Supplementary Material:
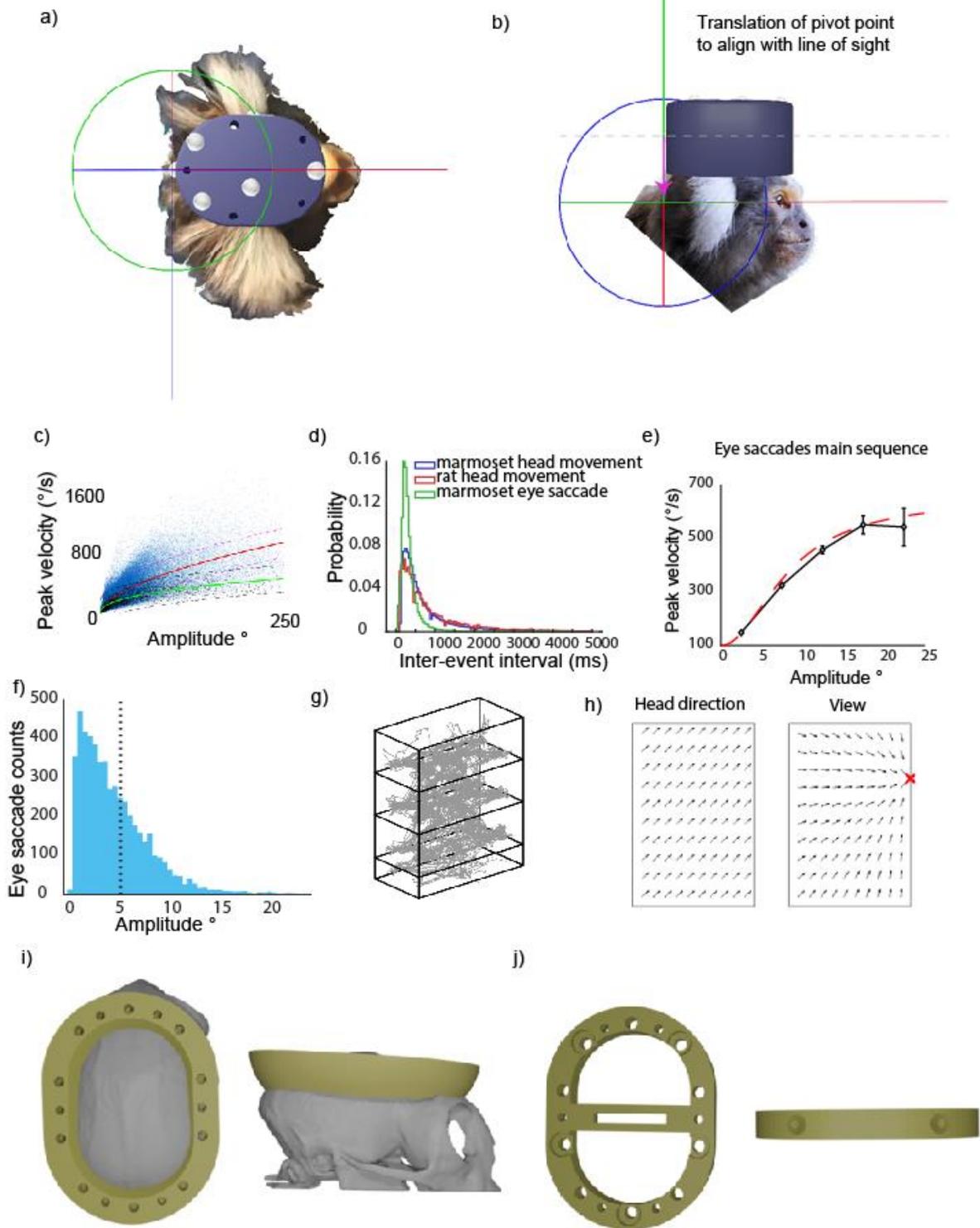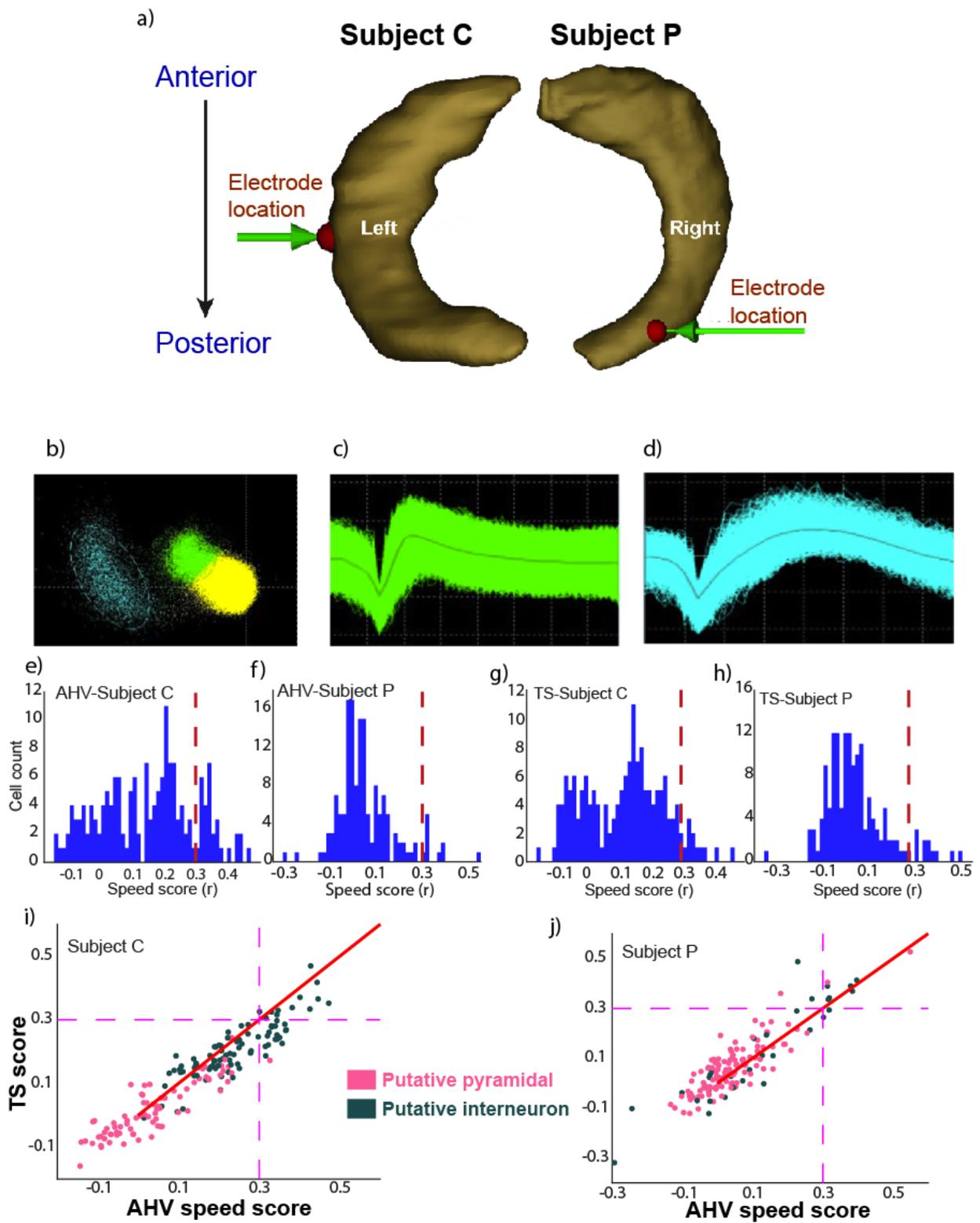
Supplementary figure 1 (a) View from the top showing the alignment of the roll axis (red) with the visual axis, assuming a cyclopean eye. **(b)** Diagram illustrating the position of the pivot point (origin of rotation angles). The position of the pivot point (originally placed in the position of the most posterior retro-reflective marker) is linearly translated downwards, along the vertical axis to align with the subject's visual axis. **(c)** Main sequence (amplitude vs peak velocity) of head movements and Naka-Rushton function fit, for marmoset (blue markers, red line) and rat (black markers, green line); dashed lines correspond to 95% confidence intervals. **(d)** Distribution of inter-event interval for marmoset and rat head movements (blue and red distributions respectively) and marmoset eye saccades (green distribution). **(e)** Main sequence (amplitude vs peak velocity) of marmoset eye saccades, error bars convey 95% confidence intervals. The dashed line corresponds to a Naka-Rushton function fit. **(f)** Distribution of marmoset eye saccade amplitudes, dashed line placed at 5°. **(g)** Example trajectory traces (gray) of the 3D position during a recording session for subject C. **(h)** Illustration taken from a previous publication[135], displays the vector direction differences between head direction and view encoding. **(i)** 3D model of the recording chamber ring placed on the skull of the marmoset. **(j)** 3D model of the spacer that houses the electrode connector (omnentics 36pin), the spacer is placed on top of the chamber ring and it serves as a head-fixation base.

a)

Subject C   Subject P

Anterior

Electrode
location

Left   Right

Posterior

Electrode
location

b)   c)   d)

e) AHV-Subject C   f) AHV-Subject P   g) TS-Subject C   h) TS-Subject P

Cell count

Speed score (r)   Speed score (r)   Speed score (r)   Speed score (r)

i) Subject C   j) Subject P

TS score

Putative pyramidal
Putative interneuron
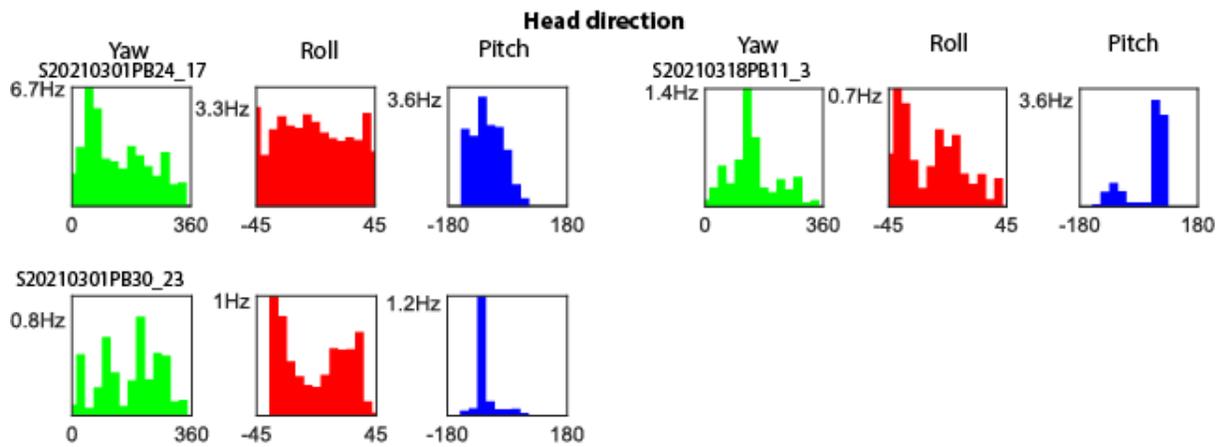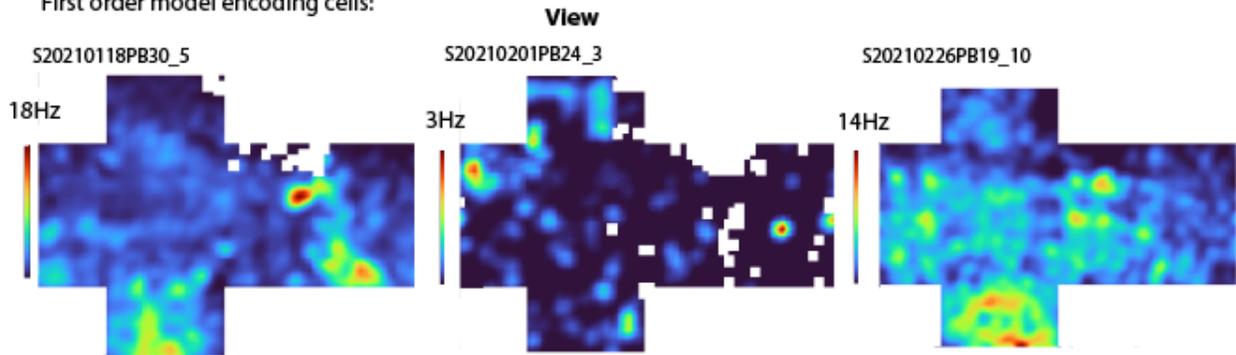
AHV speed score   AHV speed score

Supplementary figure 2 (a) MRI and micro-CT based 3D reconstruction of the electrode recording sites for subject C (left hippocampus) and subject P (right hippocampus). **(b)** Screenshot of a sorting session of one channel using Plexon software (Offline Sorter, Plexon Inc., Texas, USA). PCA view is displayed with labelled clusters, blue is a single unit, green is multi-unit activity, and yellow is the noise unit. **(c)** Multi-unit activity spike waveforms, aligned to the negative peak. **(d)** Single unit activity spike waveforms, aligned to the negative peak. **(e,f)** AHV speed scores for subject C and subject P respectively, the dashed line indicates a speed score of 0.3. **(g,h)** TS speed scores for subject C and subject P respectively, the dashed line indicates a speed score of 0.3. **(i,j)** Speed score distribution for both AHV and TS labelled according to cell type for subject C and subject P respectively, (green = putative interneuron, pink = putative pyramidal), the dashed line indicates a speed score of 0.3.
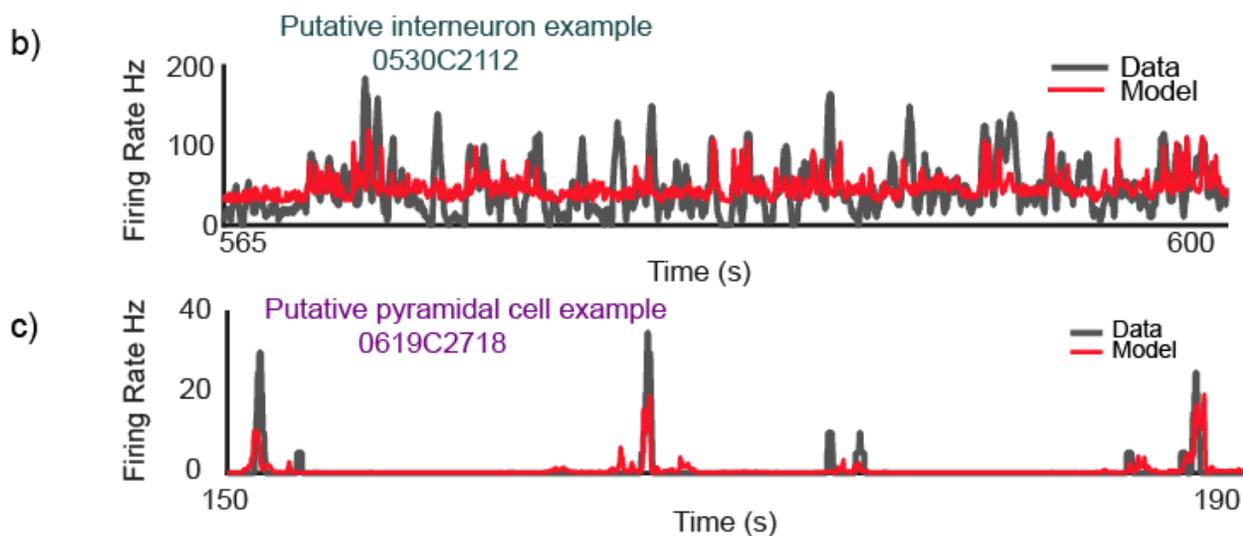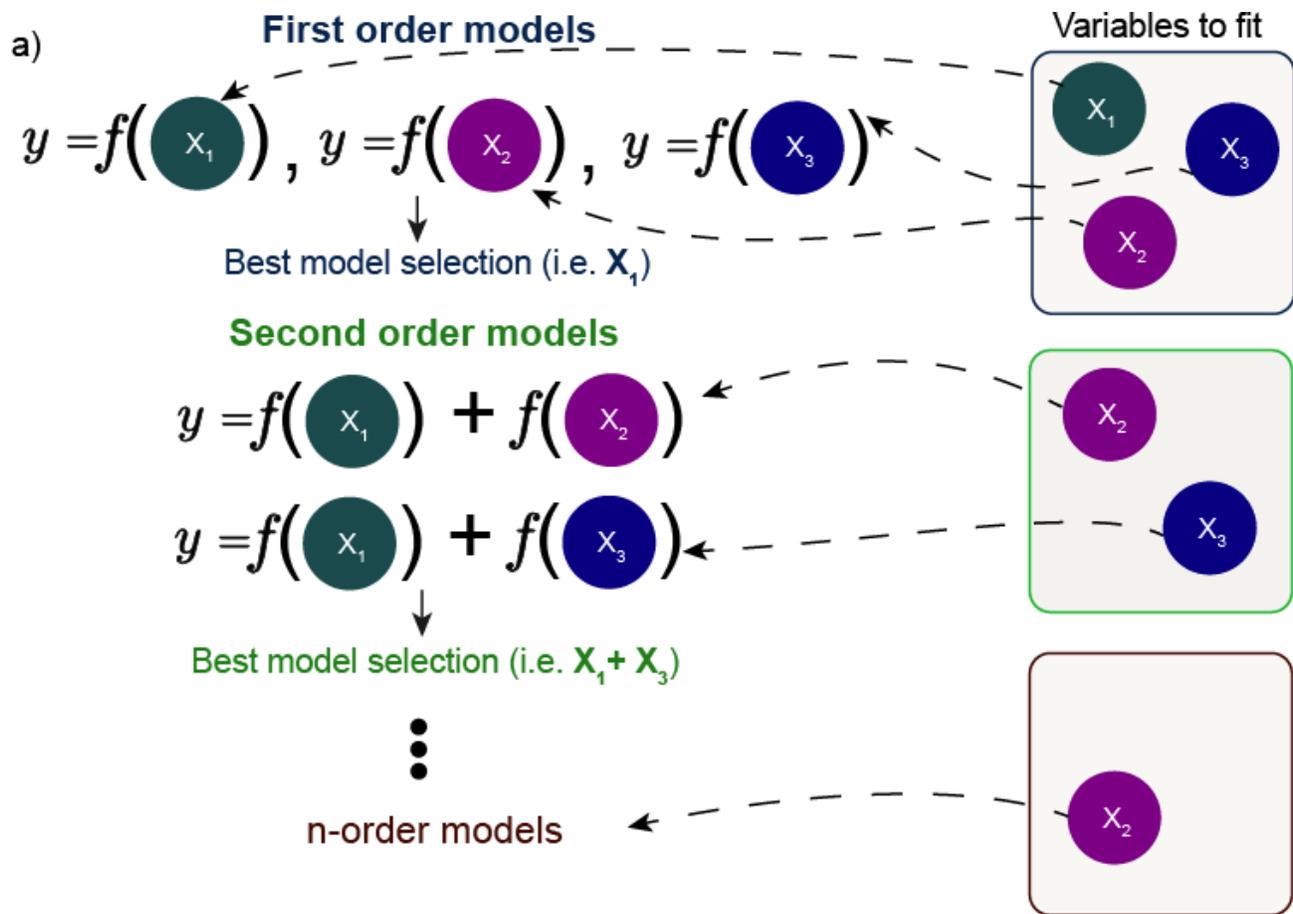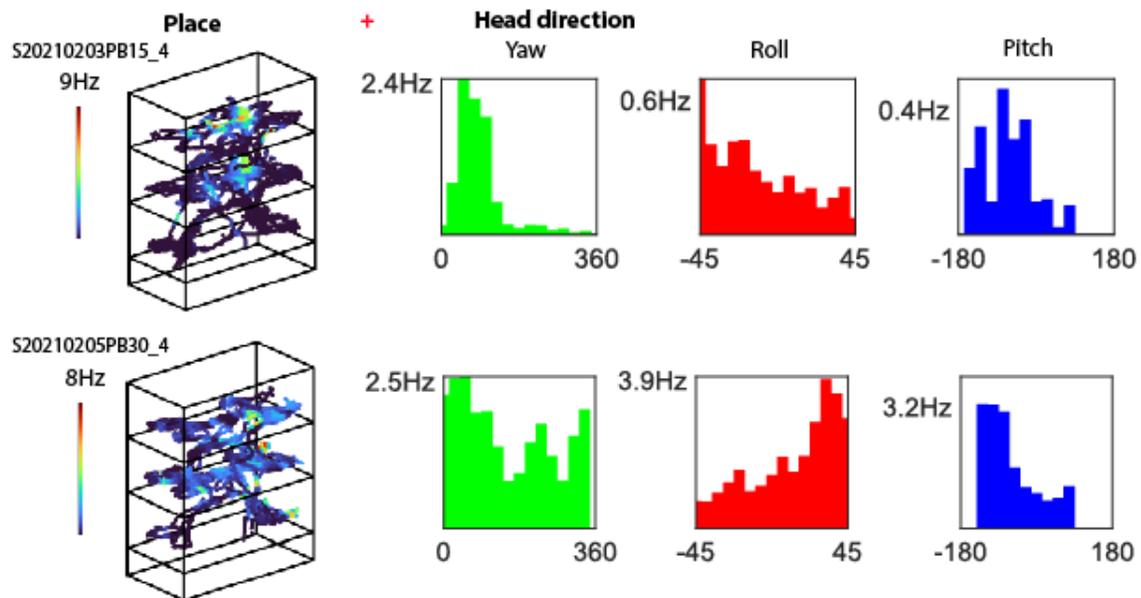
Supplementary figure 3 (a) Schematic describing the stepwise forward search GAM model selection process. **(b)** Real vs. predicted firing rate for a putative interneuron example cell (example cell from **Fig.6c**). **(c)** Real vs. predicted firing rate for a putative pyramidal example cell (example cell from **Fig.6a**).

First order model encoding cells:

View

S20210118PB30_5

18Hz

S20210201PB24_3

3Hz

S20210226PB19_10

14Hz

Head direction

S20210301PB24_17

Yaw
6.7Hz

Roll
3.3Hz

Pitch
3.6Hz

0   360   -45   45   -180   180

S20210318PB11_3

Yaw
1.4Hz

Roll
0.7Hz

Pitch
3.6Hz

0   360   -45   45   -180   180

S20210301PB30_23

0.8Hz

1Hz

1.2Hz

0   360   -45   45   -180   180

Second order model encoding cells:

Place   +   **Head direction**

S20210203PB15_4

9Hz

Yaw
2.4Hz

Roll
0.6Hz

Pitch
0.4Hz

0   360   -45   45   -180   180

S20210205PB30_4

8Hz

2.5Hz

3.9Hz

3.2Hz

0   360   -45   45   -180   180

Second order model encoding cells:

View + **Place**

S20210209PB11_3

15Hz

S20210303PB28_9

17Hz

View + **Head direction**

S20210111PB5_1

24Hz

Yaw

8.3Hz

0   360

Roll

5.6Hz

-45   45

Pitch

4.1Hz

-180   180

S20210202PB13_4

11Hz

6.1Hz

0   360

3.9Hz

-45   45

5.3Hz

-180   180

S20210301PB28_21

16Hz

4Hz

0   360

1.2Hz

-45   45

1.8Hz

-180   180

55

Third order model encoding cells:

View	+	Place	+	Head direction		
				Yaw	Roll	Pitch

C20190225C5_2

11Hz

4.1Hz / 0 - 360 (Yaw) 3.4Hz / -45 - 45 (Roll) 3.8Hz / -180 - 180 (Pitch)

C20190429C21_9

31Hz

12.4Hz / 0 - 360 9.2Hz / -45 - 45 19.1Hz / -180 - 180

S20190508C2_1

28Hz

13.1Hz / 0 - 360 12.1Hz / -45 - 45 12.1Hz / -180 - 180

C20190527C2_3

17Hz

3.6Hz / 0 - 360 4.1Hz / -45 - 45 5.3Hz / -180 - 180

S20200925C6_1

17Hz

4.1Hz / 0 - 360 3.3Hz / -45 - 45 3.7Hz / -180 - 180

S20190807C27_6

9Hz

1.9Hz / 0 - 360 1.1Hz / -45 - 45 1.3Hz / -180 - 180

56

Third order model encoding cells:

View   +   Place   +   Head direction

S20201019C21_5   60Hz   Yaw   Roll   Pitch
                                          4.1Hz   3.3Hz   3.7Hz
                                          0   360   -45   45   -180   180

S20201021C21_3   43Hz
                                          27.9Hz   20.1Hz
                                                                    33.3Hz
                                          0   360   -45   45   -180   180

S20201104C4_1   14Hz
                                          5.8Hz   5.2Hz   4.7Hz
                                          0   360   -45   45   -180   180

S20201104C21_6   45Hz
                                          21.4Hz   17.3Hz   21Hz
                                          0   360   -45   45   -180   180

S20201112C6_2   14Hz
                                          7.4Hz   9.9Hz   5.8Hz
                                          0   360   -45   45   -180   180

S20190619C27_18   12Hz
                                          0.9Hz   0.6Hz   0.9Hz
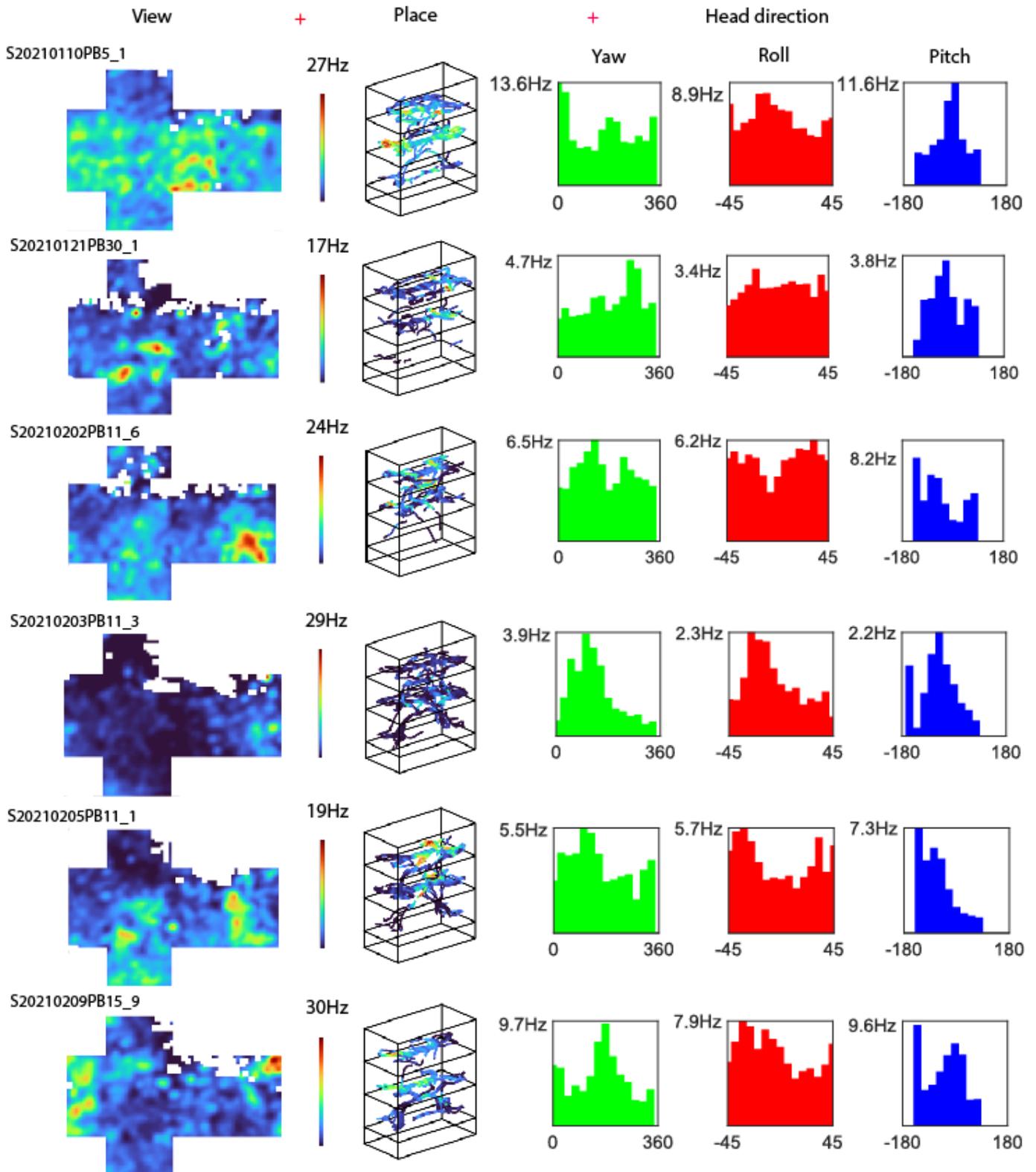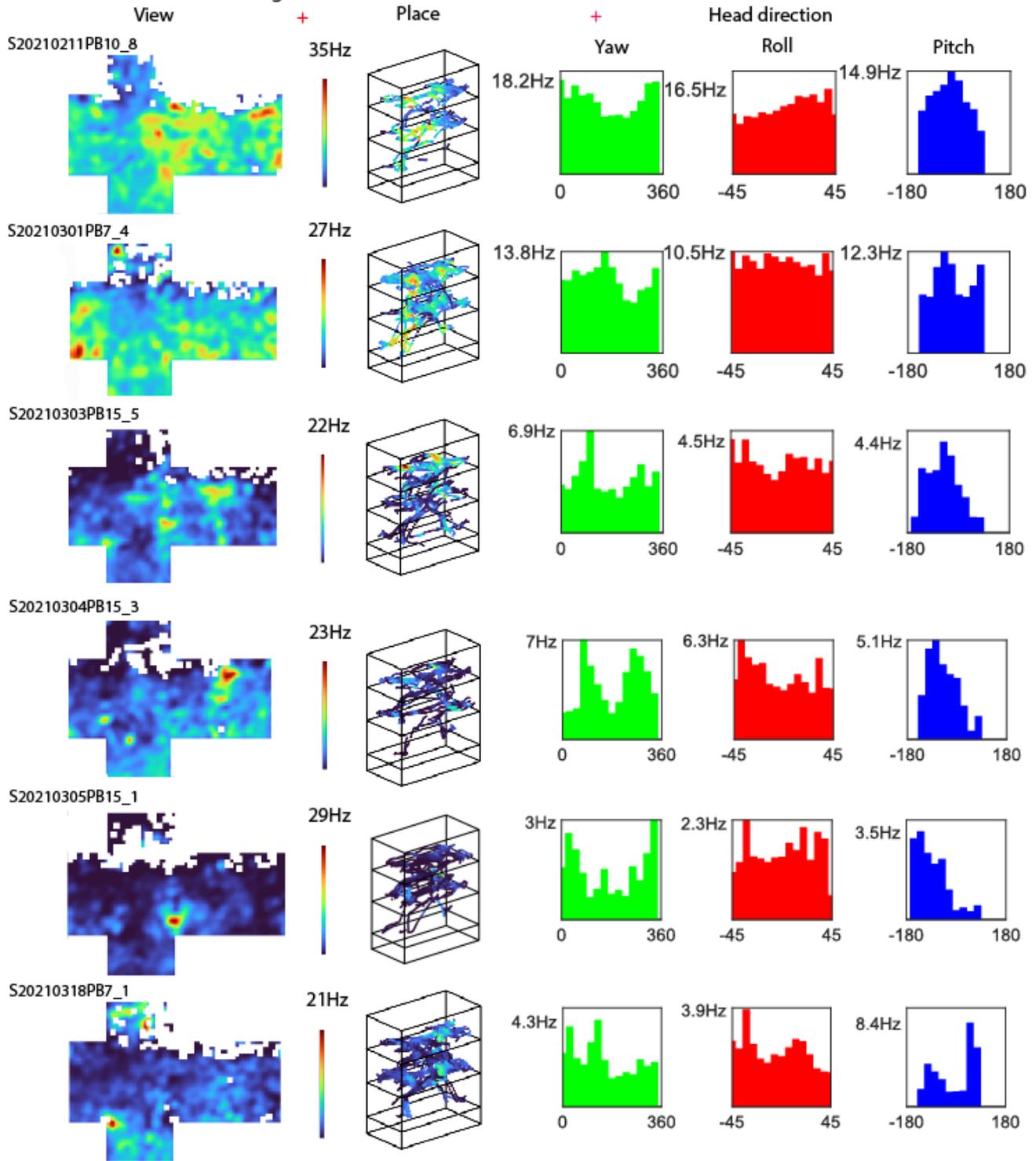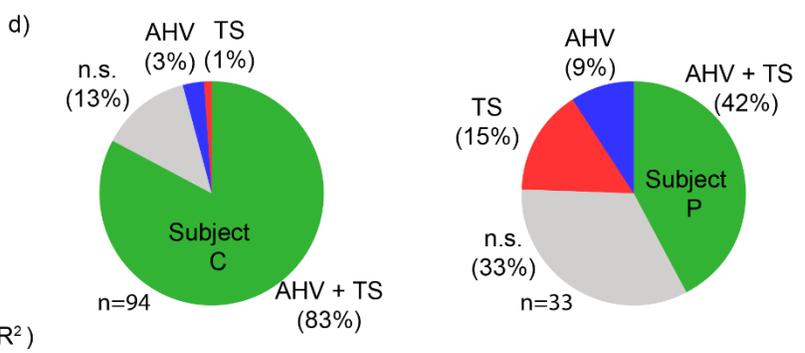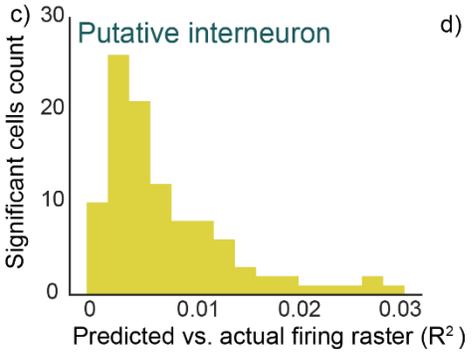   0   360   -45   45   -180   180
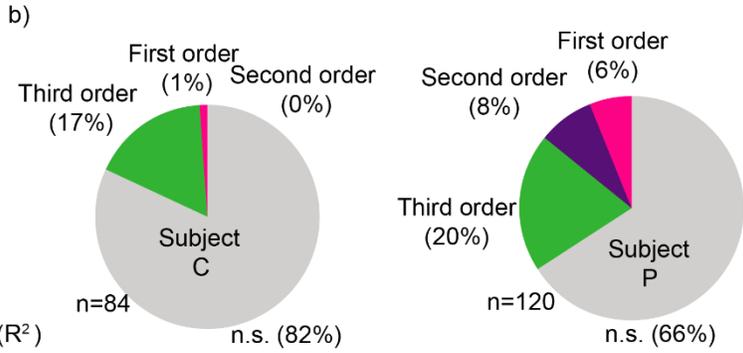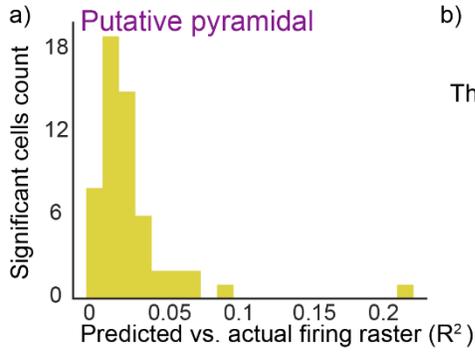
Third order model encoding cells:

Third order model encoding cells:

View + Place + Head direction

S20210211PB10_8   35Hz   Yaw   Roll   Pitch

18.2Hz   16.5Hz   14.9Hz
0   360   -45   45   -180   180

S20210301PB7_4   27Hz

13.8Hz   10.5Hz   12.3Hz
0   360   -45   45   -180   180

S20210303PB15_5   22Hz

6.9Hz   4.5Hz   4.4Hz
0   360   -45   45   -180   180

S20210304PB15_3   23Hz

7Hz   6.3Hz   5.1Hz
0   360   -45   45   -180   180

S20210305PB15_1   29Hz

3Hz   2.3Hz   3.5Hz
0   360   -45   45   -180   180

S20210318PB7_1   21Hz

4.3Hz   3.9Hz   8.4Hz
0   360   -45   45   -180   180

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Supplementary figure 4 Additional single-cell examples are provided to illustrate the diverse types of encoding observed in putative pyramidal single neurons using the GAM model. Rate maps depicting view, place, and head direction are plotted to represent the corresponding behaviors encoded by individual neurons. In the case of cells encoding only one variable (first order models), a single rate map is observed. Conversely, in cells encoding multiple variables (second and third order models) multiple rate maps are displayed, indicating the specific behaviors being encoded. In head direction rate maps, firing rates corresponding to yaw angles (horizontal head direction) are color-coded as green, roll angles (lateral tilt) as red, and pitch angles (vertical axis) as blue. In the case of third order models, the view and place rate maps share the same color map, with the maximum firing rate indicated at the top of the color bar.
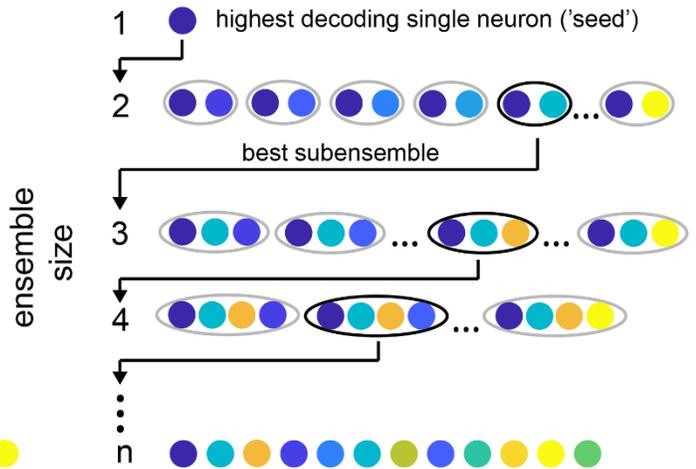
a) Putative pyramidal

b)

First order (1%)
Second order (0%)
Third order (17%)
Subject C
n=84
n.s. (82%)

First order (6%)
Second order (8%)
Third order (20%)
Subject P
n=120
n.s. (66%)

c) Putative interneuron

d)

AHV (3%) TS (1%)
n.s. (13%)
Subject C
n=94
AHV + TS (83%)

AHV (9%)
AHV + TS (42%)
TS (15%)
Subject P
n.s. (33%)
n=33

e) Pseudopopulation pool of neurons

most informative   least informative

'Best individual neuron' procedure

ensemble size
1 highest decoding single neuron
2
3
4
5
6
⋮
n
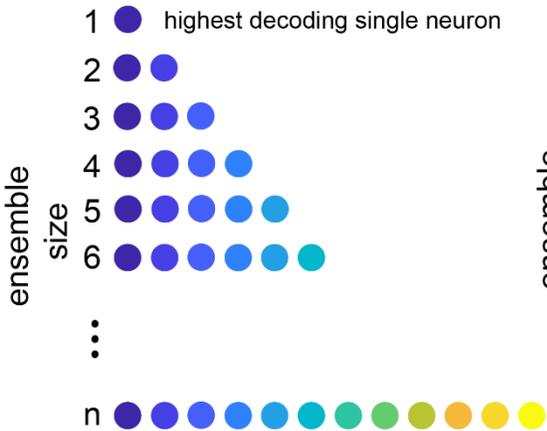
'Best ensemble' procedure

ensemble size
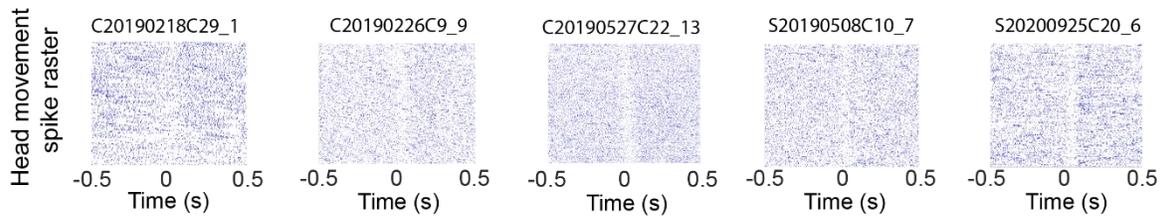1 highest decoding single neuron ('seed')
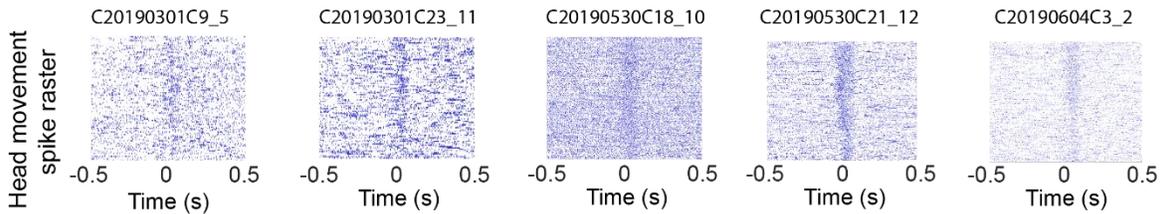2 best subensemble
3
4
⋮
n

61

Supplementary figure 5 (a) Average R^2 between predicted and real spike rasters of all significantly encoding putative pyramidal cells. **(b)** Proportion of putative pyramidal encoding cells for subject C (left) and subject P (right). **(c)** Average R^2 between predicted and real spike rasters of all significantly encoding putative interneuron cells. **(d)** Proportion of putative interneuron encoding cells for subject C (left) and subject P (right). Since each recording session is divided into 5 equally-timed folds, each predicted raster is a continuous time series approximately 8-12 min. long. **(e)** Schematic describing the best ensemble building procedure. (left) The most informative neuron is selected, as assessed by the single-neuron with the highest SVM decoding accuracy of place. (right) The most informative neuron is used as a seed to iteratively add units (looped through the remaining units) to the subsequent subensembles until the 'best ensemble' n-combination of neurons is obtained.
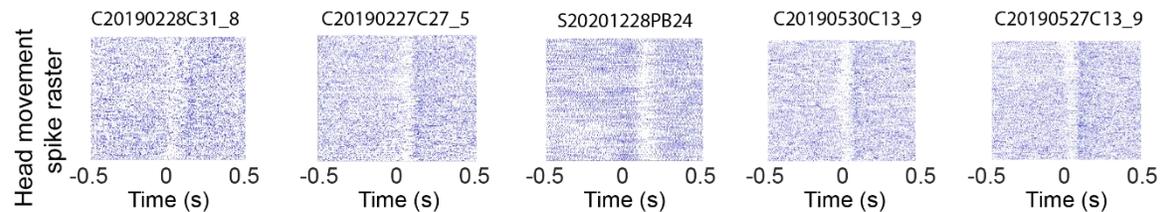
a) Subject C
Places decoded
(4 bins)

Z

X   Y

Best ensemble (all units)
Best ensemble (no sig. units)
Random combination ensemble

b) Subject P
Places decoded
(4 bins)

Z

X   Y

Best ensemble (all units)
Best ensemble (no sig. units)
Random combination ensemble

Decoding accuracy

Chance level

Ensemble size

d) **Down-modulation**

Head movement spike raster

C20190218C29_1   C20190226C9_9   C20190527C22_13   S20190508C10_7   S20200925C20_6

Time (s)   Time (s)   Time (s)   Time (s)   Time (s)

e) **Up-modulation**

Head movement spike raster

C20190301C9_5   C20190301C23_11   C20190530C18_10   C20190530C21_12   C20190604C3_2

Time (s)   Time (s)   Time (s)   Time (s)   Time (s)

f) **Up/down-modulation**

Head movement spike raster

C20190228C31_8   C20190227C27_5   S20201228PB24   C20190530C13_9   C20190527C13_9

Time (s)   Time (s)   Time (s)   Time (s)   Time (s)

Supplementary figure 6 (a,b) (top) 3D diagram of the binned place locations used to decode the subject's position, (bottom) blue and pink lines correspond to raw decoding accuracy (y axis) as a function ensemble size (number of neurons, x axis), shaded area corresponds to 95% confidence intervals. Blue solid lines correspond to the best ensemble constructed from a pool of all recorded putative pyramidal neurons. Pink solid lines correspond to the best ensemble constructed from a pool of non significantly selective cells (as per GAM encoding analysis). R^2 goodness of fit value is reported. The cyan lines correspond to decoding accuracy of a randomized combination of neurons (100 iterations), shaded area corresponds to 95% confidence intervals. The gray dashed lines correspond to chance decoding accuracy (1/4, 0.25). **(d,e,f)** Additional single-cell examples of down-modulated, up-modulated and up/down modulated cells respectively. Each raster plot corresponds to a single neuron and is aligned (time 0) with the peak velocity time of a head movement, where each row corresponds to one head movement event and each blue dot represents one neuronal spike, negative times indicate the neuron's firing before the peak velocity of a head movement, while positive times indicate the neuron's firing afterwards.

Supplementary movie 1: https://youtu.be/Vz4lMer5g8o (Recording session video example)