Evaluation of the contributions of the frontal and posterior parietal cortices in spatial working memory with repetitive transcranial magnetic stimulation

Massihullah Hamidi¹, Giulio Tononi², Bradley R. Postle¹
1. Department of Psychology, University of Wisconsin - Madison, 2. Department of Psychiatry University of Wisconsin - Madison

Introduction
- Working memory refers to the ability to maintain information in an active state when it is no longer present in the environment.
- The relative contributions of the dorsolateral prefrontal cortex (dLPFC) and posterior cortical areas to the retention of information in spatial working memory are the focus of considerable interest and debate (e.g., Goldberg-Rakic & Leung, 2002; Curtis & D’Esposito, 2003).
- We tested the necessity of the dLPFC, frontal eye fields (FEF) and 2 posterior areas for the retention of spatial information in working memory by targeting each area with high frequency repetitive transcranial magnetic stimulation (rTMS).
- rTMS allows for within-subject comparison of performance with and without disruptive rTMS applied to the area in question (Pascual-Leone et al., 2000).

Subjects & Methods
- 50 right-handed healthy subjects participated.
- 1st session - Screening and Training
  - Subjects were trained on the task to achieve an accuracy of at least 70%.
- 2nd session - MRI
  - High-resolution anatomical volumes acquired for all subjects.
- 3rd session - rTMS
  - Subjects completed 4 blocks of the task for each brain area targeted with rTMS.
  - 10 subjects were stimulated in the left hemisphere, in the intraparietal sulcus (IPS) and the PCG.
  - 12 subjects were stimulated in the right hemisphere in 12 subjects.

Targets of rTMS
- Experiment 1 (20 subjects): rTMS was applied to the FEF, superior parietal lobule (SPL), and as a control, the post-central gyrus (PCG).
- rTMS was applied to the left hemisphere in 18 subjects, and the right hemisphere in 12 subjects.
- Experiment 2 (20 subjects): rTMS was applied to the FEF, intraparietal sulcus (IPS) and the PCG.
- 10 subjects were stimulated in the left hemisphere, 10 in the right hemisphere.
- The order of region to which rTMS was applied was counterbalanced across subjects.

rTMS
- TMS pulses were delivered via Magstim Standard Rapid (Magstim Co., Whithand, UK) 70 mm air-cooled figure-eight coil.
- Each subject’s head was co-registered with his/her MRI using Xmesh NBS frameless stereotactic navigation system (Neusys, Helsinki, Finland).
- Targets of rTMS guided by individual subject’s anatomy.
- rTMS (10 Hz, 1100 MT, 3 seconds) coincided with the delay period on 50% of the trials (randomly determined order).
- Stimulation intensity was corrected for scalp-to-cortex distance using xMesh NBS’s calculation of induced electric field potential.

Task
- Target: four circles (1 degree of visual angle in diameter) presented at random locations, one in each quadrant of the screen.
- Probe: required Y/N recognition decision; matched a target location with 0.5; invalid probes were offset from the nearest target location by an average of 3.08 (S.D. = 0.4) deg along one of the 8 cardinal or ordinal axes.

Conclusions
- No evidence for a role of dIPFC in spatial working memory storage.
- Privileged role for parietal cortex in spatial working memory.
- rTMS has paradoxical region-specific effects on working memory, with rTMS of the parietal cortex making responses faster and leaving accuracy relatively unchanged.
- Spatial working memory is supported by a broadly distributed cortical network.
- rTMS has a global effect of decreasing accuracy and making subjects more likely to give a Yes response.