

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
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☒ | ☐ | 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
<i>Give P values as exact values whenever suitable.</i> |
| ☒ | ☐ | 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 Labview 2018 was used to collect data for fiber fluorometry data. Python 3.11.0 was used to collect behavioral data in the monster task. Zen Blue 3.5 software and Zen Black 2.0 software were used to acquire fluorescent images.

Data analysis MATLAB R2022a was used to analyze fluorometry and behavioral data. Codes used in this study are available from public repository (https://github.com/melissa0v0/TS_Dopamine_Optogenetics).

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](#)

The fluorometry data and the behavioral data are shared at a public deposit source (<https://doi.org/10.5061/dryad.w6m905qzv>).

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	The number of animals used for ablation studies (dopamine neurons and D1 neurons, n=6 animals) was determined by a power analysis using a pilot experiment (t-test, 6 animals for control and 6 animals for dopamine neuron ablation, data not included because the apparatus was slightly different) to be able to detect a significant difference in the failure rate for water acquisition compared to controls at 90% confidence level. The number of animals used for ablation studies (D2 neurons, n=12 animals) was determined by a power analysis using a pilot experiment (t-test, 6 animals for D2 neurons ablation and 18 animals for pooled controls) to be able to detect a significant difference in improvement of the failure rate at 90% confidence level.
Data exclusions	Two mice were excluded from Figure 1 since they could not achieve 80% accuracy in the last day of training in the monster task.
Replication	Animals were not formally divided into separate groups for "proof of principle" and "replication". Instead, we pooled all data, and displayed data from each animal (along with the average and standard error or boxplot) as much as possible. Of note, major experimental data are taken from more than 2 separate batch of experiments as indicated in the Methods and the observed tendency was conserved among the batches. all attempts at replication were successful.
Randomization	Animals were randomly selected for all experiments.
Blinding	The experimenters were blinded to the treatments of mice in ablation studies until completion of behavioral analyses. Photometry study did not require blinding as we did not compare the difference between groups.

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 anti-TH, rabbit polyclonal, AB152, Millipore Sigma.

Validation The specificity of this antibody has been verified by the company
anti-TH: https://www.emdmillipore.com/US/en/product/Anti-Tyrosine-Hydroxylase-Antibody,MM_NF-AB152#overview

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 206wild type mice, 12 tachykinin precursor 1 (Tac1)-cre (B6;129S-Tac1tm1.1(cre)Hze/J, Jackson Laboratory; RRID:IMSR JAX: 021877) heterozygous mice, 24 Tac1-cre;Ai14 (Rosa-CAG-LSL-tdTomato, Jackson Laboratory; RRID:IMSR JAX:007914) double heterozygous mice, 11 adenosine 2A receptor (Adora2A)-cre (B6.FVB(Cg)-Tg(Adora2a-cre) KG139Gsat/Mmucd, GENSAT; MGI:4361654) heterozygous mice, 24 Adora2A-cre;Ai14 double heterozygous mice, 6 vesicular glutamate transporter 2 (vGluT2)lox/lox (Slc17a6tm1Lowl/J, Jackson Laboratory; RRID:IMSR_JAX:012898) heterozygous mice, 10dopamine transporter (DAT)-cre (B6.SJL-Slc6a3tm1.1(cre)Bkmn/J, Jackson Laboratory; RRID:IMSR JAX:006660); vGluT2lox/lox double heterozygous mice, and 3 vGluT2-cre (B6J.129S6(FVB)-Slc17a6tm2(cre)Lowl/MwarJ, Jackson Laboratory; RRID:IMSR JAX:028863)heterozygous mice, 2 DAT-flp(B6N(Cg)-Slc6a3tm1.1(fipo)Fuyu/J, Jackson Laboratory; RRID: IMSR_JAX:033673) heterozygous mice, 12 Tac1-cre heterozygous; DAT-flpheterozygous double transgenic mice, 12 Adora2a-cre heterozygous; DAT-flpheterozygous double transgenic mice, male and female, aged 8-20 weeks, were used. All mice were backcrossed with C57BL/6J (Jackson Laboratory). Animals were housed on a 12 hour dark/12 hour light cycle (dark from 07:00 to 19:00) and performed a task at the same time each day.

Wild animals No wild animals were used in the study.

Reporting on sex Both male and females were used in the study.

Field-collected samples No field collected samples were used in the study.

Ethics oversight The Harvard Animal Care and Use Committee

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