

Reporting Summary

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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	Data for Study 1 was collected via the ASSISTments mathematics learning platform. Data for Study 2 was collected via freeCodeCamp's website via Google Analytics 4. The pilot survey and randomized experiment were administered using Qualtrics. Media coverage analyses used the New York Times Article Search API and the GDELT 2.0 Television News API.
Data analysis	Data analysis was primarily performed in R (4.4.1), with supplementary tasks (data pre-processing for aspiring coder study, coding open-text responses via the openAI API) completed in Python (3.11.2). All associated code files (including environment files specifying package versions) are publicly accessible via the manuscript's OSF repository (https://osf.io/xyfpt).

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 and materials associated with this paper can be found in the following repository: <https://osf.io/xyfpt>. It includes data for our analyses of math students, as well as the preliminary representative survey, randomized experiment, and media coverage analyses. Data from our second dataset (on aspiring coders) are available upon reasonable request per our Data Availability Statement.

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

Data on learners' sex was not collected in any of our datasets. Our two main datasets did not collect data on learners' gender. In our randomized experiment and preliminary survey, gender was self-reported via a multiple-choice item ("How do you identify your gender?": Man; Woman; Trans man; Trans woman; Genderqueer/other).

In our randomized experiment, out of 598 participants, 310 (51.8%) identified as women, 272 (45.5%) identified as men, 3 (0.5%) identified as trans men, 13 identified as "genderqueer/other", and none identified as trans women.

In our preliminary survey, out of 500 participants, 231 (46.2%) identified as women, 228 (45.6%) identified as men, 29 (5.8%) identified as trans men, 5 (1%) identified as trans women, and 7 (1.4%) identified as "genderqueer/other." We confirmed that the relatively high percentage of self-identified trans men is not due to a coding error.

Our preliminary survey used Prolific's representative sample quotas to approximately match the study sample to the general U.S. population on age, gender, and race/ethnicity.

No sex- or gender-based analyses were preregistered, as we did not a-priori predict that gender would interface with microdelays effects, and our preregistered sample sizes were not set to ensure sufficient power to detect subgroup effects.

Reporting on race, ethnicity, or other socially relevant groupings

In our two main datasets, no individual-level race or ethnicity data were recorded.

In some models analyzing our math students dataset, to account for between-school demographic differences, we included a school-level demographic variable—proportion of non-Hispanic White students.

In our analysis of aspiring coders, we used a learner's country (as automatically recorded by Google Analytics) as a socially-relevant category.

In our preliminary survey, race/ethnicity was self-reported via a check-all-that-apply item (Asian; Black; Middle Eastern; Native American or Alaskan Native; Native Hawaiian or Pacific Islander; White; Other) and a separate binary Hispanic/Latino item. In recording race/ethnicity, we used the canonical U.S. Census categories (with the addition of "Middle Eastern"). Race/ethnicity were not used in analyses.

Our randomized experiment did not collect any data on race, ethnicity, or other socially relevant groupings.

Population characteristics

See below

Recruitment

We did not recruit participants for the main two datasets in this paper. Participants in the preliminary survey and randomized experiment were recruited via Prolific Academic. The preliminary survey used Prolific's representative-sample quotas to approximately match the sample to the general U.S. population on age, gender, and race/ethnicity.

Ethics oversight

The randomized experiment and preliminary survey were approved by the University of Pennsylvania's Institutional Review Board (IRB). The two main datasets in this paper involved de-identified data that the partner organizations collected as part of their ongoing operations, and as such did not constitute human subjects research that would require IRB approval.

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)

Behavioural & social sciences study design

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

Study description	All studies in this manuscript were quantitative.
Research sample	Dataset 1 (math students) - U.S. primary and secondary school Students from classes that use ASSISTments' math learning platform. We did not record individual-level demographics. School-level demographics are described in Supplementary Information Table S3. This dataset was chosen because ASSISTments is widely used in U.S. primary/secondary mathematics, its outcomes feed into school grades, and student performance on ASSISTments predicts high-stakes-test scores and college enrollment. Dataset 2 (aspiring coders) - users of freeCodeCamp's Spanish-language website. Most of these users are located in Latin America. This dataset does not include individual-level demographics apart from a country identifier for each visit. This dataset was chosen because freeCodeCamp is a leading platform globally in training for technology careers. Its Spanish-language site serves a large learner base in middle-income Latin American countries where bandwidth varies widely, making it an ideal setting to examine microdelays in a globally diverse sample of self-directed learners. Preliminary survey - U.S. adults, with quotas set for the sample to approximately match the U.S. general population on gender, age, and race/ethnicity, based on census data as assessed via Prolific. Randomized experiment - U.S. Adults who (a) indicated interest in reading a popular science excerpt, and (b) opted to read the excerpt on their own time With the exception of the preliminary survey, none of the studies in this paper purport to be representative (e.g., of the general population of U.S. primary and secondary school students)
Sampling strategy	The two main datasets used in this manuscript did not involve sampling participants. Data used in our analysis of math students spanned roughly half of a school year (up until one week before Christmas, Sep 18 - Dec 18 2024). Data used in our analysis of aspiring coders spanned two months (4 July - 4 Sep 2023). A two-month window was set to maximize statistical power while still allowing most of the more advanced analyses (multiverse, multilevel GAMs) to run locally without requiring the use of cloud computing or high-performance clusters. We also run exploratory analyses on a 4-month span (4 May - 4 Sep, 2023). Randomized experiment - we used a sequential Bayesian design to collect data in batches using a preregistered threshold for stopping data collection (see Method section for more details). Preliminary survey - we preregistered a sample size of 500 participants.
Data collection	Data for the two main analyses in this manuscript was collected as part of the platforms' day-to-day operations. Both the randomized experiment and preliminary survey were digital surveys administered online using Qualtrics, with participants recruited via Prolific Academic. Thus, researchers were not present with participants at any time during data collection. Randomized experiment - Used a between-subjects design, such that each participant only saw one condition. Researchers were not blind to condition when analyzing the data.
Timing	Data were collected at the following times: Preliminary Survey - Aug 14, 2024 Randomized experiment - Feb 17-19, 2024 Dataset 1 (math students) - Sep 18 - Dec 18, 2024 Dataset 2 (aspiring coders) - May 4 - Sep 4, 2023
Data exclusions	Study 1 (math students) Preregistered Exclusions: - Observations with load times longer than or equal to 1 minute (n = 67,993). - Observations with impossible (negative) lag-to-start times (n = 35,494) - Observations that represent likely test responses (user IDs with only a single observation; n = 9,022) - Some models in the multiverse excluded outliers (see Supplementary Information Table S2) - Some models in the multiverse excluded observations that had missing data for any of the variables used in that specific model. Exploratory Exclusions: - "Skillbuilder" assignments (n = 41,506; see Supplementary Information Section S4). Study 2 (aspiring coders) Preregistered Exclusions: - Observations with missing load times (n = 81,267).

- Observations from mobile or tablet devices (n = 23,977)
- Observations with load times longer than or equal to 1 minute (n = 4,440)
- Observations that do not contain a session start event (n = 1,579)
- Some models in the multiverse excluded outliers (see Supplementary Information Table S8)

Exploratory Exclusions: N/A

Preliminary survey

Exploratory Exclusions:

- Oversampled participants (n = 2) recruited by Prolific in excess of our designation (n = 2). We retained the first 500 participants in the data.

Randomized Experiment

Exploratory Exclusions:

- Participants with duplicate participant ids (n = 9).
- Oversampled participants (n = 25) recruited by Prolific in excess of our requested sample size. We retained the first 1500 participants in the data.

Non-participation

No participants dropped out or declined to participate in our two main datasets as well as the preliminary survey. In the randomized experiment, out of 1,500 prescreened participants: 970 (64.67%) qualified based on their interest in one of the popular science excerpts, and were invited to participate in the main study. Of those invited, 612 (63.09%) opted to read the excerpt. Of these, 607 participants started reading the excerpt (598 after excluding observations with duplicate IDs).

Randomization

Our two main datasets and the preliminary survey did not involve random assignment. Our randomized experiment randomly assigned participants to one of two between-person conditions (delay / no-delay).

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

Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.

Novel plant genotypes

Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.

Authentication

Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosaicism, off-target gene editing) were examined.