Contributions of Hippocampal and Frontal Systems to Unexpected Detours in Virtual Environments

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Introduction

How past experiences are used to plan possible future paths is a question that has persisted at least since Tolman’s seminal studies of choice behavior in rodents. Rodent physiology studies have largely focused on spatial codes in the hippocampus (O’Keefe and Dostrovsky, 1971) and entorhinal cortex (Fyhn et al., 2004), and recent work suggests the hippocampus may support representations of never-before-experienced routes through an expansion of its potential neural code (Gupta et al., 2010). Studies have also explored hippocampal dynamics with neocortex including medial frontal cortex (Jones and Wilson, 2005).

In humans, two largely non-overlapping brain systems, a hippocampal-neocortical network and a frontal-parietal network, have been implicated as playing important roles for planning during navigation (Maguire et al., 1998; Sladicle & Burgess, 1991). What are the differential contributions of these systems when generating novel routes in humans?

We hypothesized that the Default network and a frontal-parietal network, have been implicated as playing important roles for creating a novel route relative to baseline.

Methods

Participants

• N=33 (mean age = 21.3 yr; 30 male); 2 participants dropped due to excessive motion.

Training Session

• 2-3 days prior to scan session (mean session duration: 1.5 hrs).

• Participants learn fixed location of hidden barriers and are trained to criterion performance on optimal routes between 4 rooms.

Scan Task

• Introduce new rule: on each trial, one additional barrier may be encountered in an unpredictable location.

• Participants are required to form a novel route to the goal.

Control barriers: irrelevant to planned route

Results

Response to Unexpected Barriers

The BOLD response reflected the upcoming ideal path as indexed by the shortest possible distance to the goal from the current position. (A) Regions including lateral prefrontal cortex, insula and frontal operculum, precuneus, and caudate head were negatively correlated with ideal path length on a trial-by-trial basis. Participants whose path errors did not increase on longer paths exhibited more activity in lateral parietal, frontal midline, posterior parietal cortex, as well as stratum and lateral orbitofrontal cortex in response to Detour barriers.

Exploratory Analysis: Path Difficulty is Reflected in End-of-Trial Activity

Response to Detours is Modulated by Aspects of the Upcoming Path and by Performance

Conclusions

1) Activity in the Default Network increased in response to unexpected barriers that required forming a new route relative to barriers that did not.

2) Detour barriers are associated with an increase in spontaneous pause rate. Pause duration at the barrier is associated with better performance, whereas rate of VTEs is associated with worse performance.

3) Ideal path length—a prospective measure of the shortest distance from the barrier to the goal—was negatively correlated with the response in lateral prefrontal regions on a trial-by-trial basis.

4) The correlation between path error and ideal path length differed across participants. This relationship was found to covary with Detour activity in the hippocampus, parahippocampal cortex, medial prefrontal cortex and posterior cingulate. Regions in the medial temporal lobe also correlated with how well the maze was remembered.

References


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