

Behavioral Performance During Task-Based fMRI

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List of Instruments

Name of Instrument	Table Name
Task fMRI - MID - Behavioral Performance	mri_y_tfmr_mid_beh
Task fMRI - MID - Post-Scan Questionnaire	mri_y_tfmr_mid_qtn
Task fMRI - SST - Behavioral Performance	mri_y_tfmr_sst_beh
Task fMRI - N-Back - Behavioral Performance	mri_y_tfmr_nback_beh
Task fMRI - N-Back (Recognition Memory) - Behavioral Performance	mri_y_tfmr_nback_rec_beh

General Information

An overview of the ABCD Study® can be found at abcdstudy.org and detailed descriptions of the assessment protocols are available at [ABCD Protocols](#). This page describes the contents of various instruments available for download. To understand the context of this information, refer to the release notes [Start Page](#) and [Imaging Overview](#).

The above table lists instruments with summary scores for participants' behavioral performance in the different task-based fMRI paradigms. Besides these curated tabulated data, users can also download the raw (trial-level) behavioral data that the summary scores data are computed from (see [Raw Behavioral Data](#) below). The tasks and stimuli listed in this document are also available at <http://fablab.yale.edu/page/assays-tools>. The behavioral performance review is part of the ABCD Study QC procedures and imaging inclusion criteria. For additional information please refer to the [MRI Quality Control & Recommended Image Inclusion Criteria](#) release note.

fMRI Monetary Incentive Delay (MID) 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 \$20, Win \$5, Lose \$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. When possible, participants who were unable to complete the task in the scanner, completed the task behaviorally outside the scanner. Variables are provided to identify participants with incomplete data for anticipation analyses, unresponsiveness suggesting inattention to the task, or suboptimal data for feedback analyses. However, these recommended thresholds are subjective, so investigators should choose inclusion/exclusion performance criteria that are appropriate for their analyses.

- *Anticipation:* If data capture is incomplete for either run 1 or run 2, this will affect the number of anticipation trials modeled. The recommended inclusion criteria (see [MRI Quality Control & Recommended Image Inclusion Criteria](#)) for MID task fMRI require that 100 total trials were acquired: `tfmri_mid_all_beh_t_nt = 100`. In addition, the recommended inclusion criteria require that the participant make at least 20 responses (i.e., button presses) per run: `tfmri_mid_beh_performflag = 1`. Both of these variables are included in the recommended inclusion criteria for MID task fMRI: `imgincl_mid_include = 1`.
- *Feedback:* If any trial type across both runs yields fewer than 4 events in either the positive feedback or negative feedback, this will reduce the reliability of analyses of feedback trials. It is suggested that analyses of feedback trials be limited to participants with at least 4 events in each feedback trial type: `tfmri_mid_beh_feedbackflag = 1`. Note that this feedback flag is not included in the default, recommended inclusion criteria for MID task fMRI, but can be used in combination with `imgincl_mid_include` to further limit the sample.

In the initial version of the MID task used for ABCD, only reaction time (RT) for positive feedback trials were calculated. For the current version of the MID task, which was implemented in late 2017, RT was calculated for all valid trials (i.e., including late responses but excluding early responses). In past releases, variables for negative feedback trials and all trials combined had empty values. In the current release, scan sessions with the current task version now have values for all of these RT variables.

Monetary Incentive Delay - Post Scan Questionnaire

After completion of the in-scanner task, participants are asked to rate how they felt when viewing the different cues and receiving the different outcomes during the MID task to determine the effectiveness and value of wins and losses.

fMRI Stop Signal Task (SST)

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 (the Stop Signal Delay) 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 in the SST task (`tfmri_sst_beh_performflag = 0`) is indicated if:

Go trials

- <300 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%
- Correct GO response time < Incorrect Stop response time

STOP trials

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

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

Concerns regarding ABCD STOP task

A number of concerns regarding the ABCD STOP task have been raised (see <https://www.biorxiv.org/content/10.1101/2020.05.08.084707v1>). One is a coding error wherein a fast response (<50msec) made when the Stop Signal Delay (SSD) was 50 msec results in all subsequent Stop trials recording this same fast response. This error disrupts the functioning of the SSD tracking algorithm. Although useful data (before the occurrence of the coding error) may be retrievable for many of these participants, we identify for possible exclusion all participants with this coding error (variable `tfmri_sst_beh_glitchflag`).

A second concern relates to the Go stimuli not being presented on trials in which the SSD was 0 msec. On these trials, participants saw only the Stop signal (up arrow) which may have created confusion for participants. Across the full sample of participants, the impact of these occasional trials appears to be minimal for both the Stop Signal Reaction Time calculation and brain activation. However, we now provide a count of 0ms SSD trials per participant (variable `tfmri_sst_beh_0ssdcnt`) which investigators can use to set a threshold for excluding participants, if desired.

Finally, in accordance with race model assumptions and best practices (Verbruggen et al., eLife 2019), the Stop Signal Reaction Time should not be estimated for participants whose Stop Fail RT > Go RT. These participants are identified by the variable `tfmri_sst_beh_violatorflag`. However, there is no compelling reason to exclude these participants from brain activation analyses unless researchers believe that doing so is warranted given the neuroimaging measurements they are investigating or given their specific research question.

More details on these matters are provided in the [Raw Behavioral Data](#) section below. The ABCD team has conducted analyses addressing these matters (<https://www.biorxiv.org/content/10.1101/2020.07.27.223057v1>) and concludes that while the concerns have legitimacy, there is little evidence that they have an actual impact on the task reaction time and fMRI data. While we await further empirical data addressing these matters we believe researchers can use these data with confidence. However, we do encourage researchers to carefully evaluate any impact that these concerns may have on their specific analyses.

Variable names for the indicator flags

- `tfmri_sst_beh_violatorflag` : Race model violators where Stop Fail RT > Go RT
- `tfmri_sst_beh_glitchflag` : Task coding error
- `tfmri_sst_beh_0SSDcount` : Number of Stop trials with 0ms SSD

Estimates of Stop Signal Reaction Time

We provide two estimates of the Stop Signal Reaction Time (Logan et al., Psychological Review, 1984), a derived measure of the response inhibition process. The mean method (`tfmri_sst_all_beh_total_mssrt`) subtracts each participant's mean SSD from their mean Go RT. (In previous data releases this variable was named `tfmri_sst_all_beh_total_meanrt`). The second estimate uses the integration method (`tfmri_sst_all_beh_total_issrt`) in which the mean SSD is subtracted from the nth Go RT with n being the participant's overall successful inhibition rate. For the integration method calculation, any Go RT omissions were replaced with the longest go RT for that participant. In addition, premature responses on Stop trials (i.e., choice responses made before the Stop signal was presented) were included when calculating the participant's probability of successful stopping and the SSD's on these trials were included in calculating the average SSD.

Variable names for SSRT

- `tfmri_sst_all_beh_total_mssrt` : Stop Signal Reaction Time, mean estimation
- `tfmri_sst_all_beh_total_issrt` : Stop Signal Reaction Time, integration estimation

Mislabeled trials

A small number of trial outcomes are mislabeled in the Stop task's E-Prime output (these are listed as Issue 6 in <http://www.biorxiv.org/content/10.1101/2020.05.08.084707v1>). Users should be aware that all of these errors were identified and corrected prior to behavioral or functional data analysis in all data releases including this one. The label corrections are detailed in the script "abcd_extract_eprime_sst" available on the ABCD Study's [GitHub page](#).

fMRI Emotional nBack Working Memory 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 reaction 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 nBack 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`).

Definition of terms

- `all_beh_0.back`: all of the 0_back trials in the session
- `run1_beh_0.back`: all 0_back trials in run 1
- `run2_beh_0.back`: all 0_back trials in run 2
- `all_beh_2.back`: all of the 2_back trials in the session
- `run1_beh_2.back`: all 2_back trials in run 1
- `run2_beh_2.back`: all 2_back trials in run 2
- `pos.face`: all trials with happy stimuli
- `neg.face`: all trials with fear stimuli
- `neut.face`: all trials with neutral stimuli
- `place`: all trials with place stimuli
- `run1_beh_0.back.pos.face`: all 0_back trials with happy stimuli in run 1
- `run2_beh_2.back.neg.face`: all 2_back trials with fear stimuli in run 2
- `run1_beh_0.back.place_rate`: accuracy for all 0_back trials with place stimuli in run 1

nBack Recognition Memory (RECMEM) Task

The Emotional nBack Recognition Memory task engages short-term memory for items presented during the fMRI Emotional nBack task. This task was performed outside the scanner after the completion of the fMRI nBack task. Both HitRate (HR) and False Alarms (FA) are provided for each condition along with key dependent variables of response bias, corrected accuracy, and d-prime.

Definition of terms

- `NEW`: any stimuli that were NOT present in the nBack task
- `OLD`: any stimuli that were present in the nBack task
- `neut.face`: neutral face stimuli
- `pos.face`: happy face stimuli
- `neg.face`: fearful face stimuli
- `place`: place stimuli
- `0.back` denotes if the stimuli were presented during 0-back
- `2.back` denotes if the stimuli were presented from 2-back

Key dependent variables

- `hr`: hit rate
- `fa`: false alarms
- `br`: response bias $[(\text{mean}(\text{FA}) / (1 - \text{mean}(\text{HR}) - \text{mean}(\text{FA}))) - 0.5]$
- `pr`: corrected recognition $[\text{mean}(\text{HR}) - \text{mean}(\text{FA})]$
- `dprime`: discriminability index $[z(\text{HR}) - z(\text{FA})]$

Behavioral tasks performed outside of the scanner

Some participants were unable to complete one or more of the fMRI behavioral tasks in the scanner (MID, SST, or nBack), instead performed the missing task or tasks outside the scanner on a laptop computer. Whether a participant performed the MID, SST, or nBack task in the scanner or on a laptop is indicated respectively, by the following variables: `ra_scan_cl_mid_scan_lap`, `ra_scan_cl_nbac_scan_lap`, `ra_scan_cl_sst_scan_lap`. For more details, see the *ABCD RA Scanning Checklist and Notes*.

Methods

Image processing and analysis methods corresponding to ABCD Release 2.0.1 are described in Hagler et al., 2019, *Image processing and analysis methods for the Adolescent Brain Cognitive Development Study*. Neuroimage, 202:116091. Changes to image processing and analysis methods in Release 3.0 and Release 4.0 are documented below. No significant changes were made to the processing pipeline for Release 5.0.

Changes for ABCD 3.0

Stop Signal Task behavioral measures

The SST behavioral variable `tfmri_sst_all_beh_total_meanrt` was removed, and two new variables were added:

- `tfmri_sst_all_beh_total_mssrt`: Stop Signal Reaction Time, mean estimation
- `tfmri_sst_all_beh_total_issrt`: Stop Signal Reaction Time, integration estimation

Changes for ABCD 4.0

Task fMRI E-Prime file behavioral responses

E-Prime files for a small number of pGUID-events have string response (e.g., "LEFTARROW" vs "RIGHTARROW") instead of numeric (i.e., 1 vs 2). Minor changes were made to handle these cases (for SST and nBack tasks), resulting in the recovery of task fMRI and behavioral results for such cases.

MID task behavioral measures

In the initial version of the MID task used for ABCD, only reaction time (RT) for positive feedback trials were able to be calculated. For the current version of the MID task, which was implemented in late 2017, RT can be calculated for all valid trials (i.e., including late responses but excluding early responses). In past releases, variables for negative feedback trials and all trials combined had empty values. In the current release, scan sessions with the current task version now have values for all of these RT variables. For participant-events using the original MID task, those variables remain empty. The method for setting the performance flag variable `tfmri_mid_beh_performflag` (in table [mri_y_tfmr_mid_beh](#)) was changed to require at least 20 responses per run to be considered acceptable performance for inclusion in analyses. The old method for setting the performance flag was to require at least 4 of each trial type across runs. This method is now used to set the new variable `tfmri_mid_feedbackflag`, which

is provided as an additional, optional filter not included in the recommended inclusion criteria used to set the inclusion flags in [mri_y_qc_incl](#) (see [MRI Quality Control & Recommended Image Inclusion Criteria](#)).

Miscellaneous changes to E-Prime file handling and variable extraction

- Truncated DICOM-derived SeriesTime instead of rounding, affecting calculated time delays.
- E-Prime file with special (problematic) characters in the file name was renamed, avoiding errors that prevented task fMRI analysis for that participant-event.
- Set E-Prime derived variables to **NaN** instead of 0 in case of missing or invalid E-Prime file.
- Created variables indicating whether experiment name matches labeling of E-Prime file (e.g., `iqc_mid_ep_exper_ok`) and has readable behavioral data (e.g., `iqc_mid_ep_behav_readable`).

Changes to data dictionaries

- modified NDA data structure `abcd_mid02`
 - added element `tfmri_mid_beh_feedbackflag`
 - changed description for element `tfmri_mid_beh_performflag`

Raw Behavioral Data

fMRI Monetary Incentive Delay (MID) Task

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

Column name	Description
<code>task</code>	Behavioral task completed
<code>subject</code>	Subject ID how it's defined in lab/project
<code>eventname</code>	The event name for which the data was collected
<code>site</code>	Data collection site ID
<code>date</code>	Date of data collection (month/day/year)
<code>time</code>	Time that data was collected (hours/minutes/seconds)
<code>mid_run</code>	Which run the task data corresponds to <code>mid_trialnum</code>
<code>mid_anticipationtype</code>	The type of anticipation for that trial
<code>mid_anticipationonset</code>	The time that the anticipation phase started
<code>mid_anticipationduration</code>	The length of time that the anticipation phase lasted

Column name	Description
<code>mid_feedbacktype</code>	The type of feedback received based on the subject's performance <code>mid_feedbackonset</code>
<code>mid_feedbackduration</code>	The length of time that the feedback phase lasted
<code>mid_acc</code>	Accuracy of the subject's performance for that trial
<code>mid_resp</code>	Whether or not the subject provided a response for that trial <code>mid_rt</code>
<code>mid_rttime</code>	The timepoint in the task when the participant responded
<code>mid_trialmoney</code>	The money resulting from the subject's performance on that trial

Notes:

The following information pertains to the variables

- `mid_anticipationonset`
- `mid_anticipationduration`
- `mid_feedbackonset`
- `mid_feedbackduration`
- `mid_rt`
- `mid_rttime`

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 raw behavioral 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](#).
 - 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_rttime` variables in the following way:
 - *Siemens/Philips Scanners*: Add 6400 ms
 - *GE DV25*: Add 4000 ms
 - *GE DV26*: Add 12,800 ms

2. All times are presented in milliseconds

fMRI Stop Signal Task (SST)

The following table provides the column names that are contained within the SST raw behavioral 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
src_subject_id	Subject IDeventname
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	E-Prime-labeled trial number within each run (note: these numbers are generated by E-Prime 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 E-Prime 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 E-Prime 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	Response times locked to the beginning of “go” slides

Column name	Description
<code>sst_go_rttime</code>	Global timing of responses to "go" slides
<code>sst_ssd_onsettime</code>	Global onset time for "ssd" slides <code>sst_ssd_resp</code>
<code>sst_ssd_rt</code>	Response times locked to the beginning of "ssd" slides
<code>sst_ssd_rttime</code>	Global timing of responses to "ssd" slides
<code>sst_ssd_dur</code>	Duration of the stop-signal delay (SSD) for STOP trials
<code>sst_stopsignal_onsettime</code>	Global onset time for "stopsignal" slides <code>sst_stopsignal_resp</code>
<code>sst_stopsignal_rt</code>	Response times locked to the beginning of "stopsignal" slides
<code>sst_stopsignal_rttime</code>	Global timing of responses to "stopsignal" slides
<code>sst_fix_onsettime</code>	Global onset time for "fix" slides <code>sst_fix_resp</code>
<code>sst_fix_rt</code>	Response times locked to the beginning of "fix" slides (note: the global timing of responses to "fix" slides was not recorded by the task)
<code>sst_leftarrow</code>	Variable that maps participants' button press responses to the "left arrow" response
<code>sst_rightarrow</code>	Variable that maps participants' button press responses to the "right arrow" response
<code>sst_expcn</code>	Whether the trial was in the GO or STOP condition
<code>sst_choiceacc</code>	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)
<code>sst_inhibitacc</code>	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)

Concerns regarding ABCD STOP task (continued)

A recent manuscript (<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 (see *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)
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 E-Prime: 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 *MRI Scanning Checklist and Notes* instrument.

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_0ssdcnt` 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 to 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*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 E-Prime 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 E-Prime 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_rtand 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 > 0ms AND sst_ssd_dur < 700ms` :
 - If the participant's first response on the trial is during the "ssd" slide, the RT and response from that slide (`sst_ssd_rtand 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_rtttime - 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 >0ms and <700ms) 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` → set `sst_choiceacc = NA/blank`
 - If `sst_primaryresp ≠ NA/blank` AND `sst_stim = sst_primaryresp` → set `sst_choiceacc = 1`
 - If `sst_primaryresp ≠ NA/blank` AND `sst_stim ≠ sst_primaryresp` → set `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` → set `sst_inhibitacc = 1`
 - If `sst_expcon ≠ GoTrial` AND `sst_primaryresp ≠ NA/blank` → set `sst_inhibitacc = 0`

fMRI Emotional nBack Working Memory Task

Column name	Description
<code>task</code>	Behavioral task completed
<code>subject</code>	Subject ID/eventname
<code>site</code>	Data collection site ID
<code>date</code>	Date at which the data were collected
<code>time</code>	Local time at which the data were collected
<code>enback_trialnum</code>	Variable constructed by the trial-level task force which indicates the trial number within each run
<code>enback_run</code>	Variable constructed by the trial-level task force which indicates the run number
<code>enback_runtrialnumber[Block]</code>	E-Prime-labeled trial number (note: these numbers are generated by E-Prime and do not necessarily correspond with the absolute trial number; e.g., the first trial may be labeled as number 3)
<code>enback_cue0back_onsettime</code>	Global onset time for the cues that begin 0-back blocks
<code>enback_cue2back_onsettime</code>	Global onset time for the cues that begin 2-back blocks
<code>enback_stim_onsettime</code>	Global onset time for each stimulus
<code>enback_fix_onsettime</code>	Global onset time for the intertrial interval following each stimulus, during which a fixation cross is presented

Column name	Description
<code>enback_cuefix_starttime</code>	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)
<code>enback_loadcon</code>	N-back load condition (0-back or 2-back)
<code>enback_stimtype</code>	Emotion condition (PosFace, NegFace, NeutFace, Place) of the stimulus
<code>enback_targettype</code>	Target status (target, lure, nonlure) of the stimulus
<code>enback_stimfile</code>	Name of the specific .bmp image presented for each stimulus
<code>enback_stim_resp</code>	Participant's button press response
<code>enback_stim_rt</code>	Response time
<code>enback_stim_acc</code>	Whether the participant's choice was accurate
<code>enback_stim_rtttime</code>	Global time of the response to the trial

Although most of the variables in this release were drawn from the raw E-Prime 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's [GitHub page](#).

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 E-Prime, which are locked to the beginning of the E-Prime task. As fMRI data begin to be collected some time after the experimenter starts the E-Prime 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 above).