nature neuroscience

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# Main Figures:	8
# Supplementary Figures:	7
# Supplementary Tables:	4
# Supplementary Videos:	0

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
+/- 1h	paired t-test	legend	44	sessions	legend	+/- s.d., all individual datapoints shown	legend	p=1e-10	legend	df=43	Follows from n

	FIGURE NUMBER	TEST USED		n			DESCRIPTIVE STATS (AVERAGE, VARIANCE)		P VALUE		DEGREES OF FREEDOM & F/t/z/R/ETC VALUE	
		WHICH TEST?	SECTION & PARAGRAPH #	EXACT VALUE	DEFINED?	SECTION & PARAGRAPH #	REPORTED?	SECTION & PARAGRAPH #	EXACT VALUE	SECTION & PARAGRAPH #	VALUE	SECTION & PARAGRAPH #
+ −	1i	paired Wilcoxon signed rank test	legend	38	sessions	legend	average +/- s.e.	legend	various, see legend	legend	various, see legend	legend
+ −	1j,k,l	paired Wilcoxon signed rank test	legend	42, 44, 31 (Panels i,j,k)	sessions	legend	average +/- s.e.	legend	various, see legend	legend	various, see legend	legend
+ −	2e-h	none	n/a	various (nr trials)	nr trials	legend	errorbars are average +/- s.e.	legend	n/a	n/a	n/a	n/a
+ −	3b	sign-test	legend	65	nr of units	legend, Table S2	individual points	legend	1e-4	legend	df=64	Follows from n
+ −	3c	paired t-test	legend	65	nr of units	legend, Table S2	average +/- s.e.	legend	1e-5, 0.0056,	legend	df=64	Follows from n
+ −	3d	paired t-test	legend	36	nr of units	legend	average +/- s.e.	legend	0.0001	legend	df=35	Follows from n
+ −	3e	paired t-test	legend	29	nr of units	legend	average +/- s.e.	legend	p=0.0003	legend	df=28	Follows from n
+ −	3f	pairswise ks-test	legend	29	nr of units	legend	full distributions shown (cdf)	legend	TP high vs. TP low, p=0.0094	legend	df=28	Follows from n
+ −	3g	pairwise ks-test	legend	30	nr of units	legend	full distributions shown (cdf)	legend	TN high vs. TN low, p=0.03	legend	df=35	Follows from n
+ −	3h	paired t-test	legend	29	nr of units	legend	average +/- s.e.	legend	Various,see legend	legend	df=28	Follows from n
+ −	3i	paired t-test	legend	30	nr of units	legend	average +/- s.e.	legend	Various,see legend	legend	df=35	Follows from n
+ −	5a,b	bootstrap	legend	128	nr of units	Page 6, Table S2	full distribution shown	legend	0.31, 0.54	legend	df=127	Follows from n
+ −	5c,d	sign-test	legend	128	nr of units	Page 6, Table S2	full distribution shown	legend	0.53, 0.41	legend	df=127	Follows from n
+ −	6a(top)	n/a	n/a	128, 65	nr of units	Table S2	average +/- s.e.	legend	none	legend	n/a	n/a
+ −	6a(bottom)	pairwise t-test	legend	128, 65	nr of units	Table S2	average +/- s.e.	legend	p<0.05 marked,	legend	cluster-size corrected for multiple comparison (bootstrap nulldistribution)	Methods, Page 20
+ −	6b	n/a		128,65	nr of units	Table S2	average +/- s.e.	legend	n/a	n/a	n/a	n/a
+ −	6c	bootstrap	legend	664	nr of units	Page 7	average +/- s.e.	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	Methods, Page 20
+ −	6f	bootstrap	text	65	nr of units	Table S2	average +/- s.e.	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	Methods, Page 20

+/-												
+/-	6g	bootstrap	text	128	nr of units	Table S2	average +/- s.e.	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	Methods, Page 20
+/-	6h,i	paired t-test	legend	65	nr of units	Table S2	average +/- s.e.	legend	0, 0.0049	legend	df=64	Follows from n
+/-	6j,k	paired t-test	legend	128	nr of units	Table S2	average +/- s.e.	legend	0.0049, 0.81	legend	df=127	Follows from n
+/-	7b	bootstrap	legend	128	nr of units	Table S2	population metric	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	n/a
+/-	7c	bootstrap	legend	65	nr of units	Table S2	population metric	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	n/a
+/-	7d	bootstrap	legend	664	nr of units	Table S2	population metric	legend	n/a	n/a	Dashed lines indicate 99% confidence of null distribution (bootstrap)	n/a
+/-	7e	bootstrap	legend	664, 65,65	nr of units	Table S2	+/- s.d. across runs	legend	n/a	n/a	n/a	n/a
+/-	7f	bootstrap	legend	65	nr of units	Table S2	+/- s.d. across runs	legend	n/a	n/a	n/a	n/a
+/-	8c,d	n/a	n/a	951	nr of pairs	Page 8	+/- s.e.	legend	n/a	n/a	n/a	n/a
+/-	8f	paired t-test	legend	951	nr of pairs	Page 8	+/- s.e.	legend	1e-6	legend	df=950	follows from n
+/-	8h	paired t-test	legend	951	nr of pairs	Page 8	+/- s.e.	legend	1e-5	legend	df=950	follows from n
+/-	8g	paired t-test	legend	951	nr of pairs	Page 8	+/- s.e.	legend	0.56, 0.45	legend	df=950	follows from n
+/-	8i	paired t-test	legend	951	nr of pairs	legend	+/- s.e.	legend	1e-14, 0.00022	legend	df=950	follows from n
+/-	8j	paired t-test	legend	951	nr of pairs	legend	+/- s.e.	legend	1e-11	legend	df=950	follows from n
+/-	7g	bootstrap	methods	664	nr of units	Table S2	+/- s.d. across runs	legend	n/a	n/a	n/a	n/a
+/-	7h	bootstrap	methods	65	nr of units	Table S2	+/- s.d. across runs	legend	n/a	n/a	n/a	n/a
+/-	S1h,g	spearman correlation	methods	181, 65	nr of units	Table S2	R2	legend	0.37, 0.25	legend	df=181,65	follows from n
+/-	S2d	Hartigan's dip test	legend, methods	181, 65	nr of units	Table S2	full distribution shown	legend	0.004, 0.34	legend	n/a	n/a
+/-	S4a-l	pairwise t-tests	legend	various (legend)	nr of units	Table S2, S4	+/- s.e.	legend	various, see legend	legend	df is equal to n	follows from n
+/-	S4m-o	bootstrap test	legend	1000 (runs)	nr of runs	legend	full distribution shown	legend	legend	legend	n/a	n/a
+/-	S6	bootstrap test	methods	1000 (runs)	nr of runs	legend	full distribution shown	legend	all are p<0.001	legend	n/a	n/a
+/-	S7	paired sign-test	legend	78	nr of VS units >1 Hz	legend	full distribution shown	legend	0.75, 0.48	legend	78	follows from n

▸ Representative figures

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

   If so, what figure(s)?

   > Fig 2 and Fig 4 shows example neurons

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 #)?

   > Yes; All other figures show statistics across all neurons

▸ 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.

   > No sample size calculation, but sample size of 1065 neurons from 44 sessions and 28 patients is well beyond the normal standards of single unit papers

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

   Where (section, paragraph #)?

   > Yes, extensively; Figure legends and methods specify throughout.

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

   > Yes

   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 #)?

   > Critical tests are bootstrap controlled (no distribution is assumed); ROC analysis does not assume a particular distribution.

   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 #)?

   > Variance is always shown with errorbars

   d. Are tests specified as one- or two-sided?

   > Yes (all are two-sided)

   e. Are there adjustments for multiple comparisons?

   > Yes, when needed (Cluster-size corrected, bootstraped null-distribution)

3. Are criteria for excluding data points reported?

   Was this criterion established prior to data collection?

   Where is this described (section, paragraph #)?

   > All well isolated neurons were included.
   > Criteria for different session groups are purely behavioral (performance requirements)

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 #)?

   > No randomization of subjects because all comparisons are within subject, trial-by-trial. Stimuli are randomized (new or old)

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 #)?

   > n/a

6. For experiments in live vertebrates, is a statement of compliance with ethical guidelines/regulations included?

   Where (section, paragraph #)?

   > Yes (methods)

7. Is the species of the animals used reported?

   Where (section, paragraph #)?

   > Yes (Humans)

8. Is the strain of the animals (including background strains of KO/transgenic animals used) reported?

   Where (section, paragraph #)?

   > n/a

9. Is the sex of the animals/subjects used reported?

   Where (section, paragraph #)?

   > Yes, Table S1

10. Is the age of the animals/subjects reported?

    Where (section, paragraph #)?

    > Yes, Table S1

11. For animals housed in a vivarium, is the light/dark cycle reported?

    Where (section, paragraph #)?

    > n/a

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

    Where (section, paragraph #)?

    > n/a

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

    Where (section, paragraph #)?

    > n/a

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

    Where (section, paragraph #)?

    > n/a

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

Where (section, paragraph #)?

> n/a

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

Where (section, paragraph #)?

> None are excluded

a. How were the criteria for exclusion defined?

Where is this described (section, paragraph #)?

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 #)?

▸ Reagents

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

> None used

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 #)?

> None used

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 #)?

   No. No repositories exist for electrophysiology data.

▶ 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.

   OSort for spike sorting; custom MATLAB scripts for data analysis and simulations

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.

   OSort is opensource and freely available.
   MATLAB scripts are available on request.

▶ Human subjects

1. Which IRB approved the protocol?

   Where is this stated (section, paragraph #)?

   Cedars-Sinai Medical Center, Huntington Memorial Hospital and California Institute of Technology (3 IRB approvals); Methods.

2. Is demographic information on all subjects provided?

   Where (section, paragraph #)?

   Yes, Table S1

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

   Where (section, paragraph #)?

   Yes, Table S1

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

   Where (section, paragraph #)?

   Sequential recruiting, all included who agreed

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 #)?

   Yes, Methods

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

   Where (section, paragraph #)?

   No photos are included

▶ 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?

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

      Where (section, paragraph #)?

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

   Where (section, paragraph #)?

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

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.

5. Is the task design clearly described?

   Where (section, paragraph #)?

6. How was behavioral performance measured?

7. Is an ANOVA or factorial design being used?

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

   If not, state area of acquisition.

   a. How was this region determined?

9. Is the field strength (in Tesla) of the MRI system stated?

    a. Is the pulse sequence type (gradient/spin echo, EPI/spiral) stated?

    b. Are the field-of-view, matrix size, slice thickness, and TE/TR/flip angle clearly stated?

10. Are the software and specific parameters (model/functions, smoothing kernel size if applicable, etc.) used for data processing and pre-processing clearly stated?

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 #)?

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 #)?

13. How were anatomical locations determined, e.g., via an automated labeling algorithm (AAL), standardized coordinate database (Talairach daemon), probabilistic atlases, etc.?

14. Were any additional regressors (behavioral covariates, motion etc) used?

15. Is the contrast construction clearly defined?

16. Is a mixed/random effects or fixed inference used?

    a. If fixed effects inference used, is this justified?

17. Were repeated measures used (multiple measurements per subject)?

    a. If so, are the method to account for within subject correlation and the assumptions made about variance clearly stated?

18. If the threshold used for inference and visualization in figures varies, is this clearly stated?

19. Are statistical inferences corrected for multiple comparisons?

    a. If not, is this labeled as uncorrected?

20. Are the results based on an ROI (region of interest) analysis?

    a. If so, is the rationale clearly described?

    b. How were the ROI's defined (functional vs anatomical localization)?

21. Is there correction for multiple comparisons within each voxel?

22. For cluster-wise significance, is the cluster-defining threshold and the corrected significance level defined?

▸ Additional comments

Additional Comments

> Note the statistical independence of the key comparisons: MS neurons were selected on novel vs. familiar alone and VS neurons on visual category alone. The comparisons between confidence levels and memory strength that follow were behaviorally defined (confidence, remembered, forgotten) and thus independent.
>
> We report individual data values and full distributions of all raw behavioral and neural data values rather than only the mean.