

# Brain Imaging predicts TMS-induced signal propagation

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<https://davi1990.github.io/>

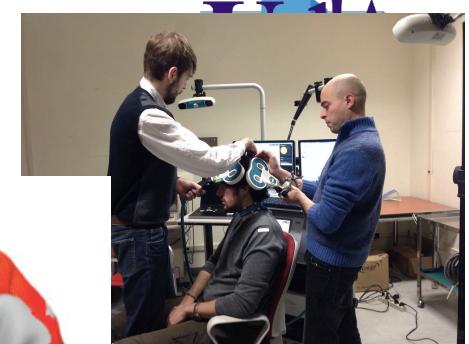
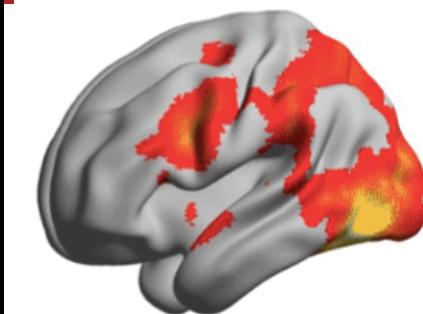
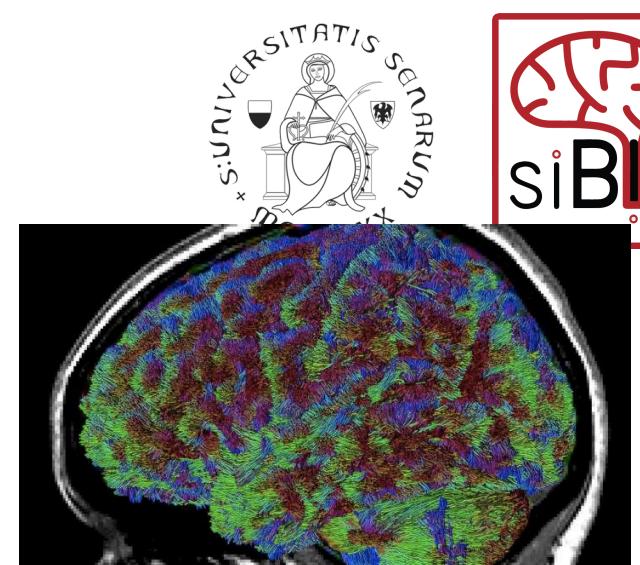
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Propagation of  
Network-Targeted Transcranial Magnetic Stimulation

work-Targeted  
Artico-cortical  
Associative Brain  
Stimulation

## What is Transcranial Magnetic Stimulation



It is well-known that the impact of a TMS pulse on the neural system depends on several variables:

- 1) The effects are not determined only by the properties of that stimulus but also on the initial brain state of the perturbed region [Silvanto and Pascual-Leone, 2008]

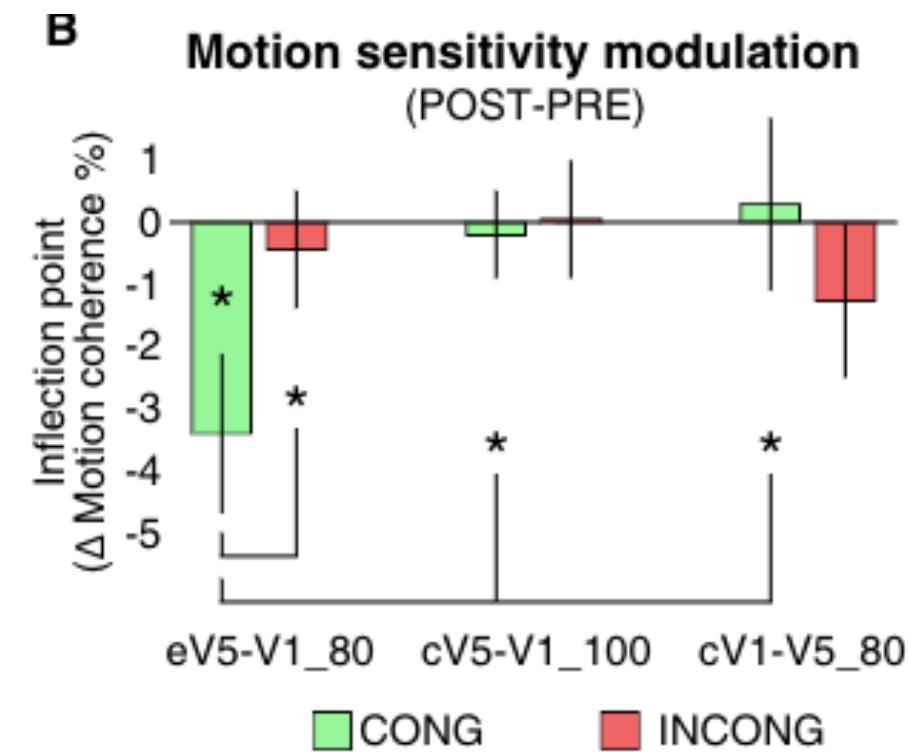
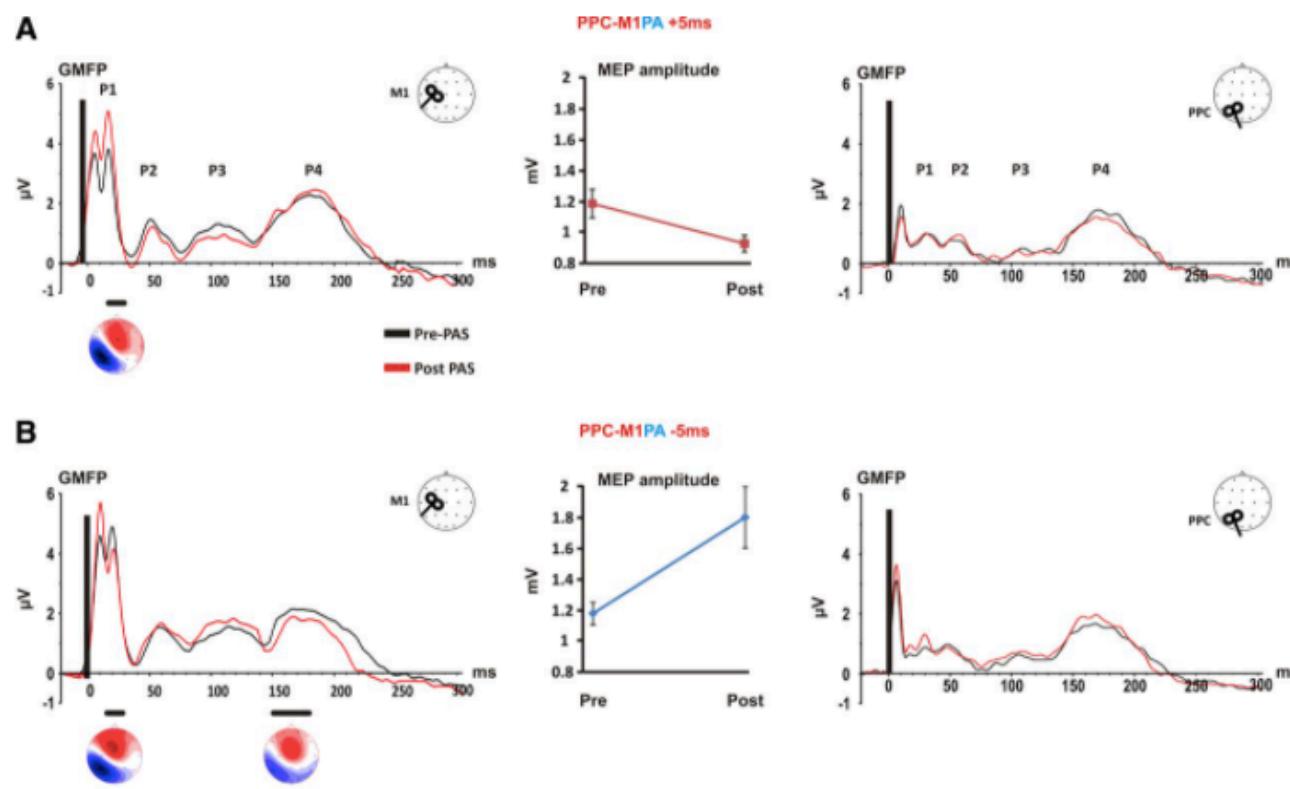
A compelling way to quantify the effect of a magnetic perturbation is to combine TMS and EEG [Thut and Pascual-Leone, 2010; Voineskos et al., 2010], thus looking at millisecond-level brain activity propagation throughout the brain and potentially study the impact of specific brain states at the time of stimulation [Bergmann et al., 2019; Schaworonkow et al., 2019].

- 2) While the understanding of TMS propagation pathways and principles is still incomplete, the vast majority of studies suggest that TMS pulses propagate along white matter tracts [O'Shea et al., 2008], with the conductivity of white matter bundles potentially shaping the propagation of action potentials [McCann et al., 2019].
- 3) Moreover, the amount of TMS signal propagation is not determined only by the underlying anatomical connection but highly depends on the initial functional state of the perturbed brain region and its connections [Silvanto and Pascual-Leone, 2008].

The complexity and organization of the structural and functional connectome can be captured *in vivo* via diffusion weighted imaging (DWI) and functional magnetic resonance imaging (fMRI) data collected during resting-state (rs-fMRI) respectively [Hagmann et al., 2008]

# Cortico-cortical paired associative stimulation

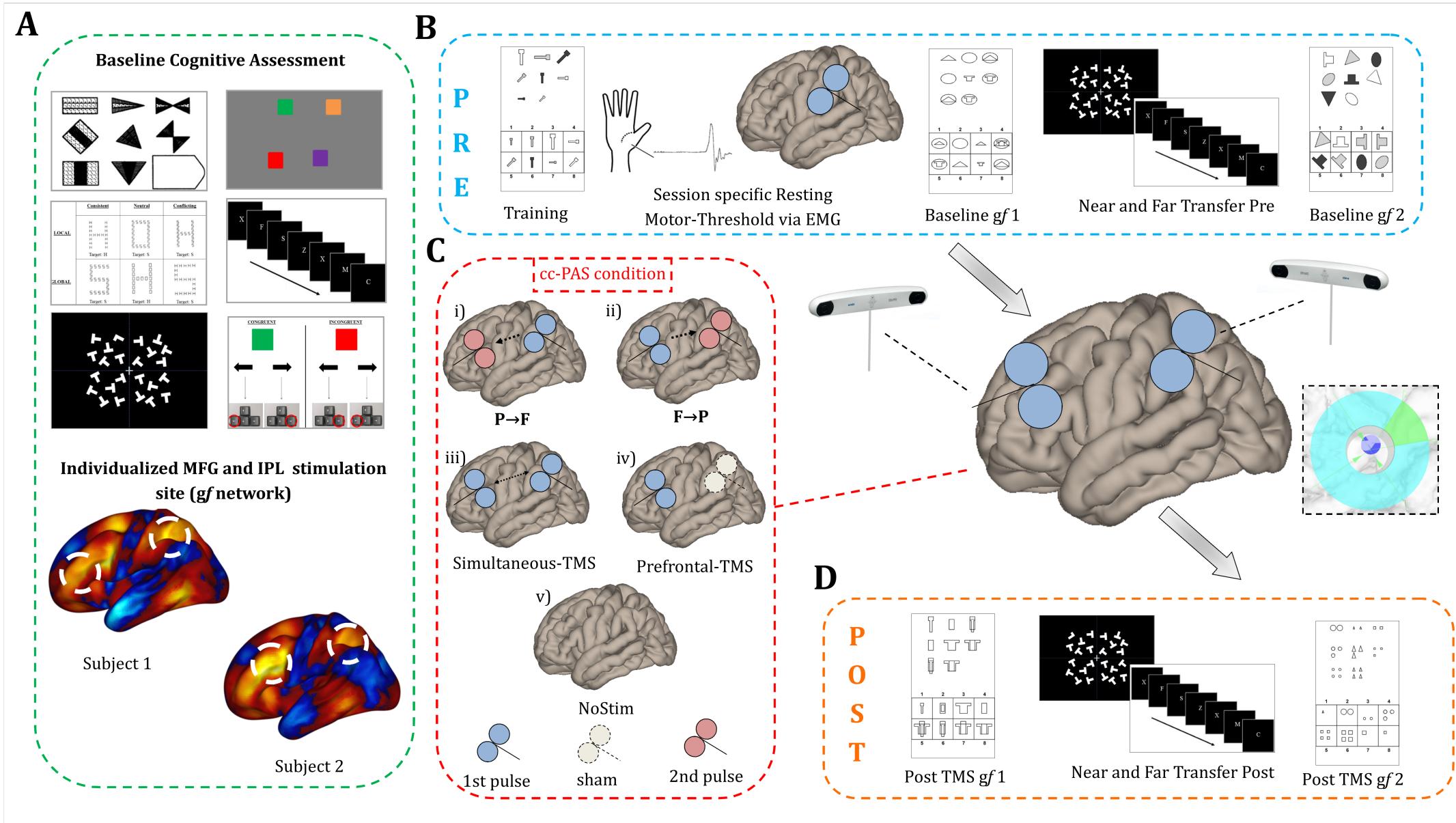
Cortico-cortical paired associative stimulation (ccPAS) is a recently established offline dual-coil transcranial magnetic stimulation (TMS) protocol based on the Hebbian principle of associative plasticity and designed to transiently enhance synaptic efficiency in neural pathways linking two interconnected (targeted) brain regions.



Veniero et al., 2013 – The Journal of Neuroscience

Chiappini et al., 2018 – Current Biology

# Network-Targeted Cortico-cortical Associative Brain Stimulation



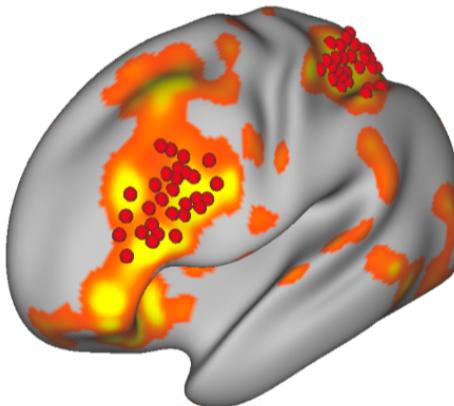
# Network-Targeted Cortico-cortical Associative Brain Stimulation

A

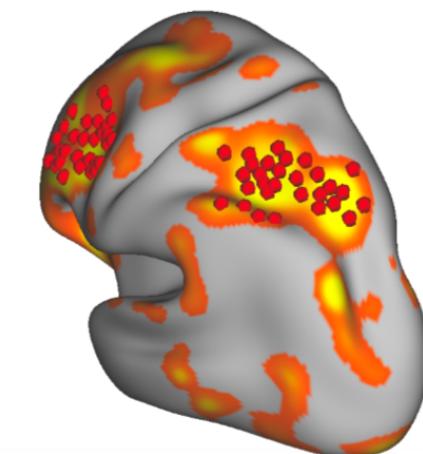


gfMRI network

B

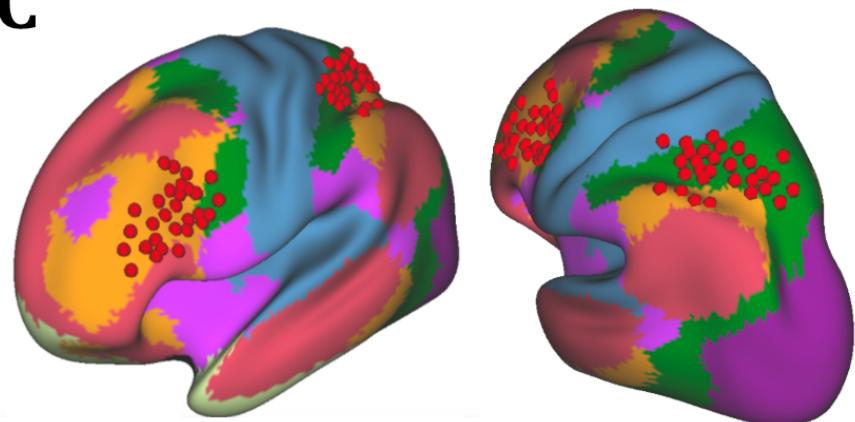


● Individual Stimulation Targets

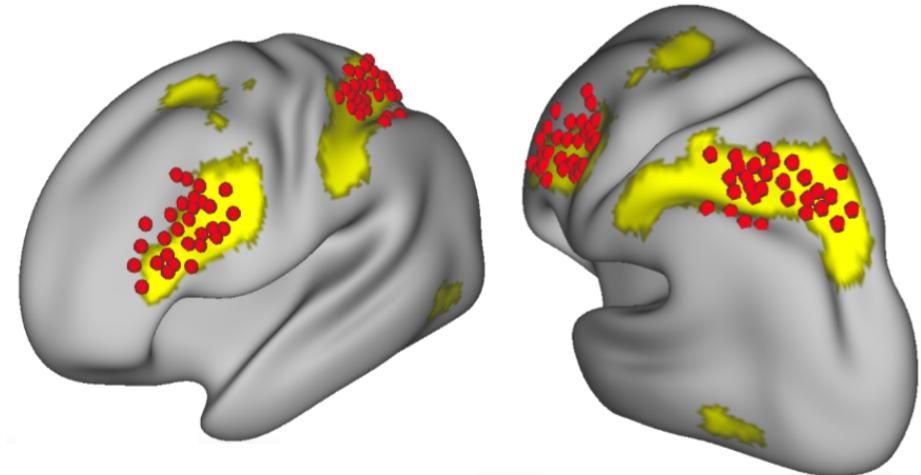


gfMRI network

C



Resting State Network (Yeo et al., 2011)

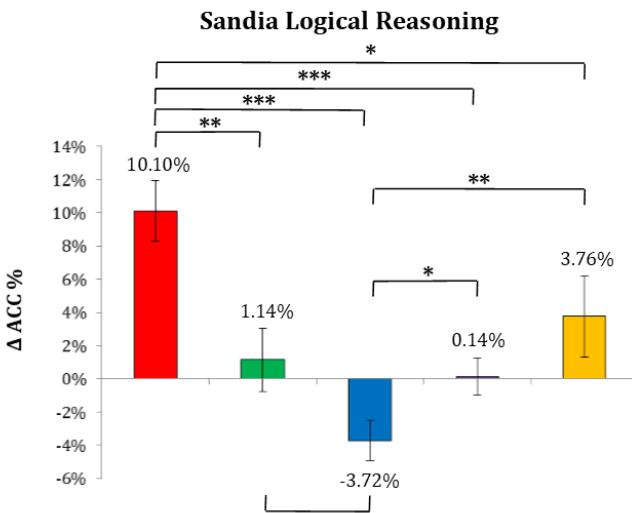
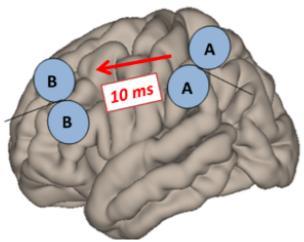


Dorsal Attention Network (Shirer et al., 2012)

# Network-Targeted Cortico-cortical Associative Brain Stimulation

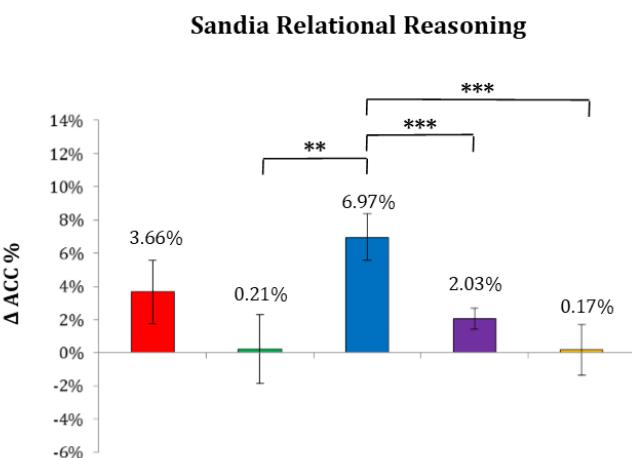
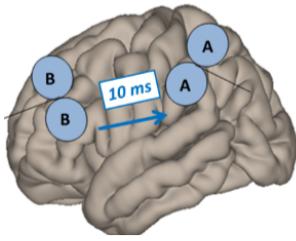
A

Parieto-Frontal (A→B)



B

Fronto-Parietal (B→A)



P-F

Simultaneous-TMS

F-P

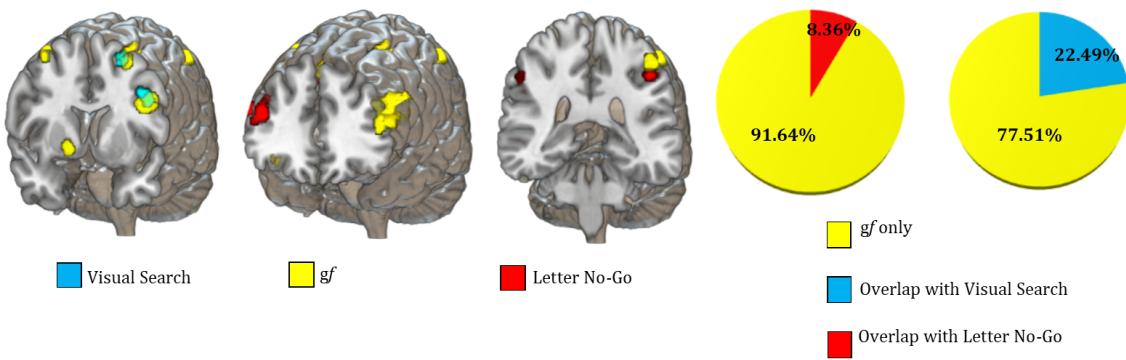
Prefrontal-TMS

NoStim

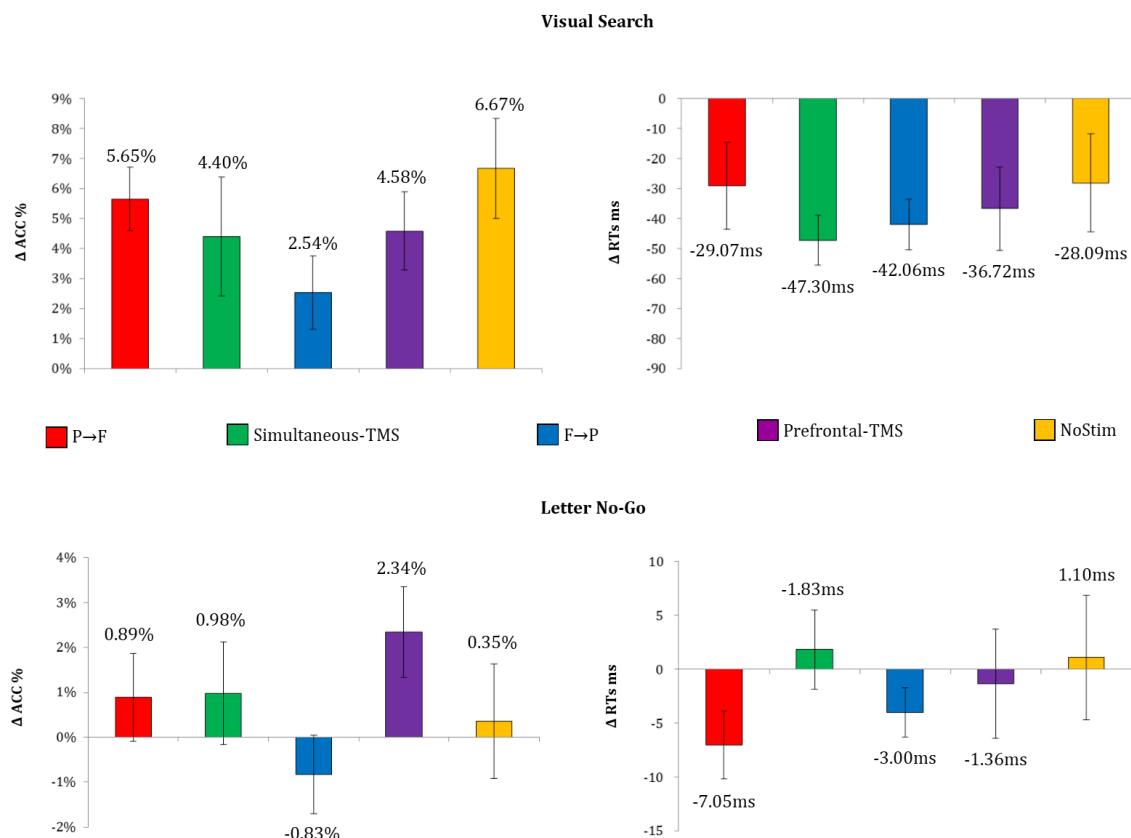
Effects on gf performance. Significant changes in logical reasoning performance (i.e., pre- and post-delta ACC) were observed after P → F cc-PAS (A), whereas a significant enhancement in relational reasoning was found after F → P cc-PAS (B). All ACC values were normalized to baseline. Error bars represent  $\pm 1$  standard error of the mean (SEM). Materials. Note: \* =  $P < 0.05$ ; \*\* =  $P < 0.01$ ; \*\*\* =  $P < 0.001$ .

# Network-Targeted Cortico-cortical Associative Brain Stimulation

**A**

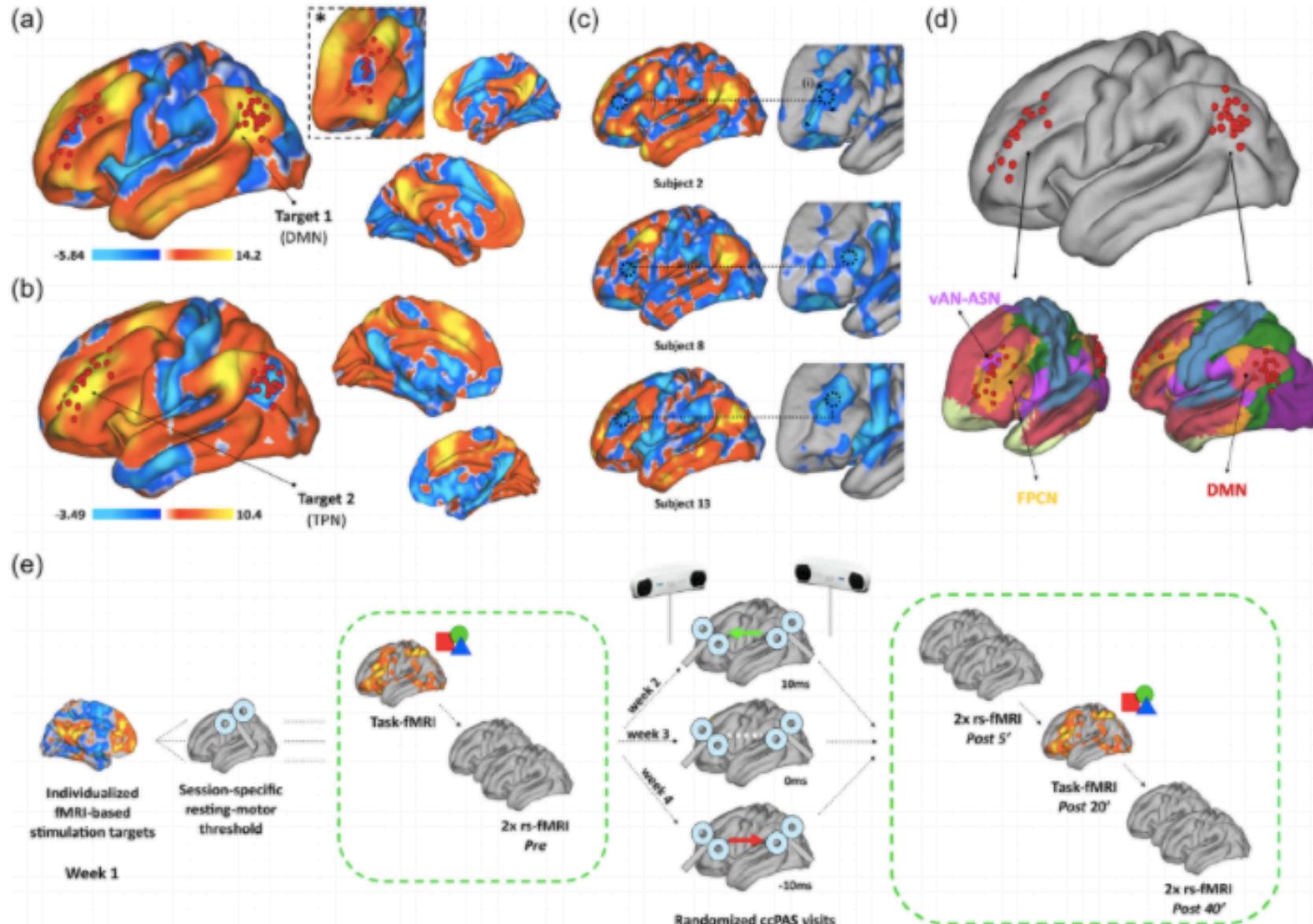


**B**



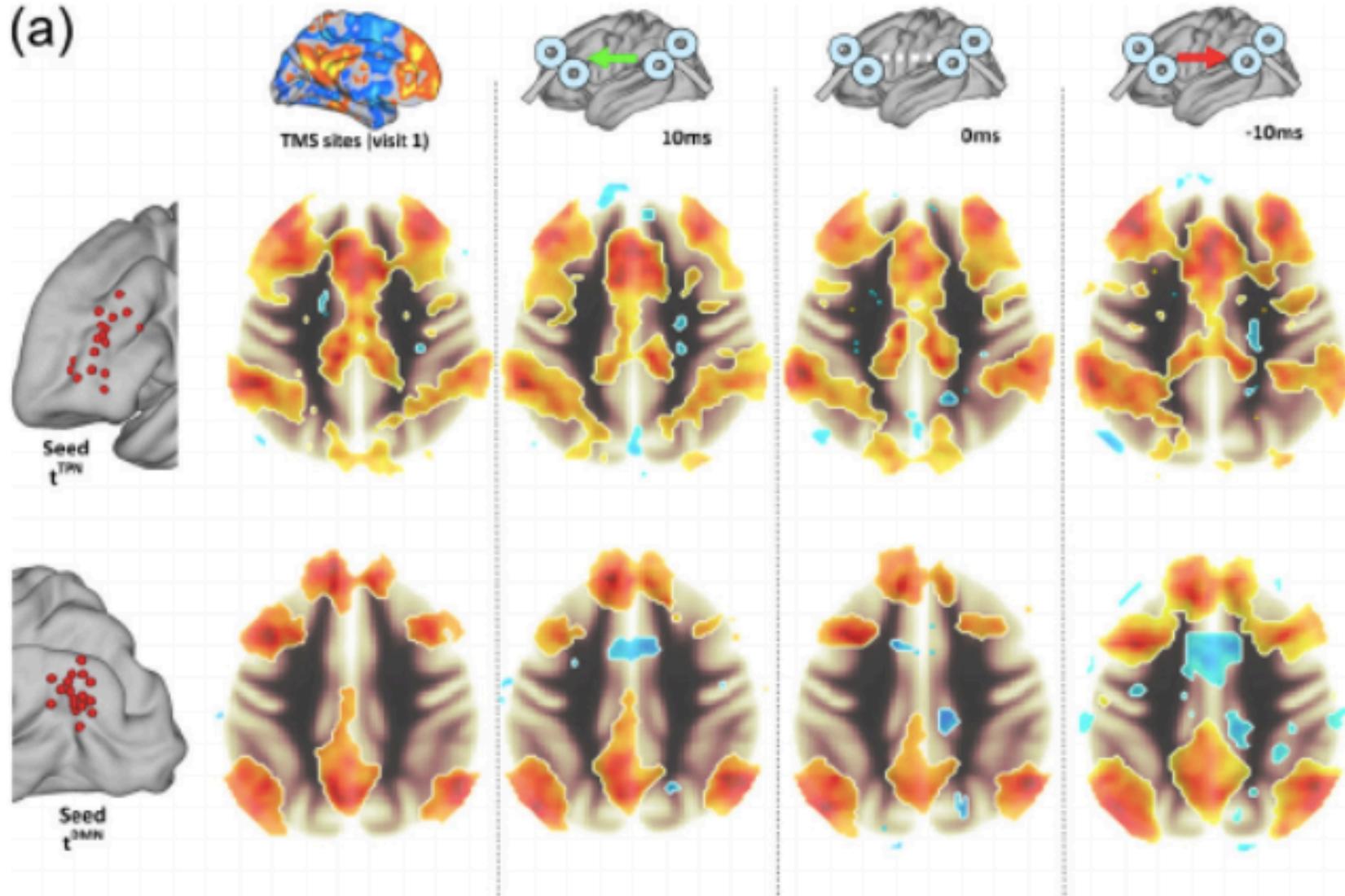
Near and far transfer. (A) Average patterns of fMRI activation during the transfer tasks (VA, LNG) and gf tasks, as well as their quantitative overlap (B). No significant changes in ACC and RTs were observed for the transfer tasks after any TMS condition. Error bars represent  $\pm 1$  SEM.

# Network-Targeted Cortico-cortical Associative Brain Stimulation



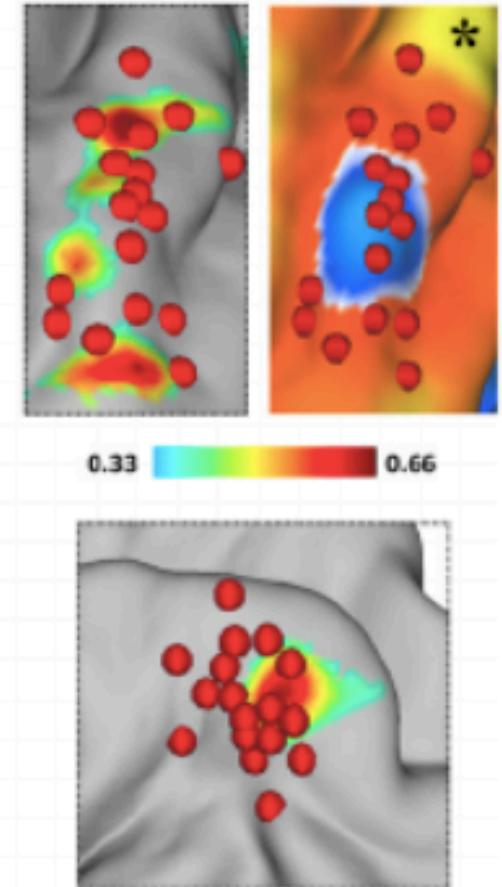
# Network-Targeted Cortico-cortical Associative Brain Stimulation

(a)

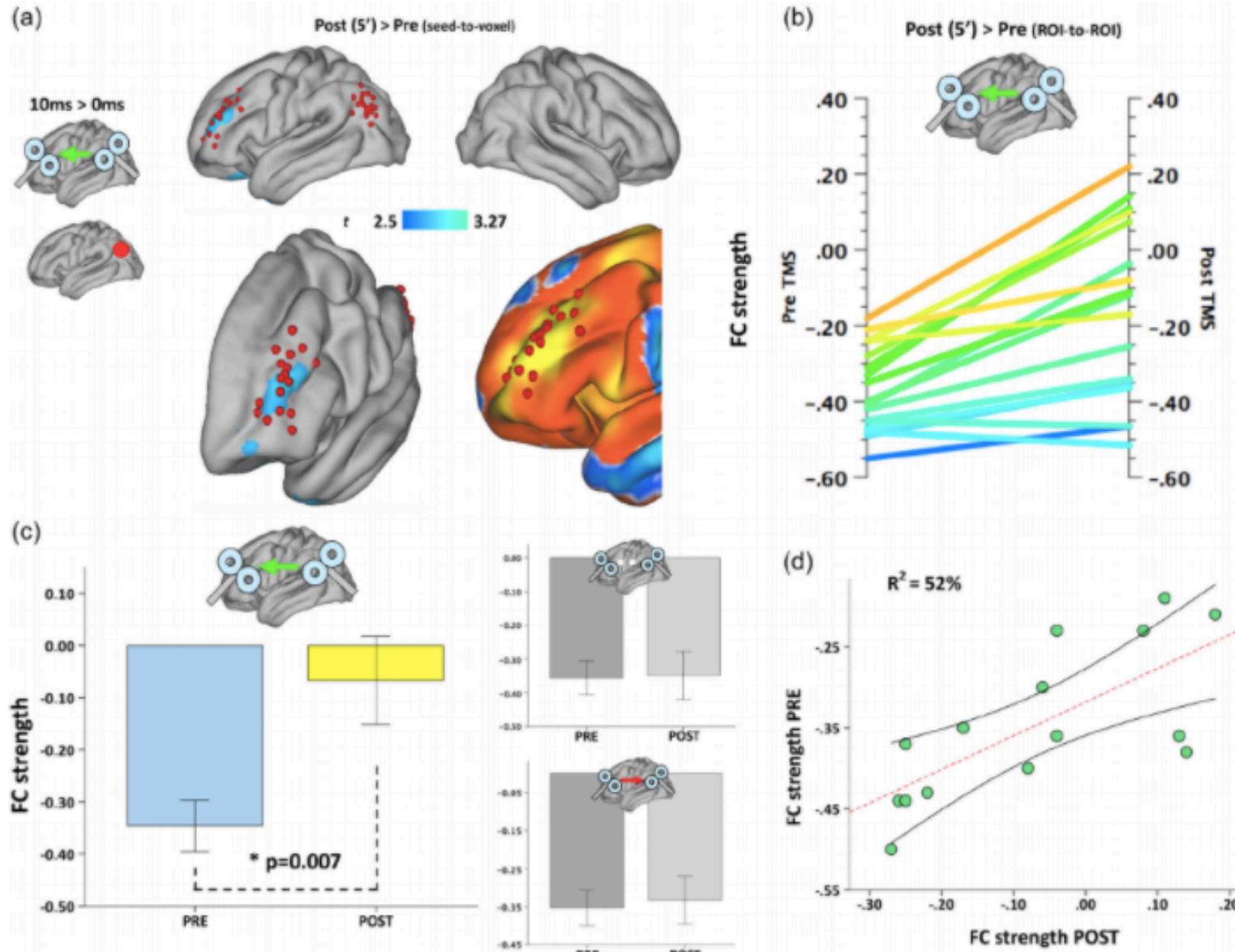


(b)

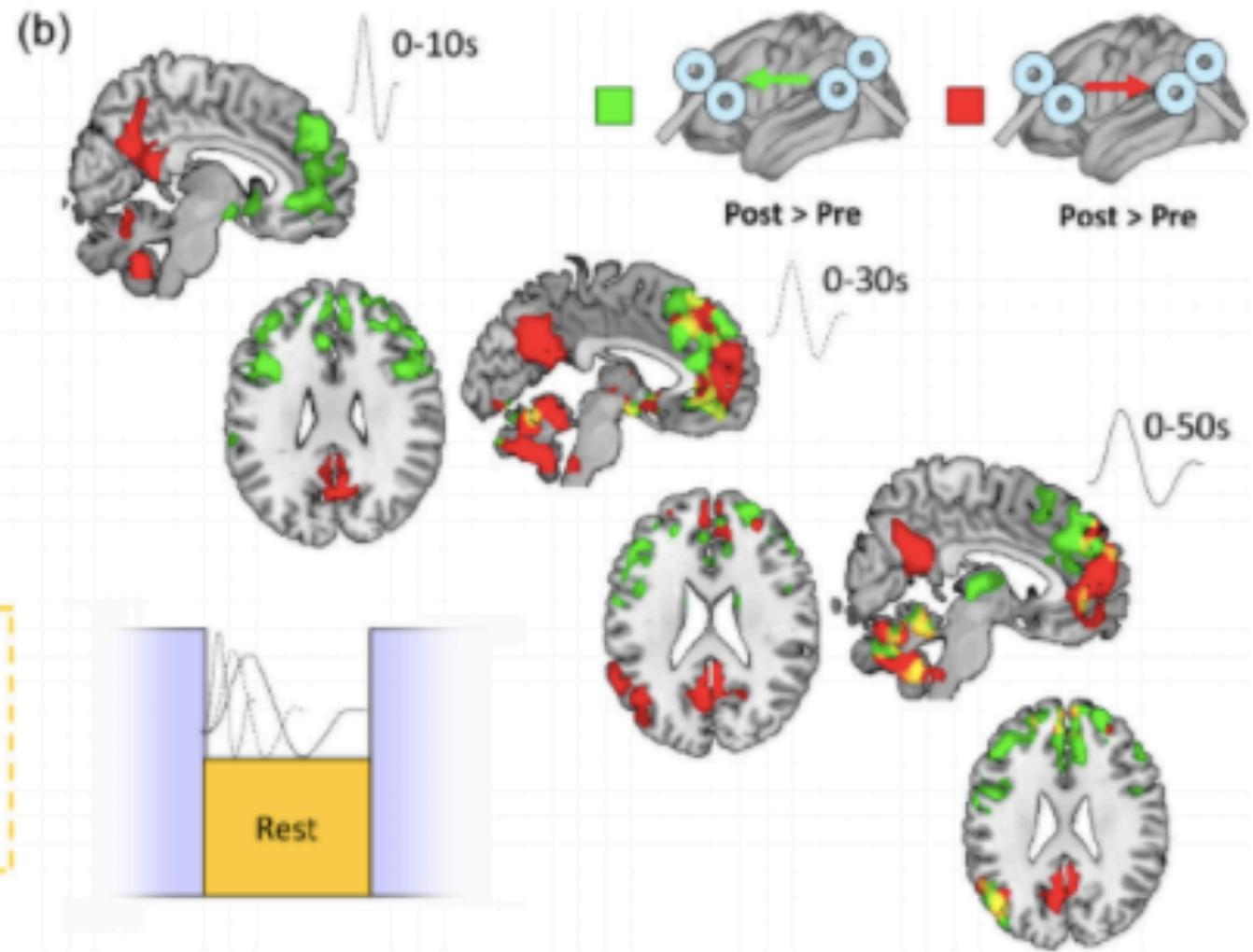
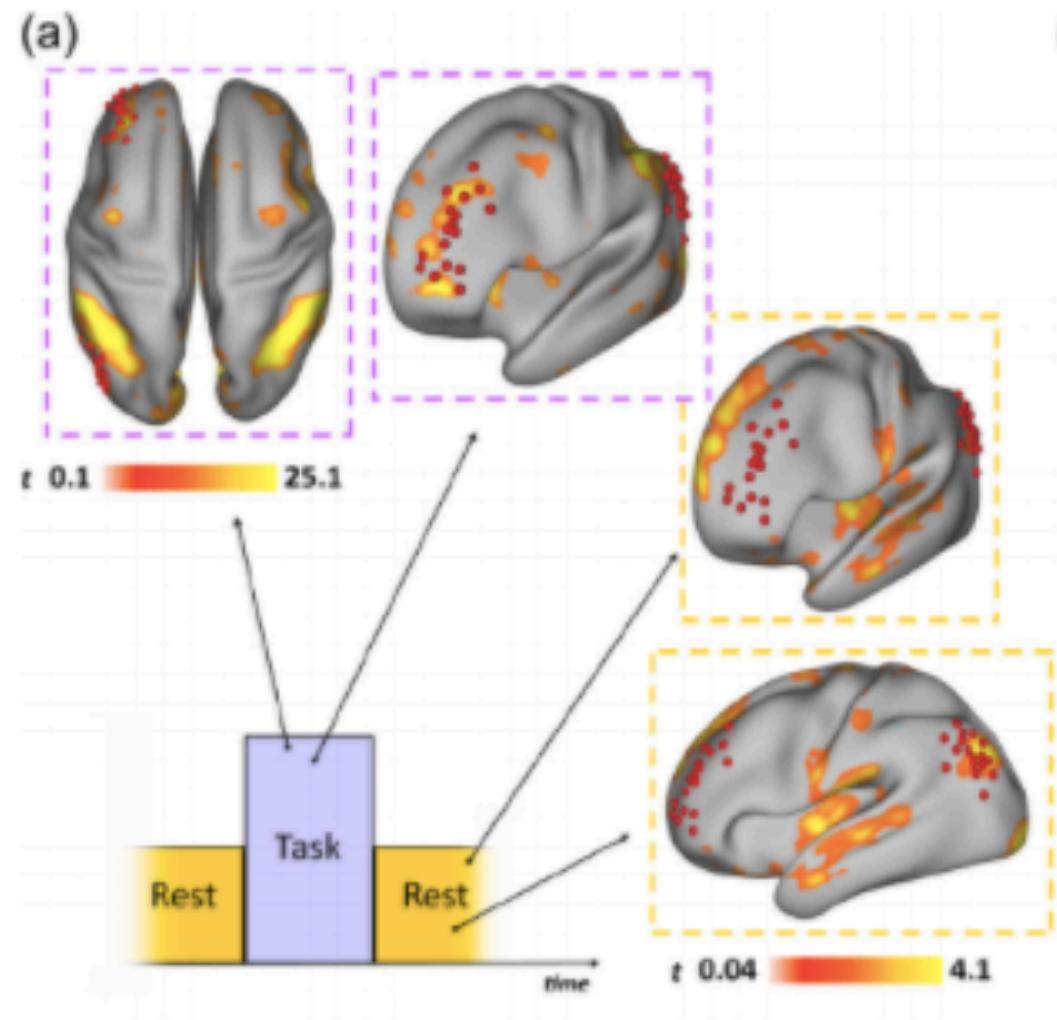
Between-sessions variability  
of TMS sites



# Network-Targeted Cortico-cortical Associative Brain Stimulation

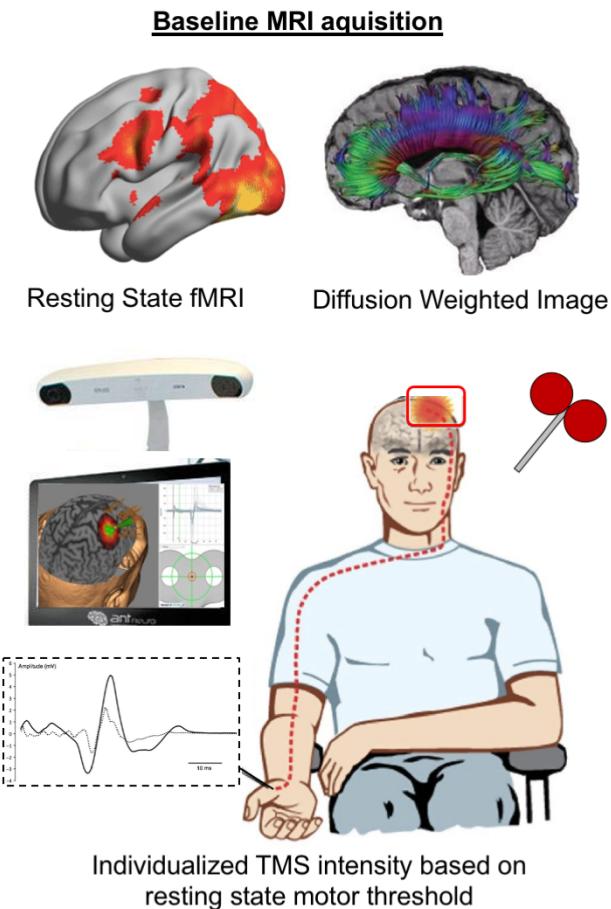


# Network-Targeted Cortico-cortical Associative Brain Stimulation

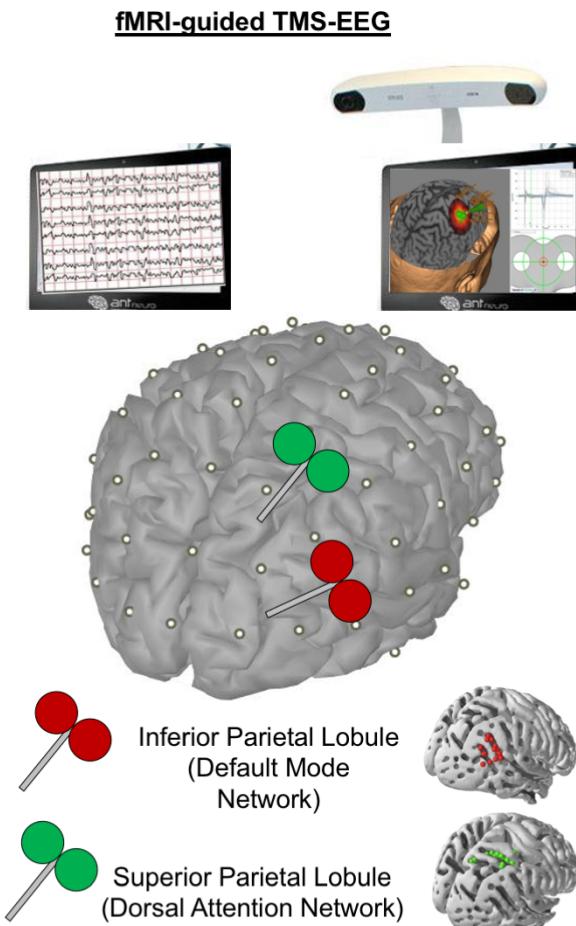


# Network Structural Connectivity Predicts Propagation of Image-Guided TMS

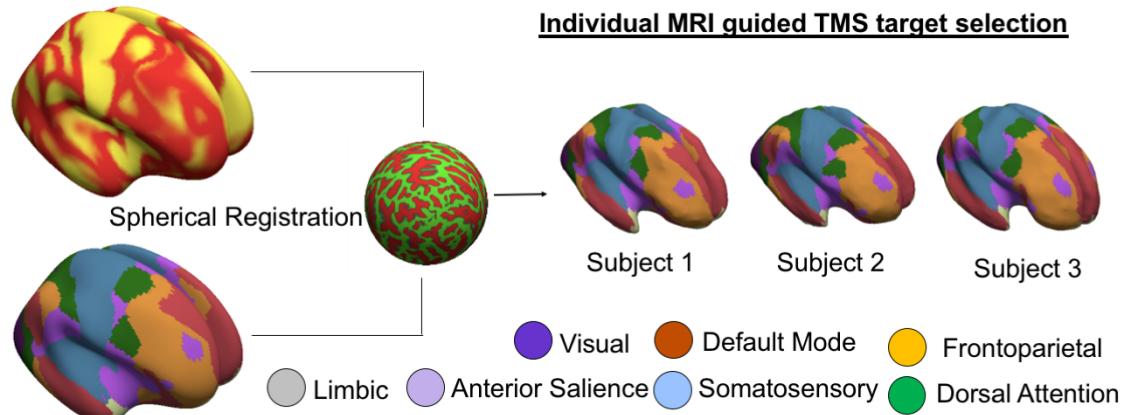
A



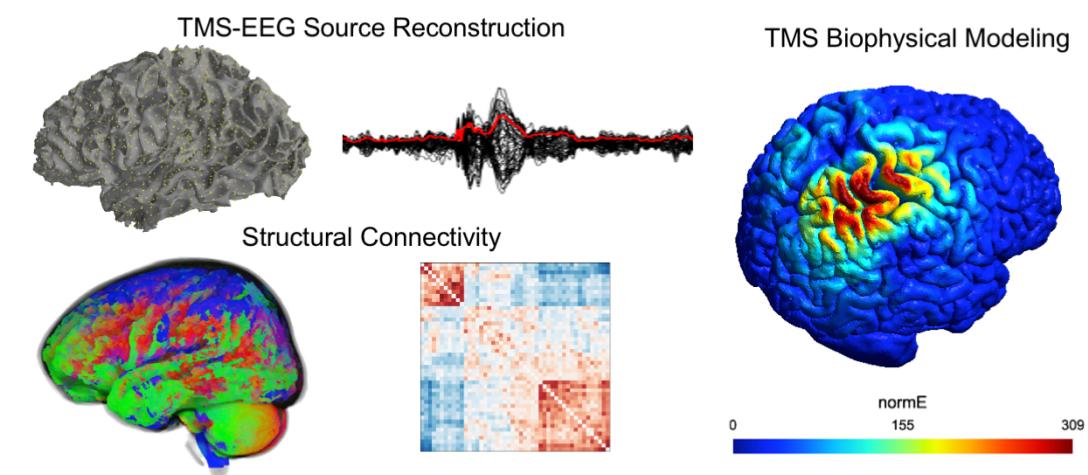
B



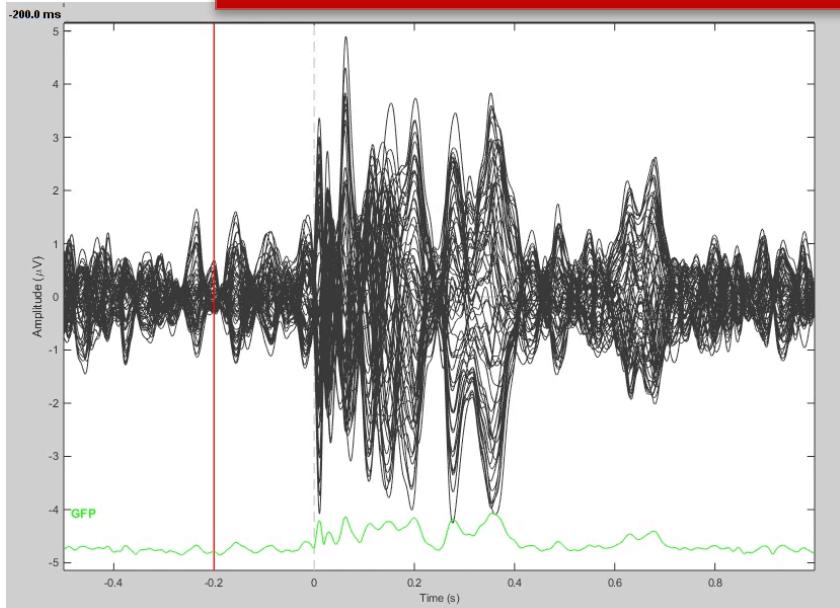
C



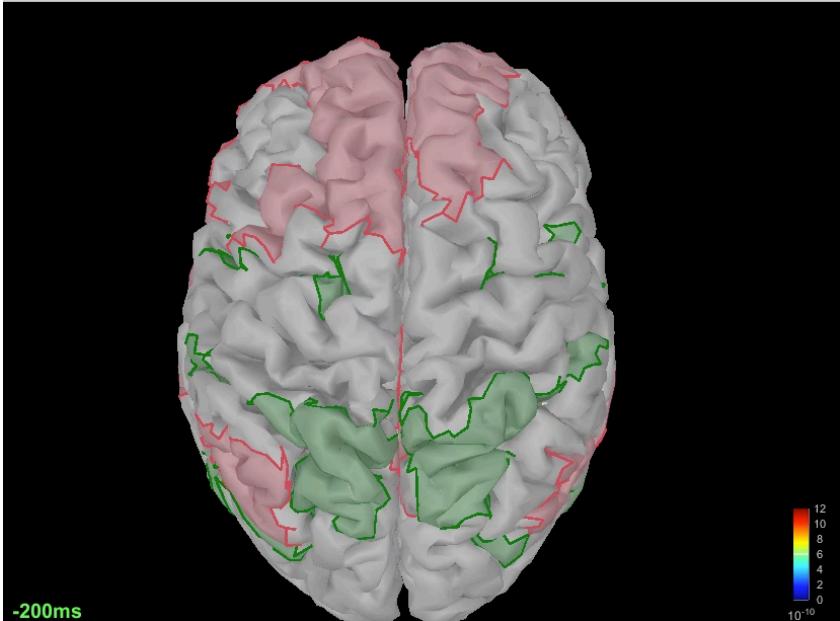
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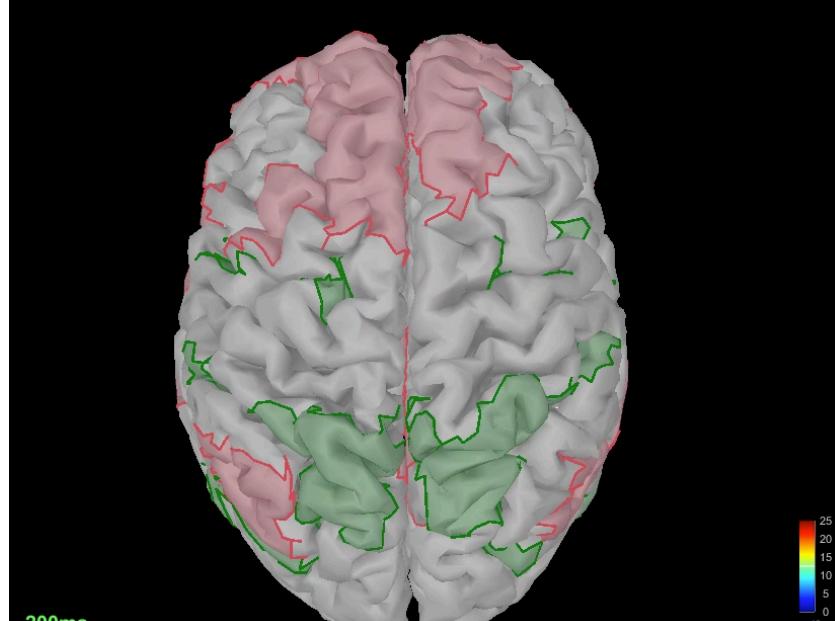
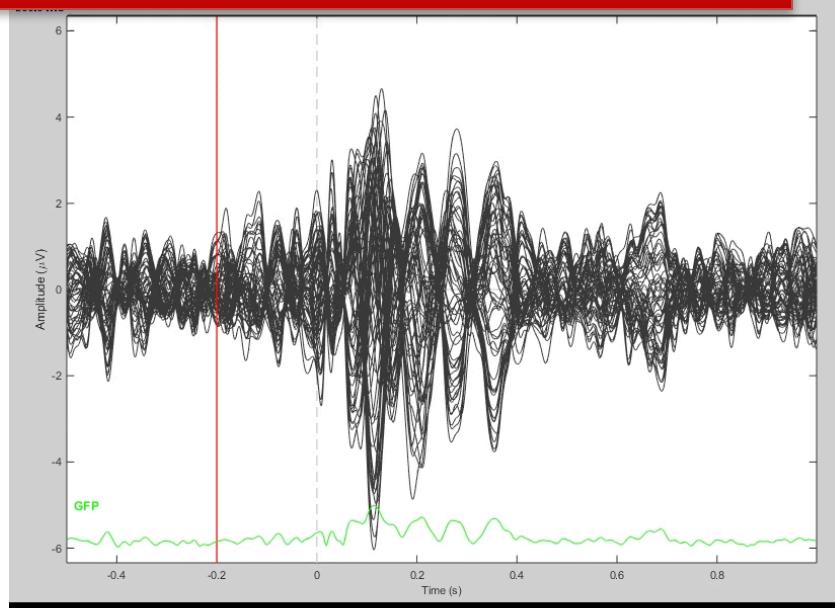
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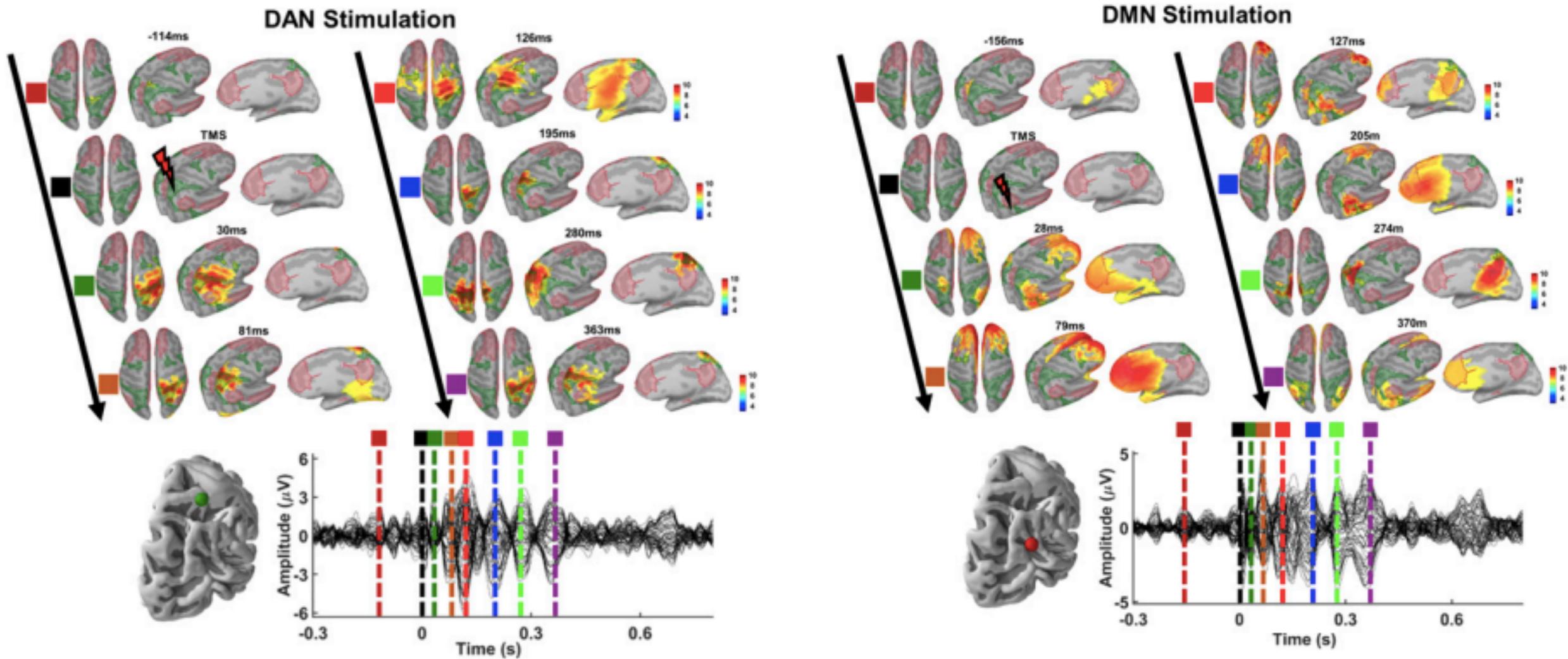
Propagation of  
TMS induced brain  
activity within the  
DMN



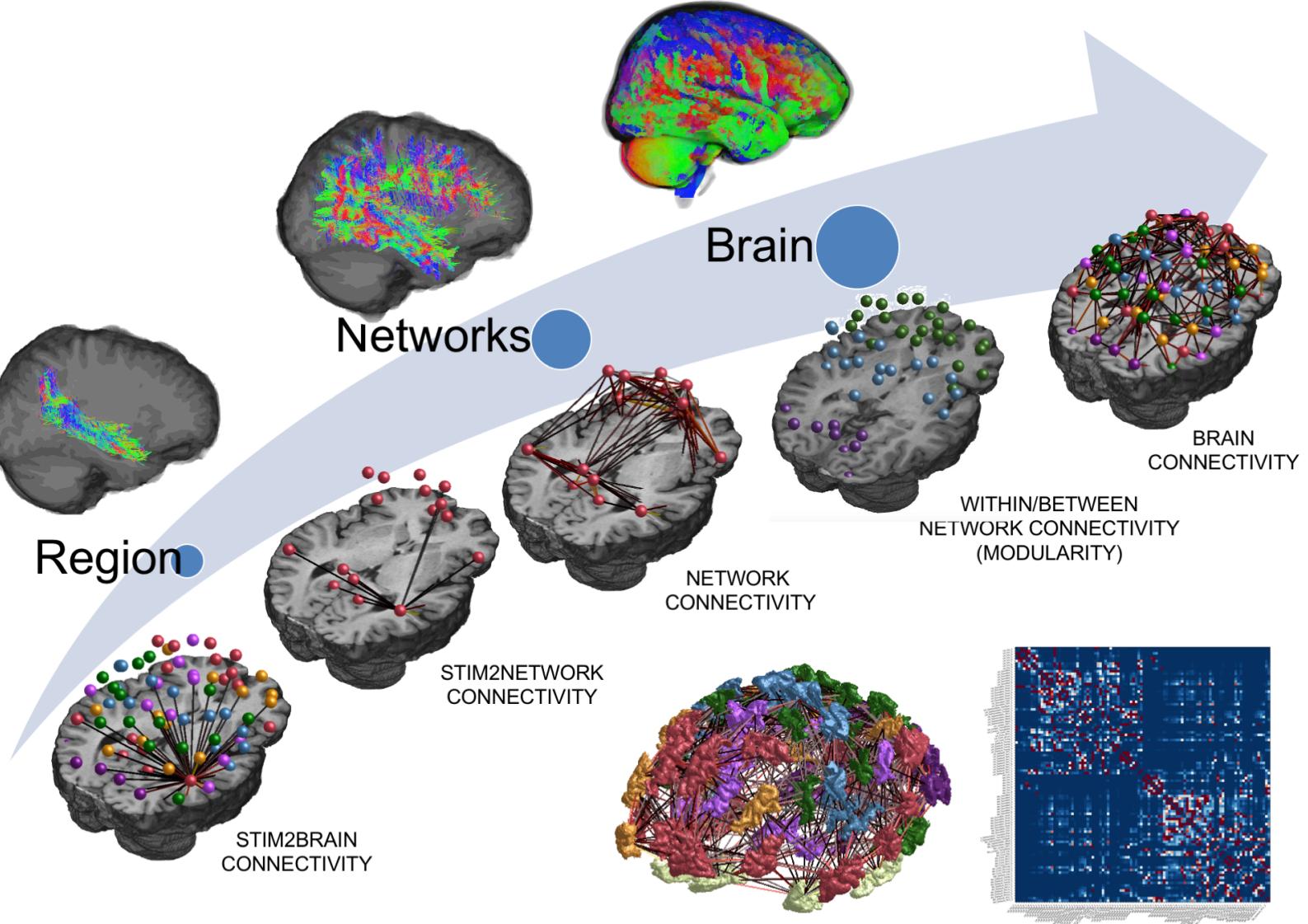
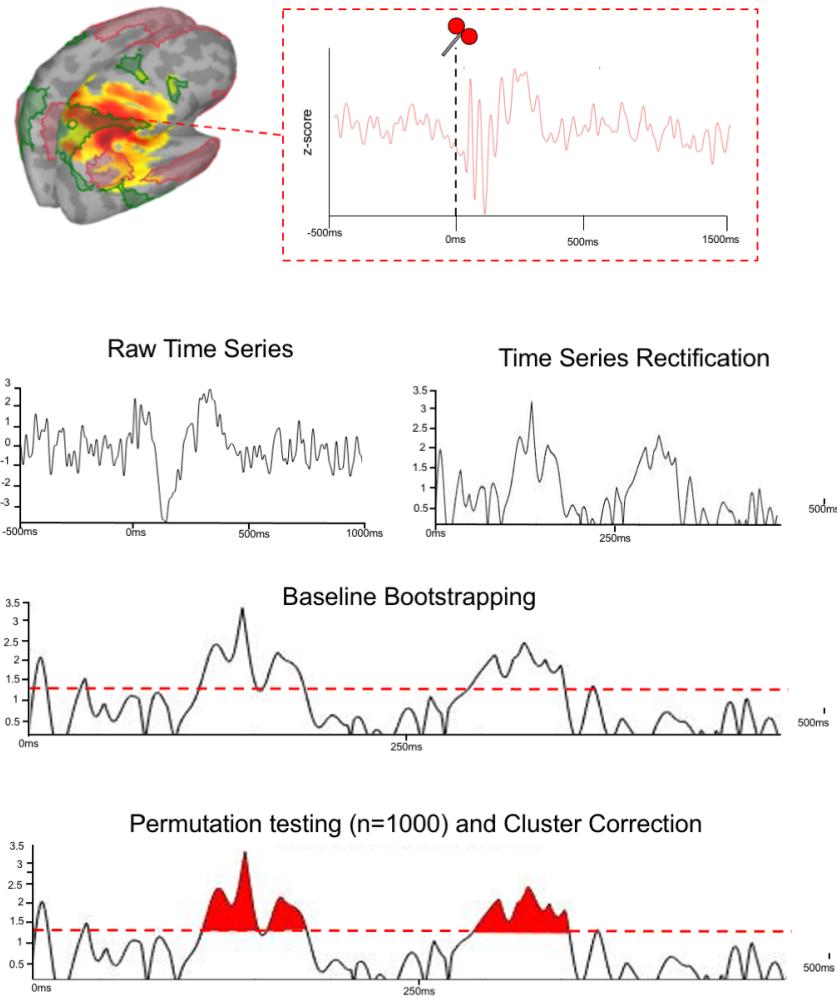
Propagation of  
TMS induced brain  
activity within the  
DAN



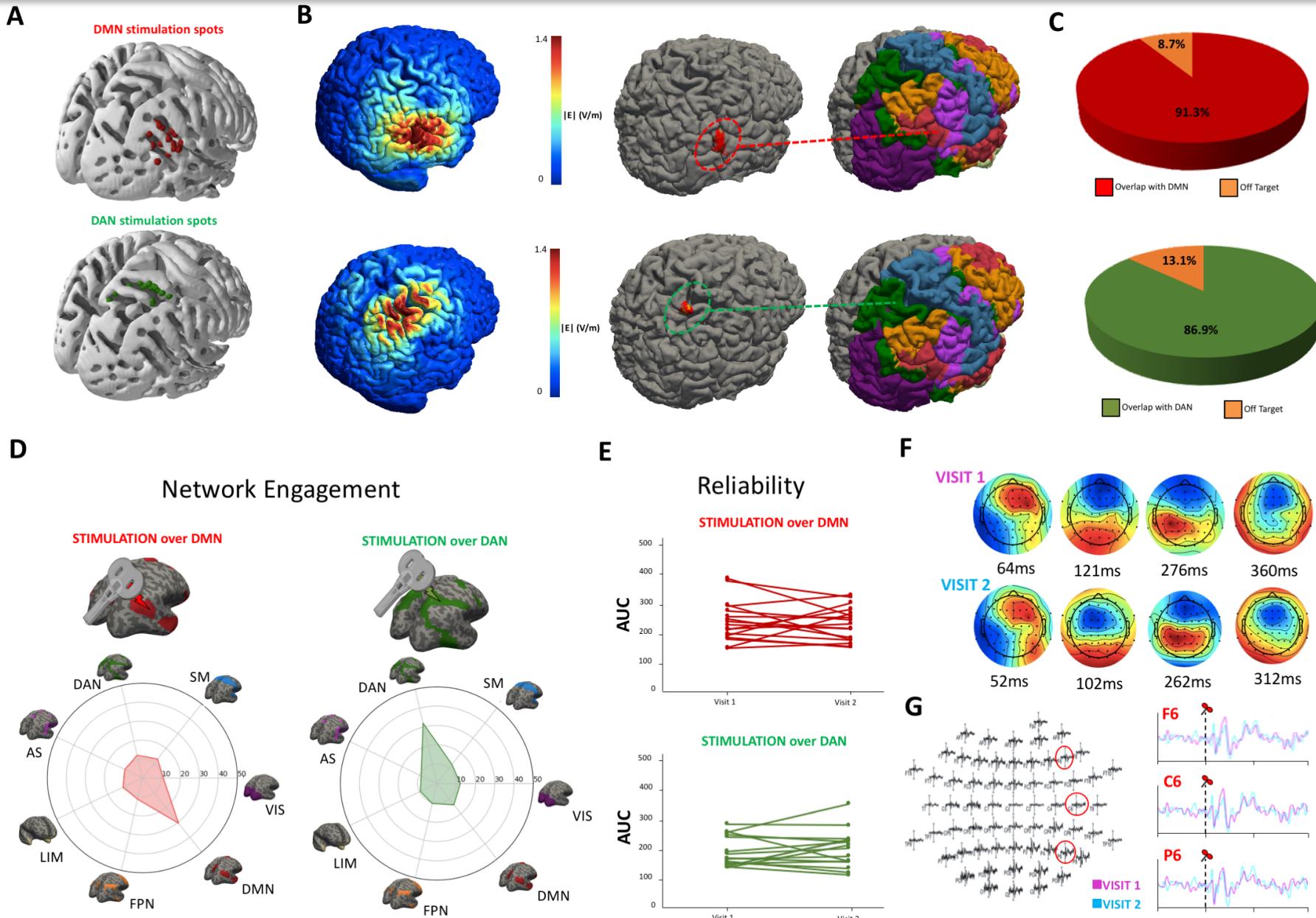
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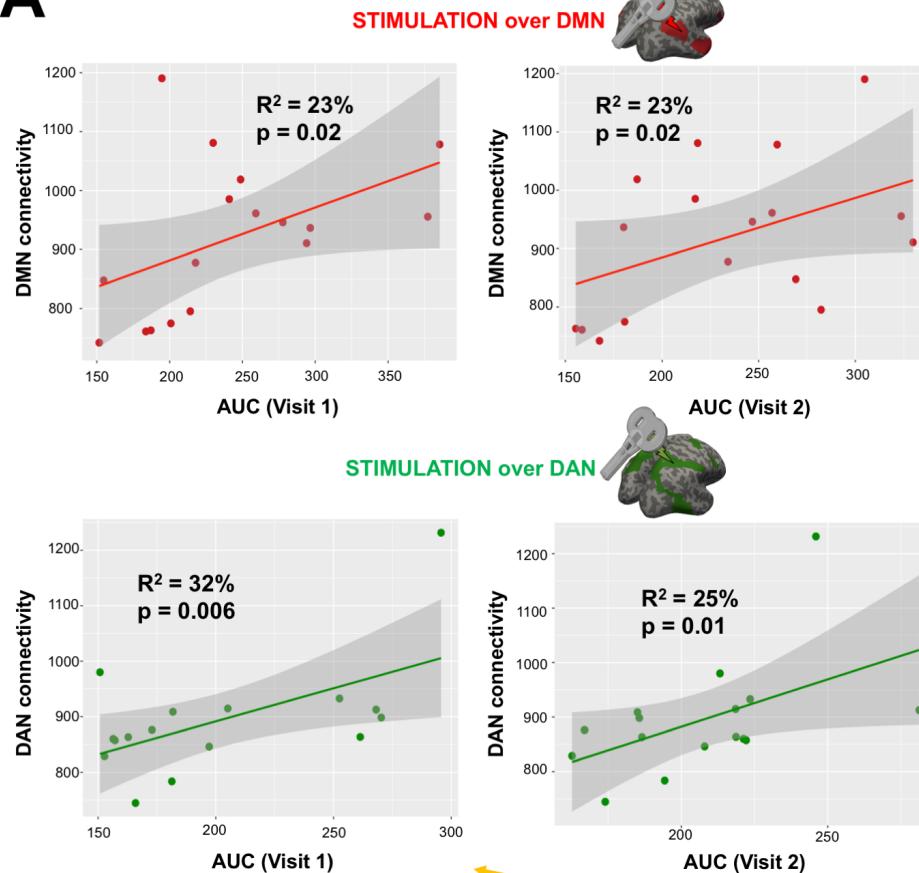


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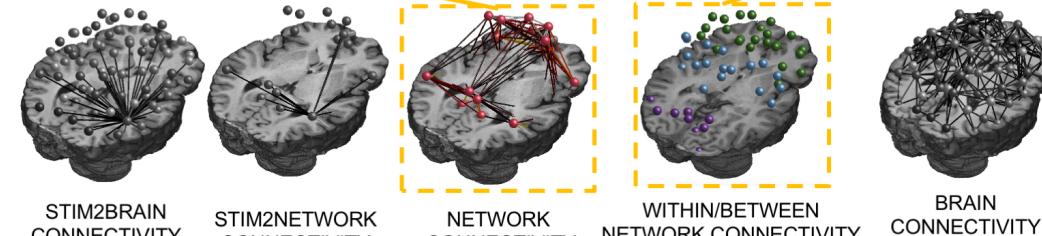
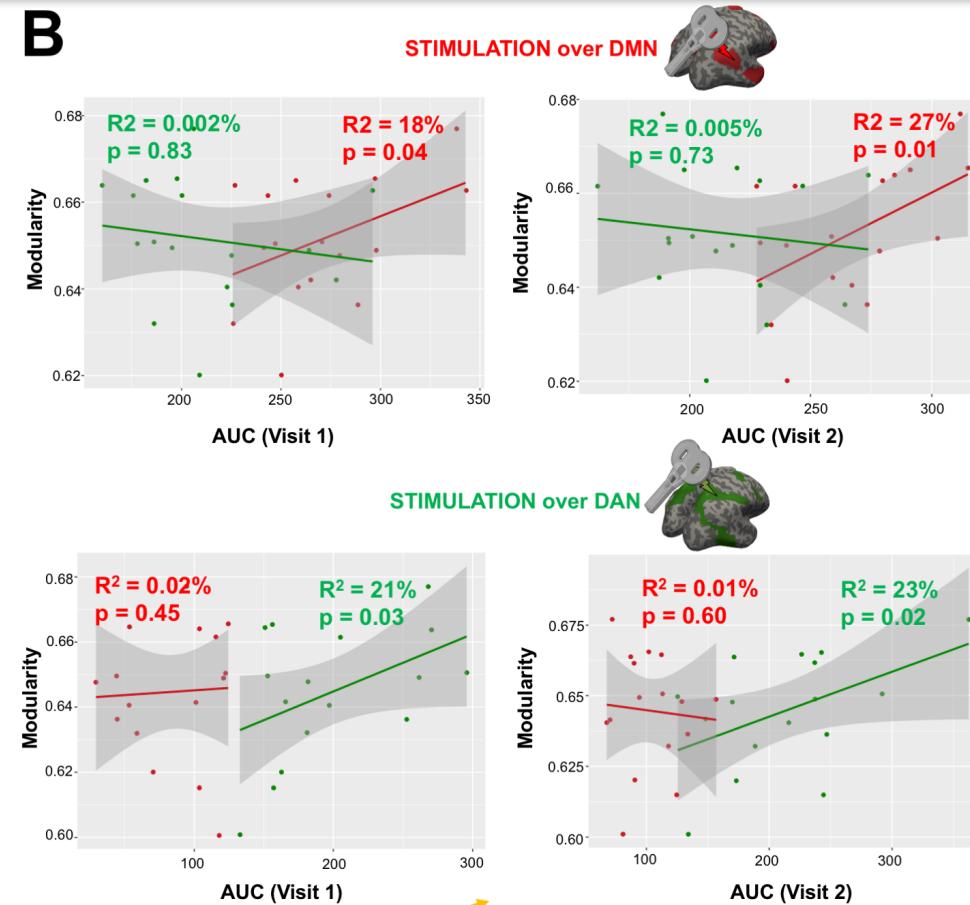


# Network Structural Connectivity Predicts Propagation of Image-Guided TMS

**A**



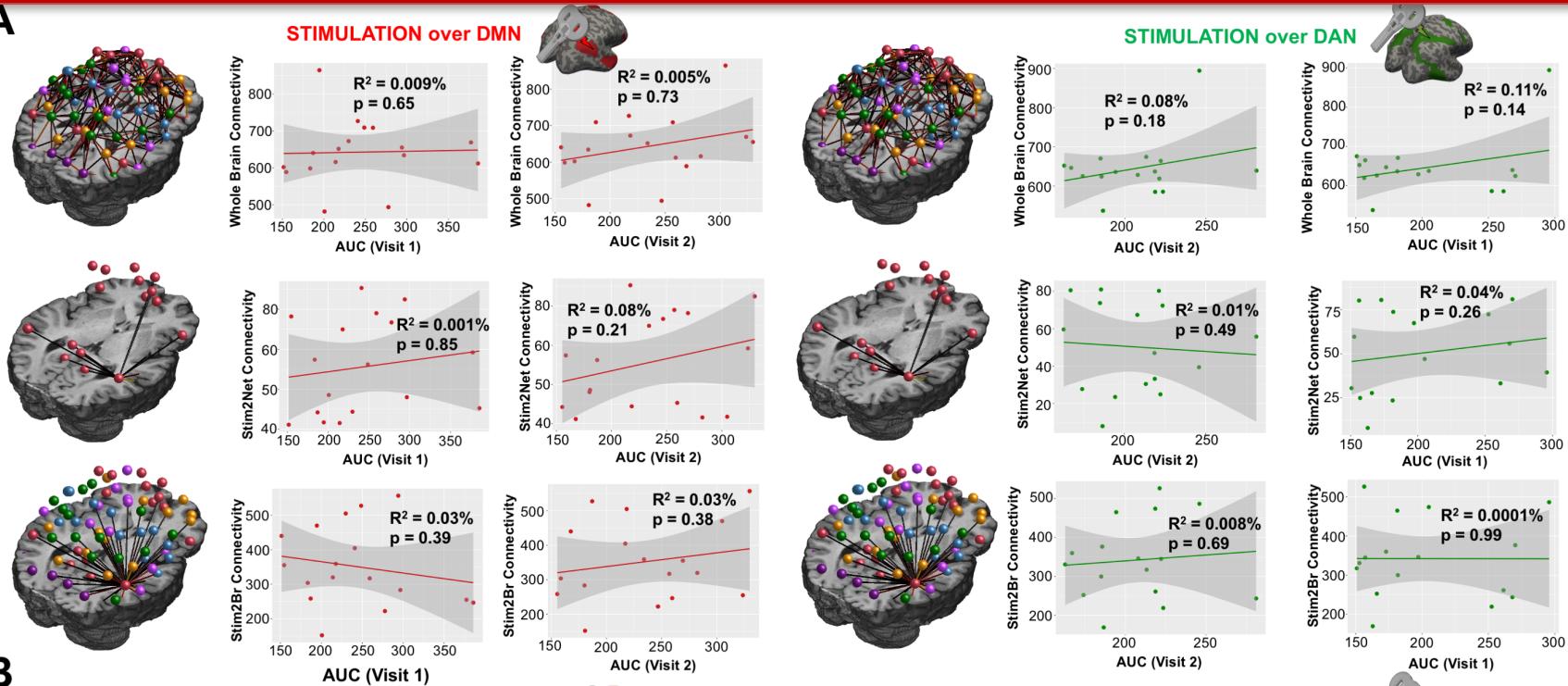
**B**



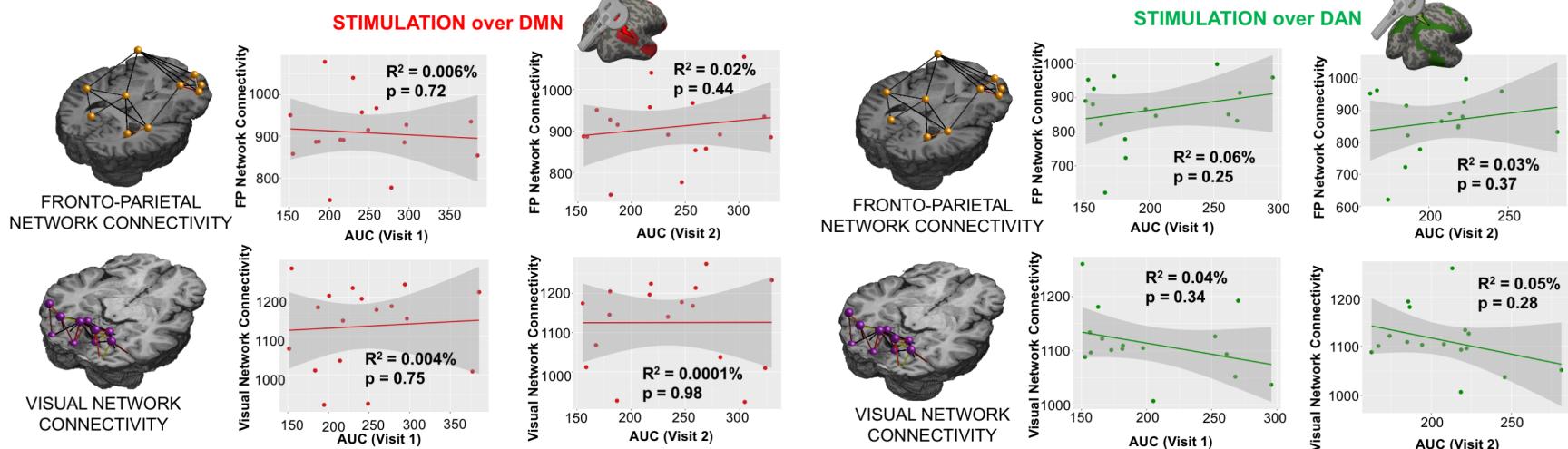
Structural Connectivity Hierarchical Framework

# Network Structural Connectivity Predicts Propagation of Image-Guided TMS

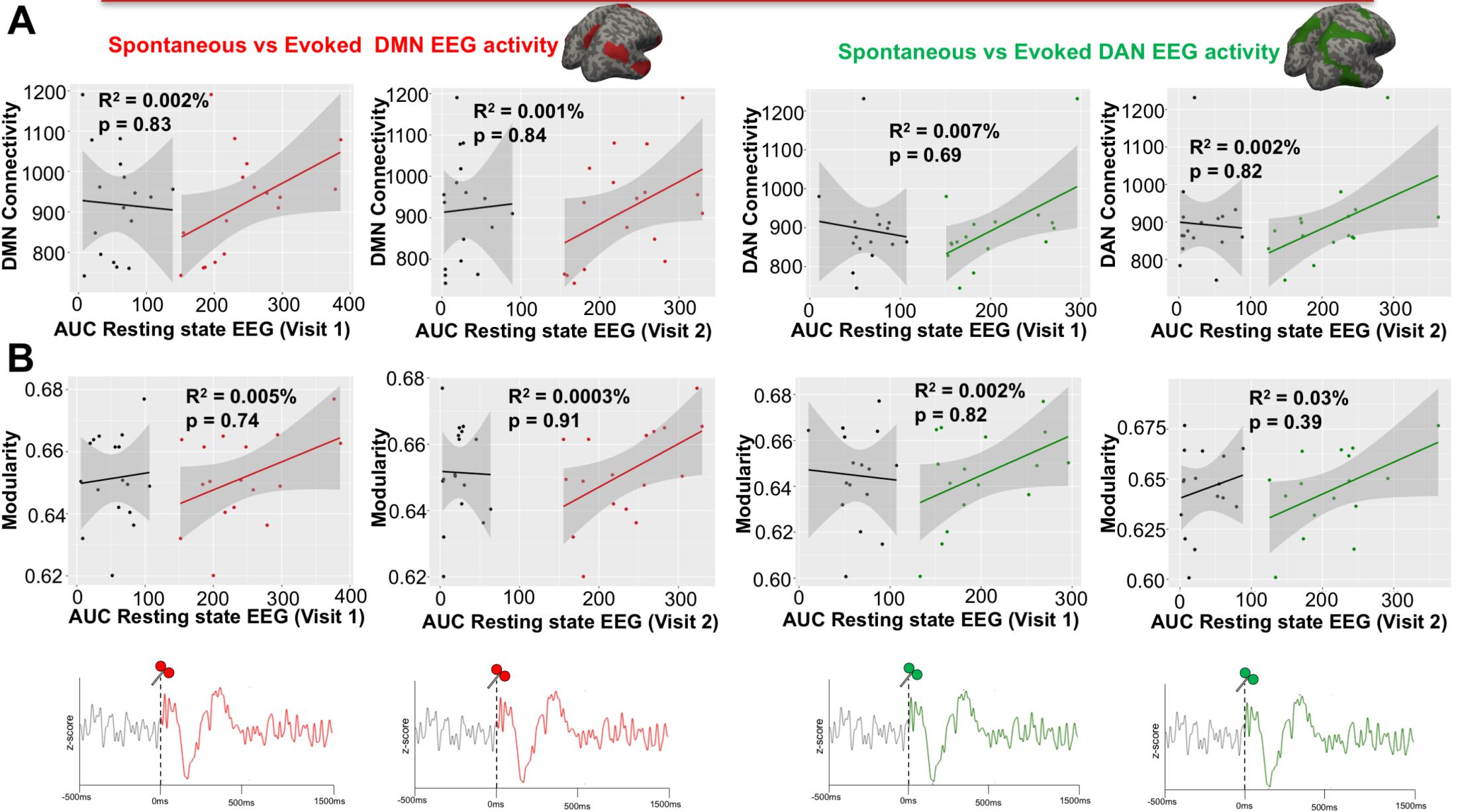
A



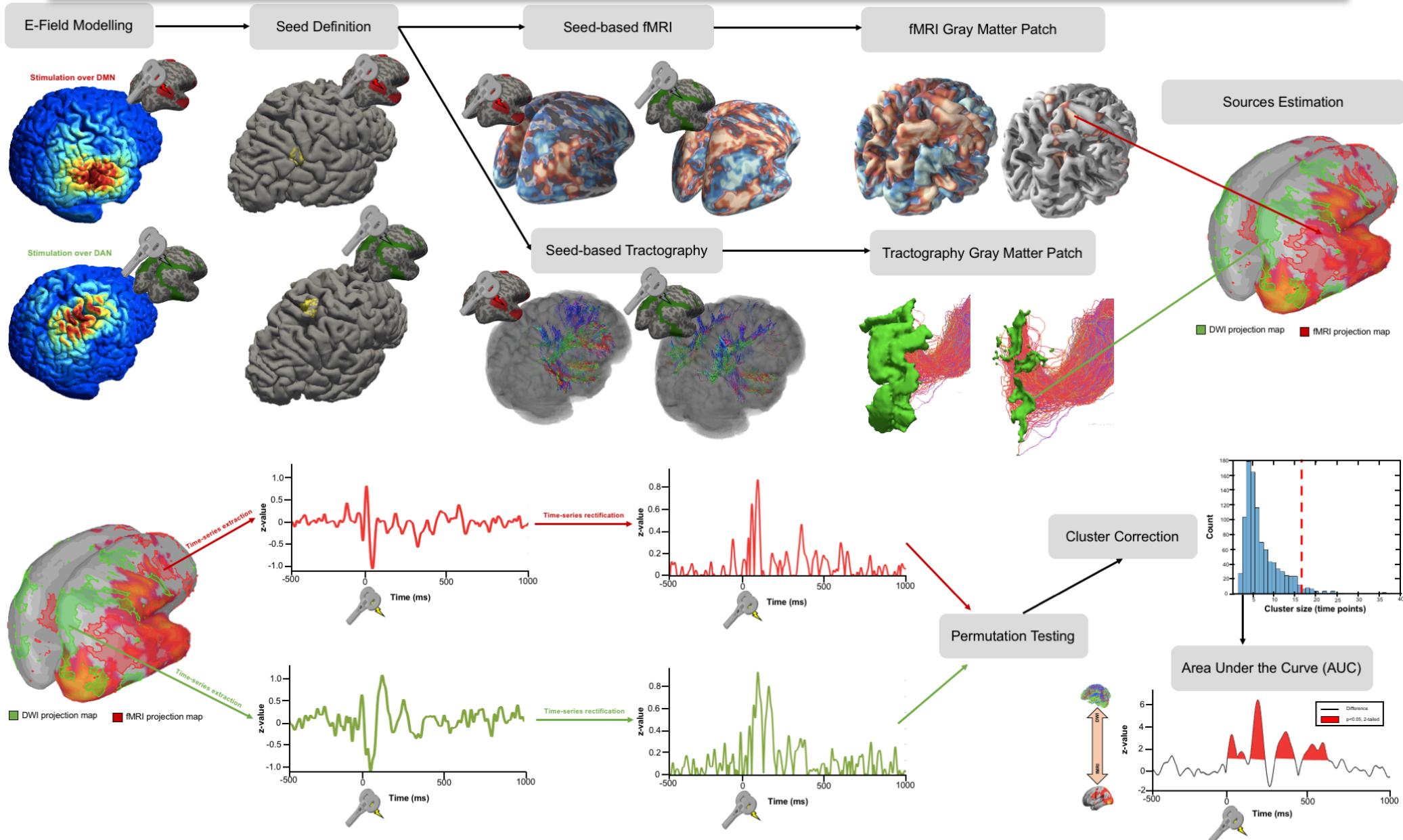
B



# Network Structural Connectivity Predicts Propagation of Image-Guided TMS

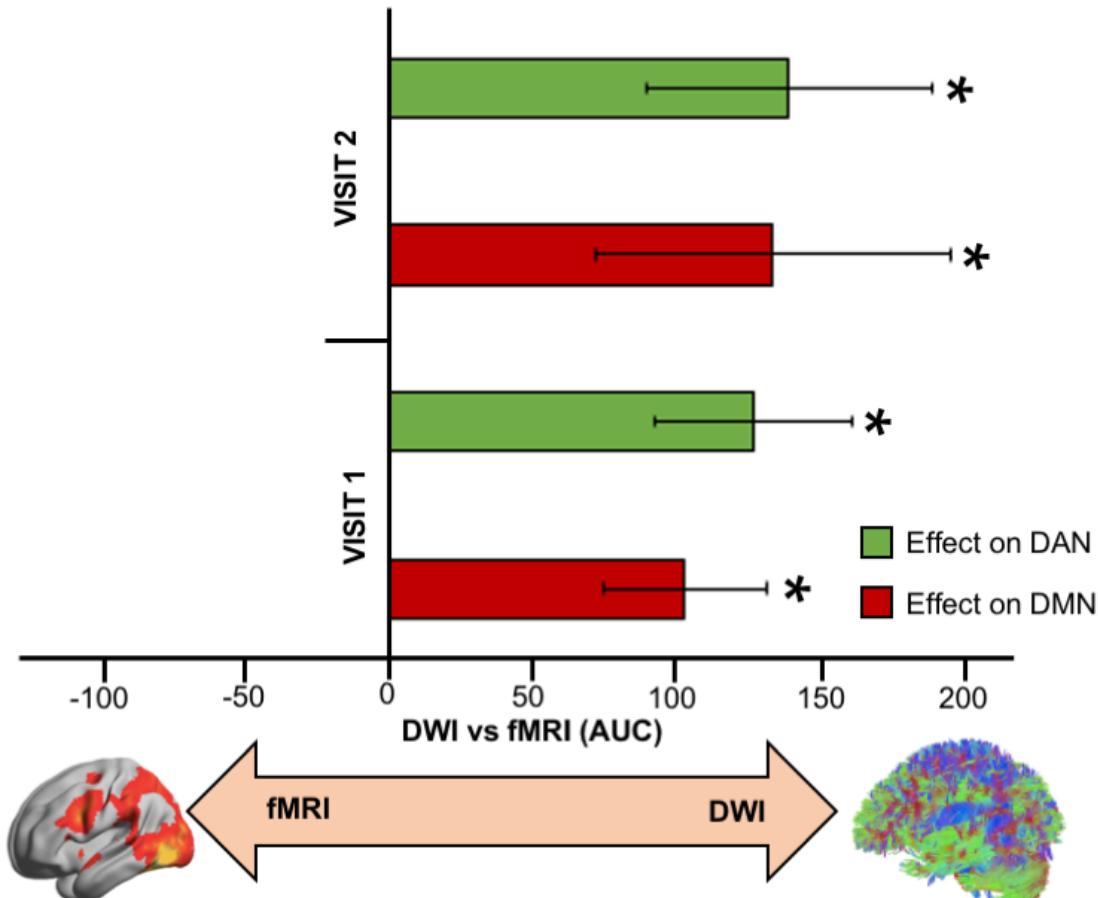


# TMS-induced signal is predicted by functional and structural connectivity?

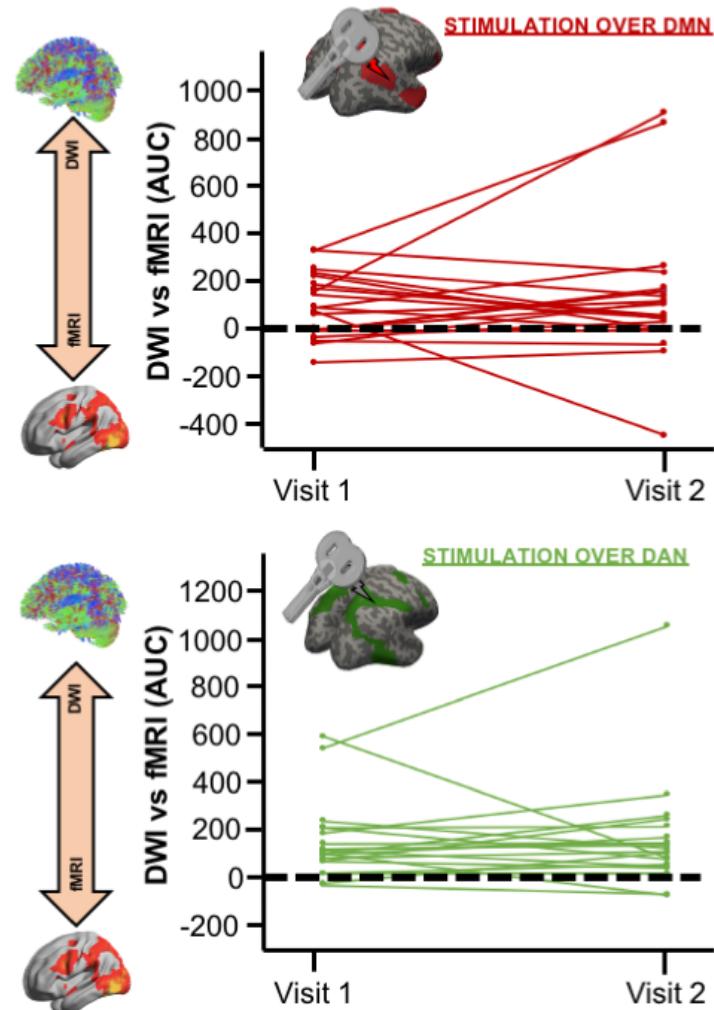


# TMS-induced signal is predicted by functional and structural connectivity?

**A**



**B**

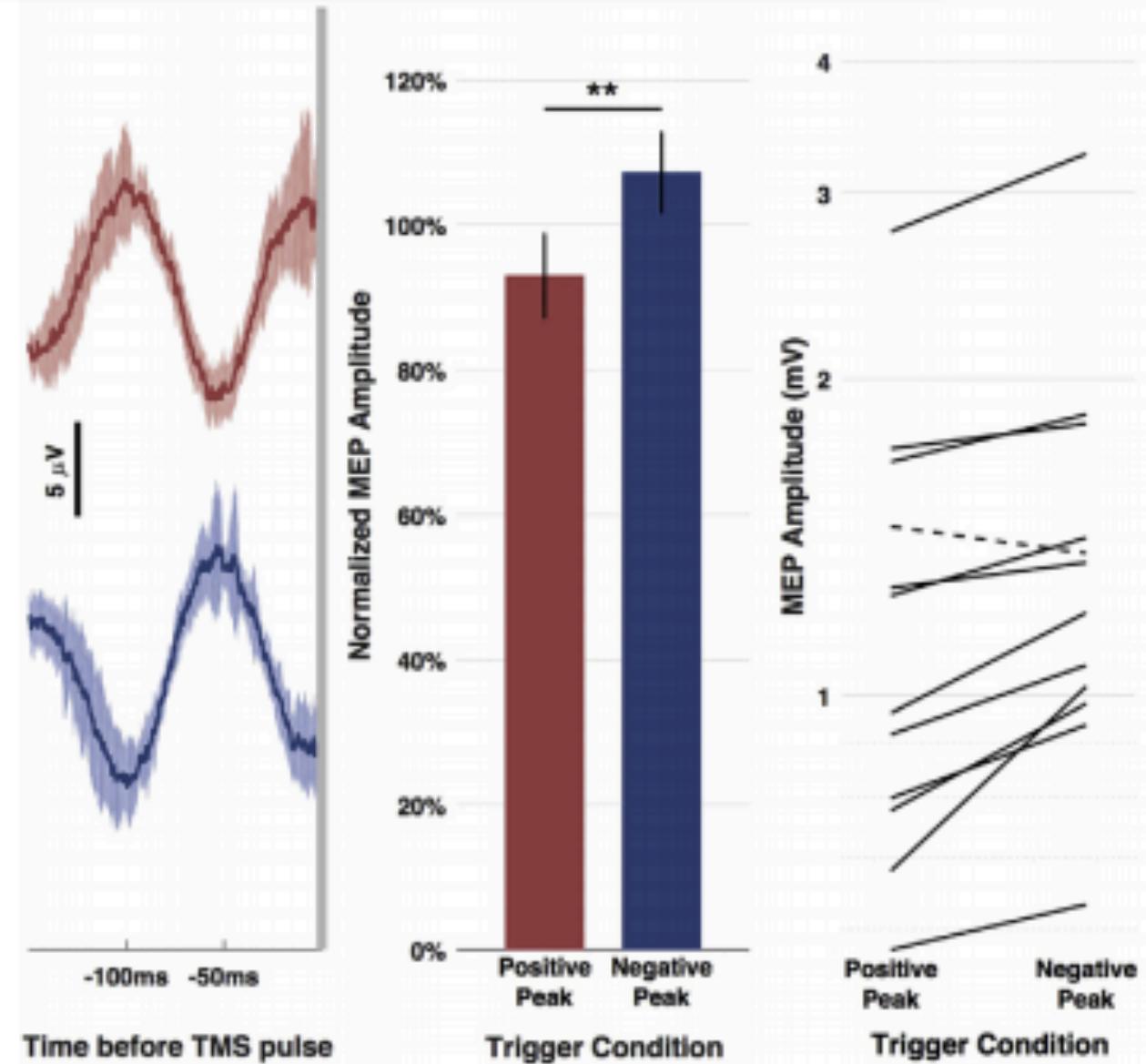


## Tractography-guided Network propagation analysis

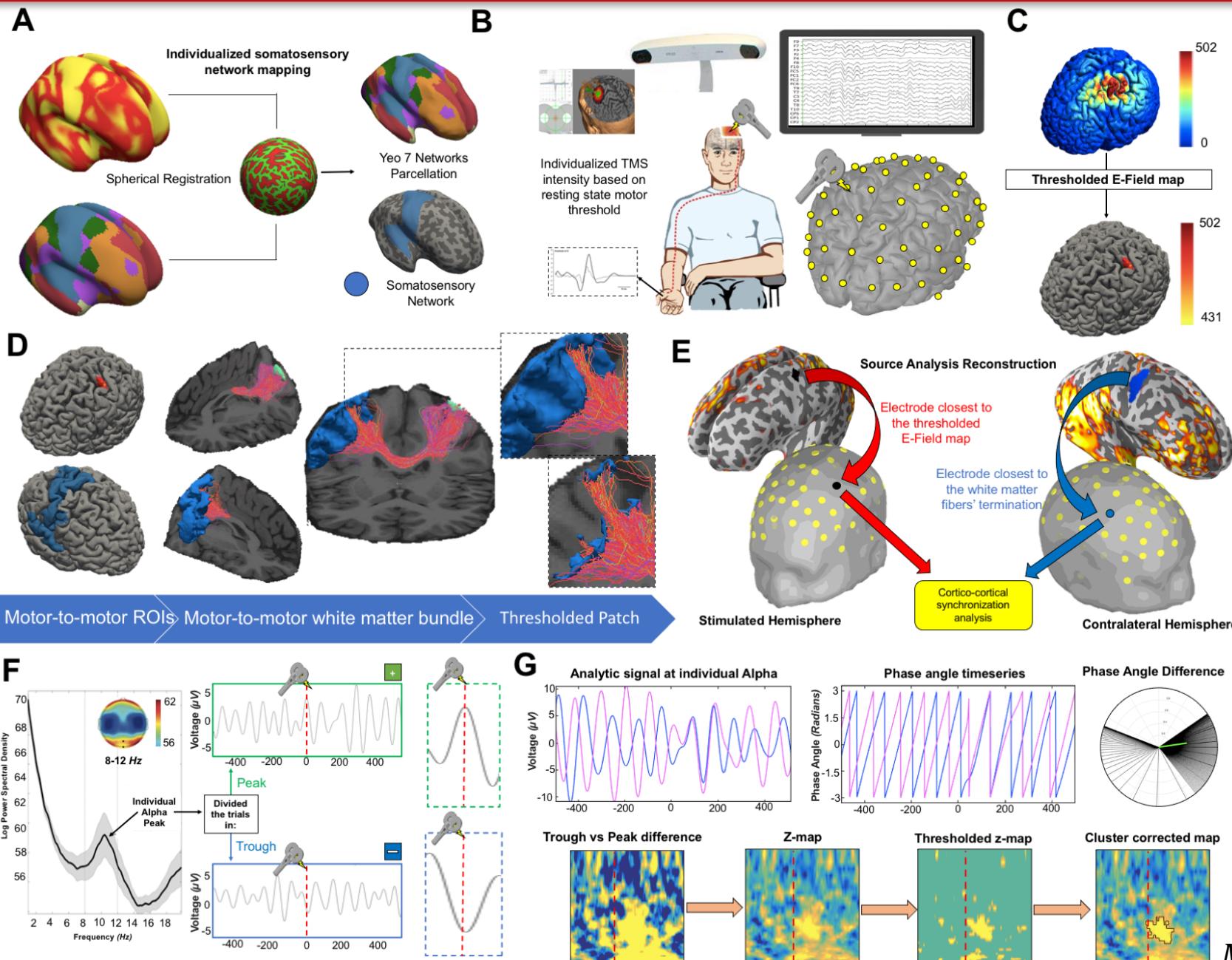
TMS was applied to target the EEG negative vs. positive peak of the sensorimotor m-rhythm in healthy subjects. Corticospinal excitability was indexed by motor evoked potential amplitude in a hand muscle.

Results showed that synchronizing TMS pulses to the trough of the alpha rhythm has shown to generate higher MEPs compared to peak phase

Findings raise the intriguing possibility that real-time information of instantaneous brain state can be utilized to control efficacy of plasticity induction in humans.

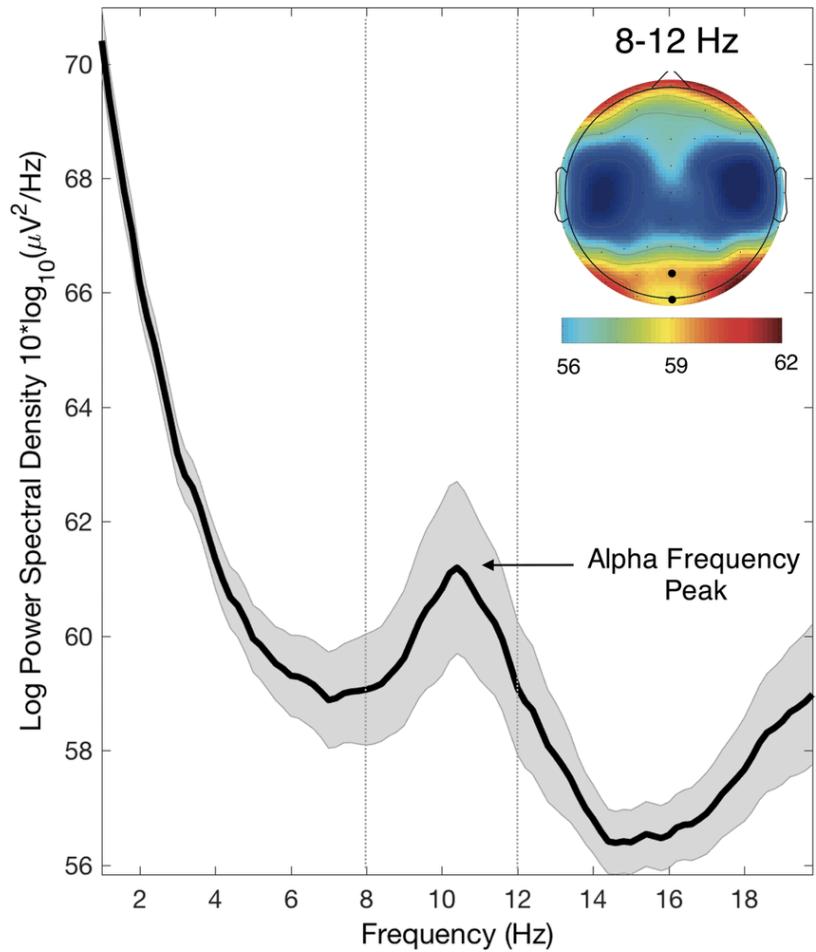


# Tractography-guided Network propagation analysis

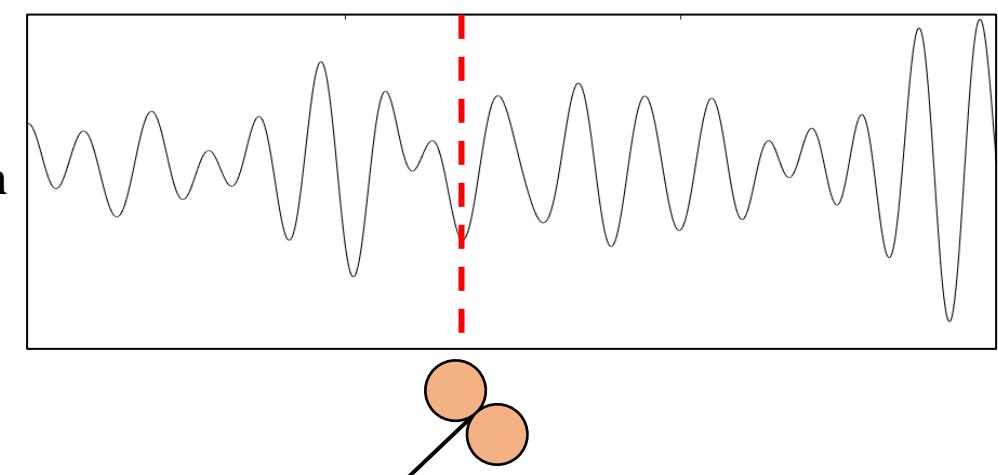
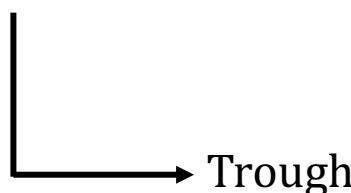
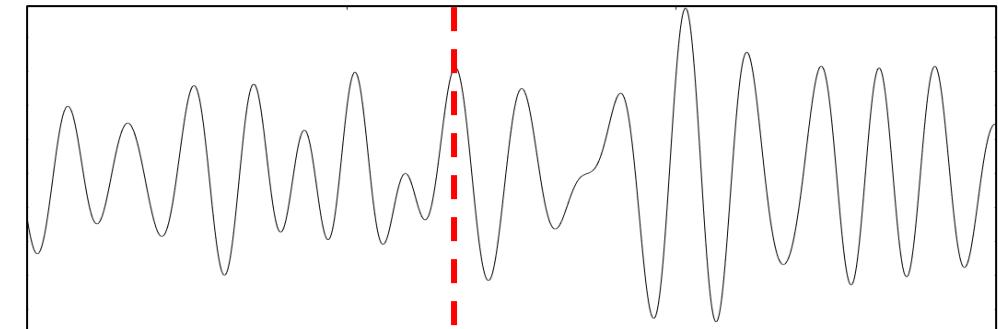
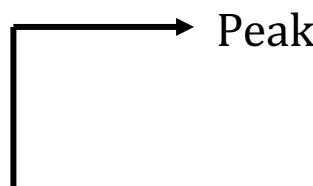


# Tractography-guided Network propagation analysis

## INDIVIDUAL ALPHA FREQUENCY

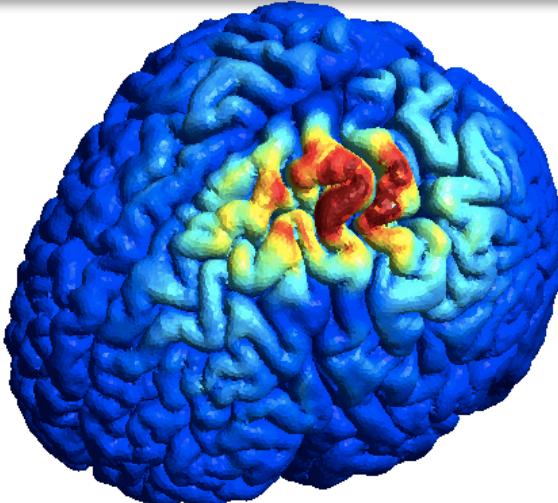


Filter the data based on  
individual Alpha  
And divided the trials into



# Tractography-guided Network propagation analysis

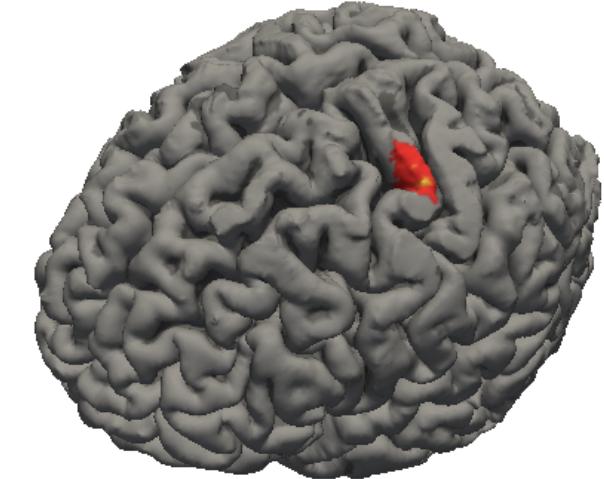
STIMULATED HEMISPHERE  
(Left)



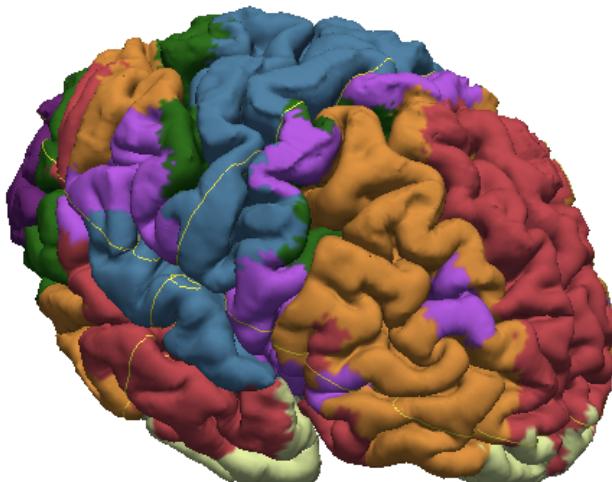
normE



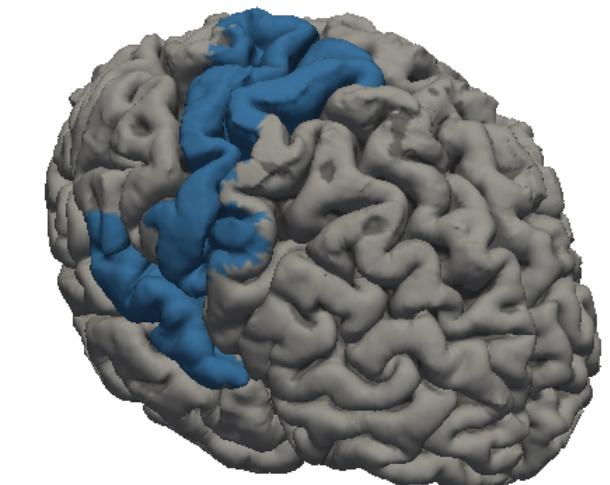
Thresholded at 83% of maximum value  
(Romero et al., 2019)



CONTROLATERAL HEMISPHERE  
(Right)



Yeo 7 Network Parcellation  
(Yeo et al., 2011)



Somatomotor (Network 2)

# Tractography-guided Network propagation analysis



# Tractography-guided Network propagation analysis

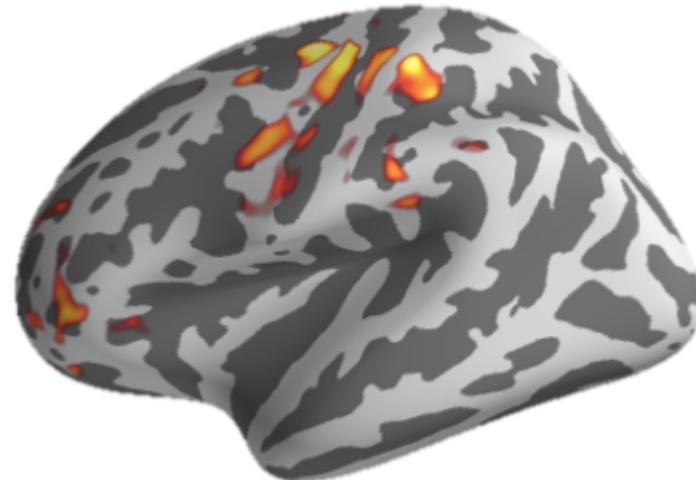
**A**

## trough vs peak comparison

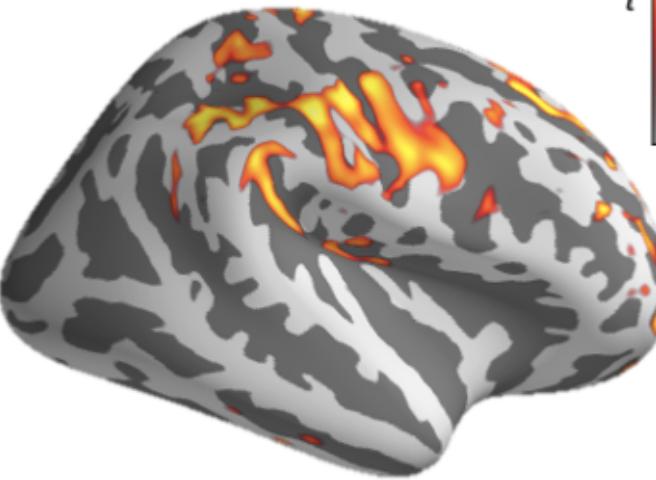
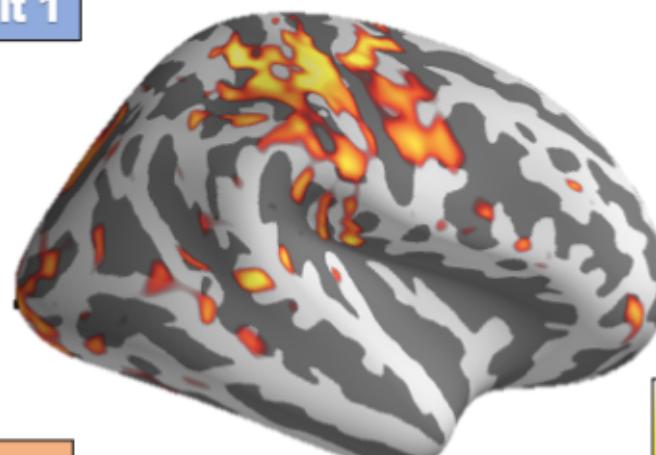
visit 1



visit 2

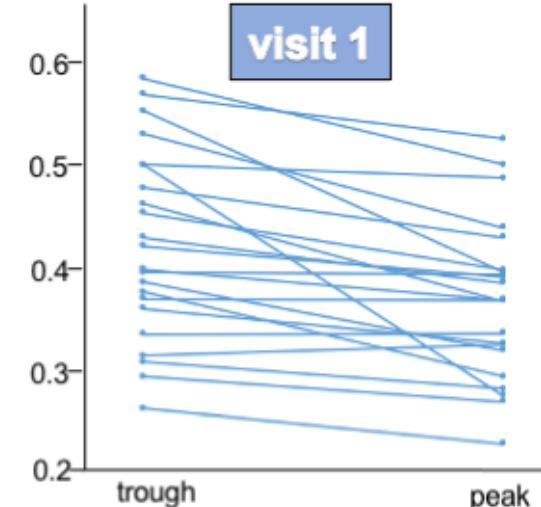
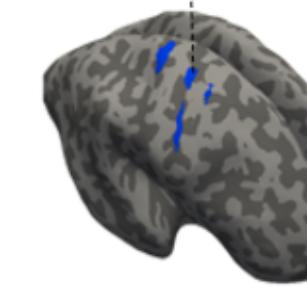
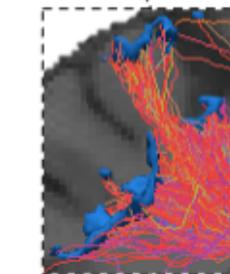
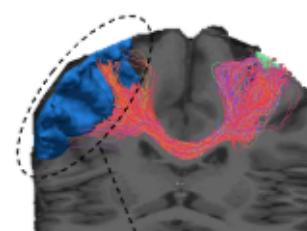


visit 1

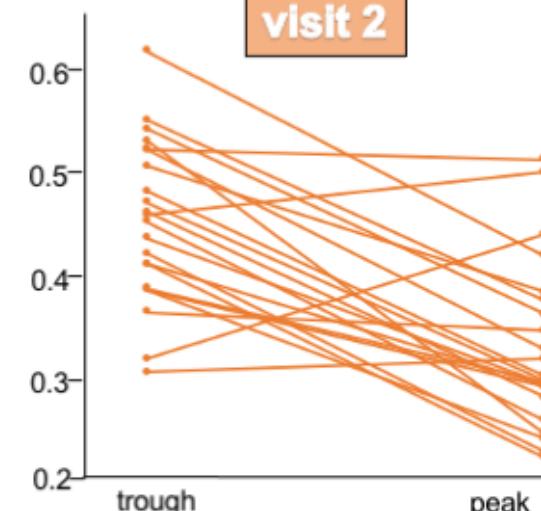
**B**

## dwi-guided cortico-cortical synchronization

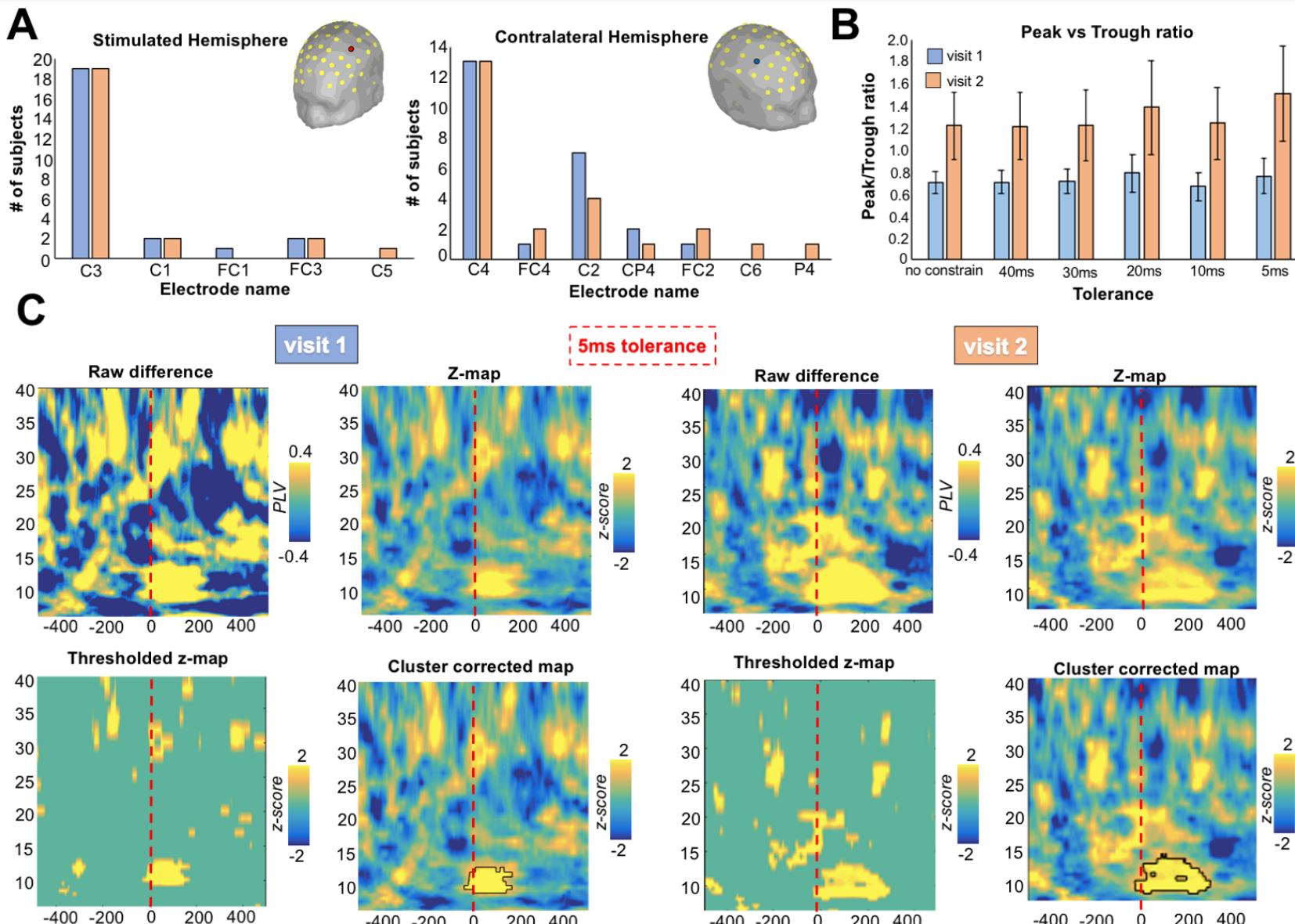
visit 1



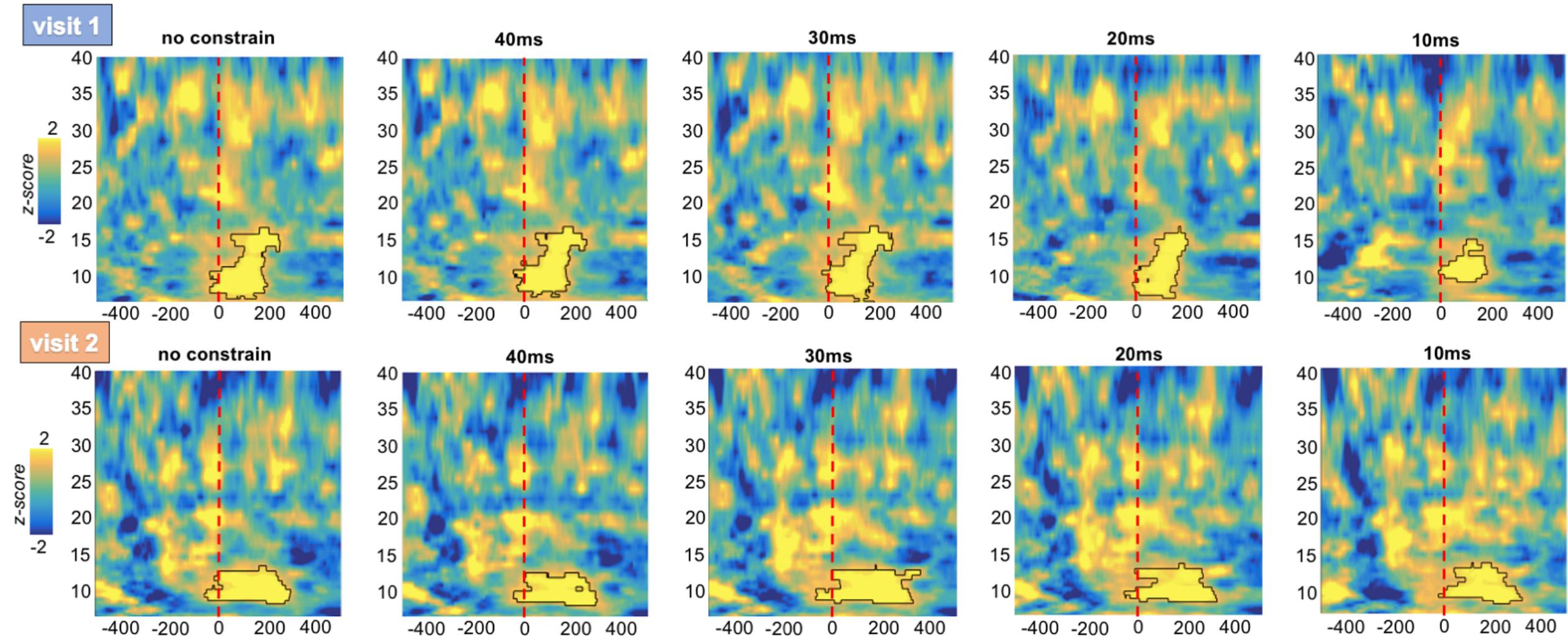
visit 2



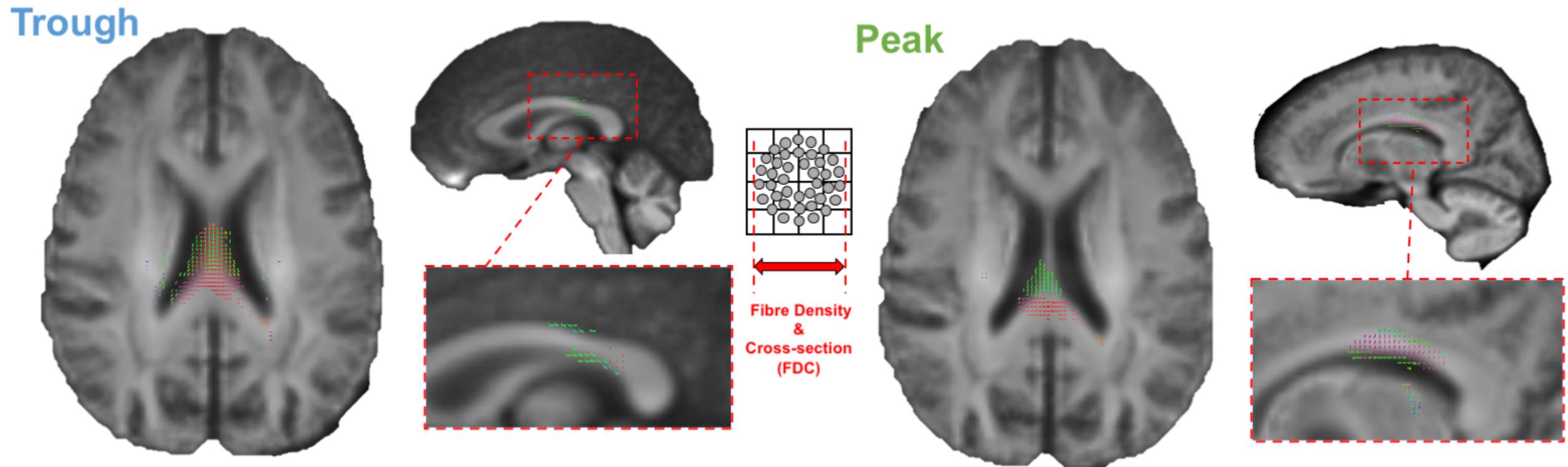
# Tractography-guided Network propagation analysis



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Thanks for your attention

