UNC Early-Life Whole-Brain Functional Parcellation (UNC-ELF)

A unified functional parcellation for early human neurodevelopment, spanning the cerebral cortex, subcortex, and cerebellum from birth to 6 years

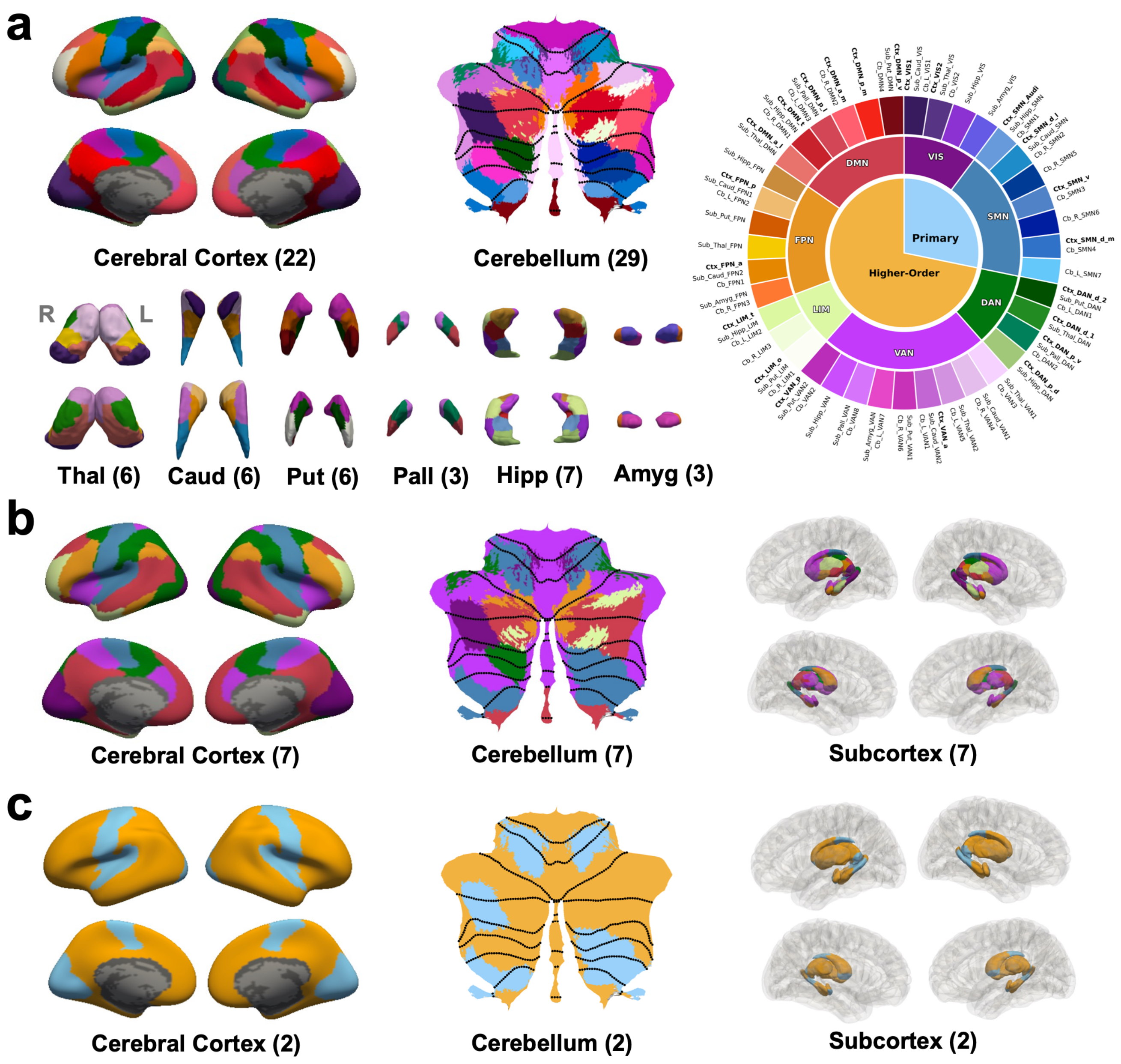

*Figure 1. Overview of the UNC **E**arly-**L**ife Whole-Brain **F**unctional (**ELF**) Parcellation.*

1. Overview

The UNC Early-Life Whole-Brain Functional Parcellation is an infant- and early-childhood-dedicated atlas resource for studying whole-brain functional organization from birth to 6 years of age. It provides age-independent and age-dependent parcellations derived within a common framework, enabling the cerebral cortex, subcortex, and cerebellum to be analyzed together rather than as separate parcellations assembled from different sources.

This release was constructed to support developmental neuroimaging studies of:

- large-scale functional organization in early life;
- cross-structure correspondence among the cerebral cortex, subcortex, and cerebellum;
- functional network refinement from infancy through early childhood; and
- whole-brain, parcel-wise, and network-level analyses in developmentally appropriate parcellation spaces.

2. Release Highlights

Component	Main resolution	High resolution	Notes
Cerebral cortex	22 networks	36 networks	Surface maps on fsaverage5, with label-name and color definition files
Cerebellum	29 networks	54 networks	Volumetric maps in parcel order and reordered network-aligned order
Subcortex	31 labels per hemisphere	Not applicable	Volumetric and surface-projected maps across 6 nuclei per hemisphere
Age-dependent parcellations	9 age groups	9 age groups	0M, 3M, 6M, 9M, 12M, 18M, 24M, 36M, and 72M
Templates	Included	Included	Cortex, cerebellum, and subcortex reference files for mapping and visualization

3. Download and Release Package

This release is prepared for public distribution through the GitHub repository and NITRC resource page associated with UNC Early-Life Whole-Brain Functional Parcellation. The GitHub-ready package contains the following major folders:

- Age_independent/
- Age_dependent/
- Templates/
- scripts/

The package is intended for academic research use. Ownership, copyright, and all rights are retained by UNC-Chapel Hill and collaborating institutions. Please acknowledge this release and cite the associated publications when using or adapting these resources.

4. Repository Contents

```
|-- Age_independent/
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```

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```

5. File Formats

Format	Use
.mgh	Cortical surface parcellation maps
.nii.gz	Volumetric parcellations, masks, and templates
.vtk	Subcortical surface-projected parcellation maps and templates
.json	Label/color definitions and network mapping files
.txt, .lut, .LUT	Label names, lookup tables, and color tables

6. Data Description

6.1 Age-independent parcellations

The age-independent release summarizes the shared functional scaffold across early life.

Main resolution

- Age_independent/Main_resolution/Cerebral cortex/: left and right fsaverage5 cortical surface maps for the 22-network cerebral parcellation (.mgh), with label-name and network/color mapping files (.txt, .json).
- Age_independent/Main_resolution/Cerebellum/: 29-network cerebellar volumetric parcellations (.nii.gz) with parcel-order and reordered representations, label tables, color tables, and visualization images.
- Age_independent/Main_resolution/Subcortex/: subcortical parcellations across thalamus, caudate, putamen, pallidum, hippocampus, and amygdala, provided as regional and combined volumes (.nii.gz), surface projections (.vtk), and color tables (.json, .lut).

High resolution

- Age_independent/High_resolution/Cerebral cortex/: 36-network cerebral cortical surface maps and labels.
- Age_independent/High_resolution/Cerebellum/: 54-network cerebellar volumetric maps in parcel-order and reordered representations.

6.2 Age-dependent parcellations

The age-dependent release provides age-specific refinements of the same large-scale scaffold for 9 developmental groups: 0M, 3M, 6M, 9M, 12M, 18M, 24M, 36M, and 72M.

- Age_dependent/Main_resolution/Cerebral cortex/: 22-network age-specific cerebral cortical maps.
- Age_dependent/Main_resolution/Cerebellum/: 29-network age-specific cerebellar maps in parcel-order and reordered representations.
- Age_dependent/Main_resolution/Subcortex/Volume /: age-specific subcortical volume maps.
- Age_dependent/Main_resolution/Subcortex/Surface /: age-specific subcortical surface projections.
- Age_dependent/High_resolution/Cerebral cortex/: 36-network age-specific cerebral cortical maps.
- Age_dependent/High_resolution/Cerebellum/: 54-network age-specific cerebellar maps in parcel-order and reordered representations.

6.3 Templates

The Templates/ folder contains reference files used for mapping and visualization:

- Templates/Cerebral_cortex/fsaverage5/: fsaverage5 cortical surface templates.
- Templates/Cerebellum/: 24-month cerebellar template files for volumetric display and SUIT-related processing.
- Templates/Subcortex/T1/: UNC 24M volumetric template and subcortical masks.
- Templates/Subcortex/Surface/: subcortical surface templates for thalamus, caudate, putamen, pallidum, hippocampus, and amygdala.

7. Network Organization

The cerebral and cerebellar parcellations are organized around large-scale functional systems, including visual, somatomotor, dorsal attention, ventral attention, limbic, frontoparietal, and default mode systems. Reordered cerebellar files follow the canonical large-scale sequence:

```
VIS -> SMN -> DAN -> VAN -> LIM -> FPN -> DMN
```

Subcortical labels are defined within 6 bilateral nuclei:

Nucleus	Labels per hemisphere
Thalamus	6
Caudate	6
Putamen	6
Pallidum	3
Hippocampus	7
Amygdala	3

Together, these yield 31 labels per hemisphere and 62 labels in the bilateral combined subcortical volume.

8. Construction Summary

This parcellation was derived from large-scale resting-state fMRI data spanning early life, including scans from the UNC/UMN Baby Connectome Project (BCP) and the Multi-visit Advanced Pediatric Brain Imaging Study (MAP). The construction framework emphasized:

- whole-brain integration across the cerebral cortex, subcortex, and cerebellum;
- structure-aware feature design for each major brain division;
- Laplacian representation and clustering of whole-brain connectivity features;
- age-independent and age-dependent outputs for shared and age-specific organization; and
- validation using reproducibility, functional homogeneity, tractography- and morphology-based coherence, and biological interpretability.

Together, these steps yielded a holistic early-life functional parcellation framework in which cortical, cerebellar, and subcortical systems can be studied jointly within a developmentally appropriate atlas space.

9. Recommended Use

The present release is intended for use after subject data have been mapped into the corresponding structural reference space for each major brain division. Because the cerebral cortex, cerebellum, and subcortex are represented in different anatomical frameworks, the recommended usage differs slightly across structures.

9.1 Cerebral cortex

The cerebral cortical parcellation is provided on the fsaverage5 surface. For infant and early-childhood data, we recommend first establishing subject-to-atlas cortical correspondence using the UNC 4D Infant Cortical Surface Atlas, which provides age-specific infant cortical surface atlases from 1 to 72 months and supports cortical surface-based analysis across early development. After this infant-dedicated surface alignment, subject-level cortical fMRI signals or derived surface maps can be resampled to fsaverage5 and analyzed using the released cortical parcellation.

A recommended workflow is:

1) reconstruct the subject cortical surfaces from structural MRI data using an infant-compatible surface-processing pipeline;

2) register the individual cortical surfaces to the age-appropriate UNC 4D infant cortical surface atlas using cortical geometric features such as convexity and curvature;

3) resample subject-level cortical surface data to fsaverage5;

4) project the subject cortical fMRI signal onto the registered and resampled cortical surface; and

5) apply the released cortical parcellation on the left and right fsaverage5 surfaces for parcel-wise signal extraction, connectivity analysis, or visualization.

The parcellation can also be resampled to other surface resolutions or spaces, including other fsaverage resolutions or the HCP fs_LR surface, using standard surface-to-surface resampling tools.

9.2 Cerebellum

The cerebellar parcellation is provided in the released cerebellar template space. To use it appropriately, the subject-specific T1-weighted image, cerebellar anatomy, and cerebellar fMRI signal should first be isolated and then aligned to the cerebellar template included in this release.

A recommended workflow is:

1) extract the subject cerebellum from the structural T1-weighted image;

2) extract the cerebellar portion of the subject fMRI data;

3) register the extracted subject cerebellum to the released cerebellar template;

4) transfer the cerebellar fMRI signal into the same template space; and

5) apply the released cerebellar parcellation for voxel-wise or parcel-wise analysis.

This structure-specific strategy is recommended because the cerebellum has distinct anatomy and benefits from dedicated template alignment rather than direct whole-brain mapping alone.

9.3 Subcortex

The subcortical parcellation is intended for use in the released UNC 24M volumetric template space. For subject-level application, the subject structural T1-weighted image should first be registered to the UNC 24M T1w template, and the resulting transform should then be applied to bring the subject fMRI data into the same template space.

A recommended workflow is:

1) register the subject T1-weighted image to the released UNC 24M T1w template;

2) propagate the corresponding transform to the subject fMRI data, or otherwise align the functional data to the same template space;

3) use the released subcortical masks to extract subcortical signals; and

4) apply the released subcortical parcellation for regional signal extraction, connectivity analysis, or visualization.

This procedure brings subject-specific subcortical anatomy into correspondence with the atlas-defined subcortical nuclei and their internal functional subdivisions.

10. Label Definitions

10.1 Cerebral cortex main-resolution 22-network labels

Label	Label name
1	VSL-1
2	VSL-2
3	SM-d-l
4	SM-d-m
5	SM-v
6	SM-Audi
7	DAN-p-d
8	DAN-p-v
9	DAN-d-1
10	DAN-d-2
11	VAN-p
12	VAN-a
13	LMB-t
14	LMB-o
15	FPN-a
16	FPN-p
17	DMN-t
18	DMN-p-v
19	DMN-p-m
20	DMN-a-m
21	DMN-p-l
22	DMN-a-l

10.2 Cerebral cortex high-resolution 36-network labels

Label	Label name
1	VSL-1
2	VSL-2_1
3	VSL-2_2
4	SM-d-l
5	SM-d-m
6	SM-v_1
7	SM-v_2
8	SM-Audi_1
9	SM-Audi_2
10	DAN-p-d
11	DAN-p-v_1
12	DAN-p-v_2
13	DAN-d-1_1
14	DAN-d-1_2
15	DAN-d-2_1
16	DAN-d-2_2
17	VAN-p_1
18	VAN-p_2
19	VAN-a_1
20	VAN-a_2
21	VAN-a_3
22	LMB-t_1
23	LMB-t_2
24	LMB-o_1
25	LMB-o_2
26	FPN-a_1
27	FPN-a_2
28	FPN-p_1
29	FPN-p_2
30	DMN-t
31	DMN-p-v
32	DMN-p-m

33	DMN-a-m_1
34	DMN-a-m_2
35	DMN-p-l
36	DMN-a-l

10.3 Cerebellum main-resolution 29-network labels

Label	Label name
1	Cb_L_VIS1
2	Cb_VIS2
3	Cb_SMN1
4	Cb_R_SMN2
5	Cb_SMN3
6	Cb_SMN4
7	Cb_R_SMN5
8	Cb_R_SMN6
9	Cb_L_SMN7
10	Cb_L_DAN1
11	Cb_DAN2
12	Cb_L_VAN1
13	Cb_VAN2
14	Cb_VAN3
15	Cb_R_VAN4
16	Cb_L_VAN5
17	Cb_R_VAN6
18	Cb_L_VAN7
19	Cb_VAN8
20	Cb_R_LIM1
21	Cb_L_LIM2
22	Cb_R_LIM3
23	Cb_FPN1
24	Cb_L_FPN2
25	Cb_R_FPN3
26	Cb_R_DMN1
27	Cb_R_DMN2
28	Cb_L_DMN3
29	Cb_DMN4

10.4 Cerebellum high-resolution 54-network labels

Label	Label name
1	Cb_54net_VIS1
2	Cb_54net_VIS2
3	Cb_54net_VIS3
4	Cb_54net_VIS4
5	Cb_54net_VIS5
6	Cb_54net_SMN1
7	Cb_54net_SMN2
8	Cb_54net_SMN3
9	Cb_54net_SMN4
10	Cb_54net_SMN5
11	Cb_54net_SMN6
12	Cb_54net_SMN7
13	Cb_54net_SMN8
14	Cb_54net_SMN9
15	Cb_54net_SMN10
16	Cb_54net_SMN11
17	Cb_54net_DAN1
18	Cb_54net_DAN2
19	Cb_54net_DAN3
20	Cb_54net_DAN4
21	Cb_54net_DAN5
22	Cb_54net_DAN6
23	Cb_54net_DAN7
24	Cb_54net_VAN1
25	Cb_54net_VAN2
26	Cb_54net_VAN3
27	Cb_54net_VAN4
28	Cb_54net_VAN5
29	Cb_54net_VAN6
30	Cb_54net_VAN7
31	Cb_54net_VAN8

32	Cb_54net_VAN9
33	Cb_54net_VAN10
34	Cb_54net_VAN11
35	Cb_54net_VAN12
36	Cb_54net_VAN13
37	Cb_54net_VAN14
38	Cb_54net_LIM1
39	Cb_54net_LIM2
40	Cb_54net_LIM3
41	Cb_54net_FPN1
42	Cb_54net_FPN2
43	Cb_54net_FPN3
44	Cb_54net_FPN4
45	Cb_54net_FPN5
46	Cb_54net_FPN6
47	Cb_54net_FPN7
48	Cbl_54net_DMN1
49	Cbl_54net_DMN2
50	Cbl_54net_DMN3
51	Cbl_54net_DMN4
52	Cbl_54net_DMN5
53	Cbl_54net_DMN6
54	Cbl_54net_DMN7

10.5 Subcortical labels

The subcortical release contains 6 nuclei per hemisphere: thalamus, caudate, putamen, pallidum, hippocampus, and amygdala. The released labels within each nucleus are listed below.

Nucleus	Label	Label name
Thalamus	1	Sub_Thal_DMN
	2	Sub_Thal_VIS
	3	Sub_Thal_VAN1
	4	Sub_Thal_FPN
	5	Sub_Thal_VAN2
	6	Sub_Thal_DAN
Caudate	1	Sub_Caud_FPN1
	2	Sub_Caud_SMN
	3	Sub_Caud_FPN2
	4	Sub_Caud_VIS
	5	Sub_Caud_VAN1
	6	Sub_Caud_VAN2
Putamen	1	Sub_Put_DAN
	2	Sub_Put_DMN
	3	Sub_Put_VAN1
	4	Sub_Put_VAN2
	5	Sub_Put_FPN
	6	Sub_Put_LIM
Pallidum	1	Sub_Pall_DMN
	2	Sub_Pall_DAN
	3	Sub_Pall_VAN
Hippocampus	1	Sub_Hipp_DAN
	2	Sub_Hipp_LIM
	3	Sub_Hipp_FPN
	4	Sub_Hipp_VAN
	5	Sub_Hipp_VIS
	6	Sub_Hipp_DMN
	7	Sub_Hipp_SMN
Amygdala	1	Sub_Amyg_VAN
	2	Sub_Amyg_VIS
	3	Sub_Amyg_FPN

11. Acknowledgments

We sincerely thank the infants, children, and families who participated in the underlying imaging studies, as well as the investigators, coordinators, MRI technologists, and data-processing teams involved in the UNC/UMN Baby Connectome Project and MAP cohort. This release also builds on supporting parcellation, registration, and visualization resources developed by collaborators and the broader neuroimaging community.

If you use this parcellation, please cite the manuscript associated with this release:

Hu, D., Cheng, J., Han, K., Wu, Z., Yin, W., Sun, Y., Liu, J., Hung, S.-C., Wang, L., Cohen, J. R., Lin, W., and Li, G. (2026). **Division-specific organization of a shared functional scaffold in the early-life human brain**. *bioRxiv*. https://doi.org/10.64898/2026.09.14.751555

Citation details will be updated upon publication.

Please also cite the relevant template resources when using the included developmental templates:

- Chen, L., Wu, Z., Hu, D., Wang, Y., Zhao, F., Zhong, T., Lin, W., Wang, L., and Li, G. (2022). A 4D infant brain volumetric atlas based on the UNC/UMN Baby Connectome Project (BCP) cohort. NeuroImage, 253, 119097.
- Wang, Y., Chen, L., Wu, Z., Li, T., Sun, Y., Cheng, J., Zhu, H., Lin, W., Wang, L., Huang, W. and Li, G., 2023. Longitudinal development of the cerebellum in human infants during the first 800 days. Cell reports, 42(4).