



Repetitive Transcranial Magnetic Stimulation of the Posterior Superior Temporal Gyrus Modulates Task-Relevant Theta Oscillations in Verbal Working Memory



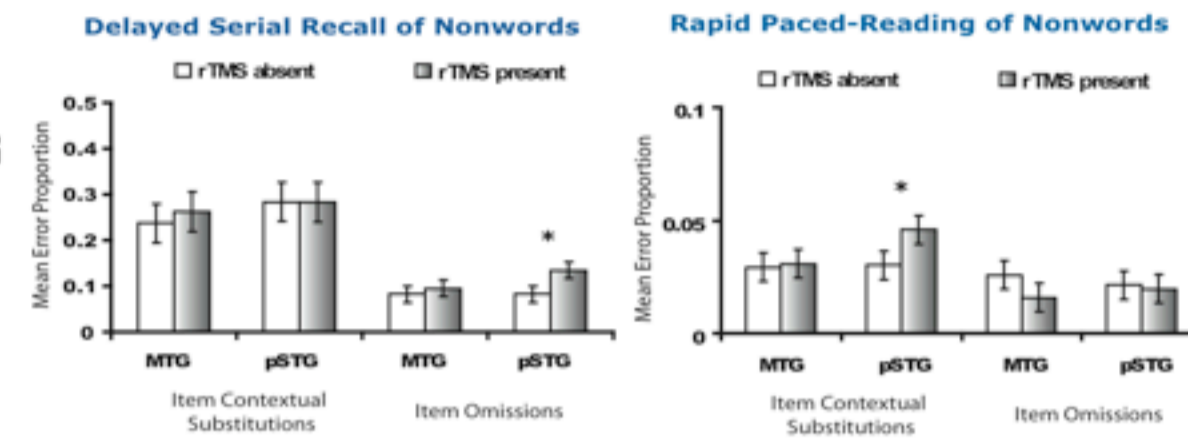
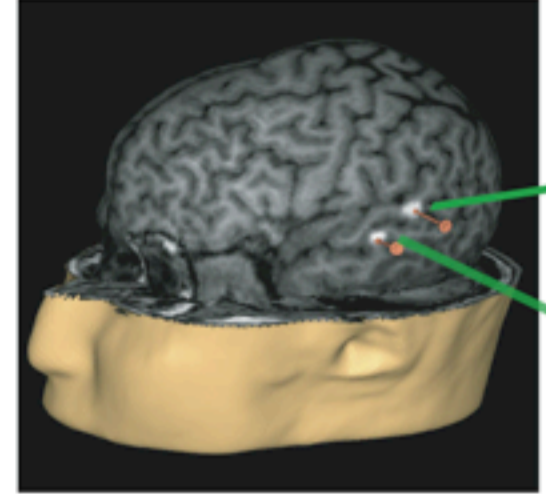
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Background

- RTMS to the posterior superior temporal gyrus (pSTG), but not the middle temporal gyrus (MTG), induces errors in verbal working memory and language production tasks (Acheson et al., in press)



- Maintenance in verbal working memory has been related to neuronal oscillations in three frequency bands: **Theta** (θ ; Gevins et al., 1997; Jensen & Tesche, 2002; Klimesch et al., 1999); **Gamma** (γ ; Jokisch & Jensen, 2007)

- rTMS effects on visuospatial WM performance are related to changes in α -band power, and in α - γ phase coupling (Hamidi et al., 2009)

Question: Do individual differences in behavioral changes caused by rTMS correspond to changes in EEG oscillations?

Methods - fMRI-guided rTMS with EEG

Subjects: 16 native English speakers (9 female), mean age 23.2 (SD = 3.4)

fMRI Localization:

Task: Overt Picture Naming (150 total pictures);

Design: Rapid, Event-Related (Mean ITI of 5 seconds, 2 second jitter), 3 runs of 6:20

Definition of pSTG: Regions showing sensitivity to parametric manipulation of word frequency

RTMS:

Regions Targeted: pSTG and the leg area of somatosensory cortex (S1; control)

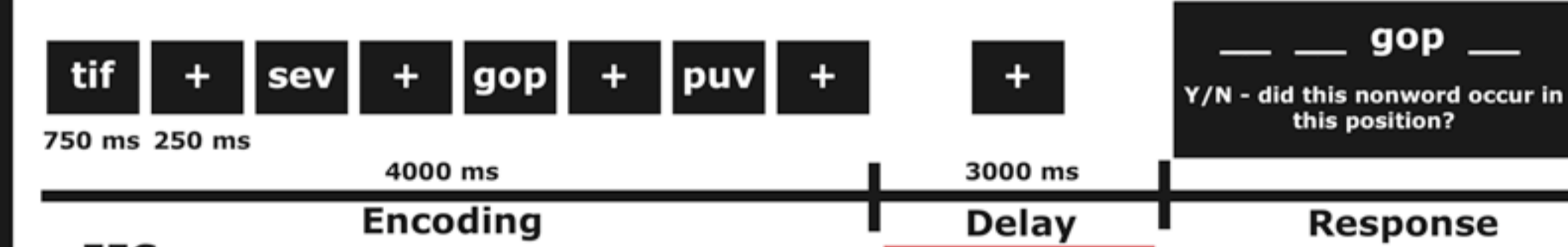
Stimulation:

- Each subject's head was coregistered with his/her MRI using eXimia Navigated Brain Stimulation (NBS) frameless stereotaxy navigation system (NEXSTIM)

- 10 Hz rTMS done at 110% MT - Magstim Standard Rapid, Whitland, UK

- Stimulation intensity was corrected for scalp-to-cortex distance (Stokes et al., 2005)

Task: Delayed, serial recognition of nonwords (112 trials/region, half with rTMS)



EEG:

Acquisition:

- 60-electrode TMS-compatible cap (Nexstim, Helsinki)

- Sample-and-hold circuit minimized TMS-induced electrical artifact by holding amplifier output constant from 100 μ S pre to 2 ms post-TMS pulse (Virtanen et al., 1999)

- Data acquired at 1450 Hz, filtered (0.1 to 100 Hz) and down-sampled to 500 Hz

TMS Artifact removal (see Hamidi et al., 2010)

- Residual rTMS-related artifact removed through two rounds of ICA (Hamidi et al., in press)

- 1st round: ICA performed on entire data set

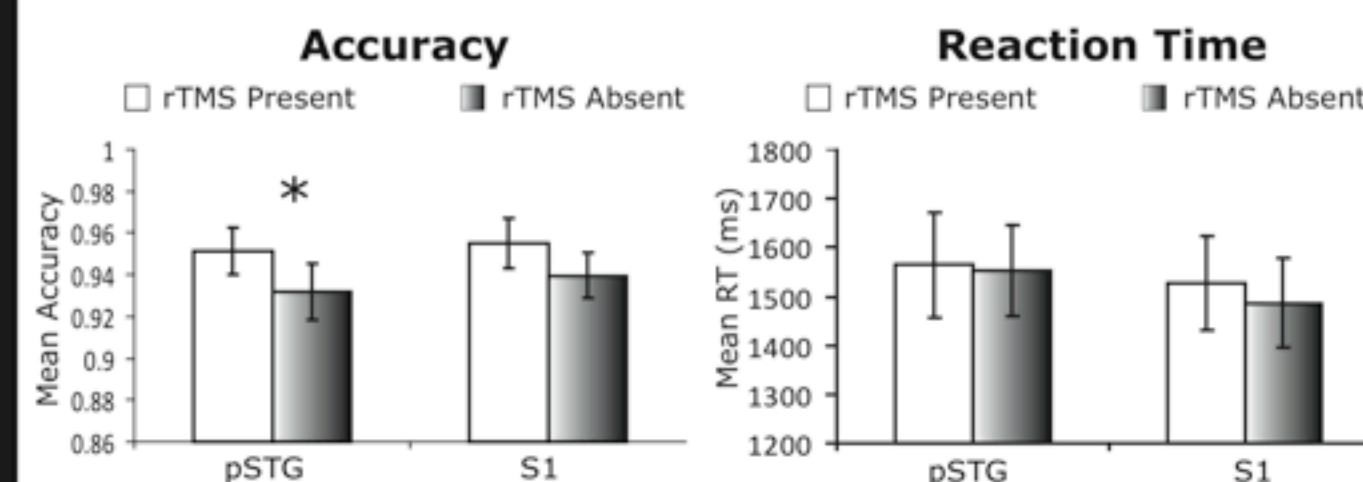
- components associated with eye-blinks, channel noise, and rTMS identified and removed

- 2nd round of ICA performed on delay-period data, and any components with rTMS removed

- Any trial that still contained rTMS artifact was removed

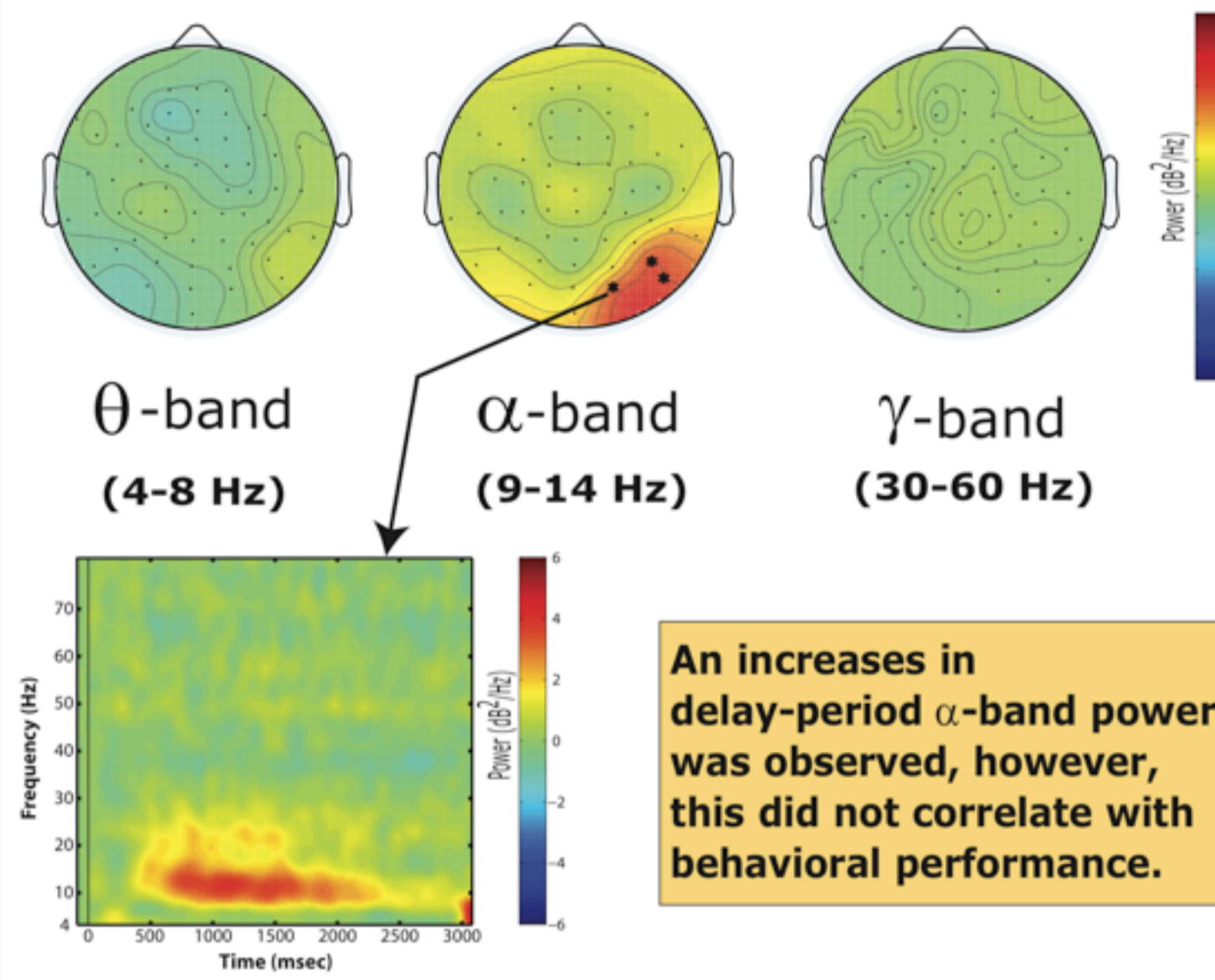
Results

Behavior



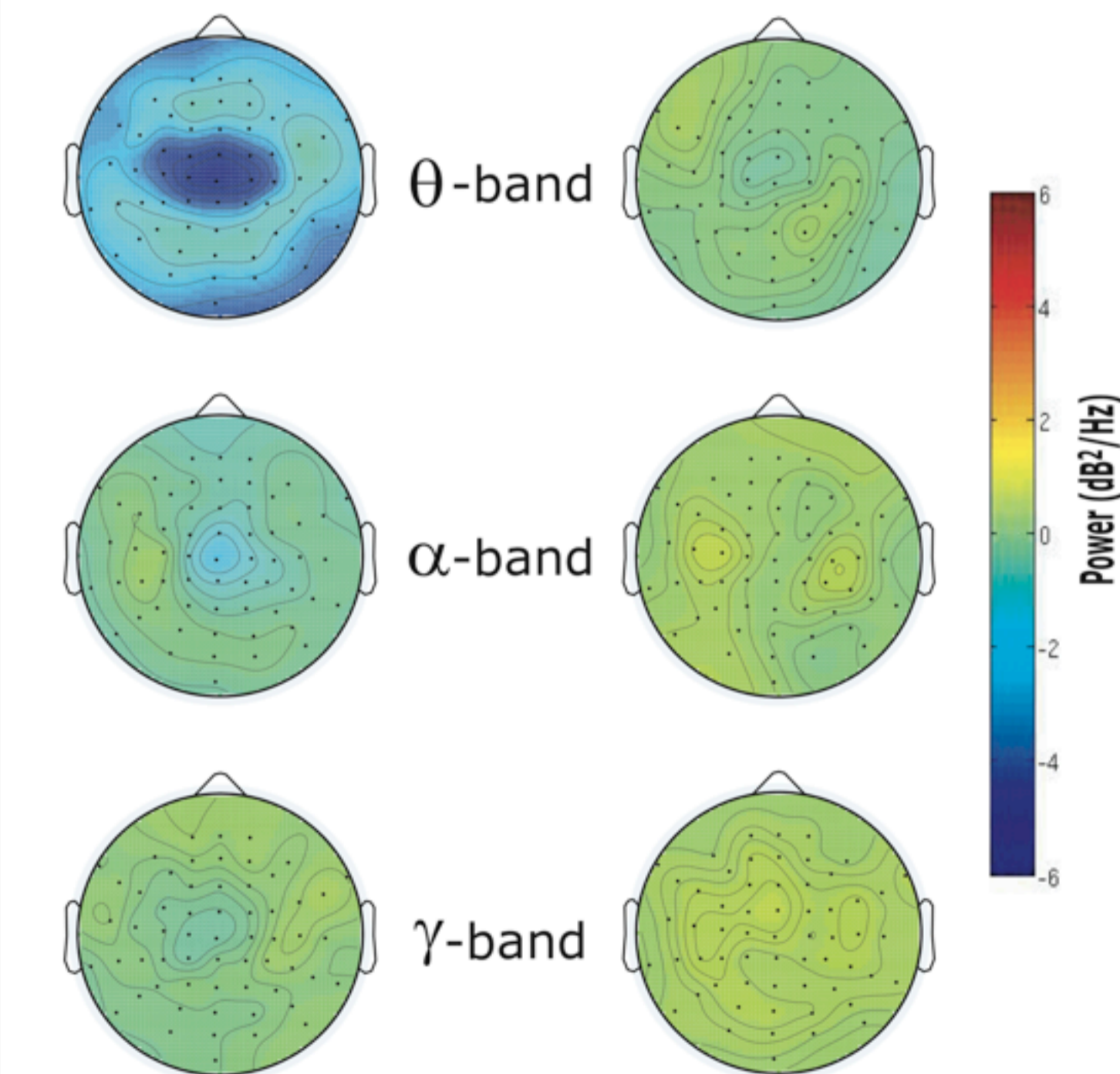
A 2 (rTMS) X 2 (Region) ANOVA revealed a main effect of TMS on accuracy ($F(1,15) = 4.61, p < 0.05$). Planned comparisons showed that rTMS to the pSTG decreased accuracy relative to no rTMS ($\mu_D = -0.02, p < 0.05$); no such effect was observed for S1 ($\mu_D = -0.014, p > 0.15$).

Delay Period Spectral Power - no rTMS



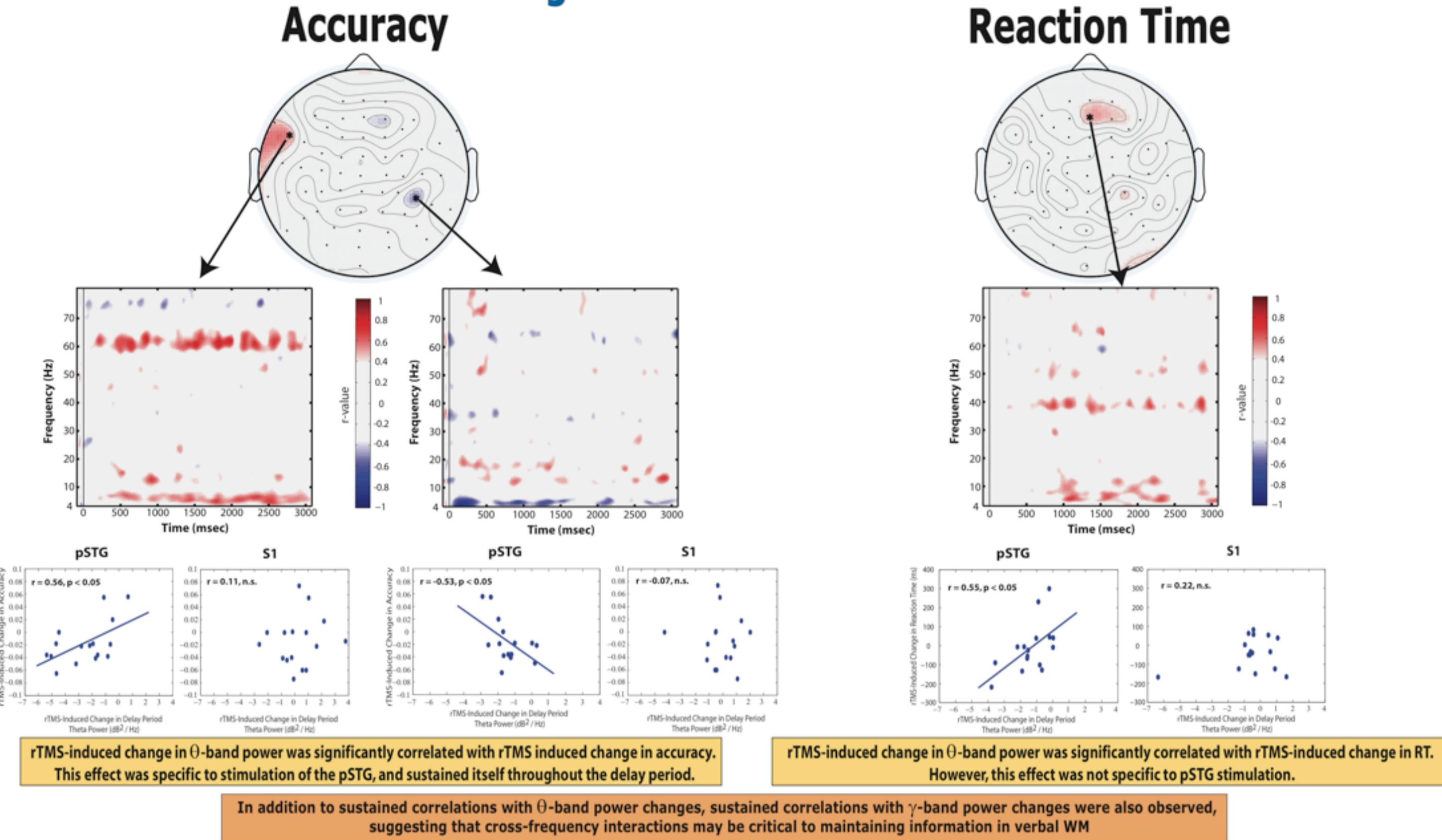
rTMS-Induced Change in Delay Period Spectral Power

pSTG (rTMS on-off) S1 (rTMS on-off)

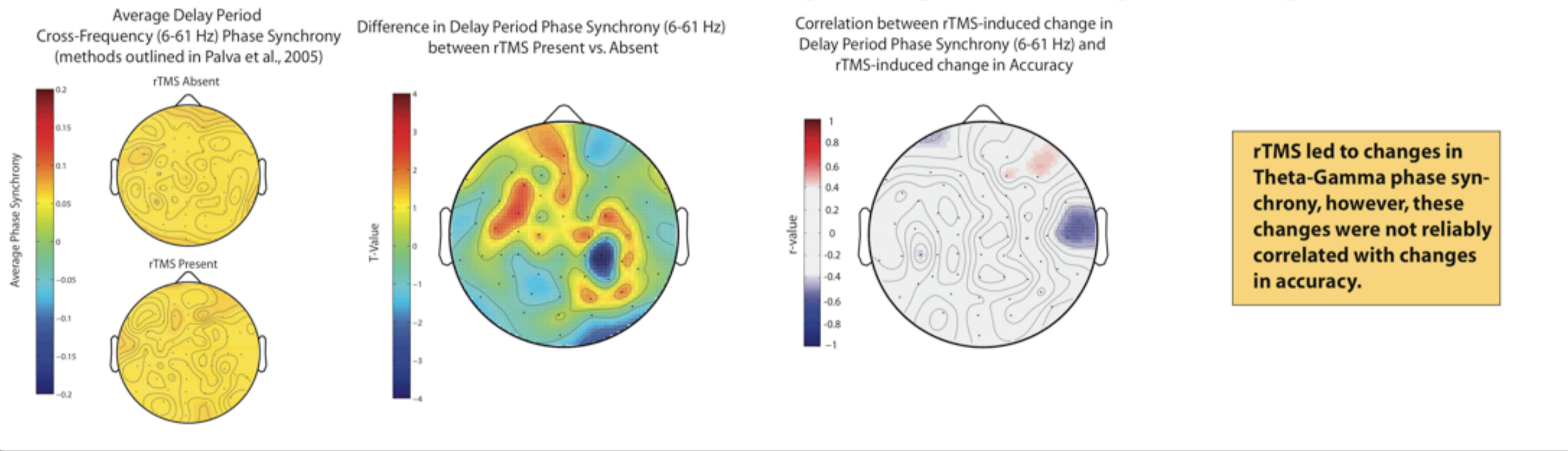


Effect of rTMS on delay-period spectral power was specific to the region involved in the task: RTMS of the pSTG led to a decrease in θ -band power; no such effects were observed for rTMS of S1.

Correlation between the rTMS-induced change in Behavior and rTMS-induced change in Theta-band Power



Effects of rTMS on Cross-Frequency Phase Synchrony



Conclusion

1. rTMS to the pSTG but not S1 (control) led to decreases in Theta-band power
2. Individual differences in rTMS-related changes in power predicted individual differences in behavior. These correlations were in different frequency bands than what would have been predicted based on:
 - a. the rTMS-absent condition (here and in Jensen et al., 2002)
 - b. rTMS studies of visuo-spatial WM literature (e.g., Hamidi et al., 1999)
3. The changes in accuracy induced by rTMS do not appear to be a result of changes in cross-frequency phase synchrony
4. Effects of rTMS are neither overlapping with nor in harmonics of the frequency of stimulation, suggesting that the effects of stimulation are biasing rather than entraining (see Johnson et al., 2010)

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