Research Plan - Elucidating the Neural Underpinnings of Place Learning Through Task-Dependant Functional Connectivity and Transcranial Magnetic Stimulation

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Introduction

- Successful everyday navigation depends upon spatial reference frames that compute egocentric (viewer-centred) and allocentric (environment-centred) information.
- Current literature implicates a network of brain areas such as the Precuneus (PCUN), Hippocampus (HPC), Retrosplenial Cortex (RSC), and the Occipital Place Area (OPA).
- There is, however, some equivocality over the underlying neural mechanisms, and the precise roles of the different brain areas, in egocentric and allocentric navigation.
- Here we intend to elucidate these neural mechanisms by using a Place Learning Task in conjunction with Resting State fMRI (RS-fMRI) and Transcranial Magnetic Stimulation (TMS).

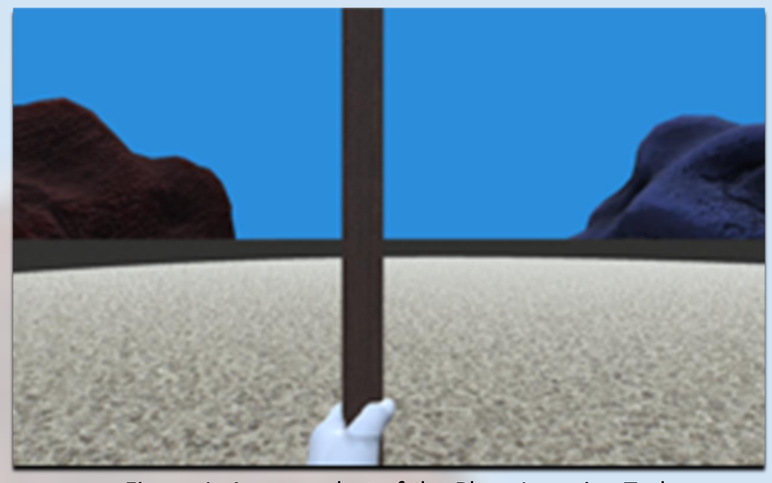

Figure 1: A screenshot of the Place Learning Task

Experiment 1 – RS-fMRI

Method

- 30 neurologically healthy participants will be recruited (based on previous experiments and practical considerations).
- T1 anatomical scans will be collected for registration and analysis.
- Participants will then complete the Place Learning Task, inside an MRI scanner while RS-fMRI scans are collected.

Proposed analysis

- Task-dependant functional connectivity will be analysed via a General Physiological Interactions approach in SPM with the CONN toolbox.
- A General linear model will be constructed with task condition, as an exploratory variable and the HPC, RSC, OPA, and PCUN as seed regions.
- Seed-Region and Seed-voxel analysis will be conducted.
- A secondary exploratory analysis will be conducted using individual trials in which participants relied more on egocentric/allocentric cues (as determined from behavioural data) as exploratory variables.

Expected findings

- We expect differences in functional connectivity between the task conditions, due to a reliance on egocentric or allocentric processing.
- The identified brain areas/network will be used to guide the stimulation targets for experiment 2.

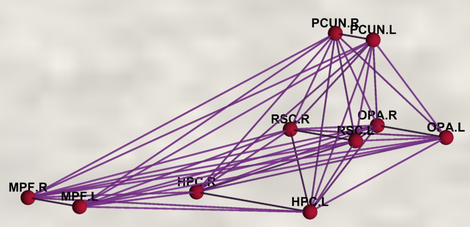

Figure 3: Example network of predicted brain areas

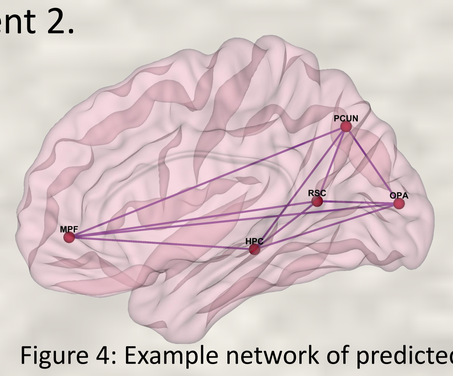

Figure 4: Example network of predicted brain areas (with brain)

Place Learning Task

- Based on a real-world task developed by Kalová et al. (2005), the Place Learning Task is a 3D desktop variant of the Morris Water Maze (Baxter, 2022).
- Participants will learn the location of a flag-pole in an initial training stage, before indicating where they thought the target was in a subsequent test stage (see figure 1).
- Feedback will be provided to participants, allowing them to learn the location.
- Using a within-subjects design, task conditions dissociate allocentric and egocentric information (see figure 2).
- Participants who learn the location of the flag-pole will be more efficient in their pathing to the target location and will be more accurate in their location selection.

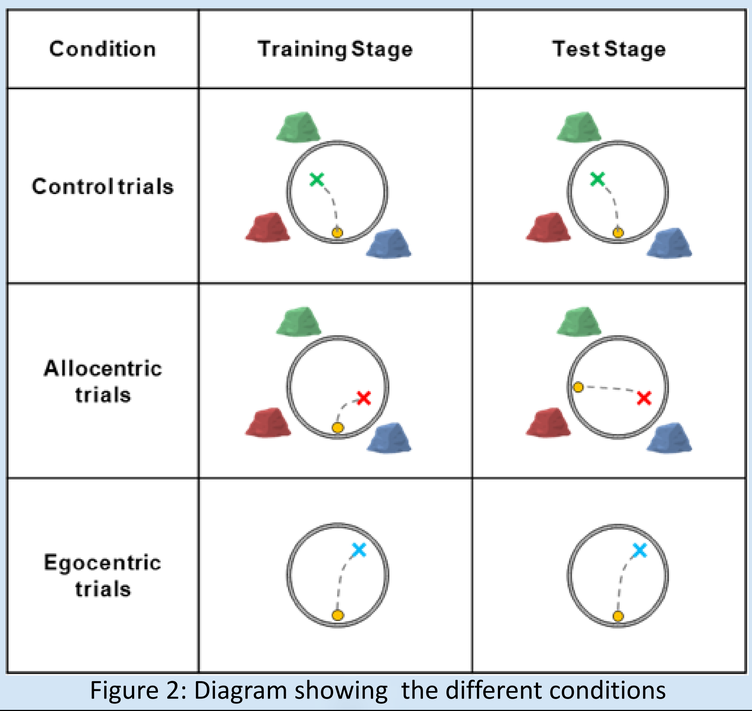

Figure 2: Diagram showing the different conditions

Experiment 2 – TMS

Method

- A power calculation conducted in R (Version 1.4.1103) determined that a sample size of 34 neurologically healthy participants will be able to detect a large effect size (Cohen's f = 0.5).
- Participants will take part in 2-3 sessions, separated by a week.
- In the first session participants' individual Resting Motor Threshold's (RMT) will first be calculated with a combined TMS-EMG approach, using an adaptive maximum likelihood parameter estimation by sequential testing approach.
- Theta Burst Stimulation (TBS) will be used to alter neural activity in the targeted brain area. Within each session participants will then receive either cTBS (inhibitory) or iTBS (excitatory) at 80% of their RMT, to one of the identified target regions. Targets will be located using neuronavigation-guided TMS based on participants anatomical brain scans.
- cTBS/iTBS, and stimulation targets will be delivered in a counterbalanced order between participants/sessions.
- Immediately after the stimulation they will complete a desktop version of the Place Learning Task.

Proposed analysis

- A within-subjects ANOVA will be conducted to look at the effects of task condition (control, egocentric, and allocentric), and stimulation target, on location error and path data.

Expected findings

- cTBS and iTBS stimulation to the target areas will differentially affect performance on the Place Learning Task. Helping us to understand the causal role of the identified brain areas in egocentric and allocentric processing.

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References:

Kalová, E., Vlček, K., Jarolímová, E., & Bureš, J. (2005). Allothetic orientation and sequential ordering of places is impaired in early stages of Alzheimer's disease: Corresponding results in real space tests and computer tests. *Behavioural Brain Research*, *159*(2), 175–186.

Baxter, R. (2022). Contributions of Motility to Large-scale Search and Navigation (Doctoral dissertation, University of Plymouth). Pearl.

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