

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 (<i>n</i>) 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. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> 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 <i>d</i> , Pearson's <i>r</i>), 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	Animal experiment video footage in the study was directly recorded using Proximie system. User study video are recorded with a personal iphone 17 pro.
Data analysis	Data analysis was done using the code developed by the authors' group. The data processing code is publicly available at Zenodo (DOI: 10.5281/zenodo.20434260).

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 code supporting the study can be found at Zenodo (DOI:10.5281/zenodo.18023650). The user study source data and data processing code is available at Zenodo (DOI: 10.5281/zenodo.20434260).

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	Sex and gender were not analyzed as covariates in this study. Participant sex and gender were not used for group assignment or statistical analysis.
Reporting on race, ethnicity, or other socially relevant groupings	Race, ethnicity, and other socially relevant groupings were not analyzed as covariates in this study and were not used for group assignment or statistical analysis.
Population characteristics	Dry-lab participants included users with varying laparoscopic and robotic-surgery experience. For the O-ring transfer task, participants included 12 novices and 6 surgeons. For the FLS peg-transfer task, participants included 8 junior surgeons and 5 senior surgeons. No demographic variables were analyzed as covariates.
Recruitment	Participants were recruited from institutional trainees, surgeons, and/or volunteer users with relevant surgical or robotic-system experience. Participation was voluntary. Participants completed standardized familiarization before task trials.
Ethics oversight	The dry-lab user study involving human participants was conducted under UC San Diego IRB protocol #800026.

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](https://www.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 statistical methods were used to predetermine sample size. Sample sizes were chosen based on typical cohort sizes in exploratory human-robot interaction experiments and standard practice in exploratory feasibility studies in surgical robotics and logistical constraints of in-vivo animal experimentation.
Data exclusions	No data were excluded. All collected data were included in the analysis, and no exclusion criteria were pre-established.
Replication	Dry-lab user-study tasks were performed by independent participants: n = 18 participants for the O-ring transfer task and n = 13 participants for the FLS peg-transfer task. Each participant completed the assigned task under each platform condition. In vivo surgical procedures were performed in n = 2 independent animals, with one laparoscopic cholecystectomy performed per animal, due to the exploratory feasibility nature of the study.
Randomization	For the dry-lab user study, participants completed all platform conditions, and the order of platform conditions was counterbalanced across participants to mitigate order effects. No random assignment to treatment groups was performed. No randomization was applied to the in vivo animal procedures, as these were exploratory feasibility procedures performed sequentially in two animals.
Blinding	Investigators were not blinded during experiments or analysis due to the operational requirements of the surgical robotic system.

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

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	Experiments were performed in two domestic female swine aged approximately 11 and 16 weeks at the time of surgery
Wild animals	No wild animals were used in this study
Reporting on sex	Both pigs were female
Field-collected samples	No field-collected samples were used in this study
Ethics oversight	All procedures were conducted with institutional animal care approval (UCSD IACUC #S08027). A licensed veterinarian administered and monitored the animals' general anesthesia, while simulation center staff assisted with sterile preparation and draping of the animal before incision. performed in accordance with institutional animal welfare guidelines.

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

Plants

Seed stocks	Not applicable
Novel plant genotypes	Not applicable
Authentication	Not applicable