**Experimental protocol**

Across the project, we ran 19 experiments, all of which involved participants learning either a route through a computer-generated maze environment or the locations of invisible goals or objects within more open computer-generated arenas. In all experiments, required sample sizes were calculated from known (or estimated) effect sizes, to ensure that we had sufficient power to detect an effect with at least 80% probability.

Experiments were designed explicitly to test existing theories of spatial learning or reinforcement learning, meaning often there were experimental groups and control groups learning similar but subtly different tasks. Two fMRI studies were conducted, one of which is archived here. The second was conducted shortly before the Covid-19 pandemic and we have been unable to retrieve all of the data from the neuroimaging suite at James Cook University Hospital. The fMRI studies were designed to determine regional neural activation under specific circumstances when learning routes through a maze.

In all experiments there were training phases during which the task was learned, followed by test phases in which what had been learned, or how well it had been learned, was tested.

Arena-based tasks

1. Boundary stability and cue type study

We ran four experiments in which participants learned the locations of two goals relative to either the boundary or landmarks. For a landmark-related goal the boundary was made unstable between trials, while for a boundary-related goal landmarks were made unstable between trials. In a second stage of training we created the opportunity to learn each of the goal locations relative to the previously unstable cue. Test trials at the end of training determined if learning the goal location relative to the previously unstable cue impaired learning compared to learning relative to the unstable cue.

1. Landmark overshadowing boundary study

We ran three experiments in which participants learned a location relative to both a landmark or array of landmarks concurrently with the opportunity to learn the same location relative to the boundary. Control conditions encouraged learning only with respect to the boundary. Test trials with landmarks removed from the arena determined if prior learning with respect to the landmarks had impaired learning with respect to the boundary.

1. Landmark overshadow geometry study

We ran three experiments in which participants learned a location relation to an array of landmark or to the geometric shape of the arena. Control conditions ensured strong learning to the geometry but no learning to the landmarks. Test trials with landmarks removed determined if prior learning with respect to the landmarks impaired (overshadowed) learning with respect to the geometry.

1. Boundary effects on episodic memory study

We ran three experiments in which participants learned the locations of objects within buildings housed within an open arena. We conducted manipulations to the boundaries of the buildings and probed where participants remembered encountering objects. Depending on the manipulation we observed a shift from memory errors relative to the positions of objects within a building to memory errors relative to the position of the building but not the relative position of the object within a building.

Maze-based tasks

1. Hedgemaze fMRI study

In this fMRI study we developed a task in which participants learned a route through a high-walled maze. Learning could be based on an association between an individual landmark and a specific turn and/or based on the sequence of turns within the maze. Probes were conducted to determine brain activation when having to rely only on the sequence of turns, on individual landmarks, or when the landmark and sequence were placed into conflict. A fuller description is provided in the Hedgemaze fMRI ReadMe document.

1. Sequence blocking study

We ran two experiments in which participants learned individual landmark-action associations with distinctive landmarks before the landmark order was fixed within a specific sequence. In control conditions participants learned the fixed sequence and landmark order concurrently, without undergoing pre-training with the landmarks alone, ensuring strong learning based on sequence. Test trials with the sequence alone determined if prior learning about the landmarks impaired learning based on sequence.

1. Return route study

We ran two experiments in which participants were trained on two different 9-junction mazes. In both mazes there were three paths leading from the junction (excluding the path taken to arrive there) and an object in the centre of each junction. The identity of the object in each junction differed across successive trials. In the landmark task the rule was to take the action associated with the object, regardless of where it occurred with the maze. In the sequence task the rule was to ignore the object and take the action associated with that junction within the sequence. At the end of training test trials were run in which the participant had to escape from the maze by reversing the actions they took on the outward trip, following the landmark- or sequence-based rule they had learned. In one experiment we recorded individual differences on a Go-No-Go behavioural inhibition task as well as scores on two spatial questionnaires and a spatial orientation task. In the other experiment we manipulated the amount of training that occurred on each task to determine if over-training affected return performance on one task more than the other.

1. Return route fMRI

The return route study above was adapted for use in a neuroimaging task. Participants learned both an outward sequence and outward landmark task before being probed with segments of the outward and return journeys. These data are yet to be processed and archived.

1. Evacuation behaviour in a realistically rendered environment

We have also developed a realistic rendering of a real building with manipulations to the environmental features (e.g., paintings, wall coverings, furniture) and complexity of route. This task is being used in our continuing impact development.

**Schematic Generic Behavioural Experimental Protocol**

Control condition

Experimental condition

Information sheet and Consent form

Instructions for training phase

Pre-experimental phase

Recruitment

Study phase

(Materials vary across studies)

Instructions for test phase

Testing all conditions under identical circumstances

Test phase

(Test format varies across studies)

Data recorded: Latencies, paths, path lengths, choices, errors.

Data recorded: Latencies, paths, time spent in search zones, errors, choices

Analysis

Comparison of Experimental and control conditions on test performance using ANOVA, t-tests, regression and associated Bayes Factors

Post experimental phase

Participant debrief