

# 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

### MRI Quality Control (QC) and Recommended Image Inclusion Criteria

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October 2021

#### Change Log

October 2021 - Data Release 4.0

- Initial release

#### List of Instruments

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Name of Instrument	Short Name
ABCD Recommended Imaging Inclusion	abcd_imgincl01
ABCD MR Findings	abcd_mrfindings02
ABCD MRI QC Raw Part 1	mriqcp103
ABCD MRI QC Raw Part 2	mriqcp203
ABCD MRI QC Raw Part 3	mriqcp302

<b>ABCD Manual FreeSurfer QC</b>	abcd_fsrfqc01
<b>ABCD Manual T2w Post-Processing QC</b>	abcd_t2wqc01
<b>ABCD Manual dMRI Post-Processing QC</b>	abcd_dmriqc01
<b>ABCD Manual fMRI Post-Processing QC</b>	abcd_fmriqc01
<b>Automated Post-Processing QC Metrics</b>	abcd_auto_postqc01

## 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*.

## ABCD Recommended Imaging Inclusion

Users of the imaging data are advised to choose inclusion criteria that are appropriate for their analyses. We provide a set of recommended inclusion criteria for each modality that take into account factors such as imaging QC, task performance, etc., and for convenience, we provide a data structure *abcd\_imgincl01* with modality-specific imaging inclusion flags based on those criteria. Each modality (T1w, T2w, DTI/RSI, rsfMRI, SST, nBack, and MID tfMRI) is scored as 1=include, 0=exclude.

### ***T1w data recommended for inclusion***

T1w series meets all criteria for inclusion (*imgincl\_t1w\_include* = 1).

<b>T1w Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>FreeSurfer QC not failed</b>	abcd_fsrfqc01	fsqc_qc ~= 0
<b>Derived results exist</b>	abcd_smrip202	smri_t1w_scs_cbwmatterlh ~= NA

***T2w data recommended for inclusion***

T2w series meets all criteria for inclusion (imgincl\_t2w\_include = 1).

<b>T2w Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>T2 series passed rawQC</b>	mriqcrp103	iqc_t2_ok_ser > 0
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>FreeSurfer QC not failed</b>	abcd_fsrfqc01	fsqc_qc ~= 0
<b>T2w manual post-processing QC not failed</b>	abcd_t2wqc01	t2w_postqc_qc ~= 0
<b>T2w registration to T1w</b>	abcd_auto_postqc01	apqc_smri_t2w_regt1_rigid < 10
<b>Derived results exist</b>	abcd_smrip302	smri_t2w_scs_cbwmatterlh ~= NA

***dmRI (DTI/RSI) data recommended for inclusion***

dmRI (DTI/RSI) series meets all criteria for inclusion (imgincl\_dmri\_include = 1).

<b>dmRI Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>dmRI series passed rawQC</b>	mriqcrp103	iqc_dmri_ok_ser > 0
<b>dmRI total number of repetitions</b>	mriqcrp103	iqc_dmri_ok_nreps >= 103 OR (mri_info_manufacturer = Philips AND iqc_dmri_ok_ser >= 2 AND iqc_dmri_ok_nreps = 51)
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>dmRI B0 unwarp available</b>	abcd_auto_postqc01	apqc_dmri_bounwarp_flag == 1
<b>FreeSurfer QC not failed</b>	abcd_fsrfqc01	fsqc_qc ~= 0
<b>dmRI manual post-processing QC not failed</b>	abcd_dmriqc01	dmri_postqc_qc ~= 0
<b>dmRI registration to T1w</b>	abcd_auto_postqc01	apqc_dmri_regt1_rigid < 17
<b>dmRI dorsal cutoff score</b>	abcd_auto_postqc01	apqc_dmri_fov_cutoff_dorsal < 47

<b>dmRI ventral cutoff score</b>	abcd_auto_postqc01	apqc_dmri_fov_cutoff_ventral < 54
<b>Derived results exist</b>	abcd_drsip201	dmri_rsrnd_fib_allfib ~= NA

***rs-fMRI data recommended for inclusion***

rsfMRI series meets all criteria for inclusion (imgincl\_rsfmri\_include = 1).

<b>rsfMRI Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>rsfMRI tfMRI series passed rawQC</b>	mriqcrp103	iqc_rsfmri_ok_ser > 0
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>rsfMRI number of frames after censoring</b>	abcd_betnet02	rsfmri_c_ngd_ntpoints > 375
<b>fMRI B0 unwarp available</b>	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
<b>FreeSurfer QC not failed</b>	abcd_fsrfqc01	fsqc_qc ~= 0
<b>fMRI manual post-processing QC not failed</b>	abcd_fmriqc01	fmri_postqc_qc ~= 0
<b>fMRI registration to T1w</b>	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
<b>fMRI dorsal cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
<b>fMRI ventral cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60
<b>Derived results exist</b>	abcd_betnet02	rsfmri_c_ngd_dt_ngd_sa ~= NA

***MID task-fMRI data recommended for inclusion***

MID tfMRI series meets all criteria for inclusion (imgincl\_mid\_include = 1).

<b>MID Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>MID tfMRI series passed rawQC</b>	mriqcrp103	iqc_mid_ok_ser > 0
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>MID behavior passed</b>	abcd_mid02	tfmri_mid_beh_performflag == 1
<b>MID degrees of freedom &gt; 200</b>	midaparc03	tfmri_mid_all_b_dof > 200

<b>MID E-prime timing match OR ignore E-prime mismatch</b>	mriqcrp302	iqc_mid_ep_t_series_match == 1    eprime_mismatch_ok_mid == 1
<b>fMRI B0 unwarp available</b>	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
<b>FreeSurfer QC not failed</b>	abcd_fsurfqc01	fsqc_qc ~= 0
<b>fMRI manual post-processing QC not failed</b>	abcd_fmriqc01	fmri_postqc_qc ~= 0
<b>fMRI registration to T1w</b>	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
<b>fMRI dorsal cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
<b>fMRI ventral cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60
<b>Derived results exist</b>	midaparc03	tfmri_ma_acdn_b_scs_cbwmlh ~= NA

***nBack task-fMRI data recommended for inclusion***

nBack tfMRI series meets all criteria for inclusion (imgincl\_nback\_include = 1).

<b>nBack Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>nBack tfMRI series passed rawQC</b>	mriqcrp103	iqc_nback_ok_ser > 0
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>nBack behavior passed</b>	abcd_nback02	tfmri_nback_beh_performflag == 1
<b>nBack degrees of freedom &gt; 200</b>	nback_bwroi02	tfmri_nback_all_b_dof > 200
<b>nBack E-prime timing match OR ignore E-prime mismatch</b>	mriqcrp302	iqc_nback_ep_t_series_match == 1    eprime_mismatch_ok_nback == 1
<b>fMRI B0 unwarp available</b>	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
<b>FreeSurfer QC not failed</b>	abcd_fsurfqc01	fsqc_qc ~= 0
<b>fMRI manual post-processing QC not failed</b>	abcd_fmriqc01	fmri_postqc_qc ~= 0
<b>fMRI registration to T1w</b>	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
<b>fMRI dorsal cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65

<b>fMRI ventral cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60
<b>Derived results exist</b>	nback_bwroi02	tfmri_nback_all_4 ~= NA

***SST task-fMRI data recommended for inclusion***

SST tfMRI series meets all criteria for inclusion (imgincl\_sst\_include = 1).

<b>SST Criteria</b>	<b>Instrument</b>	<b>Element value</b>
<b>SST tfMRI series passed rawQC</b>	mriqcrp103	iqc_sst_ok_ser > 0
<b>T1 series passed rawQC</b>	mriqcrp103	iqc_t1_ok_ser > 0
<b>SST behavior passed</b>	abcd_sst02	tfmri_sst_beh_performflag == 1
<b>SST task had no glitch</b>	abcd_sst02	tfmri_sst_beh_glitchflag ~= 1
<b>SST degrees of freedom &gt; 200</b>	mrisst02	tfmri_sa_beta_dof > 200
<b>SST total number of trials is 100</b>	abcd_sst02	tfmri_sst_all_beh_t_nt = 100
<b>SST E-prime timing match OR ignore E-prime mismatch</b>	mriqcrp302	iqc_sst_ep_t_series_match == 1    eprime_mismatch_ok_sst == 1
<b>fMRI B0 unwarp available</b>	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
<b>FreeSurfer QC not failed</b>	abcd_fsrfqc01	fsqc_qc ~= 0
<b>fMRI manual post-processing QC not failed</b>	abcd_fmriqc01	fmri_postqc_qc ~= 0
<b>fMRI registration to T1w</b>	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
<b>fMRI dorsal cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
<b>fMRI ventral cutoff score</b>	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral <= 60
<b>Derived results exist</b>	mrisst02	tfmri_sacgvf_bscs_cbwmlh ~= NA

Automated post-processing QC metrics were statistically characterized in association with manual QC variables from ABCD Release 3.0. The statistical association between manual and automated QC variables was used to guide the identification of automated QC variables that were predictive of manual QC scores. The pairwise analysis of manual-vs-auto QC scores lead to automated QC variable thresholds needed to identify anomalous scans with desired false alarm ratings. For the variables listed below, the thresholds are listed to achieve conservatively low false alarm ratings of 0.05%.

- sMRI T2w registration to T1w: less than 10
- dMRI registration to T1w: less than 17
- dMRI Maximum dorsal cutoff score: less than 47
- dMRI Maximum ventral cutoff score: less than 54
- fMRI registration to T1w: less than 19
- fMRI Maximum dorsal cutoff score: less than 65
- fMRI Maximum ventral cutoff score: less than 60

Notes:

- All imaging series have been manually reviewed at the preprocessing stage (“raw”). Series failing raw QC do not get processed (e.g., `iqc_t1_ok_ser` is 0 or empty).
- For task fMRI, the average degrees of freedom is set at an arbitrary 200; this can be increased for a more restrictive selection criteria. For single runs, the required degrees of freedom are halved (i.e., `dof > 100`).

## ABCD MR Findings (manual review)

T1w and T2w-weighted images, if available, were screened for incidental findings by a Board Certified Neuroradiologist. Any findings requiring clinical investigation were relayed to appropriate site personnel via the ABCD Coordinating Center (CC).

The most important measure is the Report Score (`mrif_score`):

- 0 = Image artifacts prevent radiology read;
- 1 = No abnormal findings;
- 2 = Normal anatomical variant of no clinical significance;
- 3 = Consider clinical referral;
- 4 = Consider immediate clinical referral.

Although not included in the recommended inclusion criteria, users may, depending on their research question and analytical design, opt to exclude participants with `mrif_score ~3` OR `mrif_score ~4`.

## ABCD MRI QC Raw Part 1 – 3 (manual and automated review)

- Protocol compliance checking
  - performed by on-site FIONA workstations to provide feedback to scan operators
  - out-of-compliance series reviewed by DAIC staff
  - criteria included whether key imaging parameters matched expected values for a given scanner, such as voxel size or repetition time
  - presence or absence of B0 distortion field map series was checked for diffusion MRI (dMRI) and functional MRI (fMRI) series
  - each imaging series checked for completeness (i.e., no missing files)
- Automated quality control metrics
  - Structural MRI (sMRI): mean and standard deviation of brain values and spatial SNR

- dMRI: mean motion (average framewise displacement), and the number of slices and frames affected by slice dropout caused by abrupt head motion
- fMRI: mean motion (average framewise displacement), the number of seconds with framewise displacements less than 0.2, 0.3, or 0.4 mm (Power, et al., 2012), temporal SNR (tSNR) (Triantafyllou, et al., 2005)
- Manual review of data quality
  - reviewers assigned binary QC score
    - 0 = reject
      - most severe artifacts or irregularities
      - rejected series excluded from subsequent processing and analysis
    - 1 = accept
  - types of images reviewed
    - T1w, T2w, dMRI, dMRI field map, fMRI, and fMRI field map
    - raw and some derived images were reviewed
    - dMRI derived images included average b=0 image, FA, MD, tensor fit residual error, and direction encoded color image
    - fMRI derived images included the average across time and the temporal standard deviation
  - inspected for signs of artifacts and poor image quality
    - presence of wrap-around field of view artifacts
    - brain cut-off due to the participant motion outside prescribed slices
    - magnetic susceptibility artifacts due to dental implants
    - T1w and T2w motion artifact (e.g. blurring and ghosting)

## FreeSurfer QC (manual review)

- Manual review of FreeSurfer cortical surface reconstruction
  - reviewers assigned binary (0|1) QC score
    - 0 = reject
      - most severe artifacts or irregularities
      - results still included in shared tabulated data
      - recommended exclusion from group analyses involving cortical surface ROIs
    - 1 = accept
  - reviewers gauged the severity of five types of artifact or processing problem
    - motion
    - intensity inhomogeneity
    - white matter underestimation
    - pial overestimation
    - magnetic susceptibility artifact
  - numeric values assigned on a scale of 0-3
    - absent, mild, moderate, or severe, respectively
    - QC score of 0 assigned if severity score of 3 for any artifact type

Note: imaging-derived results are included in shared tabulated data regardless of post-processing QC. QC variables (derived from procedures described above) are included in shared tabulated data. The overall, binary QC score described above indicates whether inclusion or exclusion is recommended



based on this criterion alone (see above *ABCD Recommended Imaging Inclusion*). FreeSurfer QC covers ~6.6% of participant-events with imaging data.

## sMRI T2w Post Processing QC (manual review)

- Manual review of DTI reconstruction
  - reviewers assigned binary (0|1) QC score
    - 0 = reject
      - most severe artifacts or irregularities
      - results still included in shared tabulated data
      - recommended exclusion from group analyses involving cortical, subcortical, and tract-based ROIs
    - 1 = accept
  - reviewers gauged the severity of four types of artifact or processing problem
    - motion
    - intensity inhomogeneity
    - magnetic susceptibility artifact
    - registration with T1w image
  - numeric values assigned on a scale of 0-3
    - absent, mild, moderate, or severe, respectively
    - QC score of 0 assigned if severity score of 3 for any artifact type

Note: The T2w Post Processing QC covers ~2.4% of participant-events with imaging data.

## dMRI Post Processing QC (manual review)

- Manual review of processed dMRI data
  - reviewers assigned binary (0|1) QC score
    - 0 = reject
      - most severe artifacts or irregularities
      - results still included in shared tabulated data
      - recommended exclusion from group analyses involving cortical, subcortical, and tract-based ROIs
    - 1 = accept
  - reviewers gauged the severity of five types of artifact or processing problem
    - B0 warping
    - image quality based on motion-related artifacts and magnetic susceptibility artifact
    - full head coverage
    - registration with T1w image
    - accuracy of fiber tract segmentation
  - numeric values assigned on a scale of 0-3
    - absent, mild, moderate, or severe, respectively
    - QC score of 0 assigned if severity score of 3 for any artifact type

Note: The dMRI Post Processing QC covers ~7.4% of participant-events with imaging data.

## fMRI Post Processing QC (manual review)

- Manual review of processed fMRI data
  - reviewers assigned binary (0|1) QC score
    - 0 = reject
      - most severe artifacts or irregularities
      - results still included in shared tabulated data
      - recommended exclusion from group analyses involving cortical, subcortical, and tract-based ROIs
    - 1 = accept
  - reviewers gauged the severity of five types of artifact or processing problem
    - B0 warping
    - image quality based primarily on magnetic susceptibility artifact
    - full head coverage
    - registration with T1w image
  - numeric values assigned on a scale of 0-3
    - absent, mild, moderate, or severe, respectively
    - QC score of 0 assigned if severity score of 3 for any artifact type

Note: The fMRI Post Processing QC covers ~6.3% of participant-events with imaging data.

## Automated Post Processing QC (automated review)

Automated QC measures were defined and calculated based on processed imaging data.

- FreeSurfer
  - number of topological defects
    - calculated from Euler number
- dMRI
  - field of view (FOV) brain cutoff
    - quantified by % intersection of brain mask with frame borders
  - registration to T1w
    - window-based estimation of geometric registration discrepancy with respect to the T1 scan, decomposed into rigid and warp components for calculation of registration error
- fMRI
  - field of view (FOV) brain cutoff
    - quantified by % intersection of brain mask with frame borders
  - registration to T1w
    - window-based estimation of geometric registration discrepancy with respect to the T1 scan, decomposed into rigid and warp components for calculation of registration error
- sMRI T2w
  - registration to T1w

- window-based estimation of geometric registration discrepancy with respect to the T1 scan, decomposed into rigid and warp components for calculation of registration error

## MRI post-processing quality control

Our manual quality control process involves manual examination of brain images from a subset of participant-events for each modality, with ratings for each dataset according to pre-defined quality criteria such as brain cutoff, residual distortion, or registration to T1. Such measures are described later in this document (see *FreeSurfer QC (manual review)*, *sMRI T2w Post Processing QC (manual review)*, *dMRI Post Processing QC (manual review)*, and *fMRI Post Processing QC (manual review)*). Because an exhaustive manual review of every scan is not practical, we deploy statistical learning/AI guided sub-sampling methods where we generate automated metrics for an array of quality control issues (see *Automated Post Processing QC (automated review)*) and sub-select participant-events to be sent for a given modality to manual review based on their quality measure scores. The automatic selection priority scores generally indicate how likely a dataset of a given type is to contain identifiable data quality issues such as a residual distortion or brain cutoff. ABCD Release 4.0 manual review post processing sampling categories included the following four primary groups:

**Failed post-processing QC from ABCD Release 3.0:** All participant-events that failed QC for a given modality in Release 3.0 were manually reviewed again after Release 4.0 processing, with the expectation that they would be likely candidates for failure, unless perhaps recovered due to improvements in the current Release 4.0 processing pipeline. These made up about 25-50% of manually reviewed participant-events.

**Random selection of participant-events:** Roughly 5% of the manually reviewed participant-events were chosen at random to account for possible biases and insensitivities of the automated measures that guide the sub-sampling selection process.

**Statistical outliers:** ROI summary vectors for all individual participant-events are used to deduce a statistical ensemble profile. Participant-events with the greatest “distance” to the ensemble are tagged as outliers and selected for manual review. The formal framework we used for defining the ensemble statistics and the “distance” measure between a scan and the ensemble is based on the Mahalanobis distance (see [https://en.wikipedia.org/wiki/Mahalanobis\\_distance](https://en.wikipedia.org/wiki/Mahalanobis_distance)). Mahalanobis distance is a scalar measure of the distance between a point **P**, defined in a multi-dimensional vector space, and a distribution **D**. In our case, participant-events are sorted based on their Mahalanobis distances, and our manual review goal targeted the top 5% of that list. These made up ~20-25% of manually reviewed participant-events.

**Classifier guided selections:** Using the manual scoring of the above sets, namely the random samples, Release 3.0 failures, and Mahalanobis distance outliers, we collected a subset of manually labeled scan data. For each participant-event we generated a set of automated measures described below in *Automated Post Processing QC (automated review)*. Using binarized (pass/fail) manual quality control (QC) labels associated with these measures, we constructed a Bayesian classifier (see [https://en.wikipedia.org/wiki/Bayes\\_classifier](https://en.wikipedia.org/wiki/Bayes_classifier)) that calculates the probability of QC failure associated with different types of QC issues (e.g., bad registration or brain cutoff) for any given dataset. participant-events are sorted based on their

QC failure probabilities, and roughly the top 3-5% were selected for manual review for each modality, making up ~30-50% of manually reviewed participant-events.

## 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.

### Changes for ABCD 3.0

#### *Post processing QC and inclusion criteria*

As in ABCD Release 2.0.1, FreeSurfer cortical surface reconstructions were reviewed for all participant-events that successfully completed FreeSurfer processing. New for Release 3.0, we used a sampling approach for dMRI and fMRI, wherein approximately 20% of the dMRI/fMRI sessions were manually reviewed for postprocessing dMRI/fMRI QC. We selected participant-events for review based on random-sampling, Bayesian classifiers based on automated QC metrics, and multivariate outlier detection. Recommended inclusion criteria were updated to include manual post-processing QC, new automated post-processing QC metrics, and additional variables (e.g., E-Prime timing match to imaging series). Modality-specific imaging inclusion flags are included in a new data structure, `abcd_imgincl01`.

#### *Protocol compliance*

The determination of protocol compliance for scans from GE scanners (reflected for example in elements `iqc_sst_1_pc_score` or `iqc_sst_total_passpc` in data structure `mriqcrp202`) was changed to use the "ImagesInAcquisition" DICOM header attribute rather than the number of DICOM files. Imaging series with missing files, i.e., fewer files than the ImagesInAcquisition, are marked as incomplete. For Siemens and Philips scans, the same DICOM header field recording the number of images collected is not available, and so series with fewer files than expected for the given series type are marked as incomplete.

### Changes for ABCD 4.0

#### *MRI raw QC*

The MRI raw QC data structures `mriqcp103` and `mriqcp203` were updated to reflect a remapping of the names and abbreviations used to categorize MRI raw QC issues. This was done to remove redundancy in the categories used previously. Also, QC issue variables were removed where inappropriate for a given scan type, such as the dMRI-specific "fa" (fractional anisotropy map issues) for sMRI or fMRI (e.g., `iqc_mid_fa_qc`).

<b>QC issue names</b>	<b>Previously used names</b>
field of view (fov)	dorsal cutoff (dco) ventral cutoff (vco) wrap around (wr)
susceptibility artifact (sus)	distortion (dis) signal dropout (sd) signal inhomogeneity (si)

horizontal banding (hb)	slice horizontal banding (hb)
other	flag other

### *Post processing QC and inclusion criteria*

We extended the sampling approach used in Release 3.0 to include FreeSurfer, dMRI, fMRI, and sMRI T2w post-processing QC. Approximately 2-7% of all participant-events were manually reviewed for post-processing QC for each modality. We selected participant-events for review based on post-processing QC failure in Release 3.0, multivariate outlier detection, Bayesian classifiers based on automated QC metrics, and random-sampling (~5% of total selected for review). Multivariate outlier detection was implemented using Mahalanobis distance calculated from the tabulated data (ROI averages) for a given imaging modality. Recommended inclusion criteria were updated to include manual post-processing QC for T2w. A new manual post-processing QC data structures was created for sMRI T2w: *abcd\_t2wqc01*. The following manual post-processing QC data structures were renamed: *freesqc01* to *abcd\_fsurfqc01*; *dmriqc01* to *abcd\_dmriqc01*; *fmriqc01* to *abcd\_fmriqc01*.

### *Changes to data dictionaries*

- Raw MRI QC
  - new versions of data structures *mriqcrp103* and *mriqcrp203* based on *mriqcrp102* and *mriqcrp202*
    - added new elements related to types of QC issues
    - removed other elements related to unused or deprecated QC issues
    - changes to DataType and Size for some elements
- Manual post-processing QC
  - new data structure *abcd\_t2wqc01*
  - new data structure *abcd\_fmriqc01* based on *fmriqc01*
    - added deap alias *fmri\_man\_postqc\_notes*
    - removed alias *fmri\_postqc\_visitid*
  - new data structure *abcd\_dmriqc01* based on *dmriqc01*
    - added deap aliases (with *dmri\_manu\_postqc\_...*)
  - new data structure *abcd\_fsurfqc01* based on *freesqc01*
    - removed alias *fsqc\_visit\_id*
    - added deap aliases (with *fsurf\_manu\_postqc\_...*)

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