

Supplementary Information for *Cellular Networks Underlying Human Spatial Navigation*

Arne D. Ekstrom¹ Michael J. Kahana^{1*} Jeremy B. Caplan¹
Tony A. Fields² Eve A. Isham² Ehren L. Newman¹ Itzhak Fried^{2,3*}

¹Volen Center for Complex Systems, Brandeis University
Waltham, MA, 02454, USA

²Division of Neurosurgery and Department of Psychiatry and Biobehavioral Science
University of California, Los Angeles, CA, 90095, USA

³Functional Neurosurgery Unit, Tel-Aviv Medical Center and Sackler School of Medicine
Tel-Aviv University, Tel-Aviv 69978, Israel

*Correspondence may be addressed to M. Kahana (E-mail: kahana@brandeis.edu)
or I. Fried (E-mail: ifried@mednet.ucla.edu)

Patient #	Age	Sex	Handedness	Right Coverage	Left Coverage	Seizure Site	# Cells
1	29	F	R	A,EC,H,F	A,EC,H,FR	left medial temporal	2
2	46	M	R	A,EC,PG,H,F	A,H,FR	right medial temporal	70
3	48	M	R	A,EC,H,FR	A,PG,H,FR	left medial temporal	92
4	42	F	L	A,H,FR	A,EC,PG,H,FR	left medial temporal	64
5	22	M	R	A,H,FR	A,H,FR	left frontal	58
6	41	M	R	A,EC,H	A,H	left medial temporal	14
7	45	M	R	EC,H,FR	A,EC,H,FR	left medial temporal	17

Table 1: **Patient Data and Recording Areas** A=amygdala, EC=entorhinal cortex, H=hippocampus, FR=frontal lobes, PG = parahippocampal gyrus

Brain Region	total # of neurons	Place	View	Goal	Place×view	Place×goal	View×goal	Place×view×goal
R. Hippocampus	41	15	5	15	4	5	3	0
L. Hippocampus	14	3	1	1	6	2	0	1
R. Entorhinal cortex	24	7	5	7	6	5	2	2
L. Entorhinal cortex	5	1	1	2	2	0	0	0
R. Parahippocampal gyrus	14	1	4	4	1	2	2	0
L. Parahippocampal gyrus	4	0	0	0	0	0	0	0
R. Amygdala	41	10	5	5	10	14	7	3
L. Amygdala	64	10	5	8	13	16	0	7
R. Frontal	25	12	4	7	1	7	7	1
L. Frontal	47	13	3	10	13	8	2	2

Table 2: **Number of cells with significant responses in ANOVA at different recording sites.** More than one main or interaction effect was sometimes present in a cell. *Bona fide* place cells were cells that had main effects of place and no main or interaction effects of view. Location-independent view responsive cells were cells with main effects of view and no place×view interaction effects. Cells with these responses are not separately listed above.

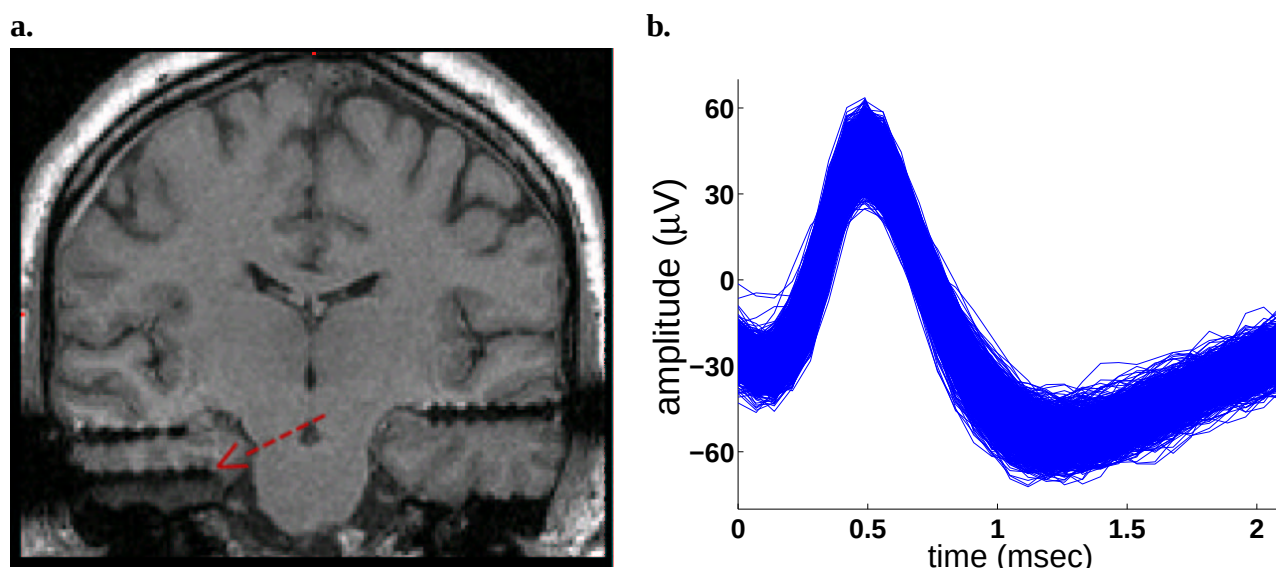


Figure 1: **Electrophysiological methods** (a.) MRI of depth electrodes directed bilaterally to the hippocampus and the right parahippocampal region (on the left in the photograph, below the hippocampal electrode, see arrow) of a patient subject. Artifact makes the contacts appear enlarged. (b.) The waveforms of a cell isolated from right parahippocampal recordings in this patient (negativity is up, with high pass filtering at 600Hz).

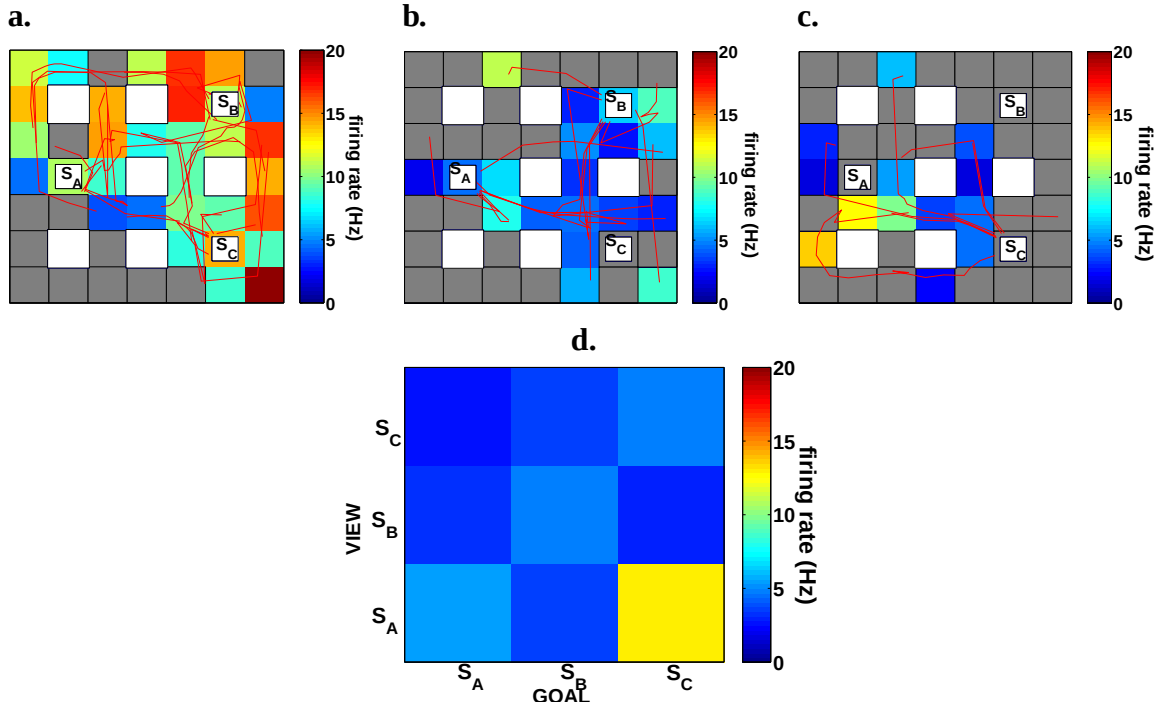


Figure 2: **Goal responsive cells: Place and View Correlates.** For the goal cell shown in Fig. 4a, we further analyzed the spatial distribution of firing. During searching for passengers (**a.**), the firing rate was elevated across most spatial positions, as would be expected for a goal cell that did not show an effect of place. The firing rate while searching for Store S_A and Store S_B was significantly lower (see Fig. 4a) and was not spatially distributed (**b.**). The firing rate of the cell was also lower across regions when searching for Store S_C although a few regions (yellow and light green regions) showed elevated rates (**c.**). These elevated regions of firing were due to the fact that this cell showed a goal $\times$ view interaction effect, shown in **d.**, such that it fired when viewing Store S_A but only when it was seen during searching for Store S_C .

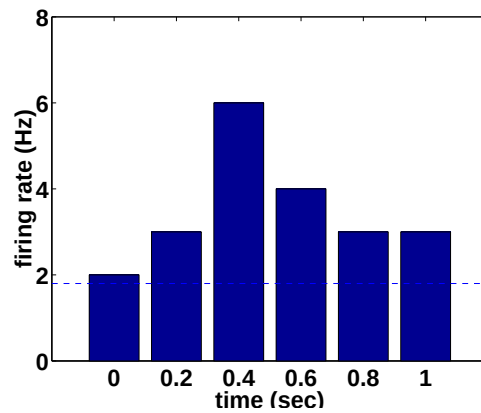


Figure 3: **Place responsive cell tuning curves.** By restricting areas of significantly high firing rate to single passes through the place field, the firing rate distributions of place responsive neurons were investigated. The mean firing rate distribution over all trajectories for this right hippocampal neuron (Fig. 2a, highest region of firing) is shown upon entry into the place selective region. The neuron typically reached a peak firing rate of up to 15 Hz on an individual traversal (data not shown). The dotted line indicates the cell's background firing rate (1.8 Hz).