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Corresponding Author:	Gregory C. DeAngelis	# Main Figures:	7
Manuscript Number:	NN-A49009A	# Supplementary Figures:	6
Manuscript Type:	Article	# Supplementary Tables:	0
		# Supplementary Videos:	5

Reporting Checklist for Nature Neuroscience

This checklist is used to ensure good reporting standards and to improve the reproducibility of published results. For more information, please read Reporting Life Sciences Research.

Please note that in the event of publication, it is mandatory that authors include all relevant methodological and statistical information in the manuscript.

Statistics reporting, by figure

- Please specify the following information for each panel reporting quantitative data, and where each item is reported (section, e.g. Results, & paragraph number).
- Each figure legend should ideally contain an exact sample size (n) for each experimental group/condition, where n is an exact number and not a range, a clear definition of how n is defined (for example x cells from x slices from x animals from x litters, collected over x days), a description of the statistical test used, the results of the tests, any descriptive statistics and clearly defined error bars if applicable.
- For any experiments using custom statistics, please indicate the test used and stats obtained for each experiment.
- Each figure legend should include a statement of how many times the experiment shown was replicated in the lab; the details of sample collection should be sufficiently clear so that the replicability of the experiment is obvious to the reader.
- For experiments reported in the text but not in the figures, please use the paragraph number instead of the figure number.

Note: Mean and standard deviation are not appropriate on small samples, and plotting independent data points is usually more informative. When technical replicates are reported, error and significance measures reflect the experimental variability and not the variability of the biological process; it is misleading not to state this clearly.

		TEST USED		n			DESCRIPTIVE STATS (AVERAGE, VARIANCE)		P VALUE		DEGREES OF FREEDOM & F/t/z/R/ETC VALUE	
	FIGURE NUMBER	WHICH TEST?	SECTION & PARAGRAPH #	EXACT VALUE	DEFINED?	SECTION & PARAGRAPH #	REPORTED?	SECTION & PARAGRAPH #	EXACT VALUE	SECTION & PARAGRAPH #	VALUE	SECTION & PARAGRAPH #
example	1a	one-way ANOVA	Fig. legend	9, 9, 10, 15	mice from at least 3 litters/group	Methods para 8	error bars are mean +/- SEM	Fig. legend	p = 0.044	Fig. legend	F(3, 36) = 2.97	Fig. legend
example	results, para 6	unpaired t-test	Results para 6	15	slices from 10 mice	Results para 6	error bars are mean +/- SEM	Results para 6	p = 0.0006	Results para 6	t(28) = 2.808	Results para 6

		TEST USED		n			DESCRIPTIVE STATS (AVERAGE, VARIANCE)		P VALUE		DEGREES OF FREEDOM & F/t/z/R/ETC VALUE	
	FIGURE NUMBER	WHICH TEST?	SECTION & PARAGRAPH #	EXACT VALUE	DEFINED?	SECTION & PARAGRAPH #	REPORTED?	SECTION & PARAGRAPH #	EXACT VALUE	SECTION & PARAGRAPH #	VALUE	SECTION & PARAGRAPH #
+ -	2d	permutation test	Results para 3,4,5,6	6 6 6 6	trials without break of fixation		error bas are mean +/- SEM	2d	0.3130 0.0000 0.0000 0.001	Result para 3,4,5,6	DSDI = -0.09 -0.80 -0.67 -0.56	
+ -	3a	permutation test	Results para 7	10 10 10 10	trials without break of fixation		error bas are mean +/- SEM	3a	0.0000 0.0000 0.4580 0.0000	Results para 7	DSDI = -0.62 -0.56 0.01 -0.71	
+ -	3b	permutation test	Results para 7	8 8 8 8	trials without break of fixation		error bas are mean +/- SEM	3b	0.0050 0.001 0.0000 0.4400	Results para 7	DSDI = 0.49 0.52 0.87 0.03	
+ -	3c	permutation test	Results para 8	8 8 8	trials without break of fixation		error bas are mean +/- SEM	3c	0.0000 0.0000 0.4740	Results para 8	DSDI = -0.74 0.80 -0.02	
+ -	res para 9	Wilcoxon signed rank	Results para 9	103 103	neurons with no less than 6 reps/ depth for each condition (hereafter "total population")		median (0.5143, 0.1703) median (0.5143, 0.7001)	Res para 9	3.6 × 10^-10 3.0 × 10^-7	Results para 9		
+ -	Supp Fig. 3a-c	permutation test	legend	equal to or greater than 6	Iteratively for each neuron in the total population		Filled bars (significnatly different zero), open bars (not significant)	Supp Fig. 3a-c	individual values not shown			
+ -	Supp Fig. 3a-c	Wilcoxon signed rank	Supp Fig. 3b-c	412 412	four depths in total population	Supp Fig. 3a-c legend	medians are plotted as filled triangles	Supp Fig. 3b-c	6.7× 10^-23 8.3 × 10^-16	Supp Fig. 3b-c	median = 0.6250 (RM) 0.8125 (DP) 1.0000 (MP)	
+ -	Supp Fig. 3d	Spearman rank correlation significant test	Supp Fig. 3d	309	DSDI values for three conditions in total population				6.9 × 10^-223	Supp Fig. 3d	R = 0.98	
+ -	res para 11	Spearman rank correlation significance test	Results para 11	103 103	total population			Res para 11	0.1964 0.0130	Results para 11	R = 0.13, 0.25	
+ -	res para 11	permutation test	Results para 11	103	total population	Results para 11		Res para 11	0.0000	Results para 11		
+ -	res para 12	Spearman rank correlation significance test	Results para 12	103	total population	Results para 12		Res para 12	0.006	Results para 12	R = 0.24	
+ -												

+ -	res para 12	Two-sample Kolmogorov –Smirnov test	Results para 12	29, 74 (sum to 103)	neurons with significant RM DSDI / the rest of neurons	Results para 12			0.0005	Results para 12		
+ -	res para 13	Spearman rank correlation significance test	Results para 13	103	total population	Results para 13			0.0002	Results para 13	R = 0.36	
+ -	res para 13	Spearman partial rank correlation significance test	Results para 13	103	total population	Results para 13			0.000377	Results para 13	R = 0.35	
+ -	res para 14	Spearman rank correlation significance test	Results para 14	26	neurons with significant and opposite depth-sign between MP and BD conditions	Results para 14			0.1731	Results para 14	R = 0.28	
+ -	res para 14	Spearman rank correlation significance test	Results para 14	38	neurons with significant and the same depth-sign between MP and BD conditions	Results para 14			2.6 × 10^-6	Results para 14	R = 0.70	
+ -	res para 14	Spearman rank correlation significance test	Results para 14	38	neurons with non-significant depth-sign selectivity in either MP or BD condition	Results para 14			0.9123	Results para 14	R = -0.02	
+ -	res para 18	Spearman rank correlation significance test	res para 18	44	neurons with DPsize condition	res para 18			7.6 × 10^-22	res para 18	R = 0.94	
+ -	res para 18	Wilcoxon signed rank test	res para 18	44	neurons with DPsize condition	res para 18	median |DSDI| (0.56, 0.52)		0.0152	res para 18		
+ -	res para 20	Spearman rank correlation significance test	res para 20	91	neurons with DPbalanced condition	res para 20			1.0 × 10^-14	res para 20	R = 0.703	
+ -	res para 20	Wilcoxon signed rank test	res para 20	91	neurons with DPbalanced condition	res para 20	median |DSDI| (0.514, 0.34, 0.17)		0.0009 3.4 × 10^-5	res para 20		
+ -	res para 22	Wilcoxon signed rank test	res para 22	83	neurons with MP +DP condition	res para 22			3.3 × 10^-7	res para 22		
+ -	res para 22	Wilcoxon signed rank test	res para 22	33,39,11	'matched', 'unclassfied', 'mismatched' neurons	res para 22	0.59571 / 0.75689 0.20614 / 0.6097 0.58129 / 0.42505		0.0001 1.8 × 10^-6 0.2061	res para 22	MP+DP vs. DP	
+ -	res para 23	Wilcoxon signed rank test	res para 23	33,39,11	'matched', 'unclassfied', 'mismatched' neurons	res para 23	0.70671 / 0.75689 0.6566 / 0.6097 0.66298 / 0.42505		0.7141 0.3018 0.0010	res para 23	MP+DP vs. MP	
+ -	res para 23	Wilcoxon signed rank test	res para 23	33	'matched' neurons	res para 23	MP: 0.7067 DP: 0.5957		0.001	res para 23	MP vs. DP	
+ -	res para 27	Wilcoxon signed rank test	res para 27	37	neurons with noise stimuli	res para 27			1.2 × 10^-7 2.1 × 10^-6	res para 27	MP vs. RM DP vs. RM	
+ -	res para 27	Spearman rank correlation significance test	res para 27	37	neurons with noise stimuli	res para 27			3.0 × 10^-4	res para 27	R = 0.67	

+ -	res para 16	Wilcoxon signed rank test	res para 16	103	total population	res para 16	median (1.00)	res para 16	0.2254	res para 16		
+ -	res para 16	Wilcoxon signed rank test	res para 16	103	total population	res para 16	median (0.028, 0.03)	res para 16	4.1 × 10^-6	res para 16		
+ -	res para 16	Spearman rank correlation significance test	res para 16	48 (M1), 55(M2)	total population from each animal	res para 16			0.2166 0.0660	res para 16	R = -0.18, -0.25	
+ -	Supp Fig. 6	Spearman rank correlation significance test	Supp Fig. 6	102	neurons with DP condition and size tuning	Supp Fig. 6			0.0557	Supp Fig. 6	R = -0.19	

Representative figures

1. Are any representative images shown (including Western blots and immunohistochemistry/staining) in the paper?

   If so, what figure(s)?

   No

2. For each representative image, is there a clear statement of how many times this experiment was successfully repeated and a discussion of any limitations in repeatability?

   If so, where is this reported (section, paragraph #)?

   N/A

Statistics and general methods

1. Is there a justification of the sample size?

   If so, how was it justified?

   Where (section, paragraph #)?

   Even if no sample size calculation was performed, authors should report why the sample size is adequate to measure their effect size.

   Based on previous literature using awake animals, we collected more than hundred neurons from two monkeys.

   Sample size calculations were not performed a priori, as stated at the end of the Methods section

2. Are statistical tests justified as appropriate for every figure?

   Where (section, paragraph #)?

   Standard nonparametric test are used.

   a. If there is a section summarizing the statistical methods in the methods, is the statistical test for each experiment clearly defined?

   Bootstrap test for DSDI value was described in Methods. Other are widely-used nonparametric tests (signed rank test, Spearman rank correlation significance test, etc.)

   b. Do the data meet the assumptions of the specific statistical test you chose (e.g. normality for a parametric test)?

   Where is this described (section, paragraph #)?

   No parametric test was used.

c. Is there any estimate of variance within each group of data? Is the variance similar between groups that are being statistically compared? Where is this described (section, paragraph #)?	In Results paragraph 12, variances of two groups are significantly different, so we used two-sample Kolmogorov–Smirnov test. For all the other places, paired test (Wilcoxon signed rank test) was used to compare between groups.
d. Are tests specified as one- or two-sided?	all standard nonparametric tests were two-sided.
e. Are there adjustments for multiple comparisons?	No multiple comparison was used.
3. Are criteria for excluding data points reported? Was this criterion established prior to data collection? Where is this described (section, paragraph #)?	We described in Results paragraph 9 that neurons not responding to speed of motion less than 7deg/s were excluded. This criterion was set up prior to data collection.
4. Define the method of randomization used to assign subjects (or samples) to the experimental groups and to collect and process data. If no randomization was used, state so. Where does this appear (section, paragraph #)?	stimulus conditions (RM, MP, DP, DPsize, DPbalanced, MP+DP) are randomly interleaved. It is described in Methods, a paragraph titled as Depth Tuning Measurement.
5. Is a statement of the extent to which investigator knew the group allocation during the experiment and in assessing outcome included? If no blinding was done, state so. Where (section, paragraph #)?	Group of neurons (congruent/opposite, matched/mismatched) was determined at the end of data collection. no data were discarded by the grouping. Not included in text.
6. For experiments in live vertebrates, is a statement of compliance with ethical guidelines/regulations included? Where (section, paragraph #)?	Yes. Methods paragraph 2 has a statement that all protocols were approved by university committee.
7. Is the species of the animals used reported? Where (section, paragraph #)?	Yes. Methods paragraph 1 (macaque mulatta).
8. Is the strain of the animals (including background strains of KO/ transgenic animals used) reported? Where (section, paragraph #)?	no genetically manipulated animals were used.
9. Is the sex of the animals/subjects used reported? Where (section, paragraph #)?	Yes. Methods paragraph 1 (male)
10. Is the age of the animals/subjects reported? Where (section, paragraph #)?	Not reported. Both monkeys are age of 6-8yr.
11. For animals housed in a vivarium, is the light/dark cycle reported? Where (section, paragraph #)?	Not reported. animals had light from 6am to 6pm. Otherwise the cage was in complete darkness.

12. For animals housed in a vivarium, is the housing group (i.e. number of animals per cage) reported?

    Where (section, paragraph #)?

Not reported. Each animal resided in their own cage. Often we paired animals if they get along each other.

13. For behavioral experiments, is the time of day reported (e.g. light or dark cycle)?

    Where (section, paragraph #)?

Not reported. experiments were conducted between 9am-1pm or 1-6pm.

14. Is the previous history of the animals/subjects (e.g. prior drug administration, surgery, behavioral testing) reported?

    Where (section, paragraph #)?

Not reported. Animals did not have prior history of other uses. One animal was used for extracellular recording from area MSTd using a task that only requires fixation during stimulus presentation.

    a. If multiple behavioral tests were conducted in the same group of animals, is this reported?

       Where (section, paragraph #)?

No other behavior tests were conducted in the animals.

15. If any animals/subjects were excluded from analysis, is this reported?

    Where (section, paragraph #)?

No animals were excluded from analysis.

    a. How were the criteria for exclusion defined?

       Where is this described (section, paragraph #)?

N/A

    b. Specify reasons for any discrepancy between the number of animals at the beginning and end of the study.

       Where is this described (section, paragraph #)?

N/A

Reagents

1. Have antibodies been validated for use in the system under study (assay and species)?

N/A

    a. Is antibody catalog number given?

       Where does this appear (section, paragraph #)?

N/A

    b. Where were the validation data reported (citation, supplementary information, Antibodypedia)?

       Where does this appear (section, paragraph #)?

N/A

2. If cell lines were used to reflect the properties of a particular tissue or disease state, is their source identified?

    Where (section, paragraph #)?

N/A

a. Were they recently authenticated?

Where is this information reported (section, paragraph #)?

N/A

Data deposition

Data deposition in a public repository is mandatory for:

a. Protein, DNA and RNA sequences
b. Macromolecular structures
c. Crystallographic data for small molecules
d. Microarray data

Deposition is strongly recommended for many other datasets for which structured public repositories exist; more details on our data policy are available here. We encourage the provision of other source data in supplementary information or in unstructured repositories such as Figshare and Dryad.

1. Are accession codes for deposit dates provided?

   Where (section, paragraph #)?

N/A

Computer code/software

Any custom algorithm/software that is central to the methods must be supplied by the authors in a usable and readable form for readers at the time of publication. However, referees may ask for this information at any time during the review process.

1. Identify all custom software or scripts that were required to conduct the study and where in the procedures each was used.

Matlab (MathWorks) was used for data analysis.
TEMPO (Reflective Computing) was used for experimental control, customized C program was used for stimulus generation and MOOG motion platform control.

2. Is computer source code/software provided with the paper or deposited in a public repository? Indicate in what form this is provided or how it can be obtained.

It can be obtained by inquiry to authors.

Human subjects

1. Which IRB approved the protocol?

   Where is this stated (section, paragraph #)?

No human subjects participated in the current study.

2. Is demographic information on all subjects provided?

   Where (section, paragraph #)?

N/A

3. Is the number of human subjects, their age and sex clearly defined?

   Where (section, paragraph #)?

N/A

4. Are the inclusion and exclusion criteria (if any) clearly specified?

   Where (section, paragraph #)?

N/A

5. How well were the groups matched?

   Where is this information described (section, paragraph #)?

   N/A

6. Is a statement included confirming that informed consent was obtained from all subjects?

   Where (section, paragraph #)?

   N/A

7. For publication of patient photos, is a statement included confirming that consent to publish was obtained?

   Where (section, paragraph #)?

   N/A

fMRI studies

For papers reporting functional imaging (fMRI) results please ensure that these minimal reporting guidelines are met and that all this information is clearly provided in the methods:

1. Were any subjects scanned but then rejected for the analysis after the data was collected?

   N/A

   a. If yes, is the number rejected and reasons for rejection described?

      Where (section, paragraph #)?

      N/A

2. Is the number of blocks, trials or experimental units per session and/or subjects specified?

   Where (section, paragraph #)?

   N/A

3. Is the length of each trial and interval between trials specified?

   N/A

4. Is a blocked, event-related, or mixed design being used? If applicable, please specify the block length or how the event-related or mixed design was optimized.

   N/A

5. Is the task design clearly described?

   Where (section, paragraph #)?

   N/A

6. How was behavioral performance measured?

   N/A

7. Is an ANOVA or factorial design being used?

   N/A

8. For data acquisition, is a whole brain scan used?

   If not, state area of acquisition.

   N/A

   a. How was this region determined?

      N/A

9. Is the field strength (in Tesla) of the MRI system stated?	N/A
a. Is the pulse sequence type (gradient/spin echo, EPI/spiral) stated?	N/A
b. Are the field-of-view, matrix size, slice thickness, and TE/TR/ flip angle clearly stated?	N/A
10. Are the software and specific parameters (model/functions, smoothing kernel size if applicable, etc.) used for data processing and pre-processing clearly stated?	N/A
11. Is the coordinate space for the anatomical/functional imaging data clearly defined as subject/native space or standardized stereotaxic space, e.g., original Talairach, MNI305, ICBM152, etc? Where (section, paragraph #)?	N/A
12. If there was data normalization/standardization to a specific space template, are the type of transformation (linear vs. nonlinear) used and image types being transformed clearly described? Where (section, paragraph #)?	N/A
13. How were anatomical locations determined, e.g., via an automated labeling algorithm (AAL), standardized coordinate database (Talairach daemon), probabilistic atlases, etc.?	N/A
14. Were any additional regressors (behavioral covariates, motion etc) used?	N/A
15. Is the contrast construction clearly defined?	N/A
16. Is a mixed/random effects or fixed inference used?	N/A
a. If fixed effects inference used, is this justified?	N/A
17. Were repeated measures used (multiple measurements per subject)?	N/A
a. If so, are the method to account for within subject correlation and the assumptions made about variance clearly stated?	N/A
18. If the threshold used for inference and visualization in figures varies, is this clearly stated?	N/A
19. Are statistical inferences corrected for multiple comparisons?	N/A
a. If not, is this labeled as uncorrected?	N/A

20. Are the results based on an ROI (region of interest) analysis?	N/A
a. If so, is the rationale clearly described?	N/A
b. How were the ROI's defined (functional vs anatomical localization)?	N/A
21. Is there correction for multiple comparisons within each voxel?	N/A
22. For cluster-wise significance, is the cluster-defining threshold and the corrected significance level defined?	N/A

Additional comments

Additional Comments	