Congruence between BOLD activation pattern and the maximal suppression effect by TMS during a simple visual discrimination task

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Problem

In Transcranial Magnetic Stimulation (TMS), strong magnetic pulses delivered by a coil placed over the subject's head are used to induce neural activity in a focal area of the brain. TMS can be used to demonstrate a causal relationship between behavior and the neural processing in a brain structure of interest by showing that a subject's task performance is diminished during TMS stimulation of that structure (i.e., the "virtual lesion" approach; e.g., Walsh & Rushworth, Neuropsych, 1999). An important question is how well the position of the maximal TMS effect coincides with the brain activation pattern observed during the task using other neuroimaging techniques such as fMRI or PET. Up to now, measurements on the motor cortex have demonstrated an agreement in the range of up to 1 cm (Classen et al, J Physiol, 1998). However, it is important to determine how well these results carry over to the rest of the brain. Here, we determined the coil position causing the maximal TMS effect in a simple visual discrimination task and compared it with the BOLD activation pattern caused by the visual stimulus.

Methods

A 4-AFC task was used in which subjects had to indicate the direction of a parafoveally flashing hook. By applying a TMS pulse over early visual areas approx. 90 ms after stimulus presentation the recognition performance in each of the 4 subjects could be significantly reduced ("visual suppression" effect; Amassian et al, Clin Neurophys, 1989, Kammer et al, Exp Brain Res, 2005). The exact timing of the TMS pulse, its strength and the initial coil position were individually determined in pre-experiments so that performance was around 50%. Starting with the initial position, the coil was positioned at equidistant grid points (7 mm spacing) and moved outwards until performance reached 100% again. At each coil position, the subject's performance was accessed using 40 trials. In addition, 10 control trials in which the stimulus was presented in the opposite visual hemifield were used to check for the subject's fixation and fatigue. Coil position was controlled by a neuronavigation system (BrainView, IPA Stuttgart, Germany).
In the fMRI experiment, blocks in which randomly oriented hooks were continuously parafoveally flashed were compared against baseline (blank screen with fixation cross). Altogether 4 activation and 4 baseline blocks of 30 sec each were used (EPI with TR/TE = 1.5sec/35ms at 3T; 19 coronal slices, 3x3x3 mm voxel size, FOV 192x192 mm). Finally, the center of gravity of the TMS map was compared with the fMRI activation.

Results

In all 4 subjects, the spatial pattern of the TMS effect was smooth and the coil positions at which the maximal suppression occurred were located next to each other. This indicates that the TMS target was probably a single continuous brain structure and not, e.g. two or more separate sub-areas. The CoG of the TMS map was consistently positioned over the inferior part of the superior occipital gyrus. As expected, the fMRI activation pattern was rather extended and covered several visual areas. The TMS CoG was consistently located over the medial-inferior part of the fMRI activation.

Conclusion

The results show that the position of the maximal TMS effect is in good accordance with a specific part of the BOLD activation pattern. The location corresponds to early visual areas V1 or V2. However, visual mapping is needed to more exactly delineate the target site of TMS. While fMRI is capable of characterizing the general pattern of brain areas activated in a certain task, TMS has the potential to specifically localize the areas which are most critical for the task.

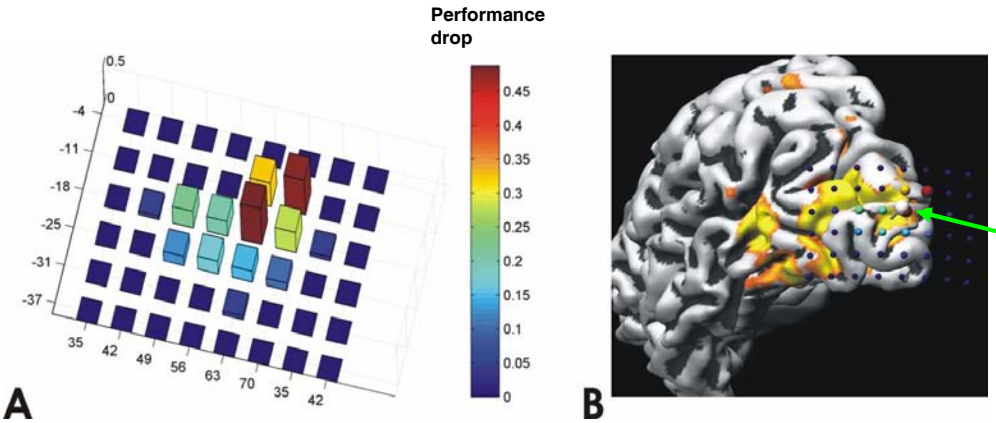

Fig. 1: Results for one typical subject. (A) Performance dependence on the coil position (B) TMS grid superimposed on the fMRI activation ($p< 10^{-6}$ uncorrected) of the left hemisphere (view from posterior).
The TMS CoG is shown as white dot with the line projecting to the closest point on the cortex.