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Main Figures: 7

Supplementary Figures:

Supplementary Tables:

Supplementary Videos:

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

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		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 #
+ -	1b	Wilcoxon signed rank	Fig. legend	nAB=16, nKI=20	experiments/ subject	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	pauditory=4.37x10-04, pvisual=4.37x 10-04 for subject AB, and pauditory=8.83x10-05, pvisual=8.82x 10-05 for subject KI	Fig. legend		
+ -	1b	Wilcoxon rank sum	Fig. legend	nAB=16, nKI=20	experiments/ subject	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	pauditory=0.03, pvisual=0.02	Fig. legend		
+ -	1b	Wilcoxon rank sum	Fig. legend	nAB=16, nKI=20	experiments/ subject	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	pauditory=0.42, pvisual=0.49	Fig. legend		
+ -	2b	Rayleigh test	Fig. legend	n=8	number of auditory trials in a 5 second timeframe	Fig. legend			p=6.59x10-06	Fig. legend		
+ -	2b	Rayleigh test	Fig. legend	n=9	number of visual trials in a 5 second timeframe	Fig. legend			p=0.24	Fig. legend		
+ -	2b	Rayleigh test	Fig. legend	n=9	number of visual trials in a 5 second timeframe	Fig. legend			p =2.5x10-05	Fig. legend		
+ -	2b	Rayleigh test	Fig. legend	n=8	number of auditory trials in a 5 second timeframe	Fig. legend			p=0.49	Fig. legend		

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+ -	3b	Tukey's test	Fig. legend	n=36	number of experiments	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	attend auditory: pITCa-ITCv=2.33x10-6, pITCa-noITC=3.67x10-6, pITCa-ITCboth=3.77x10-9, pITCv-noITC=0.99, pITCv-ITCboth=1.3x10-7, pnoITC-ITCboth=7.9x10-8; attend visual: pITCa-ITCv=1.51x10-6, pITCa-noITC=0.97, pITCa-ITCboth=5.18x10-7, pITCv-noITC=1.32x10-5, pITCv-ITCboth=3.77x10-9, pnoITC-ITCboth=4.89x10-8	Fig. legend		
+ -	3b	Wilcoxon signed rank	Fig. legend	n=36	number of experiments	Fig. legend			pattend_auditory=1.8x10-7, pattend_visual=1.4x10-7	Fig. legend		
+ -	3b	Wilcoxon signed rank	Fig. legend	n=36	number of experiments	Fig. legend			pattend_auditory=7.8x10-4, pattend_visual=3.5x10-6	Fig. legend		
+ -	results, para 5	two-way ANOVA	results, para 5	36x3x2	experiments x entrainment condition x cueing	results, para 5	ITC is color coded	Fig. 3c	pdelta=1.22x10-40; ptheta=0.0206 ; pgamma=0.006	results, para 5	Fdelta(2,210)=146.95; Ftheta(2,210)=3.95; Fgamma(2,210)=5.18	results, para 5
+ -	results, para 5	two-way ANOVA	results, para 5	36x3x2	experiments x entrainment condition x cueing	results, para 5	ITC is color coded	Fig. 3c	pdelta=0.49; ptheta=0.22; palpha=0.49; pbeta=0.56; pgamma=0.07	results, para 5	Fdelta(1,210)=0.47; Ftheta(1,210)=1.49; Falpha(1,210)=0.47; Fbeta(1,210)=0.34; Fgamma(1,210)=3.13	results, para 5
+ -	results, para 5	two-way ANOVA	results, para 5	36x3x2	experiments x entrainment condition x cueing	results, para 5	ITC is color coded	Fig. 3c	pdelta=0.90; ptheta=0.5; palpha=0.9; pbeta=0.93; pgamma=0.96	results, para 5	Fdelta(2,210)=0.1; Ftheta(2,210)=0.69; Falpha(2,210)=0.1; Fbeta(2,210)=0.06; Fgamma(2,210)=0.04	results, para 5
+ -	results, para 6	two-way ANOVA	results, para 6	36x3x2	experiments x entrainment condition x cueing	results, para 6	amplitude is color coded	Fig. 3c	pdelta=0.63; ptheta=0.71; palpha=0.88; pbeta=0.97; pgamma=0.9	results, para 6	Fdelta(1,210)=0.22; Ftheta(1,210)=0.13; Falpha(1,210)=0.02; Fbeta(1,210)=0.0008; Fgamma(1,210)=0.01	results, para 6

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+ -	results, para 6	two-way ANOVA	results, para 6	36x3x2	experiments x entrainment condition x cueing	results, para 6	amplitude is color coded	Fig. 3c	palpha= 6.6x10-08; pbeta=1.2x10-04; pgamma=2.7x10-05	results, para 6	Falpha(2,210)=20.86; Fbeta(2,210)=10.95; Fgamma(2,210)=11.73	results, para 6
+ -	3d	Wilcoxon singed rank	Fig. legend	n=72	number of trial blocks	Fig. legend	p value is color coded	Fig. legend	stars denote p values below 0.001, Bonferroni corrected	Fig. legend		
+ -	results, para 7	Wilcoxon singed rank	results, para 7	n=36	number of experiments	results, para 7	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig 4c. legend	p=0.19	results, para 7		
+ -	results, para 7	Wilcoxon singed rank	results, para 7	n=36	number of experiments	results, para 7	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig 4c. legend	pITC=3.64x10-07, palpha=3.99x10-07	results, para 7		
+ -	results, para 7	Wilcoxon singed rank	results, para 7	n=36	number of experiments	results, para 7	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig 4c. legend	p=0.072	results, para 7		
+ -	4d	Rayleigh test	Fig. legend	n=36	number of experiments	Fig. legend	mean phase, phase distribution histogram	4d	p=0.0004	4d		
+ -	4e	Rayleigh test	Fig. legend	n=18	number of paired recordings (36/2)	Fig. legend	mean phase, phase distribution histogram	4e	pITC = 0.0065; palpha=2.7x10-7	4e		
+ -	results, para 10	Wilcoxon signed rank	results, para 10	n=72	number of trial blocks	results, para 10			psupragranular=0.6, pgranular=0.38, pinfragranular=0.93	results, para 10		
+ -	5b	Wilcoxon signed rank	Fig. legend	n=72	number of trial blocks	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	psupragranular=0.507, pgranular=0.003, pinfragranular=0.129	5b		
+ -	5c	Wilcoxon signed rank	Fig. legend	n=72	number of trial blocks	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	Fig. legend	psupragranular=0.018, pgranular=0.002, pinfragranular=0.017	5c		

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+ -	5d	Wilcoxon signed rank	Fig. legend	n=72	number of trial blocks	Fig. legend	average	5d	supragranular: pdelta=0.0014, ptheta=8.1x10-12, palpha=5.5x10-5; granular: pdelta=0.03, ptheta=1.5x10-5, palpha=2.6x10-5; infragranular: pdelta=0.09, ptheta=2.9x10-5, palpha=2x10-6	5d		
+ -	results, para 12	Wilcoxon signed rank	results, para 12	n=72	number of trial blocks	results, para 12			psupragranular=0.0264, pgranular=0.0043, pinfragranular=0.0019	results, para 12		
+ -	results, para 13	Wilcoxon rank sum	results, para 13	ninhibitory=589, nexcitatory=490, nSDW=88	number of units	results, para 13	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	6b	pinhibitory-excitatory=2.33x10-4, pinhibitory-SDW= 4.09x10-11	results, para 13		
+ -	6b	Wilcoxon signed rank	Fig. legend	nall=1167, ninhibitory=589, nexcitatory=490, nSDW=88	number of units	Fig. legend	Boxplots have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data.	6b	pall=2.5x10-123, pexcitatory=4.9x10-55, pinhibitory=5.5x10-65, pSDW=8.1 x10-4	6b		

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+ -	6c	Wilcoxon signed rank	Fig. legend	nall=1167, ninhibitory=589, nexcitatory=490, nSDW=88	number of units	Fig. legend	average	6c	all: pdelta=1.5x10-6, ptheta=3.3x10-5, palpha=2.4x10-20, pbeta=9.2x10-5, pgamma=0.72 ,phgamma=0.08; excitatory: pdelta=8.3x10-6, ptheta=9.3x10-4, palpha=1.1x10-7, pbeta=0.055, pgamma=0.3, phgamma=0.0197; inhibitory: pdelta=0.002, ptheta=0.015, palpha=1.9x10-13, pbeta=6.1x10-4,pgamma=0.062, phgamma=0.75; SDW: pdelta=0.45, ptheta=0.27, palpha=0.02, pbeta=0.27, pgamma=0.2, phgamma=0.71	6c		
+ -	7a	Wilcoxon rank sum	Fig. legend	nsig-ITC=137, nno-ITC=61	during significant ITC vs. noITC periods	Fig. legend	error bars represent mean +/- SEM	7a	p<0.01	Fig. legend		
+ -	7b	one sample t-test	Fig. legend	n=72	number of trial blocks	Fig. legend	coherence difference (ITC-noITC delta and alpha coherence), the boxes have lines at lower quartile, median, and upper quartile values, while whiskers show the extent of the data	7b	delta coherence, supra p = 0.0006, gran p = 0.0135, infra p = 0.0007; alpha coherence, supra p = 0.0023, gran p = 0.033, infra p = 0.0061	7b		
+ -	online methods, para 4	Wilcoxon signed rank	online methods, para 4	n= 299-382	number of auditory trials, variable across trial blocks	online methods, para 4			p>0.05	online methods, para 4		

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.

While no sample size calculation was performed, results of previous non-human primate studies indicate that with the nonparametric tests used, applied to a moderately strong and consistent effect, at least 12 to 15 observations in 2 subjects are necessary to demonstrate statistical significance, which is stated in the methods section (1st paragraph).

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

   Where (section, paragraph #)?

Yes, this is described throughout the Results section, Figure legends and in the Online Methods section.

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

Yes, at the end of the Online Methods section in the "Statistics" paragraph (16th paragraph of the Methods).

   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 #)?

Data distribution was assumed to be normal but this was not formally tested. This statement is included at end of the Online Methods section in the "Statistics" paragraph (16th paragraph of the Methods).

   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 #)?

Data distribution was assumed to be normal but this was not formally tested. This statement is included at end of the Online Methods section in the "Statistics" paragraph (16th paragraph of the Methods).

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

Yes, at the end of the Online Methods section in the "Statistics" paragraph (16th paragraph of the Methods).

   e. Are there adjustments for multiple comparisons?

Yes.

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.

The bars in figure 4E do not report statistics, they merely illustrate the number of single units belonging to each category. Since this is a single value and not a distribution for each bar, this cannot be changed to dot or box-and-whisker plots. The bars in Figure 3B are again not statistical comparisons, they illustrate what percentage of hits and false alarms falls into each entrainment category.

4. Are criteria for excluding data points reported?

   Was this criterion established prior to data collection?

   Where is this described (section, paragraph #)?

No animals or data points were excluded from the analyses (included in the 16th paragraph of the Online Methods).

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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 #)?	Trial blocks were presented in random order. This statement is included in the 4th paragraph of the Online Methods section.
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 #)?	Data collection and analysis were not performed blind to the conditions of the experiments (Online Methods, pargraph 5).
7. For experiments in live vertebrates, is a statement of compliance with ethical guidelines/regulations included? Where (section, paragraph #)?	Yes, Online Methods, 1st paragraph.
8. Is the species of the animals used reported? Where (section, paragraph #)?	Yes, Results, 1st paragraph and Online Methods, 1st paragraph.
9. Is the strain of the animals (including background strains of KO/ transgenic animals used) reported? Where (section, paragraph #)?	N/A.
10. Is the sex of the animals/subjects used reported? Where (section, paragraph #)?	Yes, Online Methods, 1st paragraph.
11. Is the age of the animals/subjects reported? Where (section, paragraph #)?	Yes, Online Methods, 1st paragraph.
12. For animals housed in a vivarium, is the light/dark cycle reported? Where (section, paragraph #)?	N/A.
13. For animals housed in a vivarium, is the housing group (i.e. number of animals per cage) reported? Where (section, paragraph #)?	N/A.
14. For behavioral experiments, is the time of day reported (e.g. light or dark cycle)? Where (section, paragraph #)?	Yes, Online Methods, 5th paragraph.
15. Is the previous history of the animals/subjects (e.g. prior drug administration, surgery, behavioral testing) reported? Where (section, paragraph #)?	Yes, Online Methods, 1st and 2nd paragraph.

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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 #)?

N/A.

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)?

N/A.

a. Is antibody catalog number given?

Where does this appear (section, paragraph #)?

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

Where does this appear (section, paragraph #)?

2. Cell line identity

N/A.

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 #)?

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.

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 #)?

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Data availability

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 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.

No custom algorithms were used, circular statistical measures were calculated using Daniel Rizutto's PhasePACK package for Matlab, and gamma burst were detected using the peakfinder algorithm by Nathanael C. Yoder. This is described in the methods section.

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.

Human subjects

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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 #)?

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

   Where (section, paragraph #)?

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

   Where (section, paragraph #)?

5. How well were the groups matched?

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

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

   Where (section, paragraph #)?

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

   Where (section, paragraph #)?

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 #)?

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.

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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)?

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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

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