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Manuscript Number:	NN-A54775-T	# Supplementary Figures:	4
Manuscript Type:	Brief Communication	# Supplementary Tables:	3
		# 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
+ -		Wilcoxon signed rank	Main, para 4	18	sessions from 6 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	1.29e-4	Main, para4	z(18) = 4.95	Main, para4

		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 #
+ -		Wilcoxon signed rank	Main, para 4	12	sessions from 4 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	0.0011	Main, para 4	W = 0	Main, para 4
+ -		Wilcoxon rank sum	Main, para 4	30	sessions from 7 rats, 10 neural circuits	Online Methods, para 8	mean +/- SEM	Main, para 4	0.7358	Main, para 4	z = 0.33	Main, para 4
+ -	Figur e 2a	Wilcoxon signed rank	Main para 4	21	sessions from 7 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	5.95e-5	Main, para 4	z = 4.02	Main, para 4
+ -		Wilcoxon signed rank	Main para 4	18	sessions from 6 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	2.74e-4	Main, para 4	z = 3.63	Main, para 4
+ -		Wilcoxon signed rank	Main para 4	12	sessions from 4 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	2.55e-4	Main, para 4	W = 78	Main, para 4
+ -		Wilcoxon rank sum	Main para 4	30	10 neural circutes	Online Methods, para 8	mean +/- SEM	Main, para 4	0.5671	Main, para 4	z = 0.78	Main, para 4
+ -	Figur e 2b	Wilcoxon signed rank	Main para 4	21	sessions from 7 rats	Online Methods, para 8	mean +/- SEM	Main, para 4	8.52e-5	Main, para 4	z = 3.93	Main, para 4
+ -		Wilcoxon rank sum	Main, para 4	42	sessions from 7 rats	Online Methods para 8	mean +/- SEM	Main, para 4	8.83e-5	Main, para 4	z = 3.92	Main, para 4
+ -	Supp Fig 2	Wilcoxon signed rank	Main, para 4	26	sessions from 7 rats	Online Methods, para 12	mean +/- SEM	Main, para 4	9.56e-4	Main, para 4	z = 3.30	Main, para 4
+ -	Supp Fig 2	Wilcoxon signed rank	Main, para 4	26	sessions from 7 rats	Online Methods, para 12	mean +/- SEM	Main, para 4	0.0010	Main, para 4	z = 3.28	Main, para 4
+ -	Supp Flg 2	Wilcoxon signed rank	Main, para 7	26	sessions from 7 rats	Online Methods, para 12	mean +/- SEM	Main, para 7	0.5969	Main, para 7	z = 0.52	Main, para 7
+ -	Supp Fig 2	Wilcoxon rank sum	Main, para 7	26	sessions from 7 rats	Online Methods, para 12	mean +/- SEM	Main, para 7	0.1567	Main, para 7	z = 1.41	Main, para 7
+ -		Wilcoxon rank sum	Online Metho ds, para 11	1406	trials	Online Methods, para 11	mean +/- SEM	Online Meth ods, para 11	0.6320	Online Methods , para 11	z = 0.47	Online Methods, para 11
+ -		Wilcoxon signed rank	Online Metho ds, para 11	1406	trials	Online Methods, para 11	mean +/- SEM	Online Meth ods, para 11	0.4449	Online Methods , para 11	z = 0.77	Online Methods, para 11
+ -		Wilcoxon singed rank	Main, para 4	21	Sessions from 7 rats	Main, para 4	mean +/- SEM	Main, para 4	0.3051	Main, para 4	z = 1.02	Main, para 4
+ -		Wilcoxon signed rank	Main, para 4	21	Sessions from 7 rats	Main, para 4	mean +/- SEM	Main, para 4	0.4206	Main, para 4	z = 1.02	Main, para 4
+ -	Supp . Fig. 3	Two-way ANOVA	Supp Fig 3 legend	21	Sessions from 7 rats	Supp Fig 3 legend	mean +/- SEM	Supp Fig 3 legend	9.83e-215	Supp Fig 3 legend	F = 1033.46, df = 1	Supp Fig 3 legend

+ -	Supp. Fig. 3	Two-way ANOVA	Supp Fig 3 legend	21	Sessions from 7 rats	Supp Fig 3 legend	mean +/- SEM	Supp Fig 3 legend	< 0.0001	Supp Fig 3 legend	F = 2571.27, df = 1	Supp Fig 3 legend
+ -	Supp. Fig. 3	Wilcoxon rank sum	Supp Fig 3 legend	21	Sessions from 7 rats	Supp Fig 3 legend	mean +/- SEM	Supp Fig 3 legend	4.15e-6	Supp Fig 3 legend	z = 4.60	Supp Fig 3 legend
+ -	Supp. Fig. 3	Wilcoxon rank sum	Supp Fig 3 legend	21	Sessions from 7 rats	Supp Fig 3 legend	mean +/- SEM	Supp Fig 3 legend	7.14e-8	Supp Fig 3 legend	z = 4.96	Supp Fig 3 legend
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	175	cells from 2 rats	Main, para 2	percentage	Main, para 2	2.52e-18	Main, para 2	z = 40.51	Main, para 2
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	130	cells from 2 rats	Main, para 2	percentage	Main, para 2	3.17e-317	Main, para 2	z = 417.49	Main, para 2
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	160	cells from 2 rats	Main, para 2	percentage	Main, para 2	9.40e-18	Main, para 2	z = 39.15	Main, para 2
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	175	cells from 2 rats	Main, para 2	percentage	Main, para 2	9.49e-11	Main, para 2	z = 23.07	Main, para 2
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	109	cells from 2 rats	Main, para 2	percentage	Main, para 2	7.45e-140	Main, para 2	z = 320.06	Main, para 2
+ -	Supp. Table 1	Rayleigh's Z	Main, para 2	68	cells from 2 rats	Main, para 2	percentage	Main, para 2	2.72e-4	Main, para 2	z = 8.20	Main, para 2
+ -		Wilcoxon rank sum	Main, para 4	3554	trials	Main, para 4	mean +/- SEM	Main, para 4	0.8739	Main, para 4	z = 1.13	Main, para 4
+ -		Wilcoxon signed rank	Main, para 4	12	sessions from 4 rats	Main, para 4	mean +/- SEM	Main, para 4	0.0039	Main, para 4	W = 4.5, df = 12	Main, para 4
+ -		Wilcoxon signed rank	Main, para 4	18	sessions from 6 rats	Main, para 4	mean +/- SEM	Main, para 4	0.3059	Main, para 4	z = 1.02, df = 18	Main, para 4
+ -	Supp Fig 1	One-way ANOVA	Supp Fig 1 Legend	34	17 brain region LFP peak power at 2 epochs	Supp Fig 1 Legend	mean +/- SEM	Supp Fig 1 Legend	0.97	Supp Fig 1 Legend	F = 0, df = 1, 30	Supp Fig 1 Legend
+ -	Supp Fig 1	One-way ANOVA	Supp Fig 1 Legend	20	10 brain circuits at 2 epochs	Supp Fig 1 Legend	mean +/- SEM	Supp Fig 1 Legend	0.08	Supp Fig 1 Legend	F = 3.49, df = 1, 18	Supp Fig 1 Legend
+ -		Wilcoxon signed rank	Main, para 4	9	sessions from 3 rats	Online methods, para 8	Mean +/- SEM	Main, para 4	0.0078	Main, para 4	W = 1	Main, para 4
+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	12	circuits form 4 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.85	Supp Fig 4 Legend	r = 0.06	Supp Fig 4 Legend
+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	18	circuits from 6 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.97	Supp Fig 4 Legend	r = 0.009	Supp Fig 4 Legend
+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	30	circuits from 7 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.96	Supp Fig 4 Legend	r = -0.0008	Supp Fig 4 Legend
+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	12	circuits form 4 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.28	Supp Fig 4 Legend	r = -0.33	Supp Fig 4 Legend

+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	18	circuits from 6 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.08	Supp Fig 4 Legend	r = 0.413	Supp Fig 4 Legend
+ -	Supp Fig 4	Pearson Correlation	Supp Fig 4 Legend	30	circuits from 7 rats	Supp Fig 4 Legend	correlation value	Supp Fig 4 Legend	0.90	Supp Fig 4 Legend	r = 0.023	Supp Fig 4 Legend

Representative figures

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

   If so, what figure(s)?

   Supplementary Figure 4a.

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. Supplementary Figure 4a Legend.

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.

   Sample size in this study are similar to those generally employed in the field and were not pre-determined by a sample size calculation. LFP analyses: At least 4 rats per DH-PFC comparison (6 DH-PFC, 4 VH-PFC). 3 sets of item-context associations per rat. Spike-Phase analysis: 6 total rats, with at least 2 rats per site. Online Methods (page 1, paragraph 1)

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

   Where (section, paragraph #)?

   Yes, standard statistical tests are used in this study. Used tests are clearly stated in Main Section, Online Methods, Statistical Analysis section, and Supplemental Materials.

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

      Yes, general statistical tests used are summarized in Online Methods, Statistical Analysis section (page 7, paragraph 3). The setup of each individual statistical test is then clearly described within relevant analysis-specific sub-sections of the Online Methods section.

   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 #)?

      Yes. Chi2 goodness of fit testing was used to determine distribution normality. Non-parametric testing was employed where the null hypothesis was rejected. Online methods, page 7, paragraph 3.

   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 #)?

      Yes. Mean and standard error are reported for each data set. Yes. Comparisons are made across groups with similar ranges of variance as indicated by two-sample F-tests. Online methods, page 7, paragraph 3.

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

      Yes. All tests are two-sided.

e. Are there adjustments for multiple comparisons?	N/A.
3. To promote transparency, *Nature Neuroscience* has stopped allowing bar graphs to report statistics in the papers it publishes. If you have bar graphs in your paper, please make sure to switch them to dot-plots (with central and dispersion statistics displayed) or to box-and-whisker plots to show data distributions.	No bar graphs in main figs.
4. Are criteria for excluding data points reported? Was this criterion established prior to data collection? Where is this described (section, paragraph #)?	Yes. All tested subjects with multi-site electrodes provided local field potential data. Cells to be considered within spike-phase analysis must have a minimum of 50 spikes during the analyzed epoch. Main section page 2, paragraph 1.
5. 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 #)?	All subjects underwent the same experimental conditions. Randomization was applied to task structure (Online methods, paragraph 4). Randomization was applied to define confidence intervals for single neuron feature selectivity (Online methods, paragraph 17).
6. 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 #)?	All subjects underwent same testing protocol. (Online methods, paragraph 3)
7. For experiments in live vertebrates, is a statement of compliance with ethical guidelines/regulations included? Where (section, paragraph #)?	Yes. Online methods, page 1, paragraph 2.
8. Is the species of the animals used reported? Where (section, paragraph #)?	Yes. Online methods, page 1, paragraph 1.
9. Is the strain of the animals (including background strains of KO/ transgenic animals used) reported? Where (section, paragraph #)?	Yes. Long Evans were used. Online Methods, paragraph 1.
10. Is the sex of the animals/subjects used reported? Where (section, paragraph #)?	Yes. Online methods, page 1, paragraph 1.
11. Is the age of the animals/subjects reported? Where (section, paragraph #)?	Yes. Online methods, page 1, paragraph 1.
12. For animals housed in a vivarium, is the light/dark cycle reported? Where (section, paragraph #)?	Yes. Online methods, page 1, paragraph 1.

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

    Where (section, paragraph #)?

Animals were housed individually. Online methods, page 1, paragraph 1.

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

    Where (section, paragraph #)?

Animal testing occurred during the light cycle. Online methods, page 1, paragraph 1.

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

    Where (section, paragraph #)?

Animals were naive to testing prior to the experiment. Online methods, page 1, paragraph 1.

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

       Where (section, paragraph #)?

n/a.

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

    Where (section, paragraph #)?

All subjects provided data to the analysis. Online methods, page 1, paragraph 1.

    a. How were the criteria for exclusion defined?

       Where is this described (section, paragraph #)?

Successful electrode placement. Online methods, paragraph 5.

    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 #)?

No difference. Onlline methods, paragraph 5.

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. Cell line identity

    a. Are any cell lines used in this paper listed in the database of commonly misidentified cell lines maintained by ICLAC and NCBI Biosample?

       Where (section, paragraph #)?

n/a.

b. If yes, include in the Methods section a scientific justification of their use--indicate here in which section and paragraph the justification can be found.

n/a.

c. For each cell line, include in the Methods section a statement that specifies:
- the source of the cell lines
- have the cell lines been authenticated? If so, by which method?
- have the cell lines been tested for mycoplasma contamination?

Where (section, paragraph #)?

n/a.

Data deposition

Provide a Data availability statement in the Methods section under "Data availability", which should include, where applicable:
• Accession codes for deposited data
• Other unique identifiers (such as DOIs and hyperlinks for any other datasets)
• At a minimum, a statement confirming that all relevant data are available from the authors
• Formal citations of datasets that are assigned DOIs
• A statement regarding data available in the manuscript as source data
• A statement regarding data available with restrictions

See our data availability and data citations policy page for more information.

Data is available from corresponding author upon request, Online methods, paragraph 18.

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.

We encourage publication of Data Descriptors (see Scientific Data) to maximize data reuse.

Where is the Data Availability statement provided (section, paragraph #)?

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 scripts for cross-correlations, spectral power and coherency, granger causality, and spike-phase modulation.

2. If computer code was used to generate results that are central to the paper's conclusions, include a statement in the Methods section under "**Code availability**" to indicate whether and how the code can be accessed. Include version information as necessary and any restrictions on availability.

Code availability statement, Online methods, paragraph 16.

Human subjects

1. Which IRB approved the protocol?

   Where is this stated (section, paragraph #)?

n/a.

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