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

## Structural Magnetic Resonance Imaging (sMRI)

October 2021
http://dx.doi.org/10.15154/1523041

**Change Log**
October 2021 – Data Release 4.0
- Initial release

## List of Instruments

| Instruments | Short Name |
|---|---|
| **ABCD sMRI Part 1** | abcd_smrip102 |
| **ABCD sMRI Part 2** | abcd_smrip202 |
| **ABCD sMRI Part 3** | abcd_smrip302 |
| **ABCD sMRI Destrieux Parcellation Part 1** | abcd_mrisdp102 |
| **ABCD sMRI Destrieux Parcellation Part 2** | abcd_mrisdp202 |
| **ABCD sMRI Destrieux Parcellation Part 3** | abcd_mrisdp302 |

## General Information

The following information refers to the Adolescent Brain Cognitive Development Study℠ (ABCD) Data Release 4.0 available from https://nda.nih.gov/abcd. An overview of the

ABCD Study® 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*.

## Overview

- Image types
  - $T_1$-weighted ($T_1$w) 3D structural images
  - $T_2$-weighted ($T_2$w) 3D structural images
- Image processing
  - corrected for gradient nonlinearity distortions (Jovicich, et al., 2006)
  - $T_2$w images registered to $T_1$w images using mutual information (Wells, et al., 1996)
  - intensity non-uniformity correction based on tissue segmentation and sparse spatial smoothing
  - resampled with 1 mm isotropic voxels into rigid alignment with an atlas brain
- Cortical surface reconstruction
  - FreeSurfer v7.1.1 (https://surfer.nmr.mgh.harvard.edu)
  - skull-stripping (Segonne, et al., 2004)
  - white matter segmentation, initial mesh creation (Dale, et al., 1999)
  - correction of topological defects (Fischl, et al., 2001; Segonne, et al., 2007)
  - surface optimization (Dale, et al., 1999; Dale and Sereno, 1993; Fischl and Dale, 2000)
  - nonlinear registration to a spherical surface-based atlas (Fischl, et al., 1999b)
- Morphometry
  - subcortical regional volume
  - cortical volume
  - cortical thickness (Fischl and Dale, 2000)
  - cortical area (Chen, et al., 2012; Joyner, et al., 2009)
  - sulcal depth (Fischl, et al., 1999a)
- Image intensity measures
  - $T_1$w and $T_2$w intensity measures in white matter (-0.2 mm from gray/white boundary)
  - $T_1$w and $T_2$w intensity measures in gray matter (+0.2 mm from gray/white boundary)
  - Normalized $T_1$w and $T_2$w cortical gray/white intensity contrast (Westlye, et al., 2009)
- Regions of interest (ROIs)
  - subcortical structures labeled with atlas-based segmentation (Fischl, et al., 2002)
  - cortical regions labeled with the Desikan atlas-based classification (Desikan, et al., 2006)
  - cortical regions labeled with the Destrieux atlas-based classification (Destrieux, et al., 2010)
  - fuzzy-cluster parcels, based on genetic correlation of surface area (Chen, et al., 2012)

# 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 4.0

*sMRI processing: registration to atlas*

The sMRI processing pipeline has included registration to a pre-existing, custom in-house T1w atlas and rigid body resampling. In rare cases this registration step may fail (e.g., in some participants with enlarged ventricles), resulting in non-standard head orientations in the processed data for those participant-events. In the current processing pipeline, we use a new ABCD-specific atlas that reduces the frequency of failed registration to atlas.

*sMRI processing: bias correction*

The correction of sMRI T1w and sMRI T2w images for intensity inhomogeneity uses a smoothly varying bias field constrained to have uniform intensities in voxels segmented as white matter. In addition, outlier voxels, defined as voxels in the white matter mask with low T1w intensities or high T2w intensities, are removed from the white matter mask. This was done to prevent slight inaccuracies in the initial white matter mask from causing poor bias field estimation in those regions with outlier intensities in voxels labeled as white matter. In the current pipeline, the smoothing algorithm for generating the bias field was changed slightly to use a robust, sparse smoothing algorithm with parameters optimized for a slightly more flexible (less smooth) bias field to better handle locally steep intensity gradients. The removal of outlier voxels from the white matter mask was done iteratively and was limited to the outer band (~1 cm) of white matter. For T2w images, a bug in the previous implementation of the outlier removal resulted in a sparse, slightly shrunken white matter mask. Correcting this issue resulted in a less sparse white matter mask and more spatially uniform bias correction for the T2w images than before.

*T2w registration to T1w*

The procedure for registration of sMRI T2w to T1-weighted images involves a pre-registration of the T1w image to a T1w atlas, pre-registration of the T2w image to a T2w atlas (co-registered to the T1w atlas), and then fine registration between the T2w and T1w images using mutual information. In rare cases, the pre-registration of the T1w image to the T1w atlas essentially failed, subsequently resulting in a poor registration between the T2w and T1w images. To reduce the likelihood of registration failure, the T1w atlas was edited by applying a brain mask, preventing non-brain regions of the atlas from influencing the registration.

*FreeSurfer version*

The FreeSurfer version was updated from 5.3.0 to 7.1.1. Changes to FreeSurfer processing across versions are documented here: https://surfer.nmr.mgh.harvard.edu/fswiki/ReleaseNotes.

Differences in the resulting surfaces and subcortical ROIs were generally quite small and free of systematic bias, but it should be noted that the sulcal depth measure differs in scale by a

factor of 10 (i.e., now in usits of mm instead of cm), resulting in large differences in the "sulc" ROI-averages included in the tabulated imaging data (in data table abcd_smrip102).

*Changes to data dictionaries*

- new versions of data structures *abcd_smrip102*, *abcd_smrip202*, and *abcd_smrip302* based on *abcd_smrip101* and *abcd_smrip201*
    - split data strutures to separate FreeSurfer-derived morphometry, T1w intensities, and T2w intensities
    - removed unused aliases
- new versions of data structures *abcd_mrisdp102*, *abcd_mrisdp202*, and *abcd_mrisdp302* based on *abcd_mrisdp101* and *abcd_mrisdp201*
    - split data strutures to separate FreeSurfer-derived morphometry, T1w intensities, and T2w intensities
    - removed unused aliases

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