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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	All code except for proprietary code for streaming EEG (ANT Neuro), eye gaze (Tobii AB), and robotic arm control (Franka Emika) were made using open source languages (Python 3.8 and C++11). Custom code and more detailed descriptions can be found at https://github.com/kaolab-research/bci_raspy (https://doi.org/10.5281/zenodo.15164641).
Data analysis	Data analysis was performed using Python 3.8 and open source libraries. Custom code can be found at https://github.com/kaolab-research/bci_plot (https://doi.org/10.5281/zenodo.15164643).

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

Data is available at https://doi.org/10.5281/zenodo.15165133.

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	Experimental recordings were made on participants: S2, a 32-year old male; H1, a 32-year old male; H2, a 27-year old female; and H4, a 27-year old male. Sex and gender were not considered in the study design. The results are applicable to all sex and genders. A comprehensive explanation of the experimental protocol was provided to the participants prior to the experiment. Informed consent (UCLA IRB) was signed by all the participants.
Reporting on race, ethnicity, or other socially relevant groupings	The study design did not consider race, ethnicity, or other socially relevant groupings.
Population characteristics	S2 was a paralyzed participant with spinal cord injury (paraplegic, T5 complete, injury since 4 years). H1, H2 and H4 were healthy participants.
Recruitment	Paralyzed participants were enrolled via UCLA IRB approved online advertisements circulated in Los Angeles area. Healthy participants (H1, H2 and H4) were recruited via word of mouth. Paralyzed participant S2 volunteered his time. H1, H2, and H4 were compensated for their participation. As detailed in the methods, we only continued experiments if participants could perform the center-out 8 task with the 7cm and 4.7cm target sizes.
Ethics oversight	The study was approved by the UCLA IRB.

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	Sample sizes were not predetermined using statistical methods. The number of experimental days for CNN-KF control was chosen to allow participants to become proficient with the center-out 8 task. 1 paralyzed participant and 3 healthy participants were recruited for this study without a formal sample size calculation. This sample size falls within the typical enrollment in the paralyzed BCI studies. Thus, it is considered sufficient based on relevant research. Sample sizes are reported within each figure.
Data exclusions	Data from 1 day was omitted for the paralyzed participant S2. S2 felt paresthesia on that day and could not perform the experiments. No data were omitted for other participants.
Replication	The experiments in our study were replicated with 4 participants. Each subject participated in the same experimental paradigm, allowing for replication across subjects.
Randomization	Participant randomization was not relevant. The sequence of targets within different experimental sessions was randomized.
Blinding	Blinding was not applicable. We did not blind investigators or participants, instead opting for ABAB experiments. We instructed participants to perform their best in all conditions, and were encouraged to optimize their control strategy for each condition.

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	N/A
Novel plant genotypes	N/A
Authentication	N/A