Supplementary table 1: Summary of the cell distribution for RSC-implanted animals.

	Rat 599	Rat 602	Rat 628	Rat 636	Total (n)	Total (%)
No. recording sessions	28	25	16	16	85	
Total cells	591	411	48	40	1090	
HD cells	35	44	4	13	96	9
BD cells	76	16	21	3	116	11
BC-BD cells	30	5	10	1	46	4
WC-BD cells	46	11	11	2	70	6

Supplementary Table 2: Analysis of olfactory disambiguation of compartments by HD cells. Data are collapsed across trials: the p-values for analyses of individual trials are shown in Supp. Fig. 2. We compared the data against a null hypothesis of no use of olfactory cues and thus inability to distinguish the two apparatus orientations (predicting an even distribution between the zero +/- 30 degree sector and the 180 +/- 30 degree sector), and an alternative hypothesis of perfect use of olfactory cues (predicting a clustering of firing directions at zero +/- 30 degrees). 28 ensembles were recorded over 4 trials, totalling 112 data points, of which 108 lay within the sectors of interest. The predictions and data are shown in the table below, which shows that the behavior of the cells was significantly different from both hypotheses, revealing an above-chance, but incomplete, use of olfactory cues to disambiguate the compartments.

	Hypotheses		
Predicted cluster sector	**Null:** **Expected n if not using olfaction**	**Alternative:** **Expected n if using olfaction**	**Actual data**
-30 to +30 degrees	54	108	82
150 to 210 degrees	54	0	26
Total	**108**	**108**	**108**
Chi-square value testing hypothesis against data	15.56	29.56	
P value	< 0.0001	< 0.0001	

Supplementary table 3: Summary of the firing characteristics of directional neurons.

Values are mean (s.e.m)	RSC BD		RSC HD	PoS	ADN
Peak firing rate (Hz)*	5.09 (0.37) n = 116		7.59 (0.88) n = 96	5.13 (0.55) n = 39	18.17 (2.60) n = 31
Peak firing rate for closed-door trials 3 and 4 (Hz)**	**BC-BD**	**WC-BD**	**RSC HD**		
	7.19 (1.01) n = 46	6.70 (0.53) n = 70	7.01 (0.69) n = 96		
Mean firing rate for closed-door trials 3 and 4 (Hz)**	3.05 (0.37) n = 46	3.90 (0.33) n = 70	3.39 (0.39) n = 96		
ISI histogram peak latency (ms)***	35.24 (2.86) n = 116		38.35 (4.11) n = 96	35.05 (12.82) n = 39	18.16 (4.21) n = 31
	BC-BD	**WC-BD**			
	33.43 (4.40) n = 46	36.48 (3.79) n = 70			
Decay time to half-peak (ms) ****	120.60 (8.34) n = 116		135.31 (11.82) n = 96	91.28 (13.39) n = 39	75.68 (16.76) n = 31
	BC-BD	**WC-BD**			
	107.57 (11.95) n = 46	129.48 (11.36) n = 70			

HD = head direction cells; BD = bi-directional cells; WC-BD = within-compartment BD cells; BC-BD = between-compartment BD cells

* [$F_{(3,278)} = 26.3$, $p < 0.0001$]. Post hoc tests (Bonferroni corrected) showed that ADN rates were significantly higher than RSC bi-directional cells [$t(145) = 8.62$, $p < 0.001$], RSC HD cells [$t(125) = 5.0$, $p < 0.001$] and PoS HD cells [$t(68) = 5.44$, $p < 0.001$].

**Comparison of firing rates for directional cell subtypes found no difference for peak rates [$F_{(2,209)} = 0.10$, $p = 0.90$] or mean rates [$F_{(2,209)} = 1.00$, $p = 0.36$].

*** ANOVA on log-transformed data: [$F_{(3,120)} = 4.2$, $p < 0.01$]; post hoc tests (Bonferroni-corrected) showed that the ADN time-to-peak was significantly shorter than RSC bi-directional cells [$t(124) = 3.03$, $p = 0.02$] and RSC HD cells [$t(145) = 3.85$, $p = 0.001$] but not PoS HD cells [$t(68) = 1.91$, NS]. The other cell types did not differ. The ISI peak times

between within-compartment (WC) and between-compartment (BC) di-directional cells did not differ [one-tailed $t(114) = 0.52$, $p = 0.30$].

**** The decay time to half-peak, which is a measure of the proportion of longer intervals in the spike train, was also shorter for ADN neurons. ANOVA showed that this was significant [$F(3,278) = 9.60$, $p = 0.0001$]; post hoc tests (Bonferroni-corrected) showed that it was shorter than RSC bi-directional cells [$t(145) = 4.90$, $p < 0.01$] and RSC HD cells [$t(124) = 4.27$, $p = 0.001$] but not shorter than PoS HD cells [$t(68) = 2.16$, NS]. The other cell types did not differ. The decay times also did not differ between WC and BC cells [$t(114) = 1.29$, $p = 0.10$].