relate to the intensity perception of sensory stimuli?
 - Do these fluctuations reflect local or global dynamics?

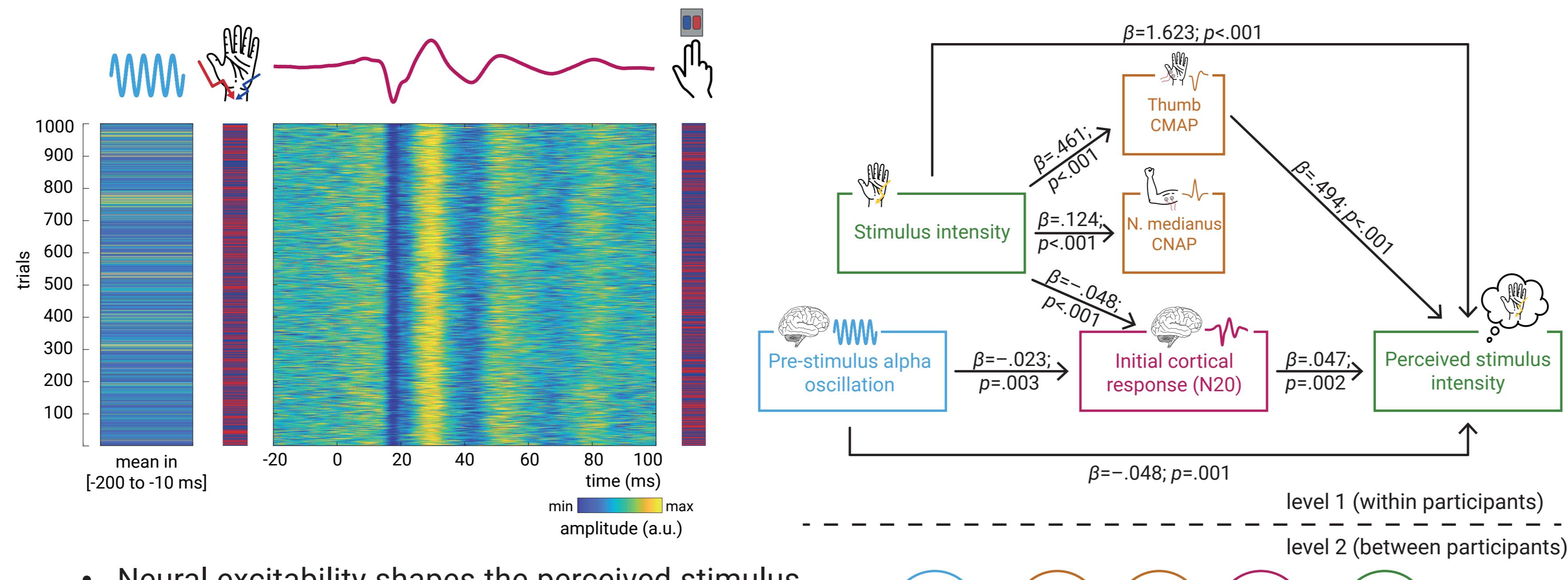
Methods

- Series of three somatosensory stimulation paradigms in humans
- Study 1 (N=31): "Resting-state" incl. median nerve stimulation
 
 - 1000 stimuli of same intensity: 1.2 x motor threshold
 - no task
- Study 2 (N=32): Somatosensory discrimination task
 
 - 1000 stimuli of two intensities
 - Task: indicate stimulus intensity by button press
 - Δintensity: slightly above least noticeable difference
- Study 3 (N=38): Alternating stimulation of median and tibial nerves
 
 - ISI varied between participants: N_{long} = 15; N_{short} = 23
- EEG measures
 - Single-trial SEPs extracted using Canonical Correlation Analysis (CCA)^[11]
 - Alpha band (8-13 Hz) activity from the same sources extracted in pre-stimulus windows from -200 to -10 ms
- Additional peripheral measures:
 - CMAP (compound nerve action potential)
 - CMAP (compound muscle action potential)

Results

Study 2

Relation between instantaneous excitability and perceived stimulus intensity



Stephani, Hodapp, Jamshidi Idaji, Villringer & Nikulin, 2021, eLife
<https://doi.org/10.7554/eLife.67838>

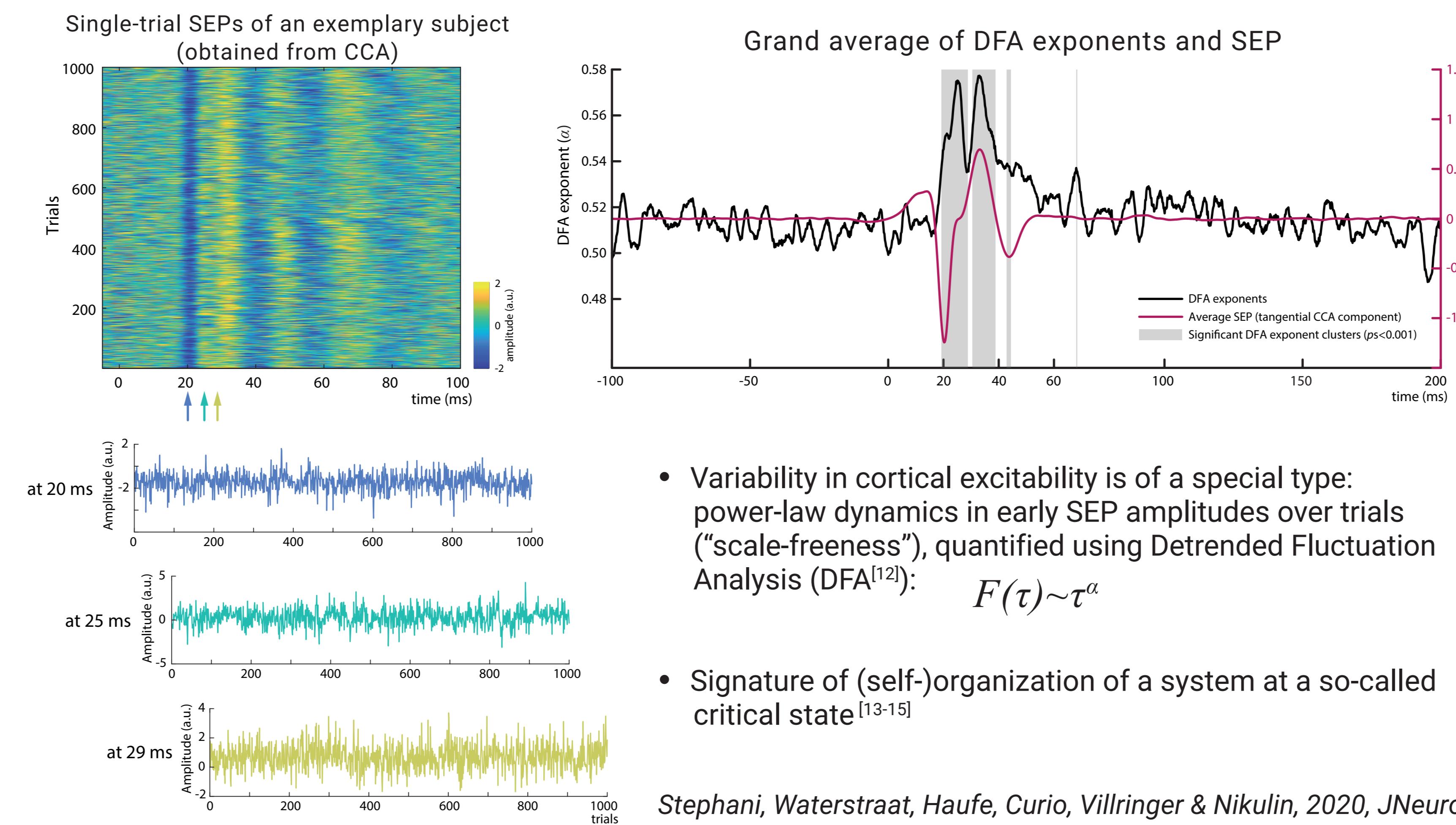
Behavioral relevance (study 2)



Temporal structure (study 1)

Study 1

Signatures of criticality in excitability fluctuations

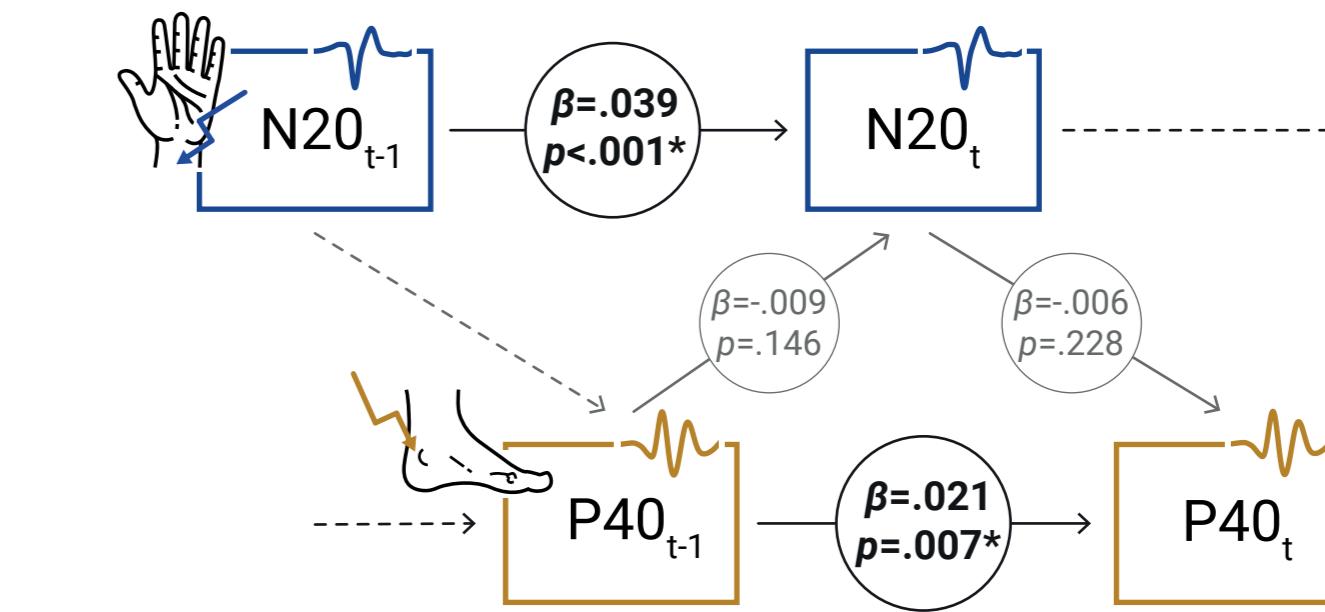


Stephani, Waterstraat, Haufe, Curio, Villringer & Nikulin, 2020, JNeurosci
<https://doi.org/10.1523/JNEUROSCI.0241-20.2020>

Study 3

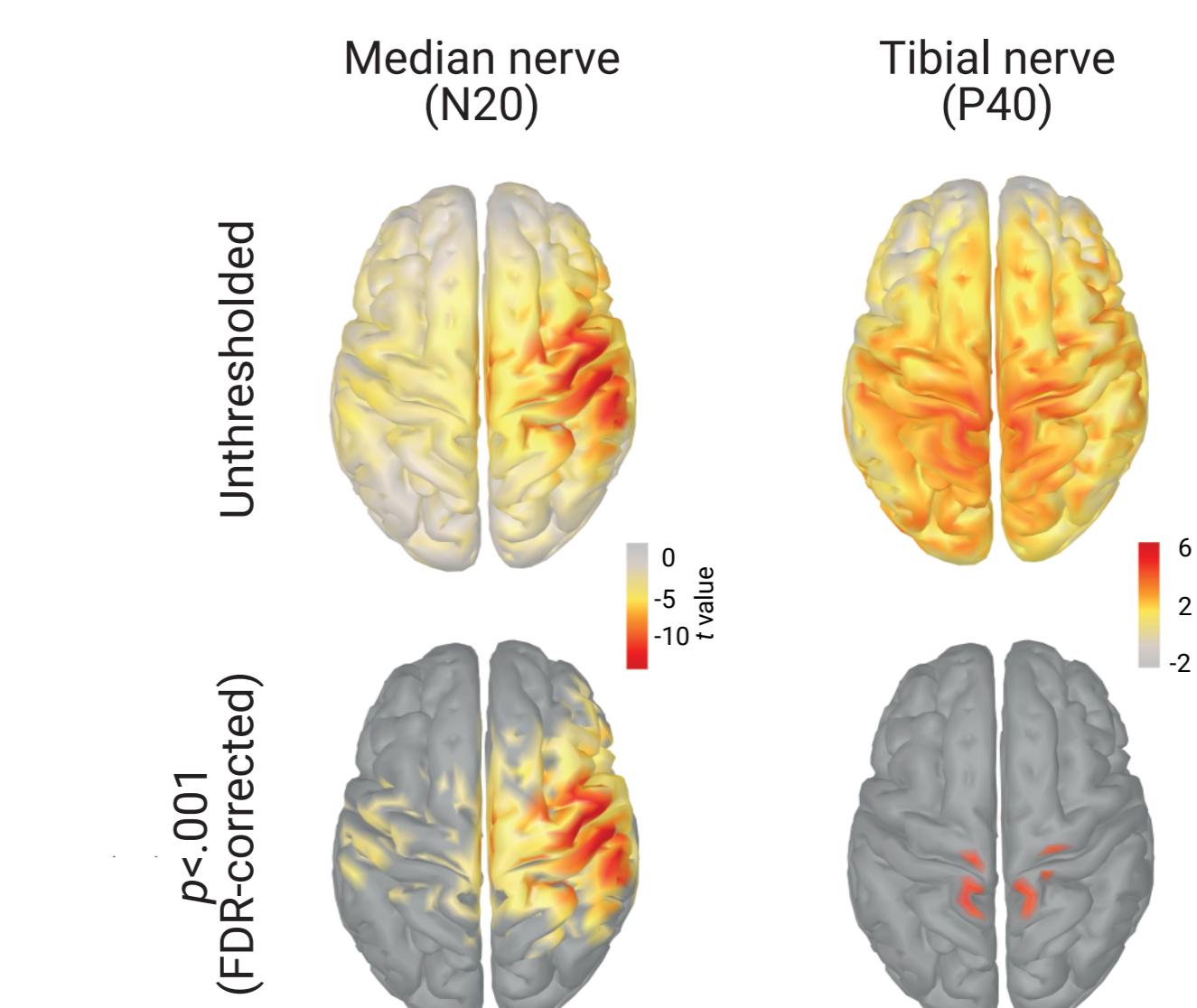
Local or global dynamics in cortical excitability?

- No dependencies between different stimulation sites regarding their SEP amplitudes but auto-correlation within somatosensory regions



Cross-lagged multi-level SEM. Path coefficients reflect random slopes on group level, derived from a bayesian model estimation with corresponding posterior predictive p-values (performed in Mplus).

- Spatially confined effects of pre-stimulus alpha oscillatory state on initial SEP amplitudes



Linear mixed effects models in source space:
N20 ~ prestimulus alpha_{vertex i} + (1|subject)
P40 ~ prestimulus alpha_{vertex i} + (1|subject)

Analysis pooled across long and short ISIs (N=38).

Stephani, Nierula, Villringer, Eippert & Nikulin, in prep.

Discussion

- Cortical excitability fluctuates over time with a temporal structure that is characteristic for dynamics near a critical state
 - Possible benefits: dynamic range, information processing and capacity are maximized^[16,17]
- Changes of cortical excitability influence how strong stimuli are perceived from earliest cortical processing onwards
 - In line with previous findings on alpha oscillations^[18,19] and extending to supra-threshold stimuli
 - Opposing signatures of stimulus intensity and excitability in initial cortical responses (may reflect the EEG's sensitivity to post-synaptic currents not potentials)
- Spatially confined neural state-response dynamics: somatotopy of excitability fluctuations

Overall, fluctuations of cortical excitability do not seem to occur randomly ("noise") but reflect embedded system dynamics ("signal") with behaviorally relevant consequences for perception.

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