Investigating the Effects of rTMS to Perisylvian Brain Regions during Verbal Working Memory Task Performance with EEG

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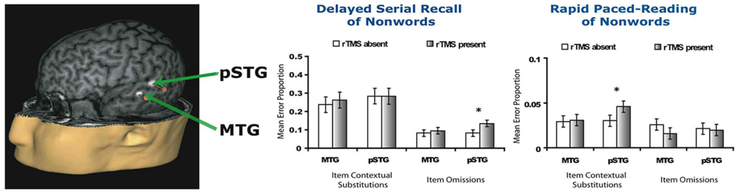
Background

- RTMS to a region associated with the serial ordering of speech sounds in language production (posterior superior temporal gyrus; pSTG), but not a lexical-semantic control region (middle temporal gyrus; MTG), induces errors in verbal working memory and language production tasks (Acheson et al., 2008)



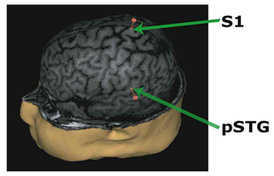
- Maintenance in verbal working memory has been related to neuronal oscillations in three frequency bands: Theta (θ; Gevins et al., 1997; Jensen & Tesche, 2002); Alpha (α; Jensen et al., 2002; Klimesch et al., 1999); Gamma (γ; Jokisch & Jensen, 2007)
- RTMS effects on visual working memory performance are related to changes in neuronal oscillations (Hamidi et al., 2009)

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

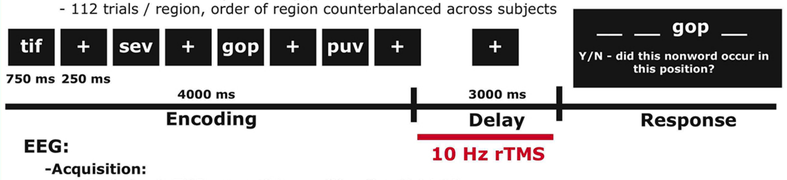
Methods - fMRI-guided rTMS with EEG

Subjects: 14 native English speakers (7 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 7:00
- **Definition of pSTG:** Regions showing sensitivity to parametric manipulation of word frequency (Graves et al., 2007)



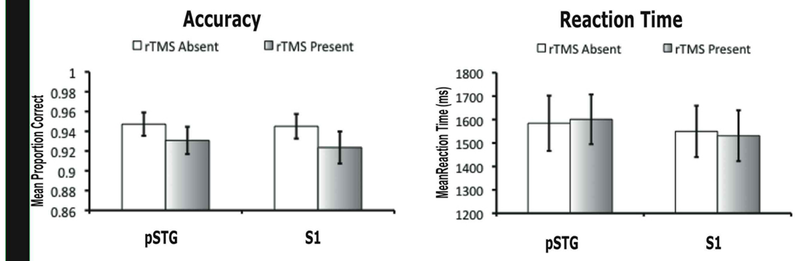
RTMS:
- **Regions Targeted:** pSTG and the leg area of somatosensory cortex (S1; control)
- **Stimulation:**
  - Each subject's head was coregistered with his/her MRI using eXimia Navigated Brain Stimulation (NBS) frameless stereotaxy navigation system (NEXSTIM)
  - 10 Hz rTMS done at 110% MT - Magstim Standard Rapid, Whitland, UK
  - Stimulation intensity was corrected for scalp-to-cortex distance (Stokes et al., 2005)
- **Task:** Delayed, serial recognition of nonwords
  - 4 nonwords presented individually at a rate of 1 / second
  - 3 second delay period followed by a Yes/No recognition probe
  - rTMS delivered during the delay period (30 pulses), randomly on half of the trials
  - 112 trials / region, order of region counterbalanced across subjects



EEG:
- **Acquisition:**
  - 60-electrode TMS-compatible cap (Nexstim, Helsinki)
  - Sample-and-hold circut minimized TMS-induced electrical arifact by holding amplifier output constant from 100 μS pre to 2 ms post-TMS pulse (Virtanen et al., 1999)
  - Data acquired at 1450 Hz, flitered (0.1 to 100 Hz) and down-sampled to 500 Hz
- **TMS Artifact removal**
  - Performed separately for each brain area and subject
  - 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

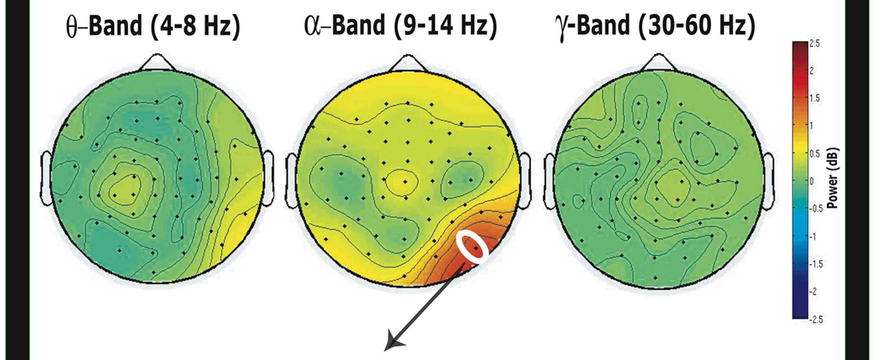
Results

Behavior

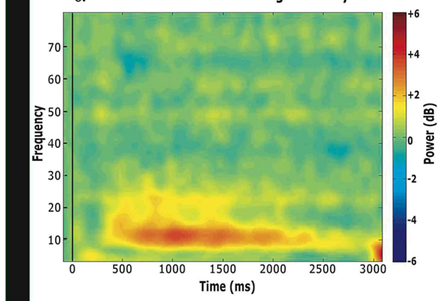


No significant behavioral effects were observed, however, there was a trend towards a main effect of TMS on mean accuracy ($F(1,13) = 3.73$ $p=0.07$)

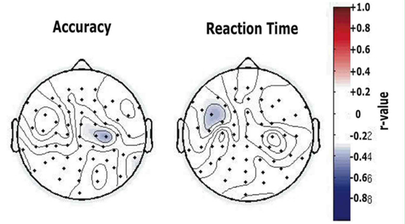
Delay Period Spectral Power vs. Baseline - no TMS



α-Band Power Sustained during the Delay Period

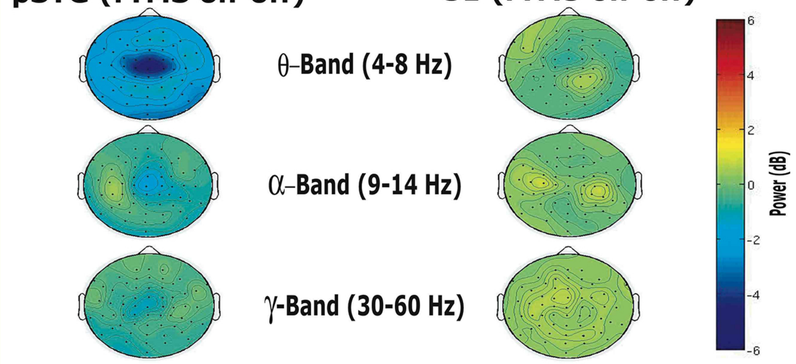


Correlation between Mean α-Band Power during the Delay Period and Mean Behavioral Performance



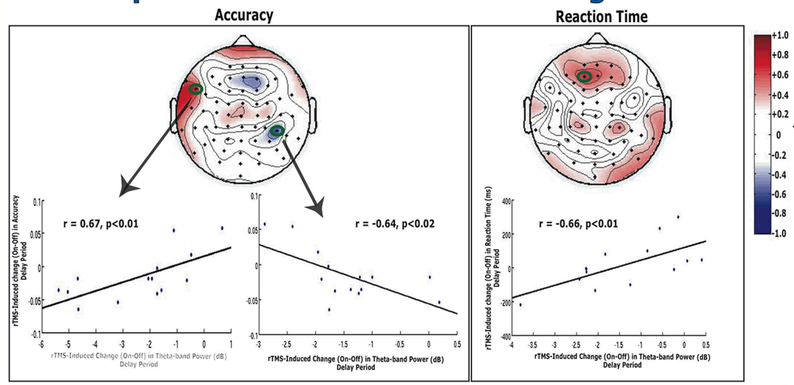
An increase in α-band power was observed during the delay period, however, this did not correlate significantly with behavioral performance

rTMS-Induced Change in Mean Spectral Power during the Delay Period



Effect of rTMS on spectral power was specific to the region involved in the task: RTMS to the pSTG led to a decrease in Theta; no such effects were observed for stimulation to S1

Correlations between rTMS-Induced Change in Mean Θ-Band power and rTMS-Induced Change in Behavior



F7: Decrease in Θ-band power led to decrease in accuracy
P4: Decrease in Θ-band power led to increase in accuracy

F3: Decrease in Θ-band power led to decrease in reaction time

Conclusions

1. In line with previous research, posterior α-band power increased during the delay period, however, this increase was not correlated with behavior
2. rTMS to the pSTG but not S1 (control) led to decreases in Θ-band power, and this decrease was correlated with accuracy and reacting time in delayed serial recognition
3. Disruptive effects of rTMS on working memory performance may come from modulating task-relevant oscillations

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