The Contributions of LO1, LO2 and V5/MT to the discrimination of speed and orientation of drifting gratings

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Introduction:

Lateral Occipital Cortex contains multiple retinotopically organized regions [1], including V5/MT, LO1 & LO2 [2]. Previous work demonstrated that TMS of these regions selectively disrupted speed, orientation and shape processing, respectively [3-4] Figure 1.

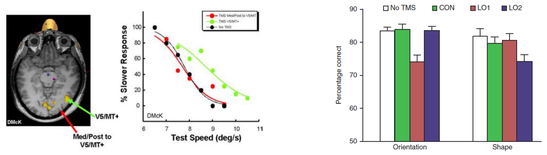

Figure 1: Effects of TMS of V5/MT on speed discrimination **(left)**. Effects of TMS of LO1 & LO2 on orientation and shape discriminations **(right)**.

Previous work tested stimulus features in isolation only. Here we investigated the effects of TMS to these target regions on (1) orientation and speed discrimination in isolation, to confirm previous work and (2) when these stimulus features were combined.

Predictions:

1. TMS of V5/MT will disrupt speed discrimination.
2. TMS of LO1 will disrupt orientation discrimination.
3. A double dissociation will be present between V5/MT & LO1 (experiment 1).
4. If LO1's orientation selectivity is cue-invariant, TMS of LO1 will disrupt orientation discrimination of drifting gratings (experiment 2).

Methods:

Retinotopic Mapping

Conventional phase-encoded retinotopic mapping sessions using 100% contrast flickering chekerboard stimuli were completed by all subjects (n = 12) Figure 2.

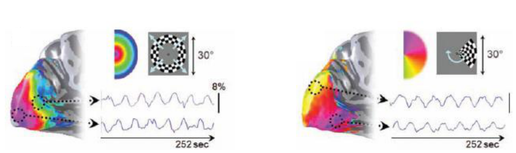

Figure 2: Example responses during eccentricity (left) and polar angle (right) mapping procedures.

fMRI sessions were conducted on a GE 3T scanner at 3mm isotropic resolution. Retinotopic data were analyzed using mrVista, part of the VISTA software package (http://white.stanford.edu/newlm/index.php/MrVista). Anatomical data were segmented into gray and white matter volumes using freesurfer (http://surfer.nmr.mgh.harvard.edu) .

Methods:

V5/MT Identification

V5/MT was defined anatomically, located within the ALITS, in each subject following published guidelines [5]. Functional definitions using fMRI were possible in a subset of subjects (n = 4): Figure 3.

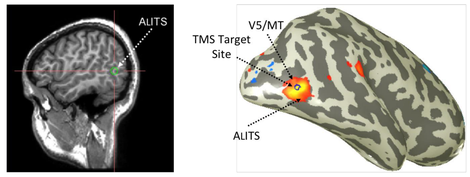

Figure 3: Anatomical definition of V5/MT in the right hemisphere of a single subject **(left)**. Functionally defined V5/MT **(hot region)** on surface reconstruction of the same subject **(right)**, with the anatomical target outlined **(blue circle).**

Psychophysics

Individual speed and orientation discrimination thresholds were measured in each subject using the method of constant stimuli (experiment 1). These thresholds were combined during experiment 2: Figure 4.

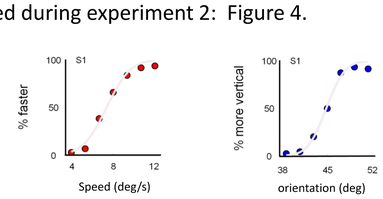

Figure 4: Psychometric functions for speed **(left)** and orientation **(right)** discrimination for a single subject. Thresholds used in TMS sessions were derived from these functions.

TMS

TMS pulses were delivered to our cortical targets whilst subjects performed speed and orientation discriminations at threshold: Figure 5.

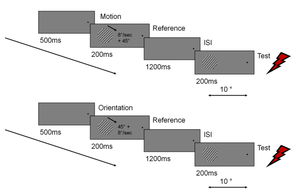

Figure 5: Trial structure schematics for speed **(left)** and orientation **(right)** discrimination TMS sessions during experiment 2. 4 biphasic TMS pulses (70 % max output) were delivered simultaneously with presentation of test stimuli **(red lightening bolts)**.

The spatial relationships between the TMS coil and our cortical targets were also recorded with each pulse train: Figure 6

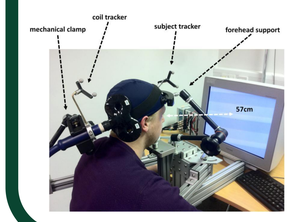

Figure 6: TMS set-up. Subjects sat in a purpose built chair with chin and forehead support. Both subject and coil were tracked in real time, allowing us to measure the spatial relationships between TMS coil and our cortical targets.

Results:

LO1 & LO2 were identifiable in all subjects in at least one hemisphere. Centroids of LO1 & LO2 were used as TMS targets as previously [4]: Figure 7.

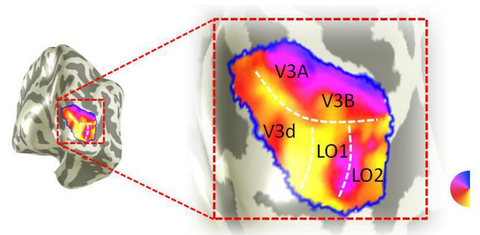

Figure 7: Polar angle representations in LO1 & LO2 and neighbouring regions of a representative subject.

Orientation discrimination of static and speed discrimination of drifting gratings

There was a highly significant site by task interaction ($F_{(4,20)}$ = 11.926, p = 0.0001). Two effects drove the interaction: **(1)** A significant reduction in orientation discrimination, compared to all other conditions, resulted from stimulation of LO1 and **(2)** A significant reduction in speed discrimination, compared to all other conditions, resulted from stimulation of V5/MT. Figure 8.

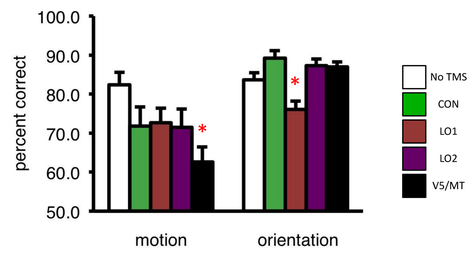

Figure 8: Effects of TMS during speed **(left)** and orientation **(right)** discriminations. TMS of V5/MT significantly disrupted speed discriminations; whereas TMS of LO1 significantly disrupted orientation discrimination – a double dissociation.

TMS of V5/MT alone induced a significant bias towards slower moving stimuli. Replicating a perceptual bias following TMS of V5/MT reported previously [3]: Figure 9.

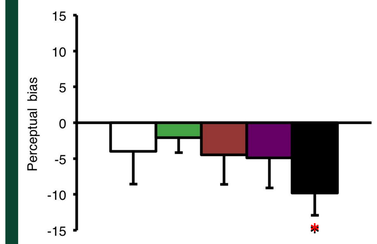

Figure 9: Response biases induced by TMS during speed discrimination. TMS of V5/MT only caused a significant bias towards slower moving stimuli (red asterisk).

The significant disruptions to performances were not due to either speed-accuracy trade-offs or imprecision in TMS delivery across tasks or target sites. These analyses were conducted as reported in [4]

Results:

Orientation and speed discrimination of drifting gratings

There was a significant site by task interaction, although of note this interaction was weaker than in experiment 1 ($F_{(4,20)}$ = 3.415, p = 0.016). Post-hoc pairwise comparisons failed to reveal significant differences. However, when considering V5/MT and LO1 ROIs only, two patterns could account for the interaction. **(1)** Speed discriminations were maximally disrupted following TMS of V5/MT and **(2)** TMS of LO1 maximally disrupted orientation discriminations – consistent with experiment 1. Figure 10.

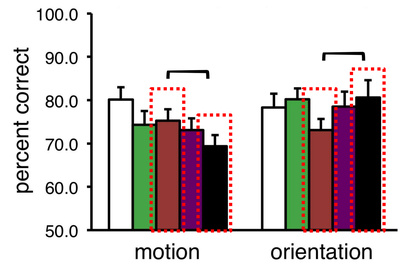

Figure 10: Effects of TMS during speed **(left)** and orientation **(right)** discriminations. TMS of V5/MT maximally disrupted speed discriminations; whereas TMS of LO1 maximally disrupted orientation discrimination. Considering V5/MT & LO1 alone reveals a double dissociation **(red dashed boxes).**

Effects of TMS not due to either speed-accuracy trade-offs or imprecision in TMS delivery across tasks or target sites.

Discussion:

- Experiment 1 demonstrated a double dissociation between V5/MT & LO1 during speed and orientation discriminations. Direct replication of previous work [3-4].
- V5/MT specialized for speed perception [3].
- LO1 specialized for orientation perception [4].
- LO2 not involved in either speed or orientation perception [2].

- Experiment 2 showed a consistent, but markedly weaker pattern of results.
- Direction of motion and orientation provide cues for orientation. These features are likely represented in different areas (V5/MT & LO1), which may explain the diminished effect sizes in experiment 2.
- LO1's orientation selectivity appears to not be entirely invariant to stimulus attributes.

References:

[1] Wandell, B.A., Dumoulin, S.O. & Brewer, A.A. *Neuron* 56, 366–383 (2007).
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[3] McKeefry, D. J., et al. *J. Neurosci.* 28 (27), 6848–6857 (2008).
[4] Silson, E. H., et al. *Nat. Neurosci.* 16 (3), 267–269.
[5] Dumoulin, S. O., *Cerebral Cortex.* 10 (5), 454–463.