

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	We collected EEG activity using a 128-channel HydroCel Geodesic Sensor Net (HGSN) connected to a NetAmps 400 amplifier (Electrical Geodesic Inc., Eugene, OR). We utilized Matlab R2020a and Psychtoolbox for the presentation and collection of behavioral data in Study I. Additionally, we employed PsychoPy 2021.2.3 to present stimuli and collect behavioral data in Studies II and III. Furthermore, we administered the word understanding questionnaire via the Sojump platform in Study II.
Data analysis	The EEG data in Study I were preprocessed in Matlab R2020a with EEGLAB, ERPLAB and customized MATLAB scripts. Behavioral data collected in the sorting, mouse tracking, and the rating tasks, along with the word understanding questionnaire, were processed in Matlab and Microsoft Excel, and subsequently analyzed with SPSS 26. In study III, a GEE regression model was constructed using RStudio 2023.12.1 or the representational similarity analysis.

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 data supporting the findings of this study are accessible on Github (<https://github.com/happytudouni/ChildFER>). The raw EEG and questionnaires data are protected and are not available due to data privacy laws. However, de-identified pre-processed EEG data can be made available upon request from the corresponding author, subject to institutional and ethical approvals.

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

In this study, the sex and gender of children and adults involved were consistent. We obtained the gender of participants through demographic survey questionnaires, and their sex was determined through observation.

Reporting on race, ethnicity, or other socially relevant groupings

All subjects were Chinese.

Population characteristics

The study included a total of 152 children (average age = 7.73, SD = 1.85, age range 5.00–11.75, with 71 females) and 41 adults (average age = 20.78, SD = 1.82, age range 18–25, with 22 females). The FPVS task involved 122 children (61 female, Mage = 7.89, SD = 1.84, range 5.00–11.75) and 33 adults (15 female, Mage = 20.91, SD = 1.89, range 18–25). Additionally, we tested a new cohort of children (N = 30, Mage = 7.87, SD = 1.71, 14 females) and adults (N = 15, Mage = 21.00, SD = 1.36, 6 females) with both upright and inverted face configurations. The final sample for the rating task included 144 children (average age = 7.76, SD = 1.86, age range 5.00–11.75, with 71 females) and 39 young adults (1.87, age range 18–25, with 20 females). The final sample for the MT task included 144 children (average age = 7.76, SD = 1.86, age range 5.00–11.75, with 71 females) and 39 young adults (average age = 20.77, SD = 1.87, age range 18–25, with 20 females). The final sample for the sorting task included 145 children (average age = 7.73, SD = 1.84, age range 5.00–11.75, with 70 females) and 39 young adults (average age = 20.77, SD = 1.87, age range 18–25, with 20 females). Additionally, scores from the guardians of 99 children were collected for the assessment of understanding emotional words (average age = 7.94, SD = 1.79, age range 5.00–11.75, with 59 females).

Recruitment

Participants were recruited through poster promotion and by word-of-mouth.

Ethics oversight

Prior written informed consent was obtained from adult participants and the guardians of child participants, with financial compensation provided post-experiment. Testing was approved by the local Research Ethics Committee of the School of Psychological and Cognitive Sciences at Peking University.

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

Behavioural & social sciences study design

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

Study description

Our experiments were all quantitative.

Research sample

The final sample included a total of 152 children and 41 college students living in Beijing, China.

Sampling strategy

Our sample size calculations for repeated measures ANOVA, conducted using G*Power, indicated that each age group required a sample size of 24. Furthermore, based on prior research on child development, we ultimately selected an average of 30 children per age group.

Data collection

The EEG and behavioral experiments were conducted in our labs at Peking University. We captured EEG activity by connecting a 128-channel HydroCel Geodesic Sensor Net (HGSN) to a NetAmps 400 amplifier (Electrical Geodesic Inc., Eugene, OR) and used Matlab R2020a to record the behavioral data during the experiment of Study I. For the behavioral experiments, the Psychopy v2021.2.3 toolbox was utilized to record participants' reaction times, accuracy, and mouse tracking trajectories. Additionally, we collected

	results from the word understanding questionnaire through the Sojump platform.
Timing	Data collection at Peking University began on September 23, 2022, and continued until July 7, 2024.
Data exclusions	In Study I, EEG data from 30 children and 8 adults were excluded due to the following reasons: 8 children exhibited excessive noise in their raw data which cannot be deleted in the further analysis, 6 children had incomplete data for at least one condition, and 16 children, along with 8 adults, failed to complete FPVS task. Behavioral data in Studies II and III were not excluded.
Non-participation	In our experiment, children who could not focus on the experiment or tolerate its duration were directly withdrawn. Out of 152 child participants, a total of 8 withdrew from the rating and mouse tracking tasks, and 7 withdrew from the sorting task. Two adults were unable to complete mouse tracking task.
Randomization	For each experiment, we randomized the order in which different conditions appeared. This approach was undertaken to ensure that the experimental results were not influenced by the order of stimulus presentation.

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		Methods	
n/a	Involved in the study	n/a	Involved in the study
☒	☐ Antibodies	☒	☐ ChIP-seq
☒	☐ Eukaryotic cell lines	☒	☐ Flow cytometry
☒	☐ Palaeontology and archaeology	☒	☐ MRI-based neuroimaging
☒	☐ Animals and other organisms		
☒	☐ Clinical data		
☒	☐ Dual use research of concern		
☒	☐ Plants		

Plants

Seed stocks	NA
Novel plant genotypes	NA
Authentication	NA