Delay-period neuronal oscillations are modulated by 10 Hz rTMS: A Simultaneous rTMS/EEG Study

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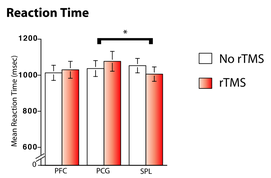
Introduction

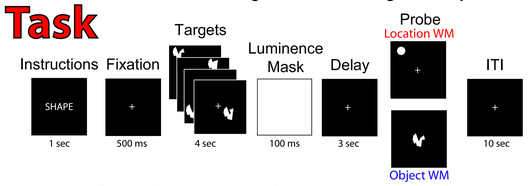
- Previous data have shown that SPL is more sensitive to 10 Hz **delay-period** rTMS than is PFC (Hamidi et al., submitted):
- The change in behavior with rTMS was **facilitatory**.
- TMS has been shown to alter neuronal oscillations (Fuggetta et al., 2007).
- Retention of information in working memory has been associated with an increase α-band (8.5-13.5 Hz) power (Jensen et al., 2002).



Does working memory-related α-band activity correspond to:
- inhibition of irrelevant brain activity (Jokisch and Jensen, 2007)?
- active support of working memory (Palva and Palva, 2007)?

- Working memory is also associated with changes in θ (4-8 Hz) (Meltzer et al., 2007) and γ (40-80 Hz) (Tallon-Baudry et al., 1998) oscillations.
- We used simultaneous rTMS and EEG to study the effect of rTMS on neuronal oscillations during tasks of working memory.

Task



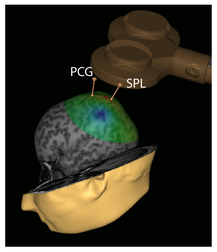
- Target: 4 abstract shapes (Arnoult and Attneave, 1956) presented one at a time (for 1 sec) at random locations, one in each quadrant of the screen.
- Probe: required Y/N recognition decision; matched a target location or shape with p=0.5.
- Location and object memory trials were randomly interleaved.

EEG

- Data were recorded with a 60-electrode TMS-compatible cap (Nexstim, Helsinki).
  - sample-and-hold circuit minimizes TMS-induced electrical artifact by holding amplifier output constant from 100 μs pre- to 2 ms post-TMS pulse (Virtanen et al., 1999).
  - Data acquired at 1450 Hz, filtered (0.1 to 500 Hz) and down-sampled to 500 Hz.

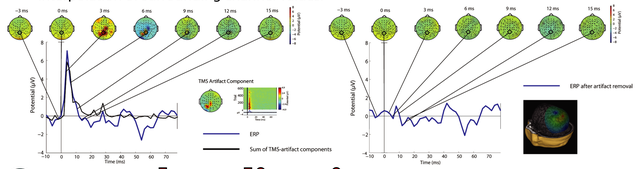
rTMS

- Each subject's head was coregistered with his/her MRI using eXimia Navigated Brain Stimulation (NBS) frameless stereotaxy navigation system (Nexstim).
- rTMS (10 Hz, 110% MT, 3 sec. - Magstim Standard Rapid, Whitland, UK) coincided with the onset of the delay-period on half the trials (randomly distributed).
- Stimulation intensity was corrected for scalp-to-cortex distance (Stokes et al., 2005).
- Location of targets determined by individual anatomy.
- Postcentral gyrus (PCG) served as a stimulation control area



TMS Artifact Removal

- Artifact removal performed separately for each brain area targeted and for each subject.
- Residual rTMS-related artifact removed through two rounds of ICA.
  - 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 only and any components associated with residual rTMS artifacts identified and removed.
- If any channels still contained rTMS artifact, the channel was removed and reconstructed using interpolation of surrounding channel values.

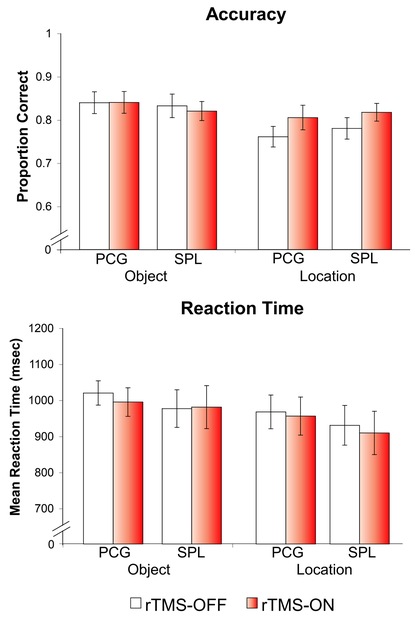


Source localization

- LORETA-KEY (Pascual-Marqui, et al., 1999) software used to produce source estimates of delay-period oscillatory activity.
- Source estimation performed in middle 2 secs of 3-sec delay-period.

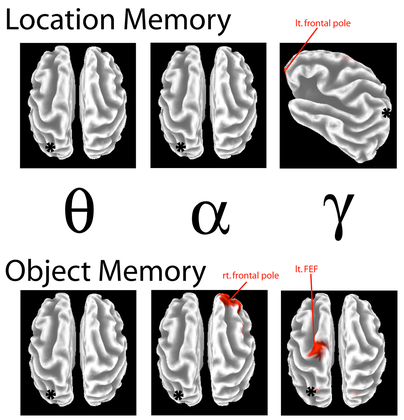
Results

N = 14



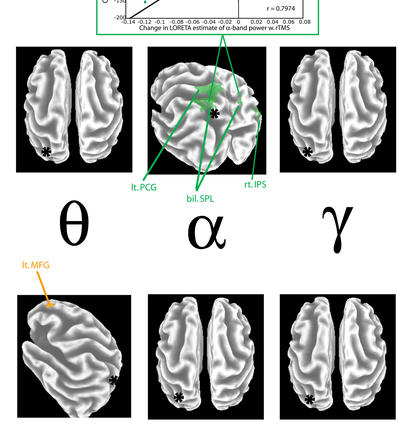
Delay-Period Source Estimate

Change with rTMS



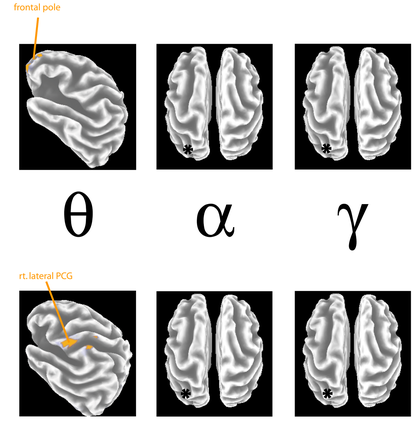
paired t-test: $p<0.005$

Correlation with RT



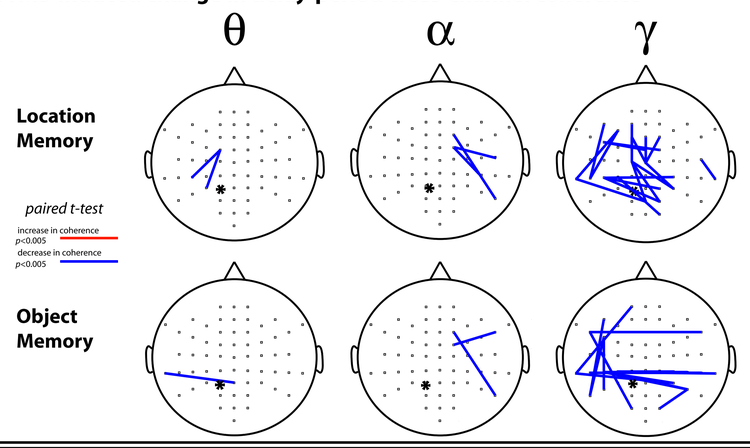
- $r < -0.703$; $p < 0.005$, RT decreases (faster response) with an increase in power.
- $r > 0.703$; $p < 0.005$, RT increases (slower response) with an increase in power.

Correlation with Accuracy

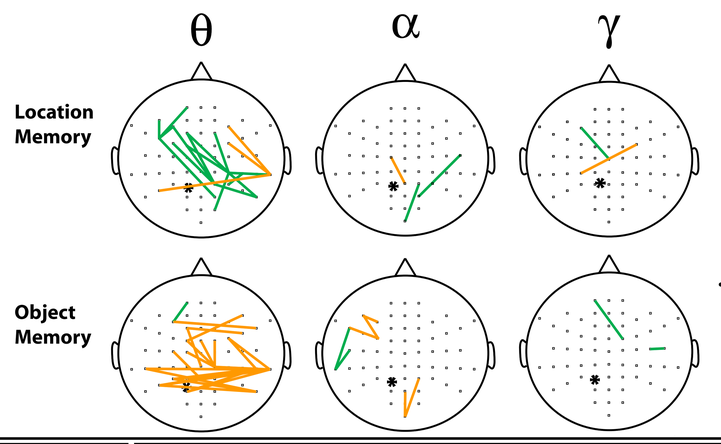


- $r < -0.703$; $p < 0.005$, RT decreases (faster response) with an increase in power.
- $r > 0.703$; $p < 0.005$, RT increases (slower response) with an increase in power.

rTMS-induced change in delay-period cross-channel coherence

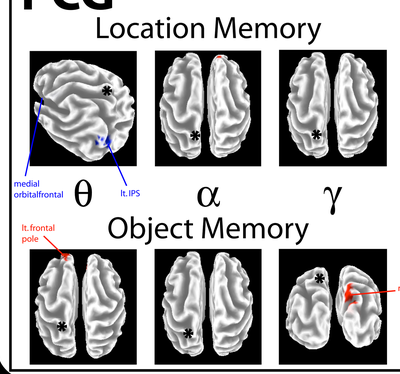


Correlation between change in coherence and change in behavior



- Change in θ-band cross-channel coherence is correlated with change in behavior
  - increased θ-band coherence slows RT in spatial trials and speeds up RT in object trials.

PCG



- In spatial memory trials, an increase in θ-band power in occipital cortex is associated with faster RT.
- In object memory trials, an increase in θ-band power in the right lateral PCG is associated with faster RT.
- No correlations with α- or γ-band power and no correlations between change in oscillatory power and accuracy.
- PCG rTMS has no reliable effect on coherence at any frequency-band and there is no correlation between change in coherence and change in behaivor at any frequency band.

Conclusions

- With rTMS to SPL, change in α-band power is positively correlated with slower performance
  - consistent with functional inhibition interpretation of α-band oscillations
- 10 Hz delay-period rTMS affects power at θ, α, and γ-bands
  - Effect is often distant to the location of stimulation
  - Effect varies across subjects
  - Effect differs with the type of information being kept in memory
- 10 Hz delay-period rTMS to the SPL leads to a general decrease in cross-channel coherence, most prominently in the γ-band.
- rTMS-evoked change in θ-band coherence correlates with change in task performance
  - the direction of this correlation differs with spatial vs. object memory.
- These results suggest a method for untangling the contribution of oscillations at various frequencies to working memory performance.

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