Effect on spatial working memory of repetitive transcranial magnetic stimulation of the dorsolateral prefrontal cortex and superior parietal cortex

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 parietal cortex (PPC) to the retention of information in spatial working memory are of considerable interest and debate (e.g., Goldman-Rakic, 1987; Curtis and D’Esposito, 2003).
- We tested the necessity of the dIPFC and PPC for the retention of spatial information in working memory by targeting these two regions 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 (Passarino Leone et al., 2000).

Subjects & Methods

- 25 right-handed healthy subjects (mean age ±23 years, S.D.=5.3); passed psychiatric screening.
- 1st session - Screening and Training
  - Subjects were trained on the task to achieve an accuracy of at least 75%.
- 2nd session - MRI
  - High-resolution anatomical volumes acquired for all subjects.
  - For 7 subjects, fMRI of task performance also acquired.
- 3rd session - rTMS
  - Subjects performed 4 blocks of the task for each brain area stimulated: middle frontal gyrus of the dIPFC, superior parietal lobule (SPL) of the PPC, and a region of post-central cortex (dlPFC) and posterior parietal cortex (PPC) to the left hemisphere.

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 y=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.

fMRI Results

- Delay-period evoked activity in a representative subject.
- fMRI activity associated with the delay period.
- fMRI-identified activity in the superior parietal lobule (SPL) of the PPC, and a region of post-central cortex (dlPFC) and posterior parietal cortex (PPC) to the right hemisphere (2 fMRI-guided).

MRS

- fMRI data was acquired on a 3T scanner (GE Signa VHT).
- High-resolution anatomical T1-weighted images (248 slices, 0.5 mm x 0.5 mm x 0.8 mm) were obtained for all participants.
- For 7 participants, a gradient echo, echoplanar sequence was used to measure the BOLD response while performing the delayed-recognition task.
- Maps of delay-period activity were merged with the anatomical image in a representative subject.

TMS

- TMS pulses were delivered via Magstim Standard Rapid (Magstim Co., Whitland, UK) 70 mm air-cooled figure-eight coil.
- Each subject’s head was registered with his/her MRI using eXimia NBS frameless stereotaxic navigation system (Nexstim, Helsinki, Finland).
- MRI-guided study - rTMS guided by anatomy.
- fMRI-guided study - rTMS targeted delay-period activity.
- tRMS (10 Hz, 110% 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 grid maps of scalp-to-cortex distance and internal electric field potential.
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- The order of region to which tRMS was applied was counterbalanced across subjects.
- 17 subjects were stimulated in the left hemisphere (5 fMRI-guided), 13 in the right hemisphere (2 fMRI-guided).

TMS Results

- All Subjects (N=25): Accuracy:
  - Repeated measures ANOVA on accuracy: tRMS (no tRMS) x Brain area
  - A main effect of stimulation: TMS (rTMS, no tRMS) x Brain area: TMS (rTMS, no tRMS) x Brain area (dlPFC, PCG, SPL)
  - No main effect of area of stimulation: TMS (rTMS, no tRMS) x Brain area
  - No interaction of Brain area xTMS
  - A main effect of stimulation
  - Repeated measures ANOVA on reaction time:
  - A main effect of stimulation
  - No evidence of regionally specific effect of tRMS on accuracy.
  - No evidence of regionally specific effect of tRMS on reaction time.
  - A reliable Brain area x TMS interaction

Conclusions

- No main effects of hemisphere stimulated: middle frontal gyrus of the dIPFC, superior parietal lobule of the PPC, and a region of post-central cortex of the dlPFC, superior parietal cortex.
- Significant interaction of tRMS x hemisphere stimulated: F(1,23)=12.32, p<0.001.
- A main effect of hemisphere stimulated: F(2,46)=11.01, p<0.001.
- A main effect of brain area stimulated: F(2,46)=8.30, p<0.001.

References