

Introduction and Method

1. Is the hippocampal map composed of fragments or is it 'one big map'?

Hippocampal place cells are thought to provide a map-like code for the spatial layout of the environment through the collective pattern of their place fields.

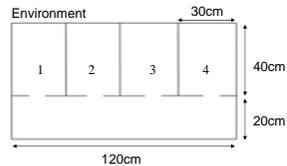
An unresolved issue is whether the place cell map is: A) Fragmentary (each cell influenced only by local cues) or B) "One Big Map" (a holistic representation in which a place cell can be influenced by information about more distant parts of the environment, even when these are not directly perceived).

To address this we recorded from rat place cells in an environment consisting of multiple identical compartments, to see whether different, local maps would form for each compartment. This was done over days. We then examined patterns of place cell 'remapping'. 'Remapping' refers to the altered firing patterns that place cells typically express in geometrically or visually different environments. We reasoned that if the map is fragmented then visual or geometric changes inside compartments will result in purely local remapping responses. By contrast, if it is "One Big Map" then remapping responses might include changes to place fields at some distance from the changed compartment.

Previous examination of place cell remapping in a multi-region environment has found evidence of purely local effects (Paz-Villagran et al., 2004). However, animals were pre-exposed to two separate environments which were then integrated, which may have encouraged formation of separate local maps which subsequently resisted change. Here, by contrast, we ask whether the place cell map for a highly familiar environment learned as a single whole shows local or non-local remapping effects to changes in a sub-region.

2. Does place field replication decrease with repeated exposure?

Place cells recorded in environments with 2 identical compartments or a hairpin maze of repeated corridors frequently have replicated fields across compartments (Skaggs & McNaughton, 1998; Fuhs et al., 2005; Barry et al., 2006; Derdikman et al., 2009). With repeated exposure some place cells have been found to reduce the duplication of fields, resulting in single field (e.g. Barry et al., 2006). Thus, we examined whether repeated exposure would result in a reduction in the number of cells expressing replicated fields across compartments.



123 Place cells were recorded from rats (n=9) while they foraged for randomly scattered food in a multicompartment environment composed of wooden walls (60cm high) and a white perspex floor. The environment was surrounded by white curtains and two light sources in the west provided a directional cue. After each 15 minute trial the floor was wiped and the walls rotated. Between each day of recording the apparatus was moved 30cm to one of three possible locations.

To examine whether the map is fragmented or holistic two manipulations were used in separate sessions.

- Colour change:** a black floor and wall covers were inserted into one compartment.
- Geometric change:** 3 compartments were removed.

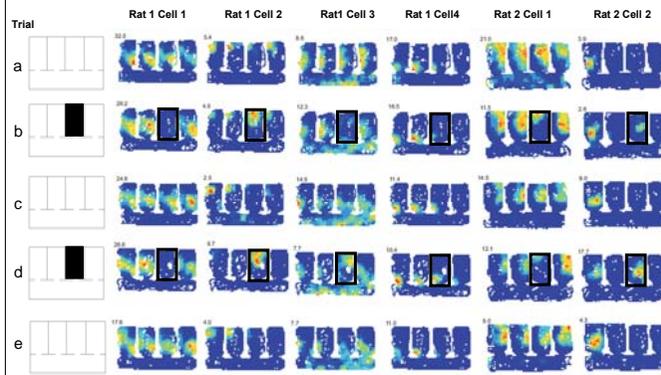
If the map is fragmented remapping should occur *only* in the changed region, but if the environment is represented as a whole remapping should also occur in unchanged compartments.

Results

1. The map consists of multiple fragments

Colour change: No cells remap in unchanged compartments

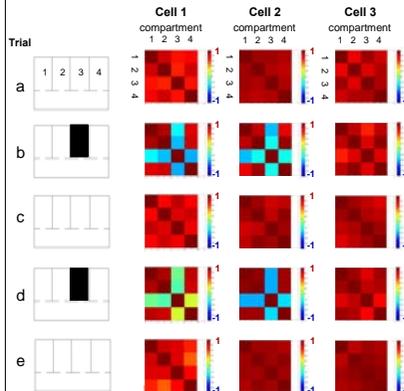
Shown below are rate maps from representative cells (4 from Rat 1, 2 from Rat 2) during a session in which on trials b and d the walls and floor in compartment 3 were changed to black via inserts. Numbers top left are the peak rate for each cell in Hz. Within the altered compartment, 59% of cells (49 of 79) showed clear remapping responses (see examples below). *no* cells showed clear remapping responses in the unaltered compartments.



Response:	Suppressed	Increased	Suppressed then relocation	No robust change	Relocation	New field
Remapping cells:	36%	19%	19%	-	19%	10%

The most common response was suppression of a replicated field within the altered compartment.

To characterise the response, rate maps were extracted for each compartment, aligned and the Pearson's correlation between the pixels in each compartment map calculated (e.g. 1 vs 2, 1 vs 3, 1 vs 4, 2 vs 3, etc).



Correlation Matrices

Left is shown the correlation matrix of comparisons for three representative place cells with repeating fields in Rat 2.

Cells 1 and 2 show a response similar to Rat 1 Cell 1 above - a clear suppressed field when black walls & floor are inserted.

This is characterised by a decrement of r-values for compartment 3 compared to the other compartments.

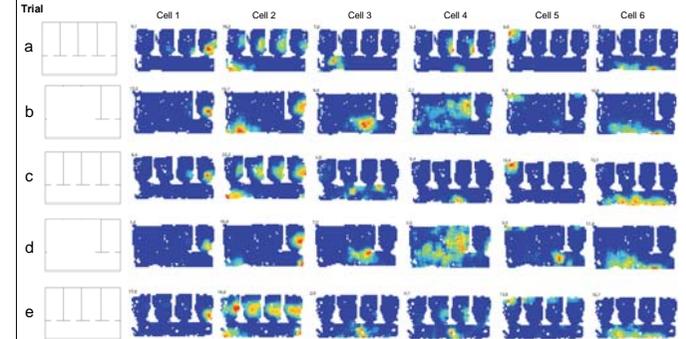
Cell 3 show a response similar to Rat 1 Cell 4 above - only a very slight change in the repeating field in compartment 3 when black walls & floor are inserted.

These correlation maps highlight the strong local effect that inserting black walls & floor can have on place cells with repeated fields.

Results

Geometric change: No cells remapping in the unchanged compartment

Shown below are rate maps from 6 representative cells from Rat 2 during a session in which on sessions b and d compartments 1, 2 & 3 were removed. Numbers top left are the peak rate for each cell in Hz. All cells remapped in the region changed, *no* cells with fields in the unchanged compartment remapped.



2. No evidence for a decrease in repeated place fields with experience

No reduction in repeated fields was observed after repeated days of exposure

4 rats were recorded for 5 or more days, with over 16 trials in total.

We examined field replication in the last trial for each rat.

From 47 place cells recorded, 34 had fields in the compartments.

90% of cells in compartments had fields replicated across compartments.

Of these 75% had a field replicated in all 4 compartments.

No reduction in replicated fields within a day

Data from 2 rats was examined over a session of 5 trials. On trial 1, 40 cells were recorded with fields replicated across compartments. On trial 5, 42 cells had fields replicated across compartments.

Conclusions

Place cells replicate firing fields across identical compartments even when the rat can freely walk between them for long periods of time.

This field replication does not decline even after repeated exposure within and across days. Induction of remapping in one compartment does not cause non-local effects.

Thus, the hippocampal map appears to be composed of multiple fragments, with each fragment corresponding to a compartment within an environment.

Current work aims to:

- Determine what defines the limits of a 'fragment'.
- Examine the factors influencing field replication, by varying the number of compartments and varying the behavioural significance of the compartments via differences in reward.

References and Acknowledgements

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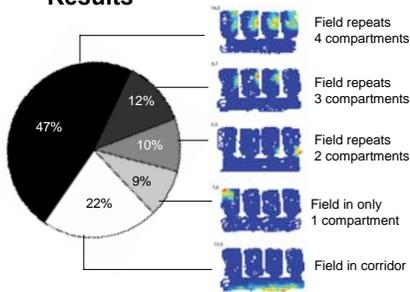
Frequent field replication across compartments

Place cells with place fields replicated across all four compartments were found in all 9 rats.

Cells with fields repeating across all four compartments were the most frequently recorded.

This indicates that place cells are strongly influenced by local visual features within regions and that self-motion information appears to be insufficient to drive differentiation in firing patterns for most cells.

Results



Above shows the firing rate maps of 5 place cells. Numbers top left are the peak rate (Hz).