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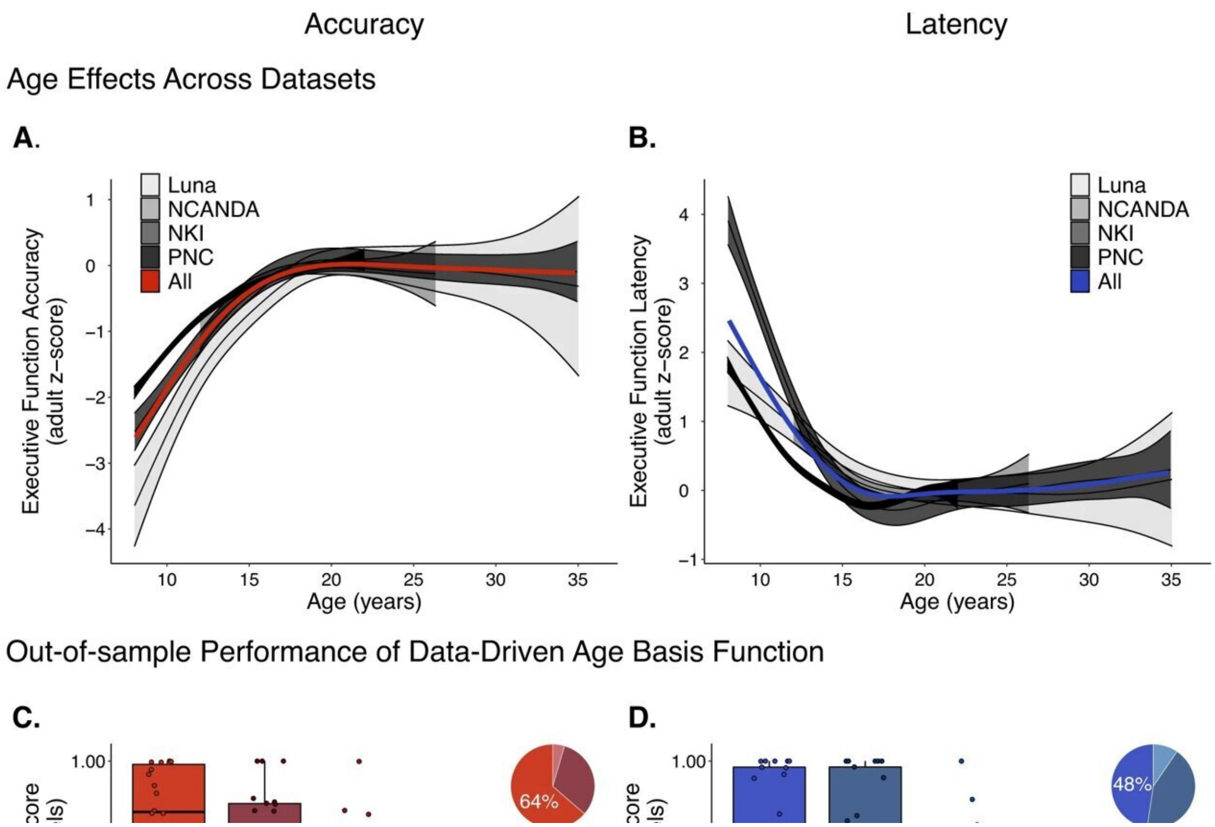

Scaled domain general executive function scores generate reproducible adolescent growth charts across datasets and tasks. Accuracy (**A**) and latency (**B**) composite (z score sum of all accuracy, latency measures; see Supplementary Table S2) executive function scores for Luna (N = 196; 666 total visits), NCANDA (N = 831; 3412 total visits), NKI (N = 588), and PNC (N = 9151) datasets. Each measure within each dataset is z scored to the performance of adults (participants 20–30 years old). Fit lines are from GAM/GAMM models. Error bars represent two times the standard error added above and below these fits (measure of center). **C**, **D** Out-of-dataset performance as boxplots (center line, median; box limits, upper and lower quartiles; whiskers, 1.5x interquartile range; points, outliers) of the single parameter data-driven age basis function for accuracy (**C**) and latency (**D**) measures relative to typical age models (quadratic [age+age^2], inverse age [1/age], linear age [age]) and an intercept only (no age) model. One dot per measure from all datasets ($N = 22$ accuracy; $N = 21$ latency). Cross-validation ("leave one dataset out") was used to validate the age basis function derived from the canonical executive trajectory. See Supplementary Fig. S11 for diagram of procedure. Potential age models were evaluated with multiple metrics of model fit and complexity (see Methods and Supplementary Fig. S11). Using the performance package (rank function) in R[55], model fit metrics were scaled 0 (worst model on that fit metric) to 1 (best model on that fit metric, accounting for the directionality of improved fit for each metric [e.g., R^2 larger values, RMSE lower values]) across candidate age models and the mean value across all model fit metrics was taken for each candidate age model to create an overall performance score (y-axis; **C**, **D**). Pie charts indicate the percent of times that each age model was the top ranked according to this procedure; color in pie chart corresponds to age models color from boxplots. Number of age parameters (# age params.) specifies the number age variables used in each candidate age model (see also Supplementary Fig. S11). Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-42540-8

At what age does an adolescent start thinking as an adult? A new study published this week in *Nature Communications* presents some of the first definitive evidence that executive function—a set of cognitive skills underlying the ability to plan, seamlessly switch from task to task, resist tempting distractions and focus on a task at hand—usually matures by the time an individual turns 18 years old.

The study collected and analyzed nearly two dozen laboratory measures of executive functions in over 10,000 participants across four unique datasets, presenting a first-of-its-kind large scale chart of cognitive development in teens. The findings have significant implications not only for psychiatrists and neuroscientists, but also for parents, educators, and potentially the judicial system in defining the boundaries of the adolescent period.

"When I talk with parents, a lot of them say, 'There is no way that my 18-year-old is a fully formed adult!'" said senior author Beatriz Luna, Ph.D., professor of psychiatry at the University of Pittsburgh School of Medicine and a world-renowned expert on neurocognitive development.

"Other important behavioral factors that complement executive function, such as the ability to control one's own emotions, can change with age. The ability to use executive function reliably improves with age and, at least in a laboratory setting, matures by 18 years of age."

Unlike the meticulously mapped out milestones of childhood, the timeline of adolescence remained less formally defined, primarily due to the complexity of developmental processes set into motion with the onset of puberty. High variability among individuals and a lack of tools for analyzing complex datasets also limited the confidence of previous attempts to build a roadmap of brain development in teens.

"In our study, we wanted to present a consensus and not just a hunch," said lead author Brenden Tervo-Clemmens, Ph.D., assistant professor of psychiatry and behavioral sciences at the University of Minnesota.

"This is developmental science meets big data. We are using tools that were not available to researchers studying cognitive and brain development until several years ago. A study of this scale was made possible only by open data-sharing and collaborators who graciously gave access to their datasets without asking anything in return," added Tervo-Clemmens, who began this research as a graduate student in Luna's lab at Pitt.

The study collected 23 distinct measures of executive function from over 10,000 participants from 8 to 35 years old. Scientists then analyzed those metrics by tracking their change over time and checking whether performance across different tests fit a single trajectory that could be described with a mathematical model.

The resulting analysis showed a common dynamic of executive function maturation that was shared between both sexes: a rapid burst of executive function development in late childhood to mid-adolescence (10–15 years old), followed by small but significant changes through mid-adolescence (15–18) that stabilized to adult-level performance by late adolescence (18–20).

By presenting reproducible growth charts across tasks and datasets, this roadmap could allow researchers to track how therapeutic and drug interventions might affect developmental milestones. For instance, adolescence is the time when many mental illnesses, which also have problems in executive function, such as schizophrenia, emerge. Charting the neurotypical brain development timeline will then allow researchers to better track any subtle shifts from the "norm" and possibly improve early diagnosis.

More information: Brenden Tervo-Clemmens et al, A canonical trajectory of executive function maturation from adolescence to adulthood, *Nature Communications* (2023). DOI: 10.1038/s41467-023-42540-8

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