nature portfolio

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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒ The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐ A description of all covariates tested
☐	☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☐	☒ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	LiveMouse Tracker (LMT) (https://micecraft.org/lmt/) Doric System fiber photometry, Doric lenses inc. Spike 2 Software (Cambridge electronic design) Microscope Zeiss Software (ZEN)
Data analysis	MATLAB_R2021a (The Mathwork) RStudio - R version 4.4.1 R package 'archetypes' version 2.2-0.1- Code and Data for archetypal analysis can be obtained on Zenodo (10.5281/zenodo.17121126). R package 'emmeans' version 1.10.5 PyCharm (Python) Code and set of Matlab scripts to simulate the full model and simulate and analyze the reduced model can be obtained on Zenodo (10.5281/zenodo.17121126).

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

Source data are provided with this paper and a comprehensive table reporting all statistical tests are provided in the Supplementary Information. In addition, the data underlying the figures, together with analysis scripts, are deposited on Zenodo (DOI: 10.5281/zenodo.17121126).
Code for the reinforcement-learning model and all data analyses is available on Zenodo (DOI: 10.5281/zenodo.17121126).

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	N/A
Reporting on race, ethnicity, or other socially relevant groupings	N/A
Population characteristics	N/A
Recruitment	N/A
Ethics oversight	N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	No formal statistical methods were used to predetermine sample sizes. Sample sizes were chosen a priori based on our previous experience with these platforms (microsocieties and VTA DA readouts), effect sizes/variability observed in prior datasets using closely related paradigms, and practical constraints of long-duration continuous recordings. For social experiments, the independent unit of replication was the triad (cage), and we targeted enough independent triads per condition to robustly estimate role distributions and test deviations from chance using sampling-based null models. For analyses relying on archetypal decomposition, we additionally ensured sufficient numbers to support stratified comparisons across sex × archetype groups (up to six groups), which increases the effective number of comparisons typical of classification-based approaches. Final sample sizes for each experiment/analysis are reported in figure legends and the statistics table; we used similar ranges in related work on individuality in semi-natural environments and dopaminergic measurements (e.g., Torquet et al., 2018; Fayad et al., 2024).
Data exclusions	For behavioral experiments, mice were excluded if at least one day of the experiment got technical issues (e.g. food dispenser blocked). For fiberphotometry and optogenetics experiments outliers were identified if the transfection of the AAV or the implantation of the optic fiber was misplaced.
Replication	The behavior in the LiveMouseTracker system was replicated several times: - 14 triads; 42mice in males triads - 14 triads; 42 mice in females triads - 16 triads; 48 mice for tube test (males and females mice) - 26 mice in lone context for females mice - 36 mice in lone context for males mice - 12 triads; 36 mice in the sex-mixed paradigm - 13 triads; 39 mice in social replacement paradigm - 114 male mice in optogenetics experiments for the 3 conditions - 99 female mice in chemogenetic experiments for the 3 conditions - 75 mice in the anesthetized electrophysiology experiments (all the conditions, lone and social contexts)

- 29 mice in the fiberphotometry experiments (all the conditions, lone and social contexts)
All experiments were performed on independent cohorts of mice. For all optogenetic/chemoenetic and fiber photometry experiments, viral expression/injection sites and optic fiber placements were verified for each mouse (post hoc) , and only correctly targeted animals were included in the analyses. All attempts at replication were successful and yielded consistent results across cohorts.

Randomization

All the experimental mice used in the study were wild-type (WT) or DAT-Cre transgenic mice.
For behavioural and fiberphotometry tracking, we used LiveMouseTracker system to perform, as much as possible, non-biased automatic analyses in coupling calcium recording and behaviour only.
For optogenetics and chemogenetics experiments, mice were randomly assigned to each condition.
Each triad were randomly composed, in receiving directly triads from Janvier laboratory.

Blinding

All the experimenters were blinded at group allocation during data collection and analysis.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☐	☒ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Antibodies

Antibodies used

n this study, the following primary antibody were used: mouse monoclonal anti-Tyrosine Hydroxylase (1/500 dilution, sigma T1299, clone TH-2). The following secondary antibody were used at 1/500 dilution: goat anti-mouse Cy3 (Jackson ImmunoResearch, 715-165-150). To mount the slices the following antibodies was used to tag the nucleus of cells: Prolong Gold Antifade Reagent (Invitrogen, P36930)

Validation

According to the manufacter's website (Merck), T1299 has been referenced in 224 publications. Find all the publications on this link: https://www.sigmaaldrich.com/FR/fr/search/t1299?focus=papers&page=1&perpage=30&sort=relevance&term=T1299&type=citation_search

According to the manufacter's website (JacksonImmunoResearch) 715-165-150 has been referenced in 769 publications. Find all the publications on this link:https://www.citeab.com/antibodies/2036175-715-165-150-cy-3-affinipure-donkey-anti-mouse-igg?utm_campaign=Widget+All+Citations&utm_medium=Widget&utm_source=Jackson+Immunoresearch&utm_term=Jackson+ImmunoResearch

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals

The study was conducted using wild type (WT) and transgenic mice with C57BL/6J background. WT mice were obtained from Janvier Laboratory. For DA neuron-specific manipulations and recording, DAT-iresCre (BAC-DAT-Cre) were employed. Males and females animals were used. Mice were housed in groups (weaning at P21 – P23) under a 12 hours light – dark cycle (7:00 a.m.– 7:00 p.m.). All physiology and behaviour experiments in mice were performed when they reached the age of 8 weeks. All the expriments were performed continuously, then occured during the dark and light cycle. Fiberphotometry recordings were performed during dark cycle.

Wild animals

No wild animals were used in this study.

Reporting on sex

This study compared both sexes in our paradigm and is a main finding of the study.
It is indicated in the methods and the figures.

Field-collected samples

No field-collected samples were used in this study.

Ethics oversight

All experiments and procedures were performed in accordance with European Commission directives 219/1990, 220/1990 and 2010/63, and approved by the ESPCI and the ethical committee #059 under APAFIS #34335-2021121318085835.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks	N/A
Novel plant genotypes	N/A
Authentication	N/A