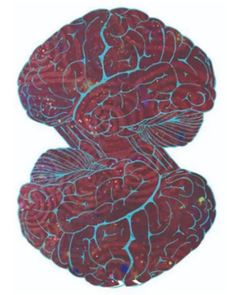
A Checklist of Quality Control For Making Atlases and Templates

Daniel Glen[1], Richard Reynolds[1], Paul Taylor[1]
[1]Scientific and Statistical Computing Core (NIMH, NIH, USA)
Contact: glend @ mail.nih.gov https://afni.nimh.nih.gov/pub/dist/doc/htmldoc/



POSTER # 1803
June 27-28, 2025
13:45-15:45

Introduction

While recent MRI projects have focused on quality control on individual structural and fMRI datasets, commonly used templates and atlases often lack proper scrutiny. One could argue that considering their widespread and repeated use in nearly every study of the brain, these kinds of datasets should be the most carefully inspected datasets. Yet, as developers and integrators of others atlases, we often find important problems in these data. This work introduces a checklist and tools within AFNI to standardize checks on these datasets for consistency, artifacts, and header properties. These tools and checklist are intended for both atlas creators and consumers of these reference datasets.

Methods

An overview of checklist features

Formats

- Datasets should be NIFTI with appropriate sform_code, qform_code (3=Talairach,4=MNI,5=Other).
- Data type=16-bit signed integers for templates, 8 or 16-bit for atlases for memory conservation.
- Provide additional information such as labels, space name, dataset version, general descriptions and citation info through header extensions (as in AFNI), JSON or other external files.

Coordinates and grids

- Avoid excessive padding, but leave space around the brain for alignment
- Ensure a useful,correct coordinate system exists with these requirements
- Meaningful origin of (0,0,0) (AC, EBZ)
- Use cardinal, non-oblique orientation
- Left-right are correct and match between template and atlas

Template intensities

- Intensities should be integers, within reasonable ranges (often in the low thousands)
- Zero values outside the head
- Avoid hyperintensities

Symmetry

- Nominally symmetric atlases and templates should be checked for asymmetries

ROI irregularities

- Avoid stairsteps and holes in atlases from 2D drawing and multi-subject averaging by correcting with "modal smoothing" in volume or surface (3dLocalstat/SurfLocalstat)
- Check for lost clusters-disconnected parts of regions (@ROI_decluster, IsoSurface)

ROI consistency

- ROIs should be consistent within the set that are distributed; whole brain, cortex, segmentation and lobule masks should correspond within the ROIs
- All labeled ROIs should be checked for existence; unlabeled ROIs are not included (@Atlasize)

ROI names

- Names should exist for each index with no duplicates
- Avoid punctuation (quotes,accents,...) to make scripting easier

Atlas space

- Clearly identify the associated template - MNI, TLRC, D99,...

Results

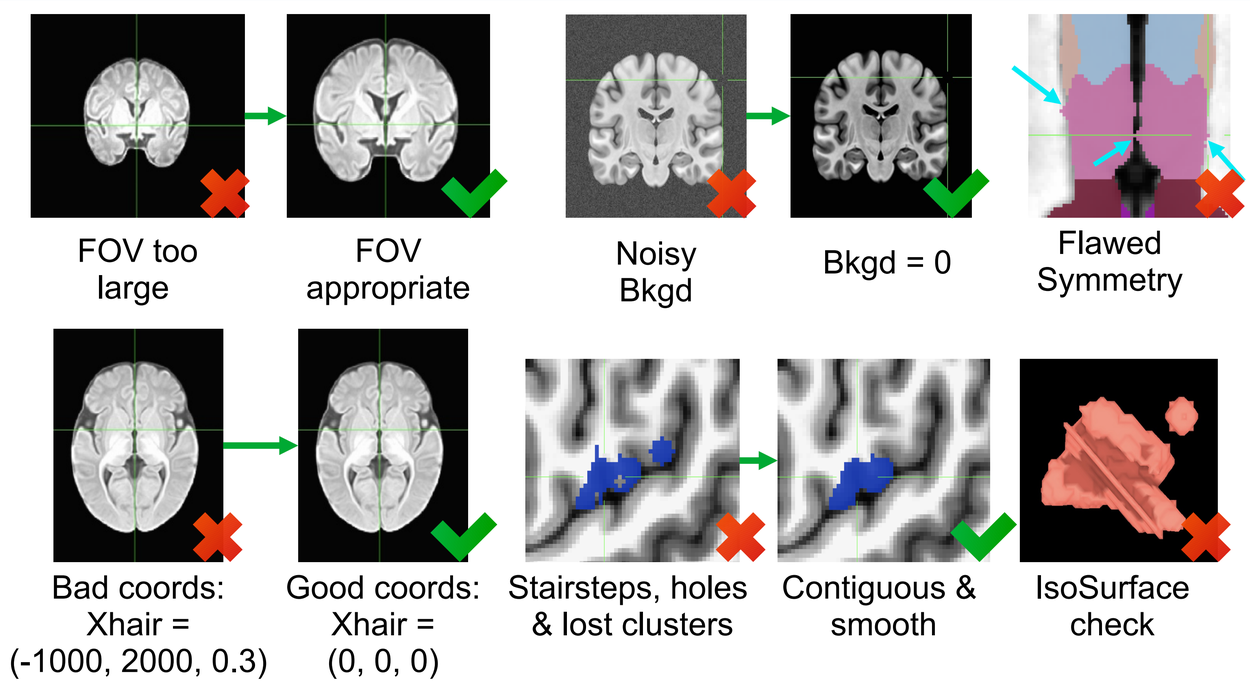
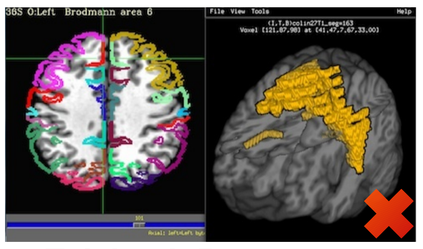
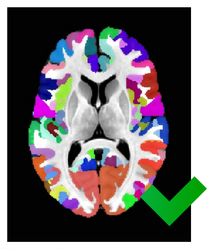


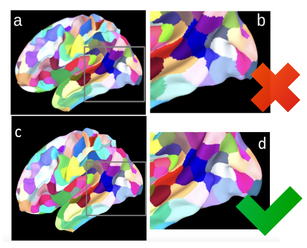
Figure 1. Examples of issues and solutions in atlases and templates



Talairach Daemon
An example of problematic atlas: poor fit and "lost" clusters

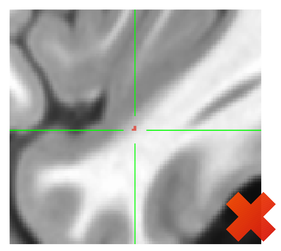


HCP Glasser
Projected to common MNI152_2009 space and ROI boundaries fixed with modal smoothing



Schaefer-Yeo
ROI boundaries fixed with modal smoothing on surface

Allen Mouse Brain
AFNI version
Contains attached coords



SAHB (Subcortical Atlas of the Human Brain)
Lost cluster discovery and repair during development

Figure 2. Examples of issues and solutions in commonly used atlases

Conclusion

AFNI has a long history of supporting and developing atlases and templates, from the early introduction of the Talairach atlas to the most recent atlases for macaque, marmoset and human brain. In that role, we curate these atlases to verify the properties for quality control. Here, we present a set of criteria and tools to promote proper implementations of these important resources for the neuroimaging community.

Acknowledgments & References

The research and writing of the manuscript were supported by the NIMH Intramural Research Program (ZICMH002888) of the NIH (HHS, USA). This work utilized the computational resources of the NIH HPC Biowulf cluster (http://hpc.nih.gov).

Amunts K, Mohlberg H, Bludau S, Zilles K (2020). Julich-Brain: A 3D probabilistic atlas of the human brain's cytoarchitecture. Science 369(6506):988-992.

Cox RW (1996). AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. Comput Biomed Res 29(3):162-173. doi:10.1006/cbmr.1996.0014

Cox RW, Ashburner J, Breman H, Fissell K, Haselgrove C, Holmes CJ, Lancaster JL, Rex DE, Smith SM, Woodward JB, Strother SC (2004). A (sort of) new image data format standard: NiFTI-1. Presented at the 10th Annual Meeting of the Organization for Human Brain Mapping.

Fonov V, Evans AC, Botteron K, Almli CR, McKinstry RC, Collins DL, et al. (2011). Unbiased average age-appropriate atlases for pediatric studies. Neuroimage 54, 313–327.

Schaefer A, Kong R,Gordon EM, Laumann TO, Zuo XN, Holmes AJ, Eickhoff SB, Yeo BT. Local-Global Parcellation of the Human Cerebral Cortex fromIntrinsic Functional Connectivity MRI, Cerebral Cortex, Volume 28, Issue 9, September 2018, Pages 3095–3114. Related poster herer: https://afni.nimh.nih.gov/pub/dist/HBM2021/Schaefer-Yeo_AFNI_Atlas_OHBM2021_Poster.pdf

Taylor PA, Glen DR, Reynolds RC, Basavaraj A, Moraczewski D, Etzel JA (2023). Editorial: Demonstrating quality control (QC) procedures in fMRI. Front. Neurosci. 17:1205928. doi: 10.3389/fnins.2023.1205928