

ABCD Human Subjects Study

Adolescent Brain Cognitive Development – ABCDSTUDY.org

Release Notes: Adolescent Brain Cognitive Development StudySM (ABCD) Data Release 3.0

MRI Quality Control (QC) and Recommended Image Inclusion Criteria

<http://dx.doi.org/10.15154/1519007>

October 2020

Change Log

October 2020 - Data Release 3.0

- Initial release

List of Instruments

Name of Instrument	Short Name
ABCD Recommended Imaging Inclusion	abcd_imgincl01
ABCD MR Findings	abcd_mrfindings02
ABCD MRI QC Raw Part 1	mriqcp102
ABCD MRI QC Raw Part 2	mriqcp202
ABCD MRI QC Raw Part 3	mriqcp302
FreeSurfer QC	freesqc01
ABCD dMRI Post Processing QC	dmriqc01
Manual fMRI Post-Processing QC	fmriqc01
Automated Post-Processing QC Metrics	abcd_auto_postqc01

Table of Contents

GENERAL INFORMATION	3
MANUAL POST PROCESSING SAMPLING STRATEGY	3
ABCD RECOMMENDED IMAGING INCLUSION	4
T1W DATA RECOMMENDED FOR INCLUSION	5
T2W DATA RECOMMENDED FOR INCLUSION	5
dMRI (DTI/RSI) DATA RECOMMENDED FOR INCLUSION	5
RS-fMRI DATA RECOMMENDED FOR INCLUSION	6
MID TASK-fMRI DATA RECOMMENDED FOR INCLUSION	6
NBACK TASK-fMRI DATA RECOMMENDED FOR INCLUSION	7
SST TASK-fMRI DATA RECOMMENDED FOR INCLUSION	7
ABCD MR FINDINGS (MANUAL REVIEW)	8
ABCD MRI QC RAW PART 1 – 3 (MANUAL AND AUTOMATED REVIEW)	8
FREESURFER QC (MANUAL REVIEW)	9
DMRI POST PROCESSING QC (MANUAL REVIEW)	10
FMRI POST PROCESSING QC (MANUAL REVIEW)	10
AUTOMATED POST PROCESSING QC (AUTOMATED REVIEW)	11
REFERENCES	11

General Information

The following information refers to the Adolescent Brain Cognitive DevelopmentSM (ABCD) Study Data Release 3.0 available from <https://nda.nih.gov/abcd>. An overview of the ABCD Study[®] is at <https://abcdstudy.org> and detailed descriptions of elements of the study are listed in <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*.

Manual Post Processing Sampling Strategy

FreeSurfer cortical surface reconstructions were reviewed for all participant-events that successfully completed FreeSurfer processing. For dMRI and fMRI, we used a sampling approach in which we initially reviewed a random sample of 10% of all participant-events included in ABCD Release 3.0. We then used the manual QC scores to train Bayesian classifiers to predict manual QC scores based on one or more automated QC metrics. Unreviewed data that was classified as problematic were selected for additional manual review. In addition, we selected participant-events for additional review based on outlier values within the derived measures from the tabulated imaging data for a particular modality. These outliers were identified using the SPSS Anomaly index procedure which produces a clustering model that explains natural groupings (or clusters) within a dataset. The resulting clustering models are applied to each case to identify its cluster group, and some indices are created for each case to measure the unusualness of the case with respect to its cluster group. All cases are sorted by the values of the anomaly indices, with the top portion of the case list identified as the set of anomalies.

ABCD Recommended Imaging Inclusion

This is a decision tree for how the ABCD Study data is recommended for inclusion in imaging data analysis. This information is condensed into the *abcd_imgincl01* instrument. Recommendations are per MR measure - T1w, T2w, DTI/RSI, rsfMRI, SST, nBack and MID fMRI. All are scored as 1=include, 0=exclude.

Automated post-processing QC metrics were statistically characterized in association with manual QC variables. 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

Note: all dMRI and fMRI series are manually reviewed at the preprocessing stage (“raw”). Series failing raw QC do not get processed (*iqc_###_ok_ser* ~> 0). Following processing of series that passed raw QC, manual postprocessing dMRI/fMRI QC was performed on a random sample of approximately 10% of series across all sites. An additional 10% of series were manually inspected based on poor automated postprocessing QC scores in brain cutoff and registration to T1. Hence,

- All series are reviewed for manual raw QC.
- All T1 series are reviewed for manual postprocessing FreeSurfer QC.
- **Approximately 20% of the dMRI/fMRI series are manually reviewed for postprocessing dMRI/fMRI QC.**

Note: 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 degrees of freedom are halved (i.e., dof > 100).

T1w data recommended for inclusion

T1w series meets all criteria for inclusion (imgincl_t1w_include = 1).

T1w Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0

T2w data recommended for inclusion

T2w series meets all criteria for inclusion (imgincl_t2w_include = 1).

T2w Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
T2 series passed rawQC	mriqcrp102	iqc_t2_ok_ser > 0
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
T2w registration to T1w: Less than 10	abcd_auto_postqc01	apqc_smri_t2w_regt1_rigid < 10

dMRI (DTI/RSI) data recommended for inclusion

dMRI (DTI/RSI) series meets all criteria for inclusion (imgincl_dmri_include = 1).

dMRI Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
dMRI series passed rawQC	mriqcrp102	iqc_dmri_ok_ser > 0
dMRI Total number of repetitions for all OK scans is 103 or more	mriqcrp102	iqc_dmri_ok_nreps >= 103
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
dMRI B0 Unwarp available	abcd_auto_postqc01	apqc_dmri_bounwarp_flag == 1
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
dMRI Manual Post-Processing QC not failed	dmriqc01	dmri_postqc_qc ~= 0
dMRI registration to T1w: less than 17	abcd_auto_postqc01	apqc_dmri_regt1_rigid < 17
dMRI Maximum dorsal cutoff score: less than 47	abcd_auto_postqc01	apqc_dmri_fov_cutoff_dorsal < 47
dMRI Maximum ventral cutoff score: less than 54	abcd_auto_postqc01	apqc_dmri_fov_cutoff_ventral < 54

rs-fMRI data recommended for inclusion

rsfMRI series meets all criteria for inclusion (imgincl_rsfmri_include = 1).

rsfMRI Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
rsfMRI tfMRI series passed rawQC	mriqcrp102	iqc_rsfmri_ok_ser > 0
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
rsfMRI Number of frames > 375	abcd_betnet02	rsfmri_c_ngd_ntpoints > 375
fMRI B0 Unwarp available	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
fMRI Manual Post-Processing QC not failed	fmriqc01	fmri_postqc_qc ~= 0
fMRI registration to T1w: less than 19	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
fMRI Maximum dorsal cutoff score: less than 65	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
fMRI Maximum ventral cutoff score: less than 60	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60

MID task-fMRI data recommended for inclusion

MID tfMRI series meets all criteria for inclusion (imgincl_mid_include = 1).

MID Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
MID tfMRI series passed rawQC	mriqcrp102	iqc_mid_ok_ser > 0
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
MID Behavior passed	abcd_mid02	tfmri_mid_beh_performflag == 1
MID degrees of freedom > 200	midaparc03	tfmri_mid_all_b_dof > 200
MID E-prime timing match OR ignore E-prime mismatch	mriqcrp302	iqc_mid_ep_t_series_match == 1 eprime_mismatch_ok_mid == 1
fMRI B0 Unwarp available	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
fMRI Manual Post-Processing QC not failed	fmriqc01	fmri_postqc_qc ~= 0
fMRI registration to T1w: less than 19	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
fMRI Maximum dorsal cutoff score: less than 65	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
fMRI Maximum ventral cutoff score: less than 60	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60

nBack task-fMRI data recommended for inclusion

nBack tfMRI series meets all criteria for inclusion (imgincl_nback_include = 1).

nBack Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
nBack tfMRI series passed rawQC	mriqcrp102	iqc_nback_ok_ser > 0
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
nBack Behavior passed	abcd_nback02	tfmri_nback_beh_performflag == 1
nBack degrees of freedom > 200	nback_bwroi02	tfmri_nback_all_b_dof > 200
nBack E-prime timing match OR ignore E-prime mismatch	mriqcrp302	iqc_nback_ep_t_series_match == 1 eprime_mismatch_ok_nback == 1
fMRI B0 Unwarp available	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
fMRI Manual Post-Processing QC not failed	fmriqc01	fmri_postqc_qc ~= 0
fMRI registration to T1w: less than 19	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
fMRI Maximum dorsal cutoff score: less than 65	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
fMRI Maximum ventral cutoff score: less than 60	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral < 60

SST task-fMRI data recommended for inclusion

SST tfMRI series meets all criteria for inclusion (imgincl_sst_include = 1).

SST Criteria	Instrument	Element value
No serious MR findings	abcd_mrfindings02	mrif_score ~=3 mrif_score ~=4
SST tfMRI series passed rawQC	mriqcrp102	iqc_sst_ok_ser > 0
T1 series passed rawQC	mriqcrp102	iqc_t1_ok_ser > 0
SST Behavior passed	abcd_sst02	tfmri_sst_beh_performflag == 1
SST degrees of freedom > 200	mrissst02	tfmri_sa_beta_dof > 200
SST Total number of trials is 100	abcd_sst02	tfmri_sst_all_beh_t_nt = 100
SST E-prime timing match OR ignore E-prime mismatch	mriqcrp302	iqc_sst_ep_t_series_match == 1 eprime_mismatch_ok_sst == 1
fMRI B0 Unwarp available	abcd_auto_postqc01	apqc_fmri_bounwarp_flag == 1
FreeSurfer QC not failed	freesqc01	fsqc_qc ~= 0
fMRI Manual Post-Processing QC not failed	fmriqc01	fmri_postqc_qc ~= 0
fMRI registration to T1w: less than 19	abcd_auto_postqc01	apqc_fmri_regt1_rigid < 19
fMRI Maximum dorsal cutoff score: less than 65	abcd_auto_postqc01	apqc_fmri_fov_cutoff_dorsal < 65
fMRI Maximum ventral cutoff score: less than 60	abcd_auto_postqc01	apqc_fmri_fov_cutoff_ventral <= 60

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.

The recommended inclusion criteria are that mrif_score $\sim$ 3 OR mrif_score $\sim$ 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. smearing 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
 - 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.

dMRI 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 five types of artifact
 - 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 ~ 10% subjects and is primarily used as an internal QC measure.

fMRI Post Processing QC (manual review)

- Manual review of fMRI 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 five types of artifact
 - 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 ~ 10% subjects and is primarily used as an internal QC measure.

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

References

Power, J.D., Barnes, K.A., Snyder, A.Z., Schlaggar, B.L., Petersen, S.E. (2012) Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion. *Neuroimage*, 59:2142-54.

Triantafyllou, C., Hoge, R.D., Krueger, G., Wiggins, C.J., Potthast, A., Wiggins, G.C., Wald, L.L. (2005) Comparison of physiological noise at 1.5 T, 3 T and 7 T and optimization of fMRI acquisition parameters. *Neuroimage*, 26:243-50.

ABCD Study[®], Teen Brains. Today's Science. Brighter Future[®]. and the ABCD Study Logo are registered marks of the U.S. Department of Health & Human Services (HHS). Adolescent Brain Cognitive DevelopmentSM Study is a service mark of the U.S. Department of Health & Human Services (HHS).