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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	Python 3.7, Psychopy 2021.2.0, Psiturk 3.0.6, jsPsych 6.1.0. The code utilized in this manuscript is available at https://github.com/sanghyunyi/Affordance2025
Data analysis	MATLAB 2020b, Python 3.7, 3.8, 3.9, FSL 6.0. The code utilized in this manuscript is available at https://github.com/sanghyunyi/Affordance2025

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 behavioral data utilized in this manuscript is available at https://github.com/sanghyunyi/Affordance2025. Group-level z-statistic maps from the GLM analyses can be accessed at https://neurovault.org/collections/22137/.

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	We recruited 21 and 32 healthy participants for the behavioral-only experiment and the fMRI experiment respectively. 2 participants were excluded from the behavioral and another 2 from the fMRI experiment because they didn' were used for the analysest complete the study. Therefore, data from the remaining 19 ((8 females, 11 males) and 30 (13 females, 17 males).
Reporting on race, ethnicity, or other socially relevant groupings	NA
Population characteristics	Behavioral only: 18 right-handed; 1 ambidextrous, 18 ~ 24 years: 6; 25 ~ 34 years: 10; 35 ~44years: 1; 45 years or above: 2 fMRI: 28 right-handed; 2 ambidextrous, 18 ~ 24 years: 12; 25 ~ 34 years: 12; 35 ~ 44 years: 4; 45 years or above: 2
Recruitment	We recruited 21 and 32 healthy participants for the behavioral-only experiment and the fMRI experiment respectively, from the local (LA county) community through a mailing list. Online data was collected from US residents through M-Turk. Because participation was voluntary, some self-selection bias may exist, as individuals with greater interest in cognitive or behavioral research may have been more likely to participate. Local recruitment could also limit demographic diversity, and online data collection may introduce environmental variability. These factors may modestly affect generalizability but are unlikely to impact the main findings, which were replicated across independent samples.
Ethics oversight	All participants provided their informed consent, and the study was approved by the Institutional Review Board of California Institute of Technology (IR20-1033).

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	We recruited 21 (19 after exclusion) and 32 (30 after exclusion) healthy participants for the behavioral-only experiment and the fMRI experiment respectively and 227 (160 after exclusion) participants online. Although no formal sample size calculation was performed, the chosen sample sizes are consistent with common practice in group-level behavioral and fMRI research.
Data exclusions	2 participants were excluded from the behavioral and another 2 from the fMRI experiment because they didn't complete the study. 67 online participants were excluded as they that didn't pass at least 2 catch trials.
Replication	We replicated the results of the behavioral-only experiment in the fMRI experiment. The two experiments were conducted independently during different time periods.
Randomization	NA (no intervention, no group)
Blinding	NA (no intervention, no group)

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

Plants

Seed stocks: NA

Novel plant genotypes: NA

Authentication: NA

Magnetic resonance imaging

Experimental design

Design type: Event-related task design

Design specifications: We designed a 3-armed bandit task variant where participants performed natural pinch, clench, or poke gestures with their right hand, each yielding binary outcomes. The fMRI experiment used 24 visual object stimuli. On each trial, participants viewed an image of an object with a human silhouette and mimed one of the three hand gestures while keeping their wrist on a provided pad. To ensure proper execution, participants watched instructional videos demonstrating the required hand gestures.

Participants were informed that each hand motion had a different reward probability for each object, requiring them to explore and identify the most rewarding gesture. The fMRI study lasted one day and consisted of six blocks, with 76-84 trials per block (averaging 80), totaling 480 trials. Each block displayed four distinct objects, and each object appeared approximately 20 times. Objects were randomly ordered, appearing once every four trials. The stimuli sets were fixed across participants, but the assignment of conditions to objects was randomized. Counterbalancing ensured no more than two objects within a block shared the same affordance or optimal response.

Each trial lasted between 7 to 11.5 seconds, averaging 9.25 seconds. It began with a jittered fixation cross displayed for 1 to 2.5 seconds, followed by a stimulus display for up to 4 seconds until the participant's response was registered. After the response, a second jittered fixation cross was shown for 1 to 2.5 seconds, followed by a reward feedback display for another jittered 1 to 2.5 seconds. Finally, a fixation cross was presented for the remaining duration to ensure a consistent total trial length.

Behavioral performance measures: Hand gesture tracked with camera

Acquisition

Imaging type(s): Functional, Structrural

Field strength: 3T

Sequence & imaging parameters: fMRI data were acquired at the Caltech Brain Imaging Center (Pasadena, CA), using a Siemens Prisma 3T scanner with a 32-channel radio-frequency coil. The functional scans were conducted using a multi-band echo-planar imaging (EPI) sequence with 72 slices,
-30 degrees slice tilt from AC-PC line, 192 mm x 192 mm field of view, 2 mm isotropic resolution, repetition time (TR) of 1.12 s, echo time (TE) of 30ms, multi-band acceleration of 4, 54-degree flip angle, in-plane acceleration factor 2, echo spacing of 0.56 ms, and EPI factor of 96.
Following each run, both positive and negative polarity EPI-based field maps were collected using similar parameters to

the functional sequence, but with a single band, TR of 5.13 s, TE of 41.40 ms, and 90-degree flip angle.
T1-weighted and T2-weighted structural images were also acquired for each participant with 0.9 mm isotropic resolution and 230 mm $\times$ 230 mm field of view. For the T1-weighted scan, TR of 2.55 s, TE of 1.63 ms, inversion time (TI) of 1.15 s, flip angle of 8 degrees, and in-plane acceleration factor 2 were used. The T2-weighted scan was acquired with TR of 3.2 s, TE of 564 ms, and in-plane acceleration factor of 2.

Area of acquisition: Whole brain

Diffusion MRI ☐ Used ☒ Not used

Preprocessing

Preprocessing software: fMRI-prep 20.2.6

Normalization: Normalization was performed according to the default fMRI-prep procedure

Normalization template: MNI

Noise and artifact removal: Framewise displacement, global signal, global signal derivative, 6 head-motion parameters (x, y, z translations and rotations), and temporal CompCor from fMRIPrep were included as nuisance variables in every analysis.

Volume censoring: fMRI-prep 20.2.6

Statistical modeling & inference

Model type and settings: Univariate analyses

Effect(s) tested: z-test

Specify type of analysis: ☐ Whole brain ☐ ROI-based ☒ Both

Anatomical location(s): The ROI was functionally defined based on the whole-brain analysis results.

Statistic type for inference (See Eklund et al. 2016): Cluster correction with a cluster-defining threshold z=3.1 at the whole brain

Correction: Cluster correction with a cluster-defining threshold z=3.1 at the whole brain

Models & analysis

n/a	Involved in the study
☐	☒ Functional and/or effective connectivity
☒	☐ Graph analysis
☒	☐ Multivariate modeling or predictive analysis

Functional and/or effective connectivity: Psychophysiological interaction analysis