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# ABCD Human Subjects Study

Adolescent Brain Cognitive Development – ABCDSTUDY.org

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## Release Notes: Adolescent Brain Cognitive Development Study<sup>SM</sup> (ABCD Study<sup>®</sup>) Data Release 4.0

### Trial Level Behavioral Data (TLBD)

<http://dx.doi.org/10.15154/1523041>

October 2021

#### Change Log

October 2021 – Data Release 4.0

- Initial release

### List of Instruments

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## General Information

The following information refers to the Adolescent Brain Cognitive Development Study<sup>SM</sup> (ABCD) Data Release 4.0 available from <https://nda.nih.gov/abcd>. An overview of the ABCD Study<sup>®</sup> is at <https://abcdstudy.org> and detailed descriptions of the assessment protocols can be viewed at <https://abcdstudy.org/scientists/protocols>.

This document describes the contents of various instruments available for download. To understand the context of this information, see *Release Notes ABCD README FIRST* and *Release Notes ABCD Imaging Instruments*.

## Trial Level Behavioral Data

The instruments released in this package contain the trial level data from each of the cognitive tasks administered in ABCD. Please note that the data are packaged in a single compressed file (i.e., zip). Data are raw values directly from the vendors with no quality control. Researchers are required to perform their own quality control of the data prior to analysis. Data files have been curated to only include necessary information for analyses and make these files as user-friendly as possible. These release notes contain important information explaining what all of the variables in these data files represent for each cognitive tasks.

More details of each of the tasks can be found in the following publications:

1. Casey, B. J. *et al.* The Adolescent Brain Cognitive Development (ABCD) study: Imaging acquisition across 21 sites. *Dev. Cogn. Neurosci.* **32**, 43–54 (2018).
2. Luciana, M. *et al.* Adolescent neurocognitive development and impacts of substance use: Overview of the adolescent brain cognitive development (ABCD) baseline neurocognition battery. *Dev. Cogn. Neurosci.* **32**, 67–79 (2018).

## ABCD Little Man Task Trial Level Behavior

### Description of cognitive task

The Little Man Task measures visuospatial processing flexibility and attention across 32 test trials. The task involves the presentation of a rudimentary male figure holding a briefcase in one hand in the middle of the screen. The figure may appear in one of four positions; right side up vs. upside down and either facing the respondent or with his back to the respondent. The briefcase may be in either the right or left hand. Using one of two buttons, respondents indicate which hand is holding the briefcase. The association between the button and response is held constant across trials and participants, i.e., there is no interference between hand and button

(left hand always associated with a button to the left of the participant and which is labeled “left”).

### Details of data in raw data files

| COLUMN NAME           | DESCRIPTION                                                                                                                                                                   |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| task                  | Behavioral task completed                                                                                                                                                     |
| subject               | Subject ID how it's defined in ABCD                                                                                                                                           |
| eventname             | The event name for which the data was collected                                                                                                                               |
| site                  | Data collection site ID                                                                                                                                                       |
| build                 | The specific Inquisit version used                                                                                                                                            |
| computer_platform     | Operating system                                                                                                                                                              |
| date                  | The date the script was run                                                                                                                                                   |
| time                  | The time the script was run                                                                                                                                                   |
| lmt_blocknum          | 3 blocks of LMT task: 1 = instructions; 2 = practice; 3 = test trials                                                                                                         |
| lmt_blockcode         | Similar to lmt_trialcode, those designated “test” are the test trials. Can also cross reference with lmt_values_stim to determine type of test trial                          |
| lmt_trialcode         | Designates what type of trial was presented (see lmt_trialnum). “littleManPresentation” designates the test trials, otherwise they are practice/instructional trials          |
| lmt_trialnum          | “Trial” number for each step/stimulus presentation in the task                                                                                                                |
| lmt_values_stim       | Numerical values for which image was displayed (practice trials are ex1.png, ex2.png, etc.; test trials are 1.png, 2.png, etc.)                                               |
| lmt_values_correctans | This is the “correct answer” for each test trial. For test trials 0 = leftButton; 1 = rightButton.”                                                                           |
| lmt_response          | In response to the stimulus: rightButton = right button was pressed; leftButton = left button was pressed; missing/0 = no response; HomeButton = home base/button was pressed |
| lmt_correct           | 0 = FALSE (not correct); 1 = TRUE (correct)                                                                                                                                   |
| lmt_latency           | Latency in milliseconds – for test trials this is time from presentation of stimulus to response                                                                              |

**NOTE:** LMT Year 2 data was administered using a different vendor than at Baseline. When applicable and available, LMT Baseline trial-level data was therefore reformatted and coded to match LMT Year 2 data format. Any wholly missing variables for LMT Baseline were not produced at that time point, therefore have been left blank. This is applicable to all participants

at baseline except those PGUIDs listed below who completed the latest Millisecond version. This will ensure consistency in data output longitudinally.

## ABCD Delay Discounting Task Trial Level Behavior

### Description of cognitive task

The delay discounting task (here, an adjusting-amount discounting task) is designed to assess decision making between monetary rewards to be delivered immediately or larger rewards to be delivered in the future. Here, both the rewards and delays are hypothetical. Participants are first introduced to two practice trials, followed by 7 blocks of 6 trials per block. Each block was characterized by a different delay to a hypothetical \$100 reward. The initial trial of each block began with a choice between a \$50 reward available immediately and a \$100 reward available after an interval of time (e.g., 1 week). Choices for the immediate reward resulted in decreases in the value of the immediate reward; choices for the delayed reward resulted in increases in the value of the immediate reward. The size of the increase/decrease of the immediate reward from trial  $n+1$  to trial  $n+2$  was  $\frac{1}{2}$  the change in size of the increase/decrease of the immediate reward from trial  $n$  to trial  $n+1$ . The final indifference point for each block approximates the amount of the immediate reward that is equivalent to the subjective value of the delayed reward. After each choice, participants were required to press a center area (“home base”) before the next trial began. (Below, these are referred to as “home-base trials”.) Three of the delay blocks also incorporated “catch trials”, which are designed to evaluate the extent to which participants are attentive to the task. In these catch trials, participants were offered the choice between \$100 delivered immediately or \$100 delivered after the corresponding delay for that block.

### Details of data in raw data files

| COLUMN NAME       | DESCRIPTION                                                                                                                         |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| task              | Behavioral task completed                                                                                                           |
| subject           | Subject ID how it's defined in ABCD                                                                                                 |
| eventname         | The event name for which the data was collected                                                                                     |
| site              | Data collection site ID                                                                                                             |
| build             | The specific Inquisit version used                                                                                                  |
| computer_platform | Operating system                                                                                                                    |
| date              | The date the script was run                                                                                                         |
| time              | The time the script was run                                                                                                         |
| trial             | Trial number                                                                                                                        |
| ddis_trialtype    | Trial type (i.e., “practice” trials are incorporated to introduce participants to the task, all remaining trials are “test” trials) |

|                             |                                                                                                                                                                                       |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ddis_countdelays            | Block number (“Practice” trials are block 0, “Test” trials are blocks 1-7)                                                                                                            |
| ddis_delays_ordinalrank     | Ordinal ranking of the delays to the larger reward (“6 hours from now” = 1, “1 day” = 2, “1 week” = 3, “1 month” = 4, “3 months” = 5, “1 year” = 6, “5 years” = 7)                    |
| ddis_delay                  | Delay to the larger reward, as presented to participants                                                                                                                              |
| ddis_delay_indays           | Delay to the larger reward, converted to total number of days to the larger reward                                                                                                    |
| ddis_delayedreward_amount   | Amount of the delayed reward (\$) for that choice                                                                                                                                     |
| ddis_immediatereward_amount | Amount of the immediate reward (\$) for that choice. Trials in which the immediate reward amount equaled \$100 were catch trials (i.e., trials 14-15 of 3 different blocks of trials) |
| ddis_delayedreward_location | Location on the computer screen of the delayed reward relative to the immediate reward (i.e., “left” side or “right” side)                                                            |
| ddis_choicelatency_ms       | Latency to make each choice (trials in which latency equaled 0 were home-base trials)                                                                                                 |
| ddis_choice                 | Choice of the immediate reward (0) or delayed reward (1). On home-base trials, the choice is automatically set to 0.                                                                  |
| ddis_indifferencepoint      | Indifference point for each trial. The indifference point on Trial 13 of each block represents the final indifference point for that block.                                           |

## ABCD Emotional Stroop Task Trial Level Behavior

### Description of cognitive task

In this task individuals categorize the emotional valence of a word as either positive or negative via a button press while ignoring a distracting face of either the same (i.e., congruent) or opposite (i.e., incongruent) emotional valence. It is designed to measure cognitive control in the presence of emotionally distracting information, which is more difficult on incongruent than congruent trials. Trials are divided into two test blocks, each of which contain 48 trials. In one block there are 75% congruent trials and 25% incongruent trials (testMC = test block, mostly congruent). In the other there is an equal percentage of congruent and incongruent trials (50%/50%) (testE = test block, equal). Cognitive control also tends to be more difficult when there is a lower proportion of incongruent trials in a block.

Details of data in raw data files

| COLUMN NAME          | DESCRIPTION                                                                                                                                                                                                                                                                           |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| task                 | Behavioral task completed                                                                                                                                                                                                                                                             |
| subject              | Subject ID how it's defined in ABCD                                                                                                                                                                                                                                                   |
| eventname            | The event name for which the data was collected                                                                                                                                                                                                                                       |
| site                 | Data collection site ID                                                                                                                                                                                                                                                               |
| build                | The specific Inquisit version used                                                                                                                                                                                                                                                    |
| computer_platform    | Operating system                                                                                                                                                                                                                                                                      |
| date                 | The date the script was run                                                                                                                                                                                                                                                           |
| time                 | The time the script was run                                                                                                                                                                                                                                                           |
| values.keyAssignment | Emotional valence mapped to left key (positive or negative)                                                                                                                                                                                                                           |
| blockcode            | Practice1 = first block of practice; repeatPractice=instruction screen for additional practice block; practice 2= second block of practice; testMC – test block with mostly congruent trials (75/25); test equal – test block with half congruent and half incongruent trials (50/50) |
| blocknum             | The number of the present block (not consecutive in some cases as as instructions (not included) are coded as blocks as well).                                                                                                                                                        |
| trialnum             | Unique trial identifier for a given block                                                                                                                                                                                                                                             |
| values.wordposition  | 1=word appears on top; 2=word appears on bottom                                                                                                                                                                                                                                       |
| values.word_y        | Vertical coordinate of current word (in % of frame)                                                                                                                                                                                                                                   |
| values.congruence    | 1= congruent 2= incongruent (emotion of word and face)                                                                                                                                                                                                                                |
| values.faceemotion   | “happy” or “angry”                                                                                                                                                                                                                                                                    |
| values.selectStim    | Item number of selected stimulus                                                                                                                                                                                                                                                      |
| stimulusitem2        | The presented face stimulus (file number)                                                                                                                                                                                                                                             |
| stimulusitem3        | The presented word stimulus                                                                                                                                                                                                                                                           |
| values.correctButton | The correct response to the trial (i.e., emotional valence of the word)                                                                                                                                                                                                               |
| response             | Actual participant response (0=missing)                                                                                                                                                                                                                                               |
| correct              | 0=incorrect 1= correct                                                                                                                                                                                                                                                                |
| latency              | Reaction time                                                                                                                                                                                                                                                                         |
| List.accuracymean    | Cumulative accuracy for the block through that trial (i.e., proportion correct for a given block)                                                                                                                                                                                     |

## ABCD Game of Dice Task Trial Level Behavior

### Description of cognitive task

The Game of Dice Task (GDT) assesses decision-making under explicit risk conditions (Brand et al., 2005). Participants are asked to guess the result of a die throw by selecting combinations of one, two, three, or four numbers for a total of 18 trials. Low-risk choices (i.e. combinations of three or four numbers) are associated with greater probability of smaller gains, whereas high-risk choices (i.e. combinations of one or two numbers) are associated with lower probability of higher gains. The total number of risky choices or net score are typically used as the index of risky decision-making.

### Details of data in raw data files

| COLUMN NAME                | DESCRIPTION                                                                                                           |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------|
| task                       | Behavioral task completed                                                                                             |
| subject                    | Subject ID how it's defined in lab/project                                                                            |
| eventname                  | The event name for which the data was collected                                                                       |
| site                       | Data collection site ID                                                                                               |
| build                      | The specific Inquisit version used                                                                                    |
| date                       | Date script was run                                                                                                   |
| time                       | Time script was run                                                                                                   |
| gdt_parameters_version     | 1 = original version with feedback (default)                                                                          |
| gdt_blocknum               | The number of the current block (Inquisit variable)                                                                   |
| gdt_blockcode              | The name of the current block (Inquisit variable)                                                                     |
| gdt_values_phase           | Practice = practice trials; test = trials with responses that contribute to outcome scores                            |
| gdt_values_currentround    | The current round (trial) number                                                                                      |
| gdt_trialnum               | The number of the currently recorded trial (Inquisit variable)                                                        |
| gdt_trialcode              | The name of the currently recorded trial (Inquisit variable)                                                          |
| gdt_latency                | Response latency in ms                                                                                                |
| gdt_values_chosen          | The selected dice faces participant is betting on (ex: "1", "12", "123", "1234")                                      |
| gdt_values_throw           | The dice face thrown                                                                                                  |
| gdt_values_row             | Participant's betting choice: For "singles" ("1", "2", etc.)<br>1 = singles; 2 = doubles; 3 = triples; 4 = quadruples |
| gdt_values_currentbet      | The amount of money currently bet based on betting choice                                                             |
| gdt_values_gain            | Amount of money won or lost in the current round                                                                      |
| gdt_values_account_balance | Amount participant owns                                                                                               |

|                           |                                                                                     |
|---------------------------|-------------------------------------------------------------------------------------|
| gdt_values_single         | counts how many times participant has bet on 1 specific dice face                   |
| gdt_values_double         | counts how many times participant has bet on 2 possible dice faces                  |
| gdt_values_triple         | counts how many times participant has bet on 3 possible dice faces                  |
| gdt_values_quadruple      | counts how many times participant has bet on 4 possible dice faces                  |
| gdt_values_safe           | counts how many times participants selected a safe bet (bets on 3 or 4 dice faces)  |
| gdt_values_risky          | counts how many times participants selected a risky bet (bets on 1 or 2 dice faces) |
| gdt_expressions_net_score | number of safe bets minus number of risky bets                                      |
| gdt_values_wins           | adds the number of winning bets                                                     |
| gdt_values_losses         | adds the number of losing bets                                                      |

## ABCD Social Influence Task Trial Level Behavior

### Description of cognitive task

The Social Influence Task (SIT) assesses risk perception and propensity for risk taking, as well as susceptibility to perceived peer influence. Over the course of 40 trials, participants are presented with a variety of risky scenarios. Participants are asked to rate an activity's risk by moving a slider bar between "very LOW risk" (left) and "very HIGH risk" (right). After submitting an initial rating, participants are shown a risk rating of the same activity that is seemingly provided by a group of peers. This peer rating condition is either 4 points lower ('-4' condition), 2 points lower ('-2' condition), 2 points higher ('+2' condition) or 4 points higher ('+4' condition) than the participant's initial rating. Participants are asked to rate the riskiness of the scenario again. For both the initial and final rating trials, participants have a time limit of 4500 ms to provide their rating.

The task is designed to try to ensure ~25% of trials (~10 trials) are in each of the peer rating conditions. To do this, the task script restricts random sampling to only those conditions that can be run given the participant's initial ratings (e.g., if a participant selected a rating of 1.8, condition -4 and condition -2 cannot be run as both of those conditions would result in a peer rating < 0). If none of the unselected peer conditions can be run due to rating constraints, yet 10 trials have already been in run in all the realistic peer conditions, the script uses the 'switch sign' method; it (randomly) selects from the unselected peer conditions and then switches the sign

(e.g., selected peer condition -4 will be run as peer condition +4 and vice versa). The script tracks how many such switches had to be made.

### Details of data in raw data files

| COLUMN NAME                 | DESCRIPTION                                                                                                                      |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| task                        | Behavioral task completed                                                                                                        |
| subject                     | Subject ID how it's defined in ABCD                                                                                              |
| eventname                   | The event name for which the data was collected                                                                                  |
| site                        | Data collection site ID                                                                                                          |
| build                       | The specific Inquisit version used                                                                                               |
| computer_platform           | Operating system                                                                                                                 |
| date                        | The date the script was run                                                                                                      |
| time                        | The time the script was run                                                                                                      |
| sit_values_practice         | Whether the trial was practice (1) or test (0)                                                                                   |
| sit_values_trialcount       | Counts the number of trials                                                                                                      |
| sit_values_scenariornr      | Numeric key for the risk scenario presented                                                                                      |
| sit_values_scenario         | Risk scenario presented                                                                                                          |
| sit_values_initialrating    | Participant's initial rating                                                                                                     |
| sit_values_rt_initialrating | Participant's reaction time (in ms) for submitting their initial rating after onset of the rating scale                          |
| sit_values_condition        | Peer rating condition (1 = '-4' condition; 2 = '-2' condition; 3 = '+2' condition; 4 = '+4' condition)                           |
| sit_values_peerrating       | Peer rating                                                                                                                      |
| sit_values_finalrating      | Participant's final rating                                                                                                       |
| sit_values_rt_finalrating   | Participant's reaction time (in ms) for submitting their final rating after onset of the rating scale                            |
| sit_values_ratingdiff       | Difference between the participant's initial and final rating                                                                    |
| sit_values_flip             | Whether or not the direction of the peer influence was flipped due to participants initial rating (0 = not flipped; 1 = flipped) |
| sit_values_countflips       | Number of flipped trials (cumulative) for the duration of the task                                                               |
| sit_values_count1           | Counts the number of time peer rating condition '-4' was presented                                                               |
| sit_values_count2           | Counts the number of time peer rating condition '-2' was presented                                                               |

|                            |                                                                    |
|----------------------------|--------------------------------------------------------------------|
| sit_values_count3          | Counts the number of time peer rating condition '+2' was presented |
| sit_values_count4          | Counts the number of time peer rating condition '+4' was presented |
| sit_values_countnr_initial | Counts the number of 'no response' for initial rating trials       |
| sit_values_countnr_final   | Counts the number of 'no response' for final rating trials         |

## ABCD Task fMRI Emotional NBack Trial Level Behavior

### Description of cognitive task

The fMRI Emotional nBack task assesses memory, emotion and face and place perceptual processes. The task is a block design working memory task using four categories of stimuli (places, positive faces, negative faces and neutral faces) and two memory load conditions (0 and 2 back). The task includes 80 trials for each of the two memory load conditions, 20 trials for each stimulus type in each of the two memory load conditions and 40 trials of each stimulus type.

Accuracy and response time (RT) are provided for all conditions. When possible, participants who were unable to complete the task in the scanner, completed the task behaviorally outside the scanner.

Poor performance in the ENback task is indicated if the overall response accuracy for the 0-back or 2-back blocks is less than 60% (tfMRI\_nback\_beh\_performflag = 0). However, in many cases, the threshold for suboptimal is subjective. Therefore, investigators should choose inclusion/exclusion performance criteria that are appropriate for their analyses.

Although most of the variables in this release were drawn from the raw Eprime output, two variables (enback\_trialnum and enbackrun) were computed with minimal pre-processing steps carried out by the ABCD trial-level task force. The code used to implement these pre-processing steps has been made publicly available on the ABCD-STUDY GitHub: <https://github.com/ABCD-STUDY>.

When possible, participants who were unable to complete the task in the scanner, completed the task behaviorally outside the scanner on a laptop computer. Whether a participant performed the nBack task in the scanner or on a laptop is indicated by the following variable in the main tabulated data: *ra\_scan\_cl\_nbac\_scan\_lap*. For more details, see the *ABCD RA Scanning Checklist and Notes*.

Note on global timing variables: All global timing variables reflect the raw global times recorded in Eprime, which are locked to the beginning of the Eprime task. As fMRI data begin to be collected some time after the experimenter starts Eprime the task, users interested in locking

events in the trial-level data to the fMRI data will need to transform these global times by subtracting the global start time of each run from all global timing variables (as detailed in the variable descriptions below).

### Details of data in raw data files

| <b>COLUMN NAME</b>           | <b>DESCRIPTION</b>                                                                                                                                                                                 |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| task                         | Behavioral task completed                                                                                                                                                                          |
| subject                      | Subject ID                                                                                                                                                                                         |
| eventname                    | The event name for the visit at which the data were collected                                                                                                                                      |
| site                         | Data collection site ID                                                                                                                                                                            |
| date                         | Date at which the data were collected                                                                                                                                                              |
| time                         | Local time at which the data were collected                                                                                                                                                        |
| enback_trialnum              | Variable constructed by the trial-level task force which indicates the trial number within each run                                                                                                |
| enback_run                   | Variable constructed by the trial-level task force which indicates the run number                                                                                                                  |
| enback_runtrialnumber[Block] | Eprime-labeled trial number (note: these numbers are generated by Eprime and do not necessarily correspond with the absolute trial number; e.g., the first trial may be labeled as number 3)       |
| enback_cue0back_onsettime    | Global onset time for the cues that begin 0-back blocks                                                                                                                                            |
| enback_cue2back_onsettime    | Global onset time for the cues that begin 2-back blocks                                                                                                                                            |
| enback_stim_onsettime        | Global onset time for each stimulus                                                                                                                                                                |
| enback_fix_onsettime         | Global onset time for the intertrial interval following each stimulus, during which a fixation cross is presented                                                                                  |
| enback_cuefix_starttime      | Global start time of the fixation cross presentation that precedes each block (note: the first of these times in each run should correspond to the beginning of fMRI data collection for that run) |
| enback_loadcon               | N-back load condition (0-back or 2-back)                                                                                                                                                           |
| enback_stimtype              | Emotion condition (PosFace, NegFace, NeutFace, Place) of the stimulus                                                                                                                              |
| enback_targettype            | Target status (target, lure, nonlure) of the stimulus                                                                                                                                              |
| enback_stimfile              | Name of the specific .bmp image presented for each stimulus                                                                                                                                        |
| enback_stim_resp             | Participant's button press response                                                                                                                                                                |
| enback_stim_rt               | Response time                                                                                                                                                                                      |
| enback_stim_acc              | Whether the participant's choice was accurate                                                                                                                                                      |
| enback_stim_rtime            | Global time of the response to the trial                                                                                                                                                           |

## ABCD Task fMRI SST Trial Level Behavior

### Description of cognitive task

The fMRI Stop Signal Task (SST) measures impulse control and impulsivity. The task requires participants to withhold or interrupt a motor response to a “go” stimulus when it is followed unpredictably by a signal to stop. To ensure approximately 50% successful and 50% unsuccessful STOP trials, a tracking algorithm varies the interval between the onset of the “go” stimulus and the onset of the stop signal based on individual performance. When possible, participants who were unable to complete the task in the scanner completed the task behaviorally outside the scanner.

Poor performance on the SST (`tfmri_sst_beh_performflag` = 0) is indicated if:

#### **GO trials**

- <150 GO trials
- Correct GO trial percentage <60%
- Incorrect GO trial percentage >30%
- Late GO trial percentage (summing correct and incorrect trials) >30%
- No Response GO trial percentage >30%

#### **STOP trials**

- <30 STOP trials.
- STOP trial accuracy (i.e., successful inhibitions) <20% or >80%

However, in many cases, the threshold for suboptimal is subjective. Therefore, investigators should choose inclusion/exclusion performance criteria that are appropriate for their analyses.

Importantly, a recent preprint manuscript ([biorxiv.org/content/10.1101/2020.05.08.084707v1](https://www.biorxiv.org/content/10.1101/2020.05.08.084707v1)) raised several concerns about the design and data recording procedures of the ABCD SST. Trial-level data users are encouraged to read this manuscript, as well as our response (<https://www.biorxiv.org/content/10.1101/2020.07.27.223057v1>), and the outline (**Appendix A**, below) of how each identified concern affects the trial-level data in this release. Two of the concerns raised have particularly important implications for the inclusion of individual subjects: 1) the fact that a subset of individuals display response time (RT) data that cannot be explained by the standard SST Independent Race Model (mean failed STOP RT > mean GO RT), and 2) a data recording glitch, which occurs when a participant makes a fast (<50ms) response on a STOP trial with a 50ms stop-signal delay and which causes all subsequent STOP trials to be incorrectly recorded as failures to stop with the same RT, altering the tracking algorithm. Therefore, in addition to the standard ABCD performance exclusion criteria outlined above, users interested in applying race models of inhibition to the trial-level data are encouraged to exclude participants from analysis who have the following flags:

- Participants with mean STOP RT > mean GO RT, indicating clear violations of Independent Race Model assumptions (tfmri\_sst\_beh\_violatorflag)
- Participants who display evidence of the recording glitch, as outlined in **Appendix A** (tfmri\_sst\_beh\_glitchflag)

However, if users are primarily interested in analyzing features of performance on the GO choice task (e.g., GO RT variability), such exclusions may not be necessary.

Task trials involved the presentation of stimuli on several different slides in Eprime: GO trials involved the presentation of a “go” slide with the choice stimulus for 1000ms, or until a participant responded, followed by a “fix” slide which presented a fixation cross for the remaining duration of the 1000ms trial and jittered intertrial interval; STOP trials involved the presentation of a “ssd” slide with the choice stimulus for the duration of the variable stop-signal delay on that trial, followed by a “stopsignal” slide that presented the stop signal (upward facing arrow) for 300ms, and finally by a “fix” slide which presented a fixation cross for the remaining duration of the 1000ms trial plus the duration of the jittered intertrial interval. The recording of RTs and responses was linked to the individual slide, rather than being locked to the onset of the trial. To facilitate use of the trial-level data, the ABCD trial-level behavioral data (TLBD) task force applied minimal pre-processing steps (outlined in **Appendix B**) to determine the first response a participant made on each trial (“sst\_primaryresp” variable), which in standard research contexts is treated as the participant’s main response, and accurately estimates the RT for this response (“sst\_primaryresp” variable). However, all relevant response, RT and onset timing variables from the individual slides have been retained, as described below, which will allow other researchers to compute response and RT variables using their own methods, if desired.

When possible, participants who were unable to complete the task in the scanner, completed the task behaviorally outside the scanner on a laptop computer. Whether a participant performed the SST in the scanner or on a laptop is indicated by the following variable in the main tabulated data: *ra\_scan\_cl\_sst\_scan\_lap*. For more details, see the *ABCD RA Scanning Checklist and Notes*.

### Details of data in raw data files

| COLUMN NAME    | DESCRIPTION                                                       |
|----------------|-------------------------------------------------------------------|
| task           | Behavioral task completed                                         |
| src_subject_id | Subject ID                                                        |
| eventname      | The event name for the visit at which the data were collected     |
| site           | Data collection site ID                                           |
| date           | Date at which the data were collected                             |
| time           | Local time at which the data were collected                       |
| sst_run        | Whether the trial occurred on the first or second run of the task |

|                          |                                                                                                                                                                                                                       |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| sst_trialnum             | Eprime-labeled trial number within each run (note: these numbers are generated by Eprime and do not necessarily correspond with the absolute trial number; e.g., the first trial in a run may be labeled as number 3) |
| sst_stimonset            | Variable constructed by the trial-level task force (see Appendix B) that indicates the global onset time of each trial                                                                                                |
| sst_beginfix_starttime   | Global “start time” (when an Eprime slide is scheduled to be presented) for the fixation slide that began each run; this time should correspond to the beginning of fMRI data collection for the run                  |
| sst_beginfix_onsettime   | Global “onset time” (when an Eprime slide actually begins to be presented) for the fixation slide that began each run                                                                                                 |
| sst_stim                 | Variable constructed by the trial-level task force (see Appendix B) that indicates the choice stimulus presented for the trial (right- or left-facing arrow)                                                          |
| sst_stimfile             | Name of the .bmp file for the presented choice stimulus, which was used to compute the “sst_stim” variable                                                                                                            |
| sst_primaryresp          | Variable constructed by the trial-level task force (see Appendix B) that indicates the first response the participant made on each trial (right- or left-facing arrow)                                                |
| sst_primaryrt            | Variable constructed by the trial-level task force (see Appendix B) that indicates the response time for the first response the participant made on each trial                                                        |
| sst_go_onsettime         | Global onset time for “go” slides                                                                                                                                                                                     |
| sst_go_resp              | Button press responses to “go” slides                                                                                                                                                                                 |
| sst_go_rt                | Response times locked to the beginning of “go” slides                                                                                                                                                                 |
| sst_go_rtime             | Global timing of responses to “go” slides                                                                                                                                                                             |
| sst_ssd_onsettime        | Global onset time for “ssd” slides                                                                                                                                                                                    |
| sst_ssd_resp             | Button press responses to “ssd” slides                                                                                                                                                                                |
| sst_ssd_rt               | Response times locked to the beginning of “ssd” slides                                                                                                                                                                |
| sst_ssd_rtime            | Global timing of responses to “ssd” slides                                                                                                                                                                            |
| sst_ssd_dur              | Duration of the stop-signal delay (SSD) for STOP trials                                                                                                                                                               |
| sst_stopsignal_onsettime | Global onset time for “stopsignal” slides                                                                                                                                                                             |
| sst_stopsignal_resp      | Button press responses to “stopsignal” slides                                                                                                                                                                         |
| sst_stopsignal_rt        | Response times locked to the beginning of “stopsignal” slides                                                                                                                                                         |
| sst_stopsignal_rtime     | Global timing of responses to “stopsignal” slides                                                                                                                                                                     |
| sst_fix_onsettime        | Global onset time for “fix” slides                                                                                                                                                                                    |
| sst_fix_resp             | Button press responses to “fix” slides                                                                                                                                                                                |
| sst_fix_rt               | Response times locked to the beginning of “fix” slides (note: the global timing of responses to “fix” slides was not recorded by the task)                                                                            |

|                |                                                                                                                                                                                             |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| sst_leftarrow  | Variable that maps participants' button press responses to the "left arrow" response                                                                                                        |
| sst_rightarrow | Variable that maps participants' button press responses to the "right arrow" response                                                                                                       |
| sst_expcon     | Whether the trial was in the GO or STOP condition                                                                                                                                           |
| sst_choiceacc  | Variable constructed by the trial-level task force (see Appendix B) for whether participants' response to the choice task (left- vs. right-facing arrow) was accurate (1) or inaccurate (0) |
| sst_inhibitacc | Variable constructed by the trial-level task force (see Appendix B) indicating, for STOP trials, whether participants successfully inhibited (1) or failed to inhibit (0)                   |

### **Appendix A. Details on the specific issues raised in the "Cautionary Note" manuscript by Bisset et al, and how they affect the use of these trial-level data**

As noted above, a recent preprint manuscript entitled "A cautionary note on stop-signal data from the Adolescent Brain Cognitive Development [ABCD] study" (available at this link: <https://www.biorxiv.org/content/10.1101/2020.05.08.084707v1>) raised several concerns about the ABCD SST's design and data recording procedures. Users of the trial-level data are encouraged to read this manuscript and any associated commentaries prior to analyzing these data. For clarity, this section provides a brief summary of each concern and the specific implications that these concerns present for analysis of the trial-level data included in this release.

#### **1. Different "go" choice stimulus presentation durations across trials**

**Summary:** On GO trials, the choice stimulus (a right- or left-facing arrow) is presented on screen until the participant responds or until a 1000ms window passes, whichever occurs first. However, on STOP trials, the visual stop signal (an upward facing arrow) replaces the "go" choice stimulus following the stop-signal delay. This causes the presentation time of the choice stimulus to be substantially shorter, on average, for STOP trials than for GO trials, which likely makes the choice task more difficult in the STOP condition. The increase in difficulty likely yields slower and less accurate choice responses in this condition (particularly for STOP trials with relative short stop-signal delays). The Independent Race Model, which is the dominant framework for estimating the main index of inhibition on the SST (stop-signal reaction time; SSRT) assumes *context independence*, which means that the "go" choice process and its average finishing time are not affected by the presentation of the stop signal (i.e., that the "go" process is identical between GO and STOP trials). As context independence is essential for accurate estimation of SSRT in the race model, and as the choice stimulus presentation durations of the ABCD SST likely cause violations of the context independence assumption, especially at short stop-signal delays, SSRT estimates drawn from applications of the race model to these data could be inaccurate.

Implications for the use of trial-level data: This issue does not affect the accurate recording of trial-level data, but it does present a problem for applications of SSRT measurement models, such as at the Independent Race Model, that assume context independence. However, the extent to which this design feature impacts estimates of SSRT, and whether this impact has a substantial effect on the rank ordering of subjects (i.e., whether individuals with high vs. low inhibitory ability still show relatively high and low SSRT estimates, respectively, even if the absolute values of SSRT are biased), has yet to be determined. Future experimental or computational modeling studies could help provide greater clarity about these questions. Current users are encouraged to carefully consider the assumptions of any measurement model they apply to these data and to consider the possible limitations of parameter estimates and measures derived from any model that assumes context independence. Another important implication related to this assumption is that individual participants who display mean RT on failed STOP trials that is longer than mean RT on GO trials (which occurs in a small subset of ABCD participants) exhibit a pattern of data that cannot be explained by a race model that assumes context independence. Therefore, users interested in applying models with this assumption should consider excluding these participants (who can be identified with the `tfmri_sst_beh_violatorflag` variable) as violators of the independence assumption.

## **2. “Go” choice stimulus is not presented on STOP trials with a 0ms stop-signal delay**

Summary: This is a special case of the first issue discussed above. Since the visual stop-signal stimulus replaces the “go” choice stimulus after the stop-signal delay, the choice stimulus is not actually presented on trials where the stop-signal delay is 0ms. This may violate assumptions of measurement models applied to the task (including the Independent Race Model) and may confuse participants.

Implications for the use of trial-level data: Similar to the first issue discussed above, the implications of this feature depend on the assumptions of the specific measurement model being applied to the data and whether users believe that this feature would substantially impact their ability to test their specific research question. Users may consider excluding these trials from analysis and/or excluding participants with a large proportion of these trials if they determine that doing so is appropriate. To facilitate these participant-level exclusions, variable `tfmri_sst_beh_0SSDcount` provides a count of how many 0ms stop-signal delay trials each participant has.

## **3. A glitch leads to incorrect stop-signal delays for some participants**

Summary: Due to a glitch in the experimental program, if a participant makes a response in <50ms on a STOP trial where the stop-signal delay is equal to 50ms, all subsequent STOP trials will be erroneously recorded as having a response with the exact same RT on the “ssd” slide. Because these trials are incorrectly coded as stopping failures by the experimental

program, all subsequent stop-signal delays will be stuck at 0ms. As the conditions that trigger this glitch are very specific, it is only present in about 3% of participants.

Implications for the use of trial-level data: As this glitch leads incorrect values of `sst_ssd_rt` to be recorded on subsequent trials and leads to stop-signal delays that do not correspond to the task's standard staircase pattern, users are encouraged to exclude participants who show evidence of the glitch (who can be identified with the `tfmri_sst_beh_glitchflag` variable). However, users should also note that, because the glitch primarily affects the `sst_ssd_rt` variable, but the pre-processing steps (outlined in **Appendix B**) ignore the "ssd" slide on trials with 0ms stop-signal delays, the constructed variables in the trial-level data (`sst_primaryresp`, `sst_primaryrt`, `sst_choiceacc`, `sst_inhibitacc`) should be accurate for subsequent trials.

#### **4. Stop-signal duration is shorter for trials with stop-signal delays >700ms**

Summary: If the stop-signal delay for a given STOP trial is >700ms, the stop-signal stimulus is not presented for the standard 300ms and is instead presented for a shorter duration (1000ms minus the stop-signal delay). As the Independent Race Model assumes "stop" context independence in addition to "go" context independence, and the shorter presentation time on these trials may violate this assumption, these trials may be inappropriate to include in race model analyses.

Implications for the use of trial-level data: As these trials are relatively rare (roughly 1% of STOP trials in the data set), users may consider excluding them from analysis and/or excluding participants with a large proportion of these trials if they determine that doing so is appropriate.

#### **5. Non-uniform conditional trial probability**

Summary: As reviewed in detail in Bisset et al, the probability of encountering a stop signal on a given trial in the ABCD SST is not uniform and instead depends on the recency of previous STOP trials. The most notable feature of the conditional trial probability distribution is that STOP trials are never repeated two times in a row, which could allow participants learn this contingency and therefore improve their performance on the task. However, the authors provide evidence that, at least for the baseline ABCD session, participants did not appear to learn the contingency.

Implications for the use of trial-level data: Unless users encounter compelling evidence that participants are learning the conditional trial probability contingencies, no adjustments are necessary.

#### **6. Trial accuracy incorrectly coded**

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Summary: The experimental program incorrectly classified a small number (<1%) of correct “go” choices as incorrect “go” choices and a small number (2-3%) of incorrect “go” choices as correct “go” choices. In addition, <1% of stop failure trials were incorrectly classified as correctly inhibited STOP trials. These incorrect classifications were recorded in a column of the raw Eprime output (“TrialCode”) that is not included in this trial-level data release and was not used to generate any of the constructed variables in the minimally pre-processed data columns.

Implications for the use of trial-level data: As the column with these errors is not included in the data release, and as these errors would only have minimal impacts on participants’ stop-signal delays produced by the tracking algorithm, no adjustments are necessary.

## **7. Stop-signal delay values start at 50ms**

Summary: The initial stop-signal delay value of 50ms, which is relatively low, could present problems if it leads to abnormally high stop success rates on the first few trials of the task or if it drives participants to shift their strategy over the course of the experiment. The authors provide evidence that stopping accuracy is elevated on the first 10 trials relative to the rest of the trials, and specifically that the first 7 trials have stop success rates >.60.

Implications for the use of trial-level data: Users can consider removing the first 7 to 10 STOP trials of the task or conducting separate sensitivity analyses in which these trials are removed.

## **8. Low STOP trial probability**

Summary: The authors point out that the stop trial probability on the ABCD SST (.167) is somewhat lower than stop trial probabilities on most other SST paradigms (.25-.33). However, there are currently no indications that this low stop trial probability impacts inferences from the task.

Implications for the use of trial-level data: Unless users encounter compelling evidence that this design feature impacts inferences, no adjustments are necessary.

## **Appendix B. Details of minimal pre-processing steps**

These pre-processing steps were conducted to facilitate the use of the trial-level data in most applications by creating variables that record participants’ first response on each trial (regardless of which slide this response occurs on), the global onset times of each trial, easily interpretable names for the stimuli and responses, and variables that indicate separately whether participants made accurate decisions on the choice task and whether they succeeded in inhibiting responses on STOP trials. The code used to implement the following pre-processing steps has been made publicly available on the ABCD-STUDY GitHub:

<https://github.com/ABCD-STUDY>.

---

### **1. Create general stimulus onset variable for all trials**

- For GO trials, set `sst_stimonset` = `sst_go_onsettime`
- For STOP trials in which `sst_ssd_dur` > 0ms, set `sst_stimonset` = `sst_ssd_onsettime`
- For STOP trials in which `sst_ssd_dur` = 0ms, set `sst_stimonset` = `sst_stopsignal_onsettime`

### **2. Create variable with details of the presented stimulus**

- For any trial in which `sst_stimfile` = "images/Right\_Arrow.bmp", set `sst_stim` = "right\_arrow"
- For any trial in which `sst_stimfile` = "images/Left\_Arrow.bmp", set `sst_stim` = "left\_arrow"

### **3. Determine response mapping for the participant**

- Responses on the Eprime slides (`sst_go_resp`, `sst_fix_resp`, `sst_ssd_resp`, `sst_stopsignal_resp`) are sometimes recorded as integers (e.g., 1 or 2) and sometimes recorded as strings (e.g., "LEFTARROW"). Therefore, the mapping between raw response data and the "right\_arrow" and "left\_arrow" responses must be established for each participant. If raw responses were integers, the `sst_leftarrow` and `sst_rightarrow` columns were used to establish response mapping. If raw responses were strings, the presence of "right" or "left" in the string was used to establish response mapping.

### **4. Compute primary response and primary RT for GO trials**

- If the participant's first response on the trial is during the "go" slide, the RT and response from that slide (`sst_go_rt` and `sst_go_resp`) are recorded as the participant's primary RT and response for that trial. Subsequent responses during the following "fix" slide are ignored.
- If the participant's first response on the trial is instead during the "fix" slide (i.e., their response latency was >1000ms), the reconstructed RT (`sst_fix_rt` + 1000) and the response (`sst_fix_resp`) from the "fix" slide are recorded as the participant's primary RT and response for that trial.
- If the participant fails to respond during either the "go" or "fix" slide, their response and RT on that trial are treated as missing (blank)

### **5. Compute primary response and primary RT for STOP trials**

---

- If `sst_ssd_dur` is  $>0\text{ms}$  and  $<700\text{ms}$ :
  - If the participant's first response on the trial is during the "ssd" slide, the RT and response from that slide (`sst_ssd_rt` and `sst_ssd_resp`) are recorded as the participant's primary RT and response for that trial. Subsequent responses during the following "stopsignal" and "fix" slides are ignored.
  - If the participant's first response on the trial is during the "stopsignal" slide, the reconstructed RT (`sst_stopsignal_rtime` - `sst_ssd_onsettime`) and the response (`sst_stopsignal_resp`) from that slide are recorded as the participant's primary RT and response for that trial. Subsequent responses during the following "fix" slide are ignored.
  - If the participant's first response on the trial is during the "fix" slide, the reconstructed RT (`sst_fix_rt` + 300 + `sst_ssd_dur`) and the response (`sst_fix_resp`) from that slide are recorded as the participant's primary RT and response for that trial.
  - If the participant fails to respond during any of these three slides, their primary response and RT on that trial are treated as missing (blank)
- If `sst_ssd_dur` = 0ms:
  - If the participant's first response on the trial is during the "stopsignal" slide, the RT (`sst_stopsignal_rt`) and the response (`sst_stopsignal_resp`) from that slide are recorded as the participant's primary RT and response for that trial. Subsequent responses during the following "fix" slide are ignored.
  - If the participant's first response on the trial is during the "fix" slide, the reconstructed RT (`sst_fix_rt` + 300) and the response (`sst_fix_resp`) from that slide are recorded as the participant's primary RT and response for that trial.
  - If the participant fails to respond during either of the two slides, their response and RT on that trial are treated as missing (blank)
- If `sst_ssd_dur` > 700ms:
  - Same procedures as used above (for if `sst_ssd_dur` is  $>0\text{ms}$  and  $<700\text{ms}$ ) are implemented, unless the first response is on the "fix" slide, in which case the RT is calculated simply as `sst_fix_rt` + 1000

## **6. Compute accuracy variables**

- To compute the `sst_choiceacc` variable for each trial:
-

- If `sst_primaryresp = NA/blank`, `sst_choiceacc = NA/blank`
- If `sst_primaryresp ≠ NA/blank` and `sst_stim = sst_primaryresp`, `sst_choiceacc = 1`
- If `sst_primaryresp ≠ NA/blank` and `sst_stim ≠ sst_primaryresp`, `sst_choiceacc = 0`
- To compute the `sst_inhibitacc` variable for each trial:
  - If `sst_expcon = GoTrial`, `sst_inhibitacc = NA/blank`
  - If `sst_expcon ≠ GoTrial` and `sst_primaryresp = NA/blank`, `sst_inhibitacc = 1`
  - If `sst_expcon ≠ GoTrial` and `sst_primaryresp ≠ NA/blank`, `sst_inhibitacc = 0`

## ABCD Task fMRI MID Trial Level Behavior

### Description of cognitive task

The fMRI Monetary Incentive Delay (MID) task measures domains of reward processing, including anticipation and receipt of reward and losses, and trial-by-trial motivation in speeded responses to win or avoid loss. Each trial of the MID task begins with an incentive cue of five possible trial types (Win \$0.20, Win \$5, Lose \$0.20, Lose \$5, \$0-no money at stake), a delay, a target during which the participant responds to either win money or avoid losing money and feedback.

Task performance is individualized to maintain a 60% accuracy rate.

In the main tabulated data for release 3.0, which includes summary scores across subjects rather than trial level data, flags are provided to identify subjects with incomplete data for anticipation analyses or suboptimal for feedback analyses. However, the threshold for suboptimal is subjective so investigators should choose inclusion/exclusion performance criteria that are appropriate for their analyses.

- **Anticipation flag** If data capture is incomplete for either run 1 or run 2, this will affect the number of anticipation trials modelled. These data are flagged and investigators should decide if it is appropriate for their analysis to exclude these subjects.
- **Feedback flag** If any trial type across both runs yields less than 4 events in either the positive feedback or negative feedback, the data is flagged. Investigators should decide if it is appropriate for their analysis to exclude these subjects.

Poor performance in the MID task is determined as any trial type across both runs that yields less than four events in either the positive or negative feedback, indicated by the behavioral performance flag `tfMRI_mid_beh_performflag = 0` in the tabulated data.

When possible, participants who were unable to complete the task in the scanner, completed the task behaviorally outside the scanner on a laptop computer. Whether a participant performed the MID task in the scanner or on a laptop is indicated by the following variable in the main tabulated data: `ra_scan_cl_mid_scan_lap`. For more details, see the *ABCD RA Scanning Checklist and Notes*.

## Description of variables in curated data files

The following table provides the column names that are contained within the MID curated data files, as well as a brief description of the variable and what type of data it contains.

| COLUMN NAME              | DESCRIPTION                                                      |
|--------------------------|------------------------------------------------------------------|
| task                     | Behavioral task completed                                        |
| subject                  | Subject ID how it's defined in lab/project                       |
| eventname                | The event name for which the data was collected                  |
| site                     | Data collection site ID                                          |
| date                     | Date of data collection (month/day/year)                         |
| time                     | Time that data was collected (hours/minutes/seconds)             |
| mid_run                  | Which run the task data corresponds to                           |
| mid_trialnum             | Trial number (range = 1-50)                                      |
| mid_anticipationtype     | The type of anticipation for that trial                          |
| mid_anticipationonset    | The time that the anticipation phase started                     |
| mid_anticipationduration | The length of time that the anticipation phase lasted            |
| mid_feedbacktype         | The type of feedback received based on the subject's performance |
| mid_feedbackonset        | The time that the feedback phase started                         |
| mid_feedbackduration     | The length of time that the feedback phase lasted                |
| mid_acc                  | Accuracy of the subject's performance for that trial             |
| mid_resp                 | Whether or not the subject provided a response for that trial    |
| mid_rt                   | How quickly the subject responded                                |
| mid_rtttime              | The timepoint in the task when the subject responded             |
| mid_trialmoney           | The money resulting from the subject's performance on that trial |

## Details of data in curated data files

The following table provides details on the values that are contained in specific columns within the MID curated data files.

| VARIABLE             | VALUE   | DETAILS                             |
|----------------------|---------|-------------------------------------|
| mid_anticipationtype | LL      | Large Loss                          |
|                      | SL      | Small Loss                          |
|                      | LR      | Large Reward                        |
|                      | SR      | Small Reward                        |
|                      | Neutral | Neutral                             |
| mid_feedbacktype     | *_PF    | Positive Feedback (Acc = 1)         |
|                      | *_NF    | Negative Feedback (Acc = 0)         |
| mid_acc              | 1       | Responded correctly to the stimulus |

|                |      |                                                                                                                                                                |
|----------------|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                | 0    | Failed to respond correctly to the stimulus                                                                                                                    |
| mid_resp       | 1    | Provided a response to the stimulus                                                                                                                            |
|                | n/a  | Response not recorded for the stimulus                                                                                                                         |
| mid_rt         | n/a  | Response not recorded for the stimulus                                                                                                                         |
| mid_rtime      | n/a  | Response not recorded for the stimulus                                                                                                                         |
| mid_trialmoney | 0    | No money gained or lost during trial resulting from:<br>1) Neutral trials (regardless of accuracy), or<br>2) *_PF on any loss trial (avoided losing any money) |
|                | -5   | Lost \$5 (LL_NF)                                                                                                                                               |
|                | -0.2 | Lost \$0.20 (SL_NF)                                                                                                                                            |
|                | 5    | Won \$5 (LR_PF)                                                                                                                                                |
|                | 0.2  | Won \$0.20 (SR_PF)                                                                                                                                             |

### Details of variables with timing values in curated data files

The following information pertains to the mid\_anticipationonset, mid\_anticipationduration, mid\_feedbackonset, mid\_feedbackduration, mid\_rt, and mid\_rtime variables:

- 1) All times have already been corrected and represent the actual start time of the task. In other words, as this task was carried out as an fMRI task, the “PrepTime” times for each of the runs has already been subtracted out, producing the times contained in the curated data files. These times are consistent with those produced by the “abcd\_extract\_eprime” scripts, which are publicly-available in the ABCD study’s GitHub page using the link provided in the “GitHub” section below
  - a. **NOTE: IF YOU ARE ANALYZING THESE BEHAVIORAL DATA WITH THE MID FMRI DATA AND YOU DO NOT PLAN ON REMOVING ANY INITIAL FRAMES PRIOR TO ANALYSIS, YOU MUST ADJUST THE mid\_anticipationonset, mid\_feedbackonset, AND mid\_rtime VARIABLES BASED ON THE FOLLOWING:**
    - i. Siemens/Philips Scanners: Add 6400 ms
    - ii. GE DV25: Add 4000 ms
    - iii. GE DV26: Add 12,800 ms
- 2) All times are presented in milliseconds

## ABCD NIH Toolbox® Cognition Measures Trial Level Behavior

The NIH Toolbox Cognition measures trial level behavior are comprised of a series of .csv (comma separated values) files. There is a single format used for all measures. Definitions for the columns of these spreadsheets can be found at <https://nihtoolbox.force.com/s/article/definition-of-columns-in-the-ipad-app-exports?r=2560&ui-knowledge-components-aura-actions.KnowledgeArticleVersionCreateDraftFromOnlineAction.createDraftFromOnlineArticle=1>

### **Description of cognitive tasks**

The NIH Toolbox® Cognition (“Core”) Battery is comprised of seven measures covering six cognitive domains including executive function, attention, episodic memory, language, processing speed, and working memory. Brief descriptions of the seven tasks, domain(s) assessed, and scoring information relevant to item level analysis follows. For additional information on the NIH Toolbox and the individual tasks, please refer to the NIH Toolbox Technical Manuals (<https://www.healthmeasures.net/explore-measurement-systems/nihtoolbox/obtain-and-administer-measures/209-nih-toolbox-technical-manuals-for-ac>). Detailed scoring processes can also be found in the *Toolbox\_Scoring\_and\_Interpretation\_Guide\_for\_iPad\_v1.7* at <https://nihtoolbox.force.com/s/article/nih-toolbox-scoring-and-interpretation-guide>

#### **NIH Toolbox Picture Vocabulary Test (Language)**

This measure of receptive vocabulary is administered in a computerized adaptive format. That is, the next question a participant receives depends on his/her response to the previous question; Computer Adaptive Testing (CAT) ensures a test that is tailored to the participant's needs. The respondent is presented with an audio recording of a word and four photographic images on the iPad screen, and is asked to select the picture that most closely matches the meaning of the word. This task is included in the calculation of the Crystallized Composite Score.

*Scoring Process:* Item Response Theory (IRT) is used to score the Picture Vocabulary Test. A score known as a theta score is calculated for each participant; it represents the relative overall ability or performance of the participant. A theta score is very similar to a z-score, which is a statistic with a mean of zero and a standard deviation of one.

#### **NIH Toolbox Oral Reading Recognition Test (Language)**

The participant is asked to read and pronounce words as accurately as possible. The test administrator scores them as right or wrong. The test is given via CAT. This task is included in the calculation of the Crystallized Composite Score.

*Scoring Process:* IRT is used to score the Oral Reading Recognition Test. A theta score is calculated for each participant, representing the overall reading ability or performance of the

participant. A theta score is similar to a z-score, which is a statistic with a mean of zero and a standard deviation of one.

### **NIH Toolbox Flanker Inhibitory Control and Attention Test (Executive Function & Attention)**

The Flanker task measures both a participant's attention and inhibitory control. The test requires the participant to focus on a given stimulus while inhibiting attention to stimuli (rows for ages 8-85) flanking it. Sometimes the middle stimulus is pointing in the same direction as the "flankers" (congruent) and sometimes in the opposite direction (incongruent). Twenty trials are conducted for ages 8-85; if a participant scores  $\geq 90\%$  on the fish stimuli (with no more than one congruent and one incongruent trial incorrect), 20 additional trials with arrows are presented. The test takes approximately three minutes to administer. This test is recommended for ages 3-85. This task is included in the calculation of the Fluid Composite Score.

*Scoring Process:* Scoring is based on a combination of accuracy and reaction time and is identical for both the Flanker and DCCS measures (described below). A 2-vector scoring method is employed that uses accuracy and reaction time, where each of these "vectors" ranges in value between 0 and 5, and the computed score, combining each vector score, ranges in value from 0-10. For any given individual, accuracy is considered first. If accuracy levels for the participant are less than or equal to 80%, the final "total" computed score is equal to the accuracy score. If accuracy levels for the participant reach more than 80%, the reaction time score and accuracy score are combined.

### **NIH Toolbox Dimensional Change Card Sort Test (DCCS) (Executive Function)**

The DCCS is a measure of cognitive flexibility. Two target pictures are presented that vary along two dimensions (e.g., shape and color). Participants are asked to match a series of bivalent test pictures (e.g., yellow balls and blue trucks) to the target pictures, first according to one dimension (e.g., color) and then, after a number of trials, according to the other dimension (e.g., shape). "Switch" trials are also employed, in which the participant must change the dimension being matched. For example, 15 after four straight trials matching on shape, the participant may be asked to match on color on the next trial and then go back to shape, thus requiring the cognitive flexibility to quickly choose the correct stimulus. This test takes approximately four minutes to administer and is recommended for ages 3-85. This task is included in the calculation of the Fluid Composite Score.

*Scoring Process:* Scoring is based on a combination of accuracy and reaction time. A 2-vector scoring method is employed that uses accuracy and reaction time, where each of these "vectors" ranges in value between 0 and 5, and the computed score, combining each vector score, ranges in value from 0-10. For any given individual, accuracy is considered first. If accuracy levels for the participant are less than or equal to 80%, the final "total" computed score is equal to the accuracy score. If accuracy levels for the participant reach more than 80%, the reaction time score and accuracy score are combined.

### **NIH Toolbox Picture Sequence Memory Test (Episodic Memory)**

The Picture Sequence Memory Test is a measure developed for the assessment of episodic memory for ages 3-85 years. It involves recalling increasingly lengthy series of illustrated objects and activities that are presented in a particular order on the iPad screen, with corresponding audio-recorded phrases played. The participants are asked to recall the sequence of pictures demonstrated over two learning trials; sequence length varies from 6-18 pictures, depending on age. Participants are given credit for each adjacent pair of pictures they correctly place (i.e., if pictures in locations 7 and 8 are placed in that order and adjacent to each other anywhere, such as slots 1 and 2, one point is awarded), up to the maximum value for the sequence, which is one less than the sequence length. (That is, if 18 pictures are in the sequence, the maximum score on that trial is 17 – the number of adjacent pairs of pictures that exist). The test takes approximately seven minutes to administer. This test is recommended for ages 3-85. This task is included in the calculation of the Fluid Composite Score.

*Scoring Process:* The Picture Sequence Memory Test is scored using IRT methodology. The number of adjacent pairs placed correctly for each of trials 1 and 2 is converted to a theta score, which provides a representation of the given participant's estimated ability in this episodic memory task. All normative standard scores are provided.

### **NIH Toolbox List Sorting Working Memory Test (Working Memory)**

The List Sorting test requires immediate recall and sequencing of different visually and orally presented stimuli (i.e., “working memory”). Pictures of different foods and animals are displayed with accompanying audio recording and written text (e.g., “elephant”), and the participant is asked to say the items back in size order from smallest to largest, first within a single dimension (either animals or foods, called 1-List) and then on two dimensions (foods, then animals, called 2-List). The test takes approximately seven minutes to administer and is recommended for ages 7-85, though a supplemental test designed for ages 3-6 is also available, if desired. This supplemental test also provides normative scores, though it may not be appropriate for all children in this age range (especially 3-year-olds). This task is included in the calculation of the Fluid Composite Score.

*Scoring process:* List Sorting is scored by summing the total number of items correctly recalled and sequenced on 1-List and 2-List, which can range from 0-26. This score is then converted to the nationally normed standard scores.

### **NIH Toolbox Pattern Comparison Processing Speed Test (Processing Speed)**

This test measures speed of processing by asking participants to discern, as quickly as possible, whether two side-by-side pictures are the same or not. The items are presented one pair at a time on the iPad screen, and the participant is given 85 seconds of response time (excluding any time needed for the given iPad to “load” the items) to respond to as many items as possible (up to a maximum of 130). The items are designed to be simple so as to most purely measure processing speed. Overall, the test takes approximately three minutes to administer. This test is recommended for ages 7-85.

*Scoring process:* List Sorting is scored by summing the total number of items correctly recalled and sequenced on 1-List and 2-List, which can range from 0-26. This score is then converted to the nationally normed standard scores. This task is included in the calculation of the Fluid Composite Score.

*Scoring process:* The participant's raw score is the number of items answered correctly in 85 seconds of response time, with a range of 0-130. This score is then converted to the NIH Toolbox normative standard scores.

## **Descriptions of Toolbox Cognitive Domains**

### **EXECUTIVE FUNCTION**

Executive Function is the capacity to plan, organize, and monitor the execution of behaviors that are strategically directed in a goal-oriented manner. NIH Toolbox focuses on set shifting (i.e., the capacity for switching among multiple aspects of a strategy or task) and the inhibition of automatic response tendencies that may interfere with achieving a goal. In NIH Toolbox, Executive Function is measured by:

*NIH Toolbox Flanker Inhibitory Control and Attention Test*  
*NIH Toolbox Dimensional Change Card Sort Test*

### **ATTENTION**

Attention refers to the allocation of one's limited capacities to manage the abundance of environmental stimulation. It is the foundation for all mental processes. There are several forms of attention, including sustained, selective, and divided. Sustained attention is closely linked to the level of wakefulness or the maintenance of an alert state. Selective attention serves to direct sensory and thought processes to a particular stimulus or sector of the visual field so that action can be taken. Divided attention is the ability to attend to more than one stimulus, spatial sector, or modality simultaneously, and overlaps with Executive Function. Attention is measured by:

*NIH Toolbox Flanker Inhibitory Control and Attention Test*

### **EPISODIC MEMORY**

Episodic Memory refers to cognitive processes involved in the acquisition, storage, and retrieval of new information. It involves conscious recollection of information learned within a context. The term "learning" refers to the acquisition of skills and knowledge, while the term "memory" refers to the persistence of this learning over time and/or the facility with which one is able to spontaneously recall the information following a delay. Episodic Memory can be verbal, as in remembering a conversation or a list of grocery items, or nonverbal, as in imagining a place one visited or a picture one saw a week ago. Episodic Memory is measured by:

*NIH Toolbox Picture Sequence Memory Test*

### **LANGUAGE**

Language refers to a set of mental processes that translate thought into symbols (e.g., words, gestures) that can be shared among individuals for purposes of communication. NIH Toolbox

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focuses on two aspects of language. The first is receptive word knowledge, which is fundamental to learning and has a very high association with overall intelligence (or what has been called the "g-factor"). The second aspect taps reading, defined as the cognitive process of deriving meaning from text and is reflective of the level and quality of prior educational experiences. An oral reading measure provides a robust indication of verbal intelligence that is relatively undisturbed by many medical conditions that affect the brain. Language is measured by:

*NIH Toolbox Picture Vocabulary Test*  
*NIH Toolbox Oral Reading Recognition Test*

### **PROCESSING SPEED**

Processing Speed is defined as either the amount of time it takes to process a set amount of information, or, conversely, the amount of information that can be processed within a certain amount of time. It is a measure that reflects mental efficiency. Processing Speed is central for many cognitive functions and domains and is sensitive to change and/or disease. Processing Speed is measured by:

*NIH Toolbox Pattern Comparison Processing Speed Test*  
*NIH Toolbox Oral Symbol Digit Test (Supplemental Measure)*

### **WORKING MEMORY**

Working Memory refers to the ability to store information until the amount of information to be stored exceeds one's capacity to hold that information. Working Memory also refers to the capacity of an individual to process information across a series of tasks and modalities, hold the information in a short-term buffer, manipulate the information, and hold the products in the same short-term buffer. With its notion of an active computational workspace, Working Memory is a conceptual update to the construct "short-term memory" that refers to a passive storage buffer. Working Memory is measured by:

*NIH Toolbox List Sorting Working Memory Test*

## **KSADS-COMP Trial Level Behavior**

The Kiddie Scheduled for Affective Disorders and Schizophrenia for School-Aged Children (KSADS) is the most widely used and well validated diagnostic interview for children and adolescents. The KSADS-COMP is the computer administered version of the KSADS used in the ABCD Study (<https://www.kennedykrieger.org/ksads-comp>). All diagnostic criteria have been updated for DSM-5, and include several new disorders introduced in DSM-5. The DSM-5 KSADS-COMP covers over 50 of the most commonly found diagnoses in children and adolescents (i.e., KSADS-COMP modules), from which ABCD uses a subsample. These are listed in the following table along with the name of the instrument in the 4.0 release in which they are found. For specific details on the individual questions within each module, please refer to the data dictionary for each instrument at [https://nda.nih.gov/data\\_dictionary.html?source=ABCD%2BRelease%2B4.0&submission=ALL](https://nda.nih.gov/data_dictionary.html?source=ABCD%2BRelease%2B4.0&submission=ALL)

| Module                                                                                               | Instrument                  |
|------------------------------------------------------------------------------------------------------|-----------------------------|
| <i>Parent Report on Youth</i>                                                                        |                             |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) ADHD Individual Questions                         | attn_deficit_hyperactiv_p01 |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Agoraphobia Individual Questions                  | agoraphobia_p01             |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Alcohol Use Disorder Individual Questions         | alcohol_use_disorder_p01    |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Autism Spectrum Disorders Individual Questions    | autism_spectrum_dis_p01     |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Bipolar Disorders Individual Questions            | bipolar_disorders_p01       |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) DMDD Individual Questions                         | disruptive_mood_dysreg_p01  |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Depressive Disorders Individual Questions         | depressive_disorders_p01    |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Drug Use Disorder Individual Questions            | drug_use_disorders_p01      |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Eating Disorders Individual Questions             | eating_disorders_p01        |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Generalized Anxiety Disorder Individual Questions | generaled_anx_disorder_p01  |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Homicidality Individual Questions                 | homicidality_p01            |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) ODD Individual Questions                          | opp_defiant_disorder_p01    |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Panic Disorder Individual Questions               | panic_disorder_p01          |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Psychotic Disorders Individual Questions          | psychosis_p01               |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Separation Anxiety Disorder Individual Questions  | separation_anxiety_p01      |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Sleep Problems Individual Questions               | sleep_problems_p01          |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Specific Anxiety Disorder Individual Questions    | social_anxiety_disorder_p01 |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Specific Phobia Individual Questions              | specific_phobia_p01         |

|                                                                                                       |                             |
|-------------------------------------------------------------------------------------------------------|-----------------------------|
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Suicidality Individual Questions                   | suicidality_p01             |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Tic Disorder Individual Questions                  | tic_disorders_p01           |
| ABCD Parent Diagnostic Interview for DSM-5 (KSADS) Obsessive Compulsive Disorder Individual Questions | obs_compulsive_disorder_p01 |
| <i>Youth Report on Youth</i>                                                                          |                             |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Alcohol Use Disorder Individual Questions           | alcohol_use_disorder01      |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Bipolar Disorders Individual Questions              | bipolar_disorders01         |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Conduct Disorder Individual Questions               | conduct_disorder01          |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) DMDD Individual Questions                           | disruptive_mood_dysreg01    |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Depressive Disorders Individual Questions           | depressive_disorders01      |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Drug Use Disorder Individual Questions              | drug_use_disorders01        |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Eating Disorders Individual Questions               | eating_disorders01          |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Generalized Anxiety Disorder Individual Questions   | generalized_anx_disorder01  |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Sleep Problems Individual Questions                 | sleep_problems01            |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Specific Anxiety Disorder Individual Questions      | social_anxiety_disorder01   |
| ABCD Youth Diagnostic Interview for DSM-5 (KSADS) Suicidality Individual Questions                    | suicidality01               |

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