The role of neuronal oscillations in retention of information in working memory

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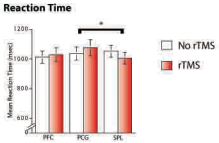
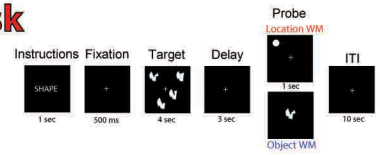
Introduction

- Previous data have shown that SPL is more sensitive to **delay-period** rTMS than is PFC (Hamidi et al., submitted):



- The change in behavior with rTMS is **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 in α-band (9-12 Hz) power (Jensen et al., 2002).
  - α-band power increases with increasing memory load
  - the increase in α-band power depends on the type of information being held in memory (Jokisch and Jensen, 2007).
- We use simultaneous rTMS and EEG to determine whether facilitation of working memory with parietal stimulation is associated with changes in neuronal oscillations.

Task

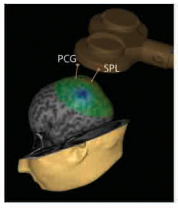


- Target: 4 abstract shapes (Arnoult and Attneave, 1956) presented one at a time (for 1 sec) at random locations, one in each quadrant of the screen.
- Probe: required Y/N recognition decision; matched a target location or shape with p=0.5.
- Location and object memory trials were randomly interleaved.

EEG

- Data were recorded with a 60-electrode TMS-compatible cap (Nexstim, Helsinki).
  - sample-and-hold circuit minimizes TMS-induced electrical artifact by holding output of the amplifier constant from 100 μs pre- to 2 ms post-TMS pulse (Virtanen et al., 1999).
  - Impedance for each electrode was kept below 3 kΩ.
  - Data sampled at 1450 Hz.
  - Prior to analysis data were filtered (0.1 to 500 Hz) and down-sampled to 500 Hz.

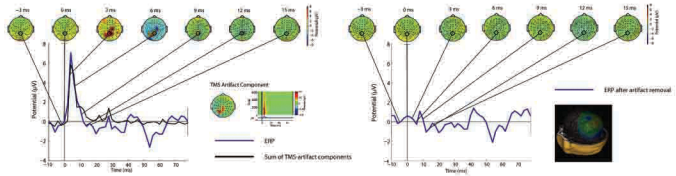
rTMS



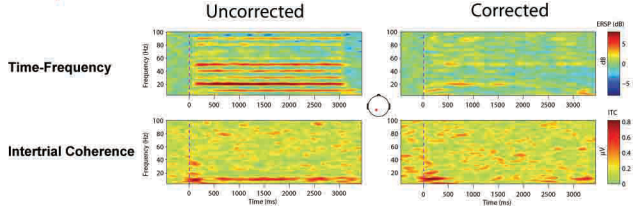
- Each subject's head was coregistered with his/her MRI using eXimia Navigated Brain Stimulation (NBS) frameless stereotaxy navigation system (Nexstim).
- rTMS (10 Hz, 110% MT, 3 sec. - Magstim Standard Rapid, Whitland, UK) coincided with the onset of the delay-period on half the trials (randomly determined order).
- 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

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.
  - Data from 1 sec before the onset of the delay-period until 1 sec after the onset of the probe isolated.
  - Trials with signal outside a threshold value (usually ±60 μV) removed.
  - 2nd round of ICA performed 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.

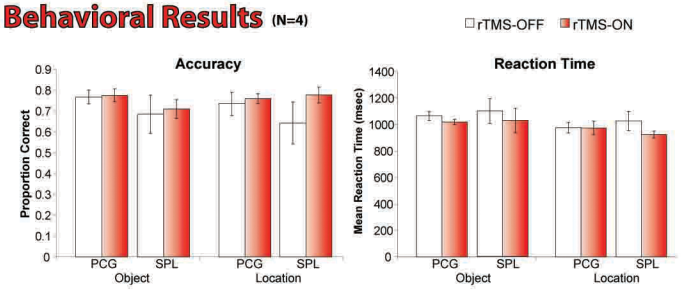


Removal of TMS artifact in a representative subject.

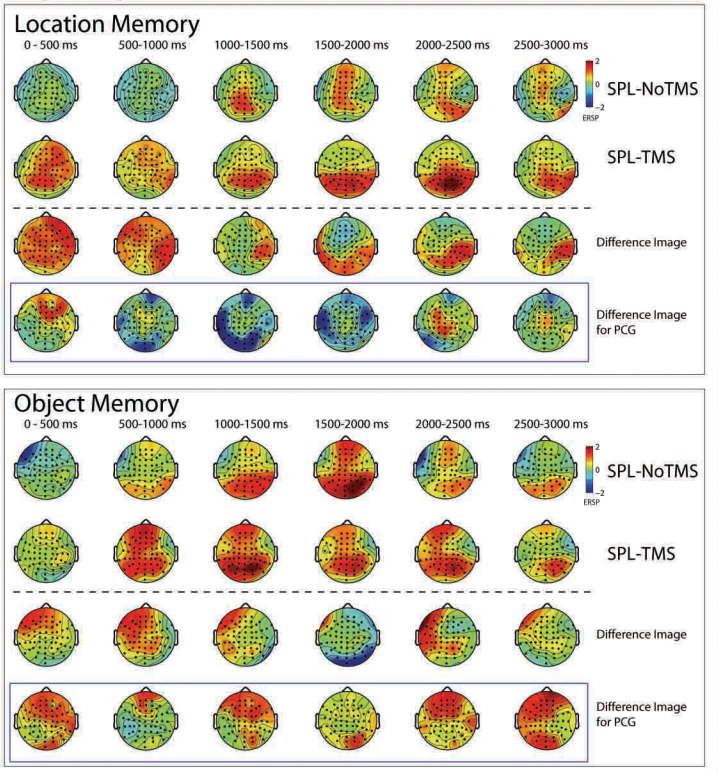


Time-frequency and intertrial coherence plots from the electrode closest to the rTMS target.

Behavioral Results (N=4)



Alpha power



Conclusions

- The results further replicate that parietal rTMS can improve performance on spatial cognitive tasks (Klimesch et al., 2003; Luber et al., 2007; Hamidi et al., submitted).
- These results also provide first evidence that rTMS-related improvement is associated with changes in neuronal oscillations.
  - Specifically, rTMS leads to a sustained increase in α power over right posterior electrodes. Further work required to determine whether critical feature of this effect is in right hemisphere, per se, or contralateral, vis-a-vis coil placement.
  - Effect is regionally specific (no effect of PCG rTMS) and task-specific (no effect of rTMS on object memory trials).
- This method may be effective in determining the function of α in working memory.
  - e.g., suppression (Jensen et al., 2002) vs. coherence/binding (Palva and Palva, 2007) vs. inhibition of retreival (Klimesch et al., 2004).

Arnoult, M.D. and Attneave, F. (1956) "The quantitative study of shape and pattern perception." Psychological Bulletin, 53(6): 452-471.
Fuggetta, G. et al. (In Press) "Acute modulation of cortical oscillatory activities during short trains of high-frequency repetitive transcranial magnetic stimulation of the human motor cortex: A combined EEG and TMS study." Human Brain Mapping.
Hamidi, M. et al. (Submitted) "Evaluating Frontal and Parietal Contributions to Spatial Working Memory with Repetitive Transcranial Magnetic Stimulation."
Jensen, O. et al. (2002) "Oscillations in the Alpha Band (9-12 Hz) Increase with Memory Load during Retention in a Short-term Memory Task" Cereb. Cortex, 12(8): 877-882.
Jokisch, D. and Jensen, O. (2007) "Modulation of Gamma and Alpha Activity during a Working Memory Task Engaging the Dorsal or Ventral Stream." J Neurosci., 27(12): 3244-3251.
Klimesch, W. et al. (2003) "Enhancing cognitive performance with repetitive transcranial magnetic stimulation at human individual alpha frequency." Eur. J. Neurosci. 17(5): 1129-1133.
Luber, B. et al. (2007) "Facilitation of performance in a working memory task with rTMS stimulation of the precuneus: Frequency- and time-dependent effects." Brain Res. 1128(1): 120-129.
Palva, S. and Palva, J. M. (2007) "New vistas for α-frequency band oscillations." Trends in Neurosciences, 30: 150-158.
Stokes, M.G. et al. (2005) "A simple metric for scaling motor threshold based on scalp-cortex distance: Application to studies using transcranial magnetic stimulation." J. Neurophysiol. 94(6): 4520-4527.
Virtanen, J. et al. (1999) "Instrumentation for the measurement of electric brain responses to transcranial magnetic stimulation." Med Biol Eng Comput., 37(3): 322-326.

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