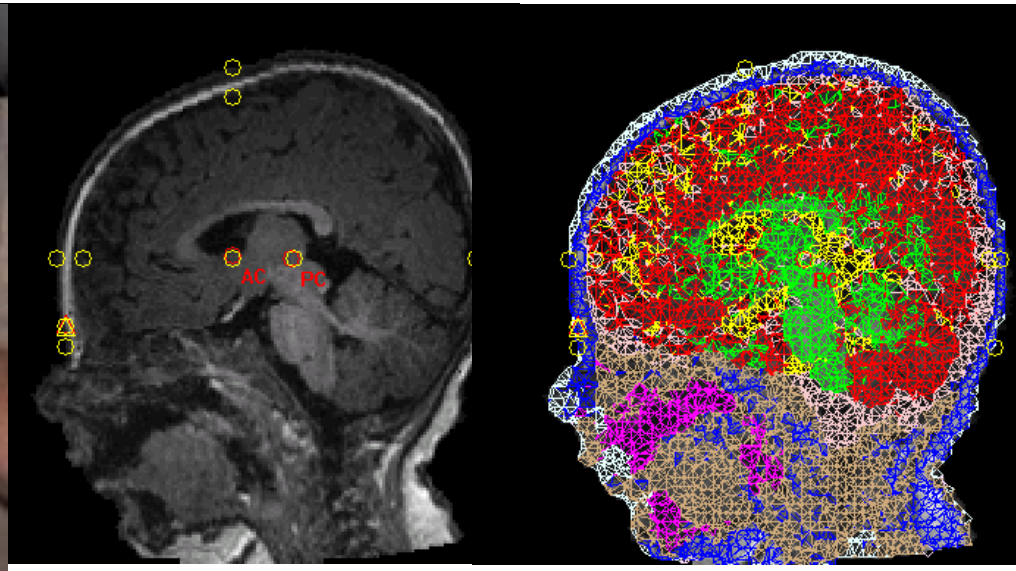
UNIVERSITY OF SOUTH CAROLINA

What's inside a baby's head?
Structural and functional brain development in infants
http://jerlab.psych.sc.edu/pdf/icisplenary2010.pdf

John E. Richards
University of South Carolina



Developmental psychologists studying infant cognitive development often use brain development as an explanation for cognitive development. Until recently it has been impossible to "look inside the baby's head" to determine brain developmental status. Recently normally developing infants and children have had brain imaging with MRI. This includes early scattered reports of functional MRI (fMRI), the NIH MRI study of normal brain development, and my own use of 3T structural MRIs. These studies have resulted in revealing findings about the nature of the infant brain and its relation to cognitive development.

The presentation will have two parts. First, I have begun to develop neurodevelopmental databases of structural MRIs for infants and children. This is 1) to create an appropriate age-relevant template for the segmenting of infant head materials for the functional brain imaging and 2) to analyze the structural development of specific individuals who participate in the psychophysiological experiments. I will present preliminary work developing age-appropriate average brain stereotaxic atlases for infants.

Second, the presentation will describe an approach to studying the brain-cognitive relation in infant development with cortical source models of EEG/ERP. High-density EEG is recorded while infants participate in cognitive psychophysiological tasks (e.g., recognition memory; spatial cueing; hidden objects). These infants also have a structural (anatomical) MRI. A realistic model of the spatial topography of the materials in the baby's head is constructed. Source analysis models of the event-related potentials taken in the psychophysiological tasks give the location of the brain activity during the task; presumably these are tied to the psychological processes involved in the tasks. This “functional neuroimaging” may be used in conjunction with structural analysis of the MRI to assess structural and functional aspects of infant cognitive and brain development.

Neural basis of infant attention

Richards, J.E., Reynolds, G.D., & Courage, M.L. (2010). The neural bases of infant attention. ***Current Directions in Psychological Science, 19,*** **41-46.**

Richards, J.E. (2010). Attention in the brain in early infancy. In S. Johnson (Ed.), ***Neoconstructivist views on infant development*** **(pp. 1-37). New York: Oxford University Publishing.**

National Institutes of Health

National Institute of Child Health and Human Development

Lisa Freund

Neurodevelopmental MRI Database

Example Uses

Functional brain development and attention

Neurodevelopmental MRI Database

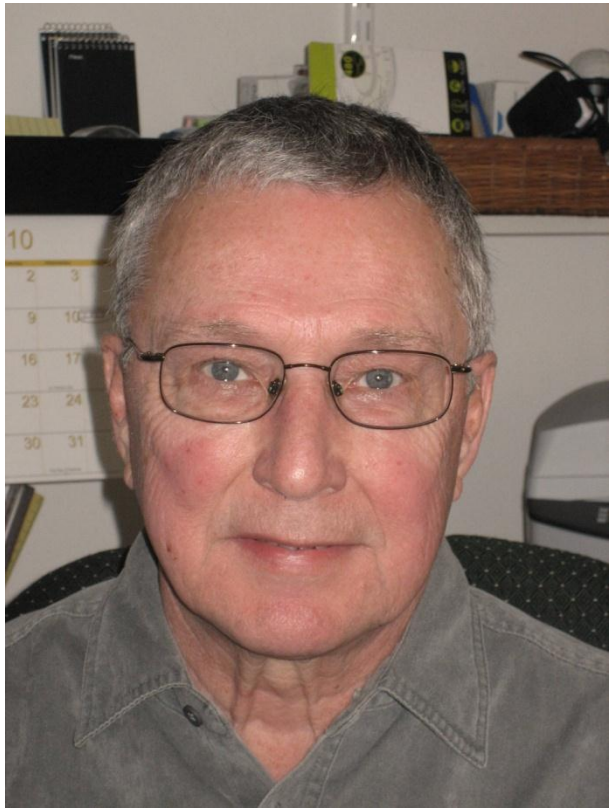
What is structure of infant brain?

How to segment brain for cortical source analysis?

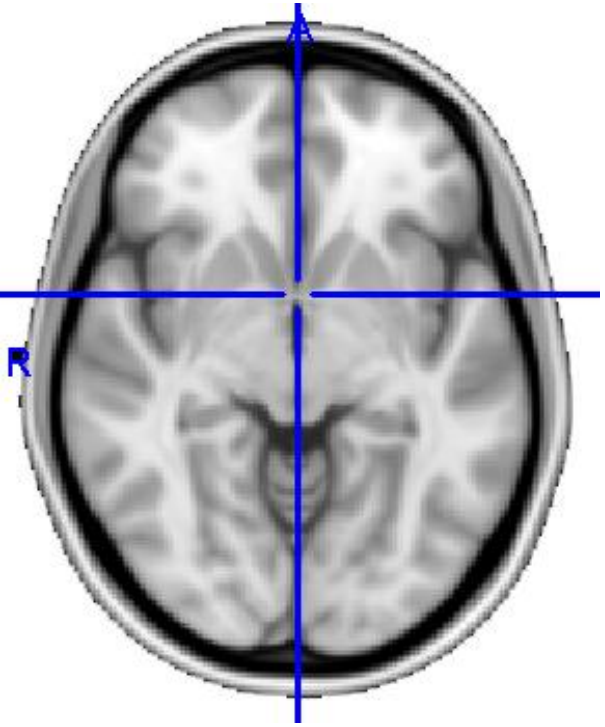
Sanchez, C.E., Richards, J.E., & Almli, C.R. (revision submitted). Age-specific MRI brain templates for health brain development from 4 to 24 years.

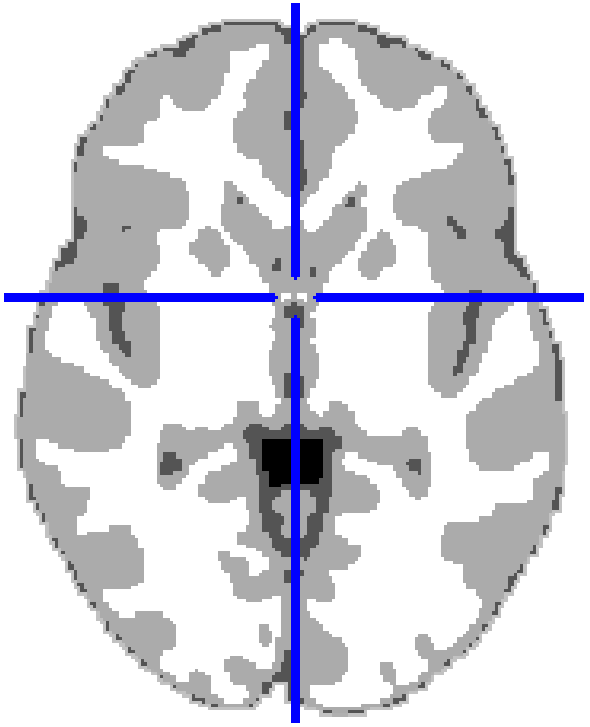
Carmen Sanchez

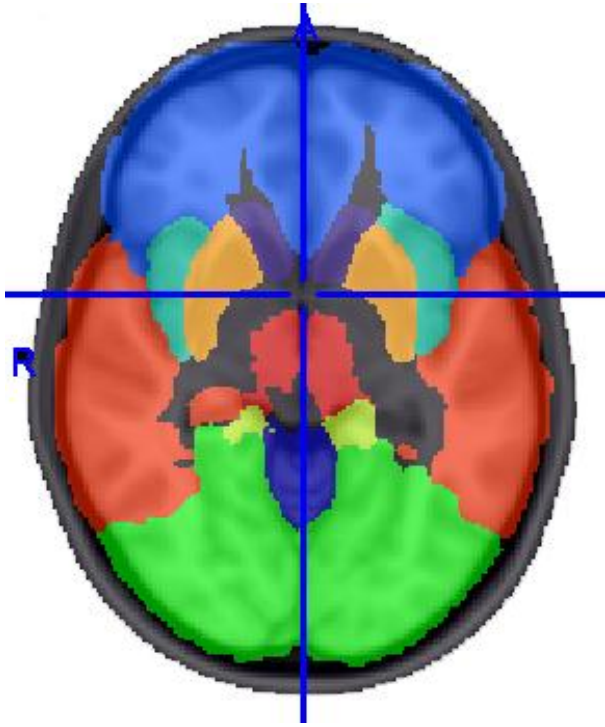
Robert Almli



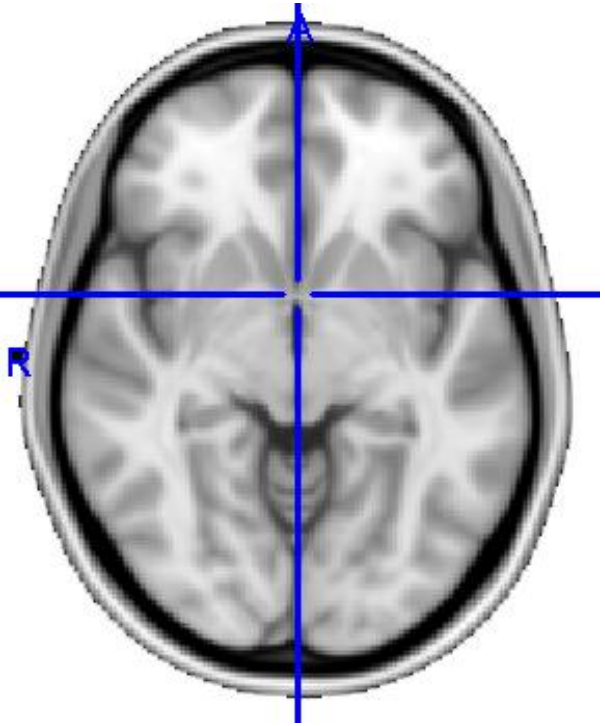
MNI Template, Priors, Stereotaxic Atlas

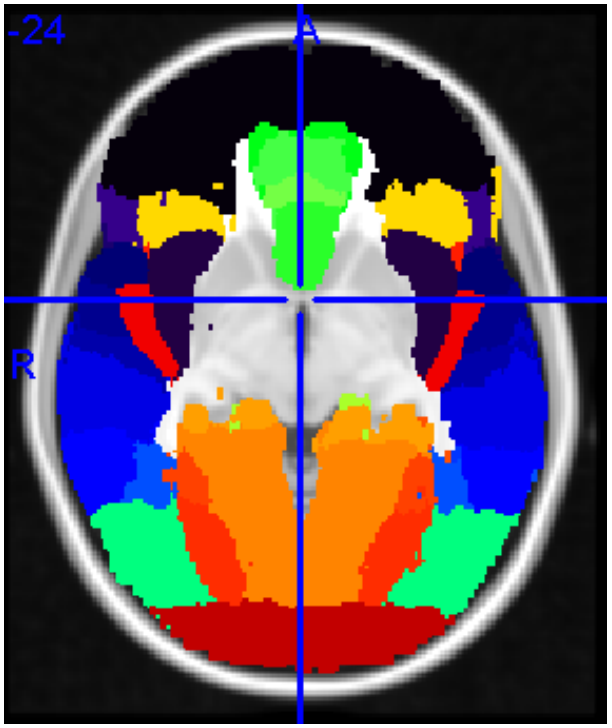






“Harvard-Oxford” Cortical





Seth Pollack

Neurodevelopmental Database (1500+ MRIs)

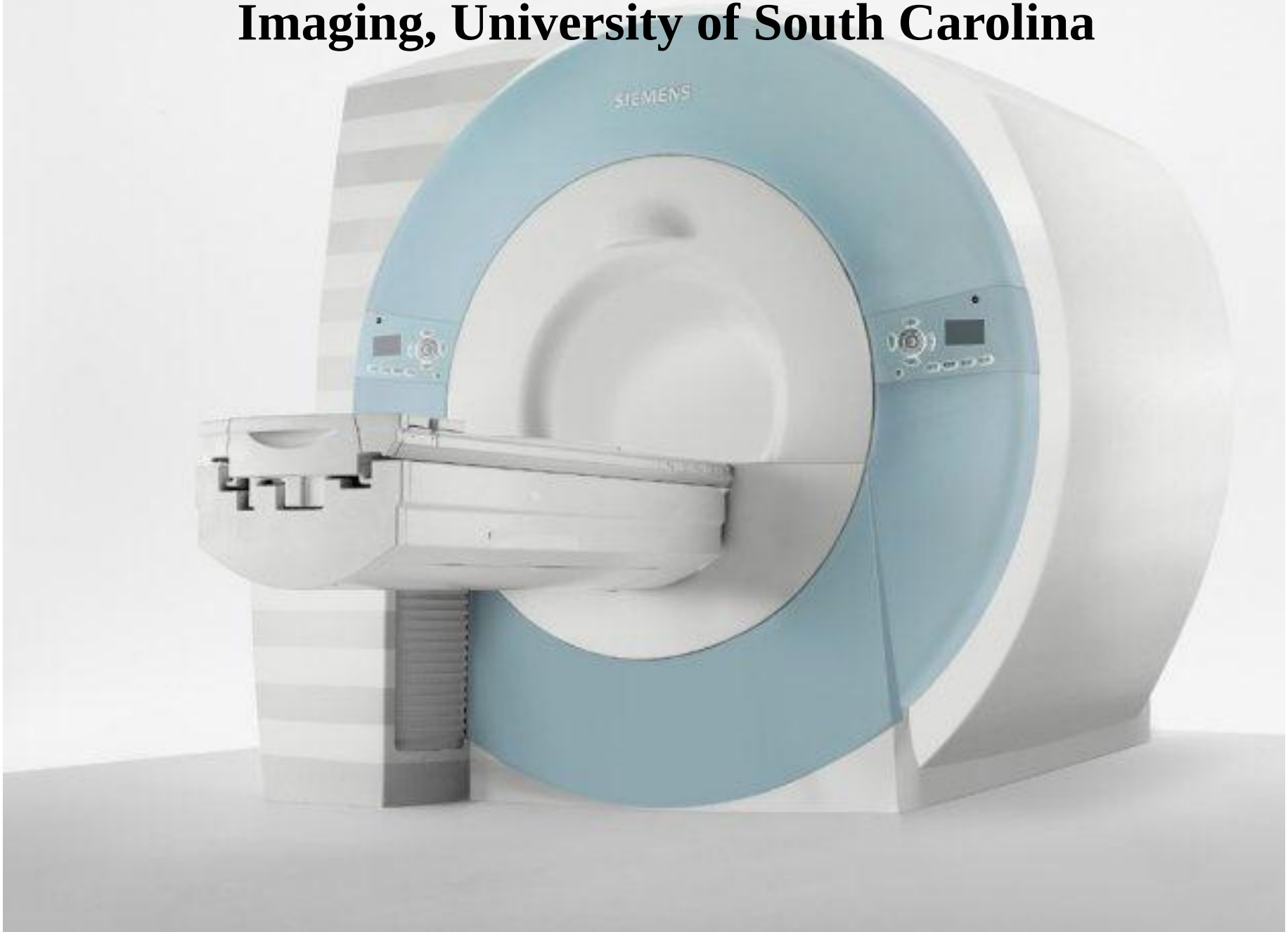
NIH MRI Study of Normal Brain Development
Objective 1: 4.5 through 21 yrs
T1W, T2W, PDE, DTI, other, 1.5T
Nonsedated normal children

JER
Normal adolescents; adults
3.0T, T1W, T2W, PDE

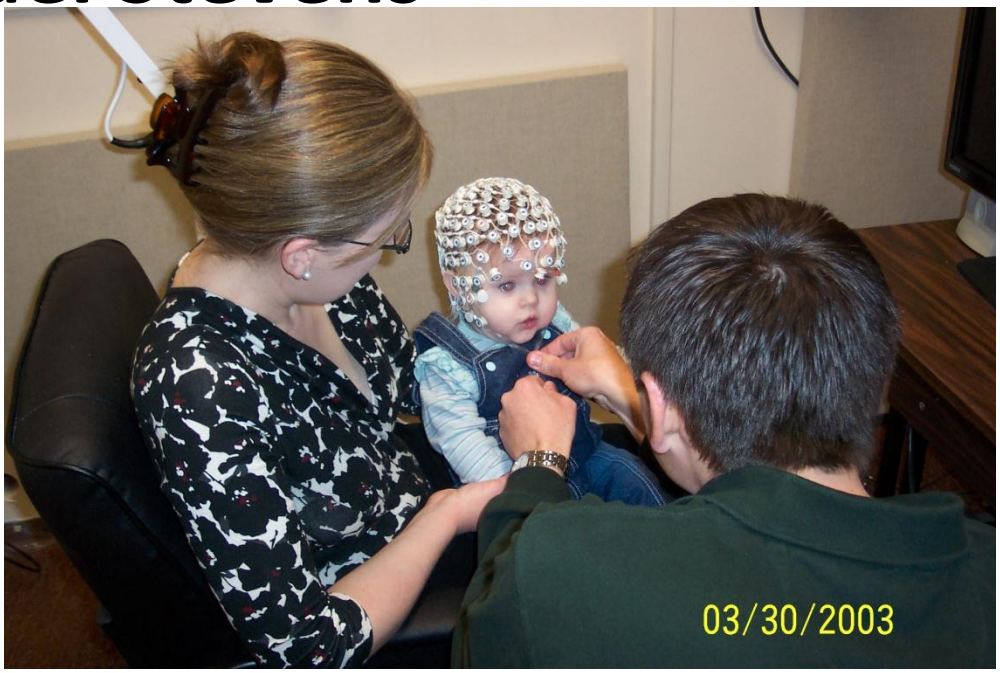
NIH: Objective 2: 1 mo through 4.0 yrs
1.5T; 2D; T1W, PDE, DTI, other

JER
3, 4.5, 6, 7.5, 9, 10.5, 12 months
3.0T, T1W, T2W, PDE

3.0T Siemens Trio System at McCausland Center for Brain Imaging, University of South Carolina



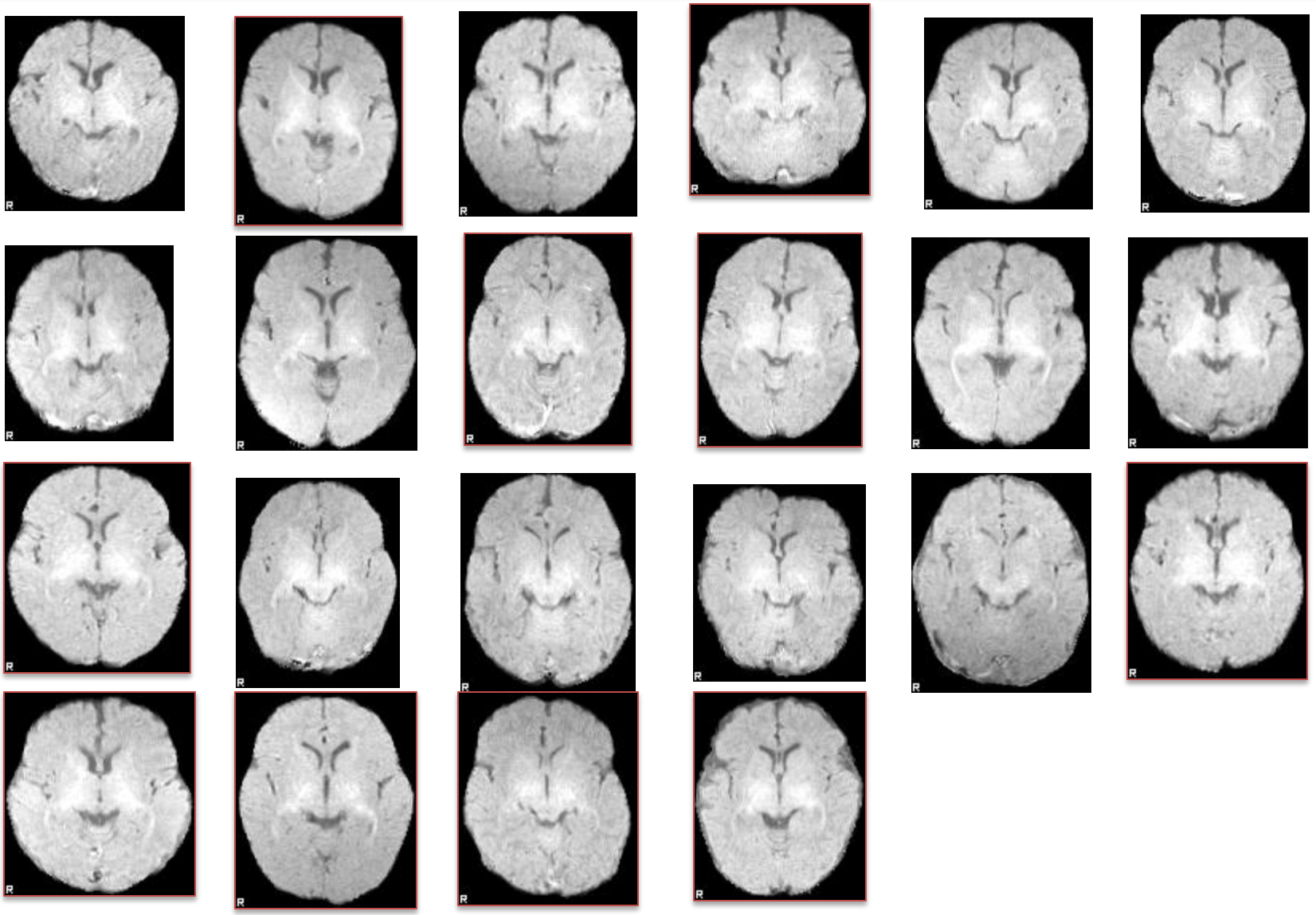
Michael Stevens



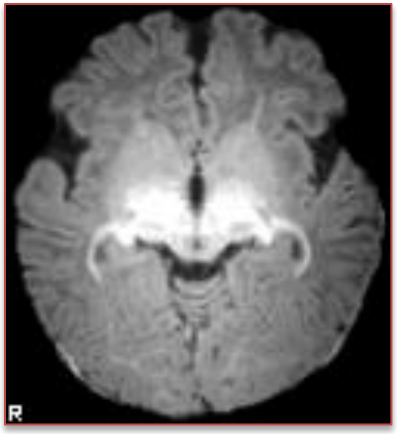
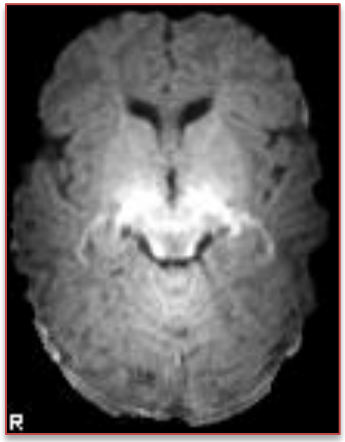
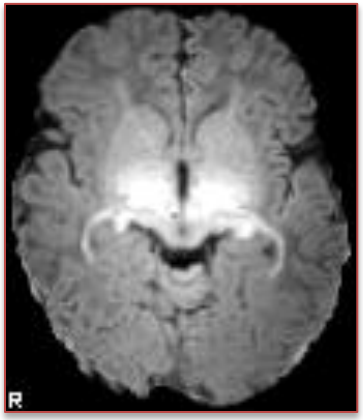
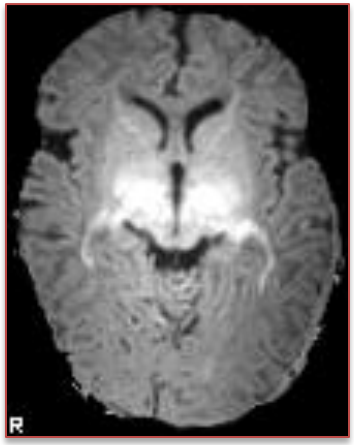

SIEMENS

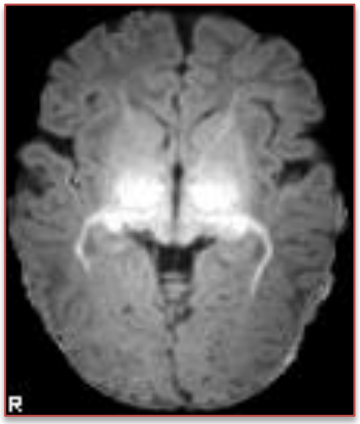
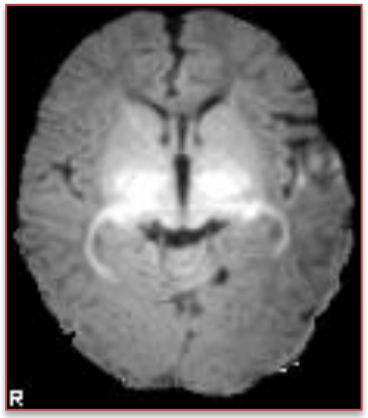

09/21/2006

3-0 Months Axial 1-5T (NIH Rigid to avg)

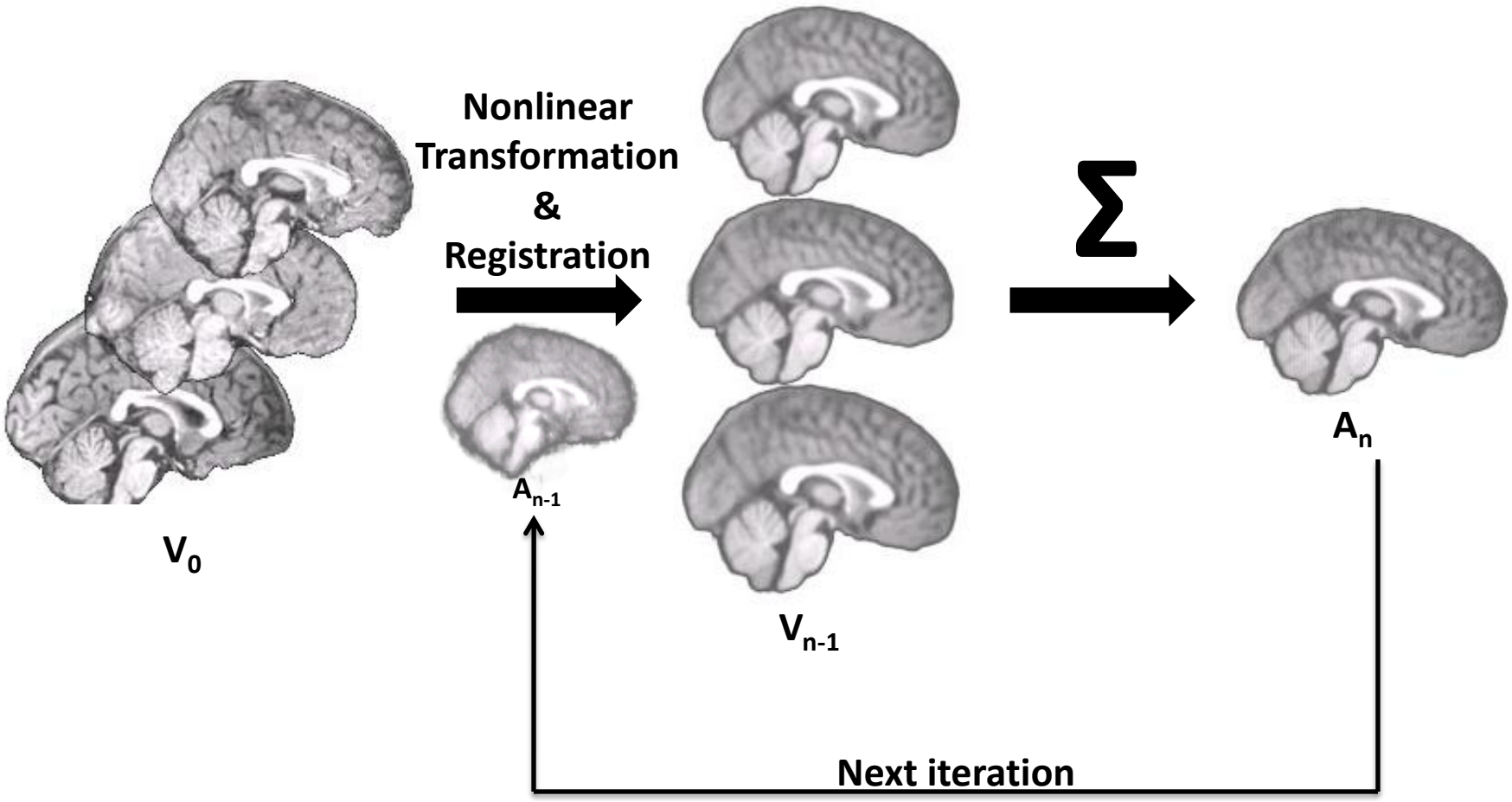


3-0 Months 3T Axial (JER rigid to avg)

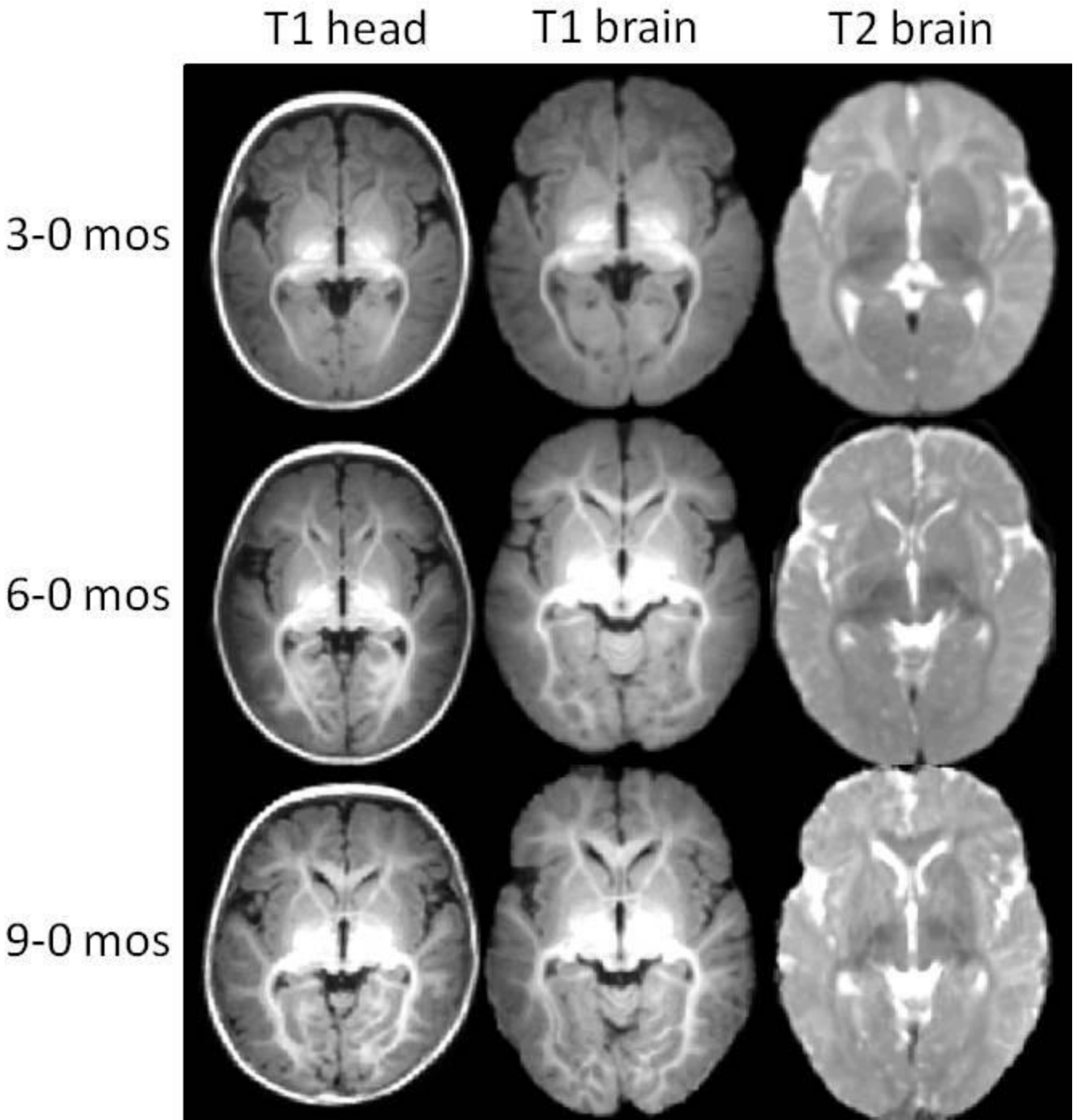



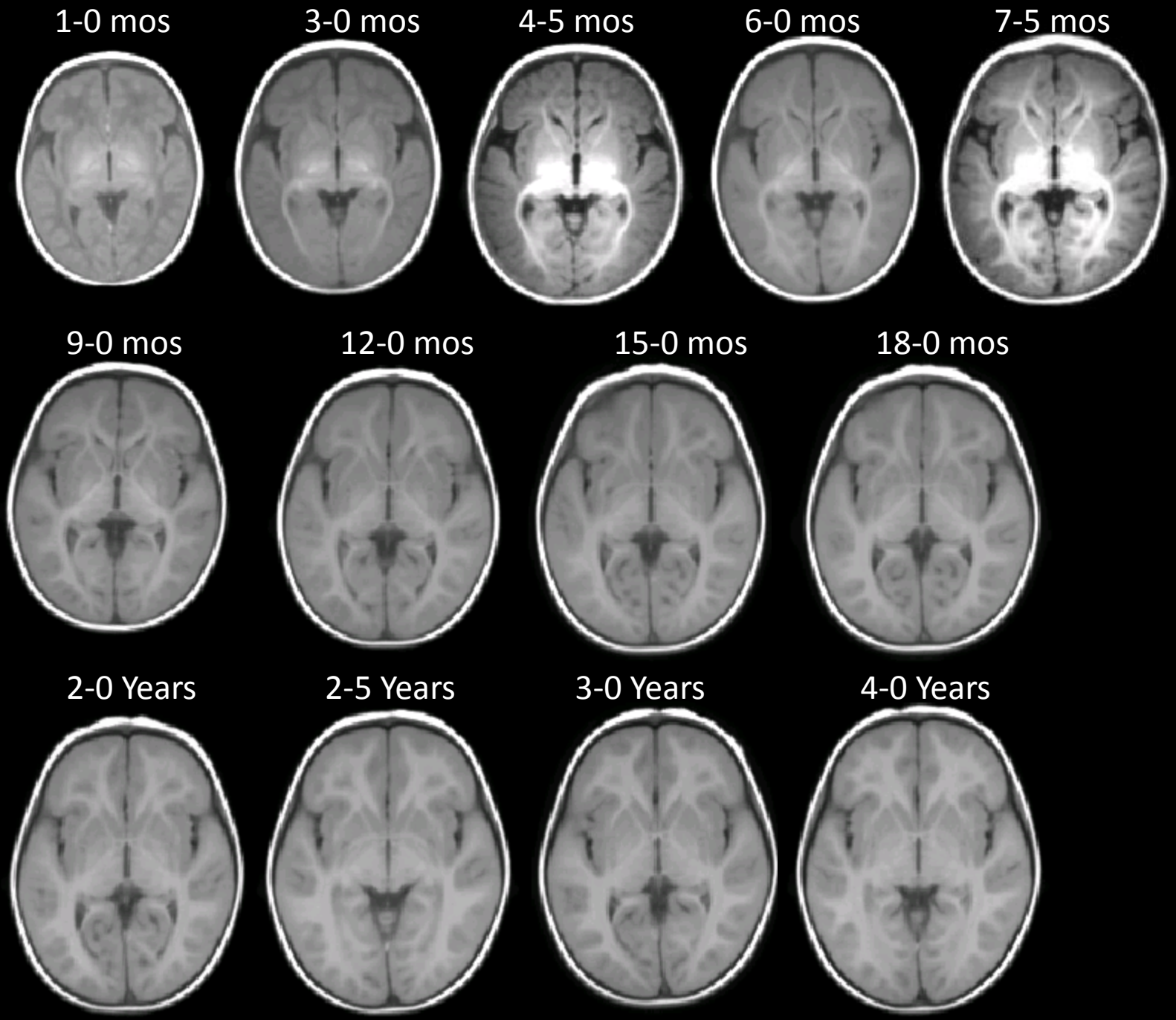
Template average iterative process

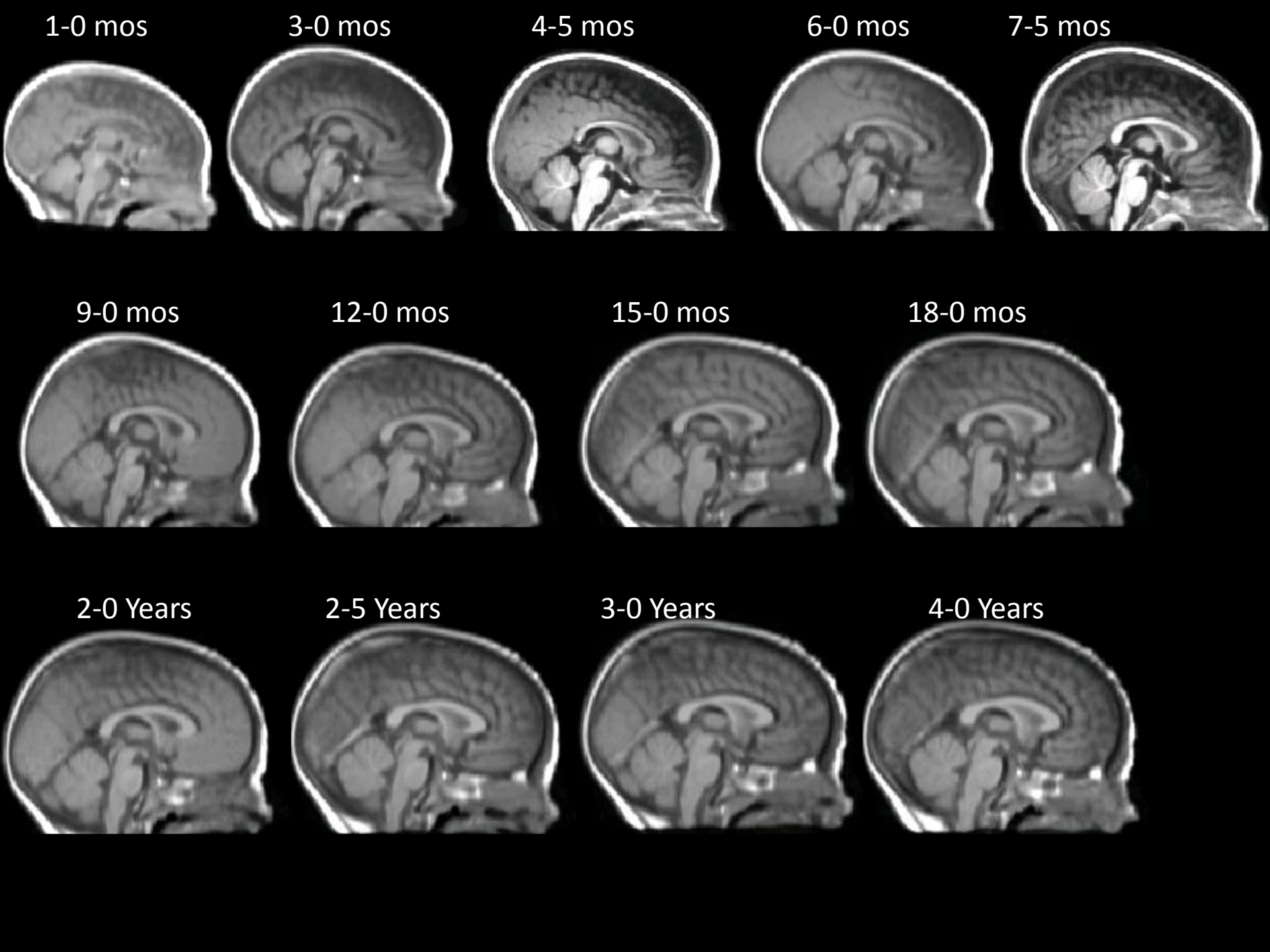


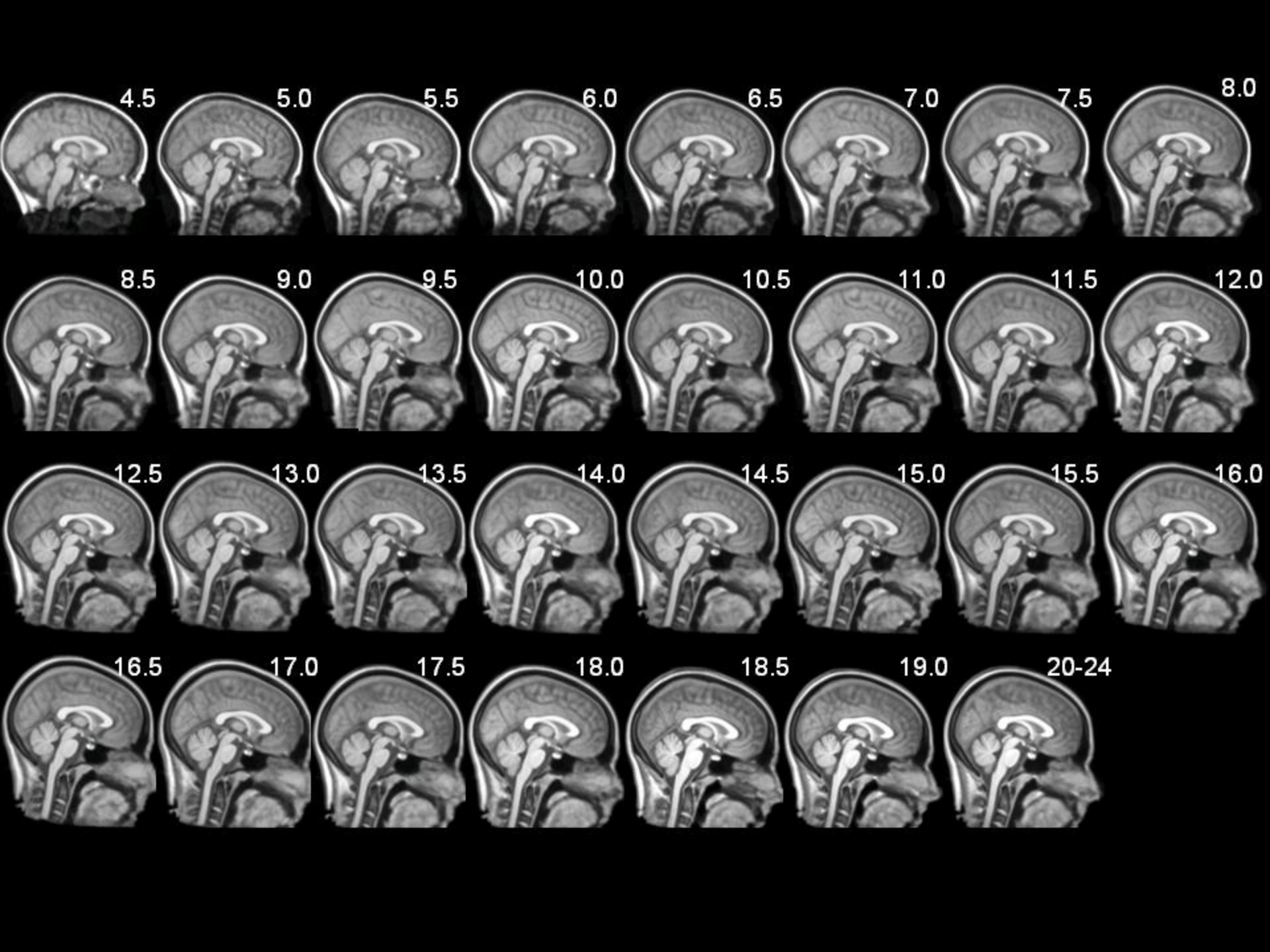
Last iteration: Subject to Average Template Transformation Indices

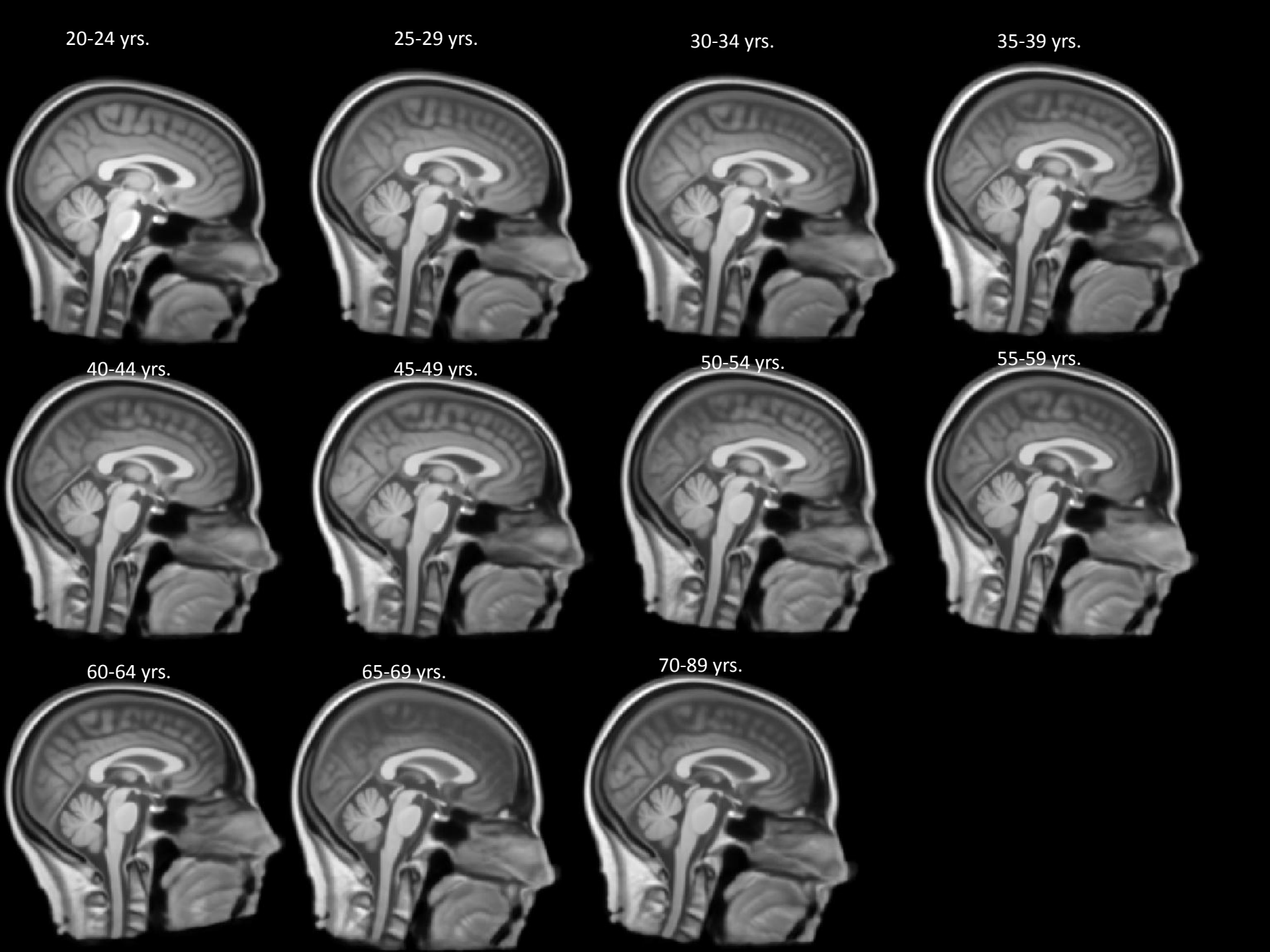
SGE: Sun Grid Engine (~150 processor cores 1700 MRIs)

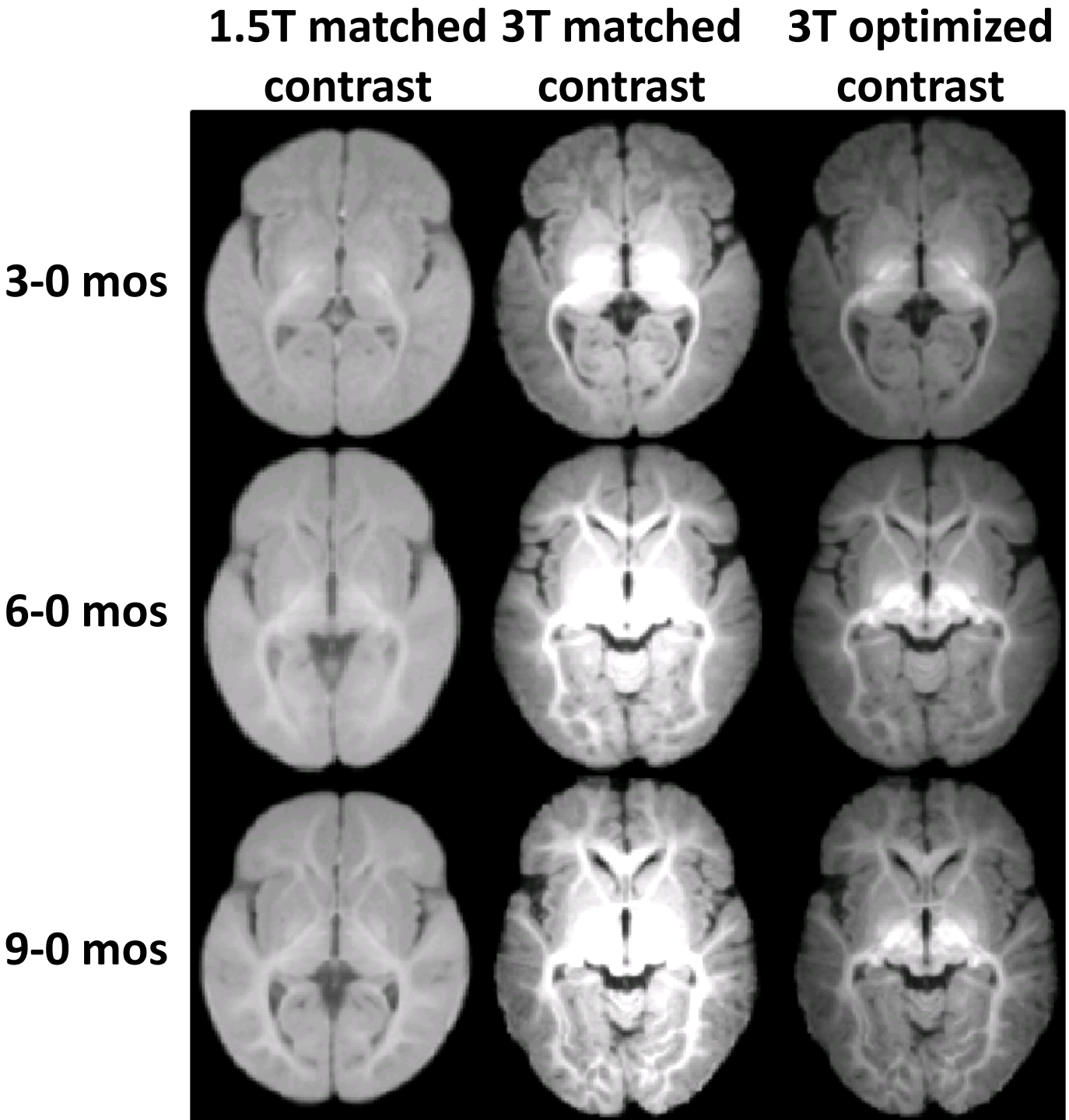

T1 head
T1 brain
T2 brain
3-0 mos
6-0 mos
9-0 mos


1-0 mos
3-0 mos
4-5 mos
6-0 mos
7-5 mos
9-0 mos
12-0 mos
15-0 mos
18-0 mos
2-0 Years
2-5 Years
3-0 Years
4-0 Years

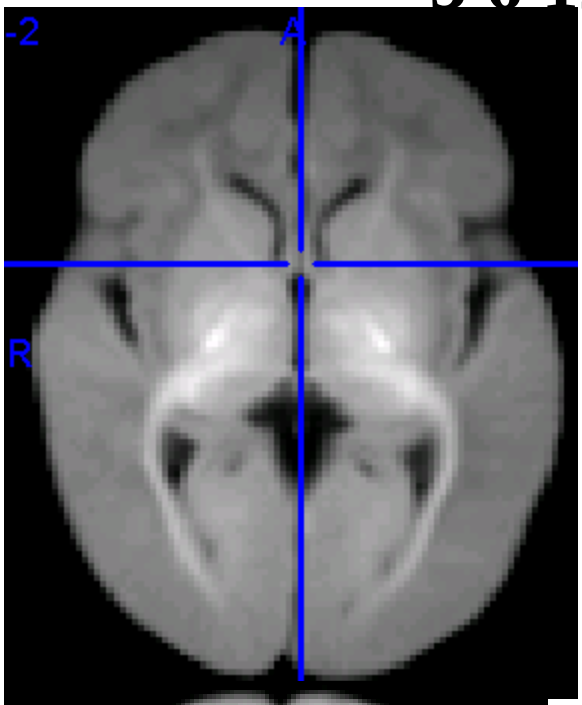

1-0 mos
3-0 mos
4-5 mos
6-0 mos
7-5 mos
9-0 mos
12-0 mos
15-0 mos
18-0 mos
2-0 Years
2-5 Years
3-0 Years
4-0 Years

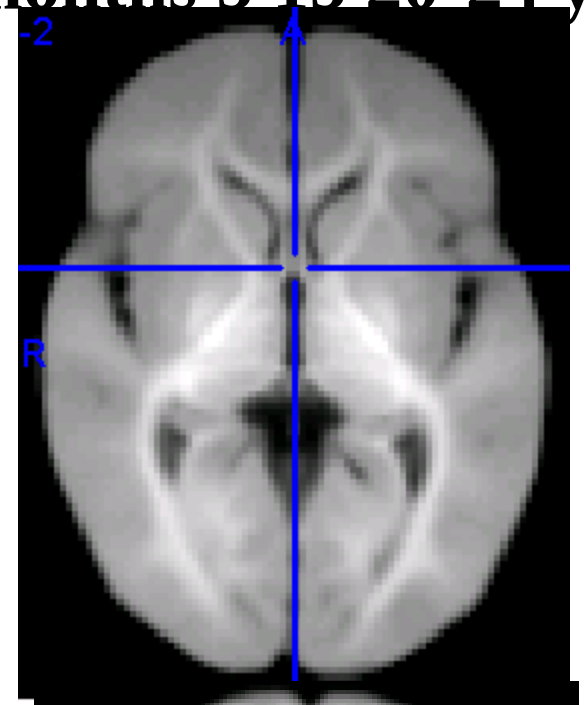

4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
15.5
16.0
16.5
17.0
17.5
18.0
18.5
19.0
20-24

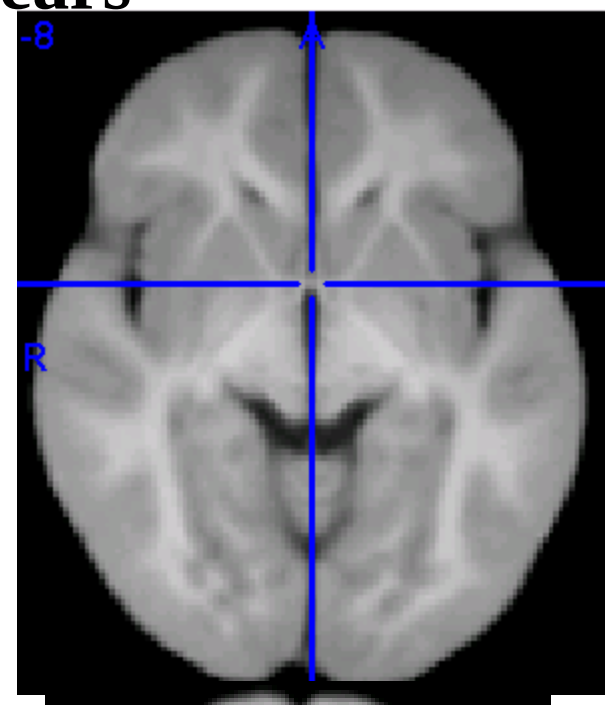

20-24 yrs.
25-29 yrs.
30-34 yrs.
35-39 yrs.
40-44 yrs.
45-49 yrs.
50-54 yrs.
55-59 yrs.
60-64 yrs.
65-69 yrs.
70-89 yrs.


1.5T matched contrast
3T matched contrast
3T optimized contrast
3-0 mos
6-0 mos
9-0 mos

3 6 12 months 5 15 20-24 years



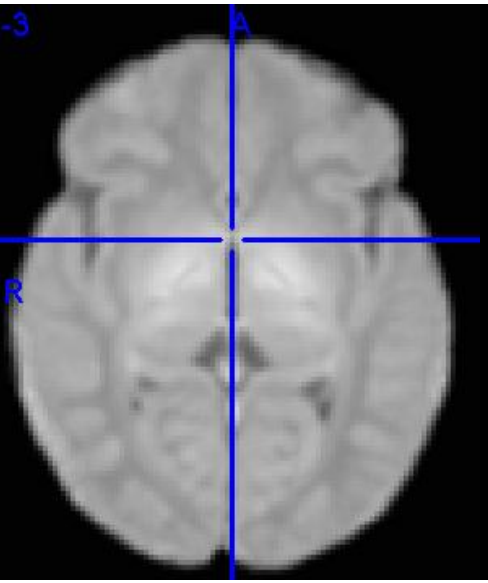




Segmenting:
White matter, gray matter, CSF, other matter
(Partial volume estimates)

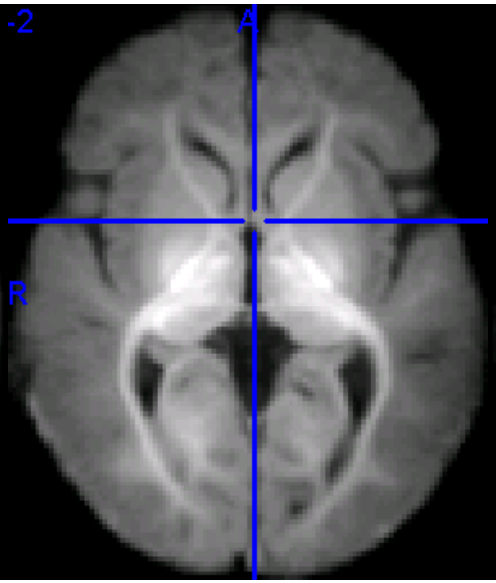
T1W in First Year

1-0Mo (1.5T 2D)



3-0Mo

4-5Mo

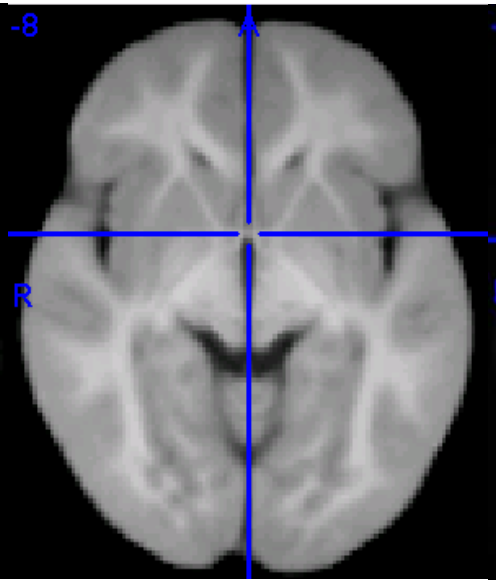


6-0Mo

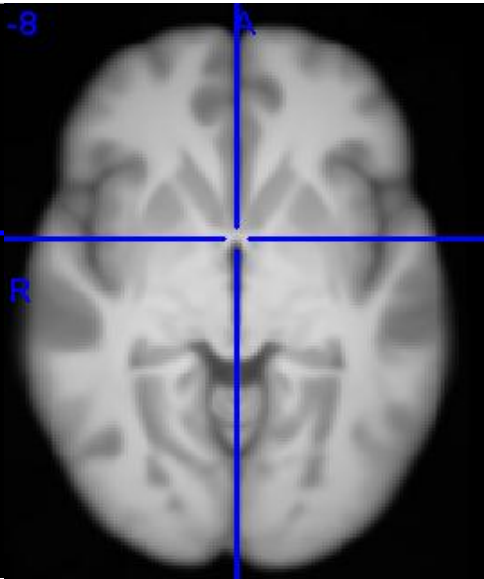
7-5Mo

9-0Mo

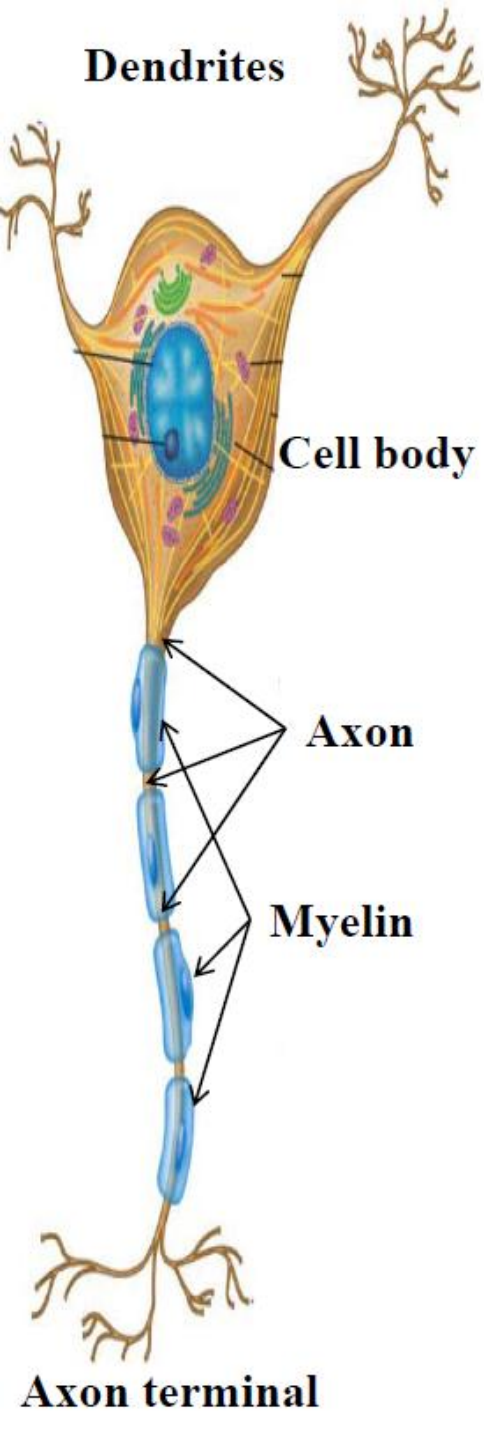
12-0Mo (1.5T 2D)



20-24Yrs



T1W, GM WM PVEs



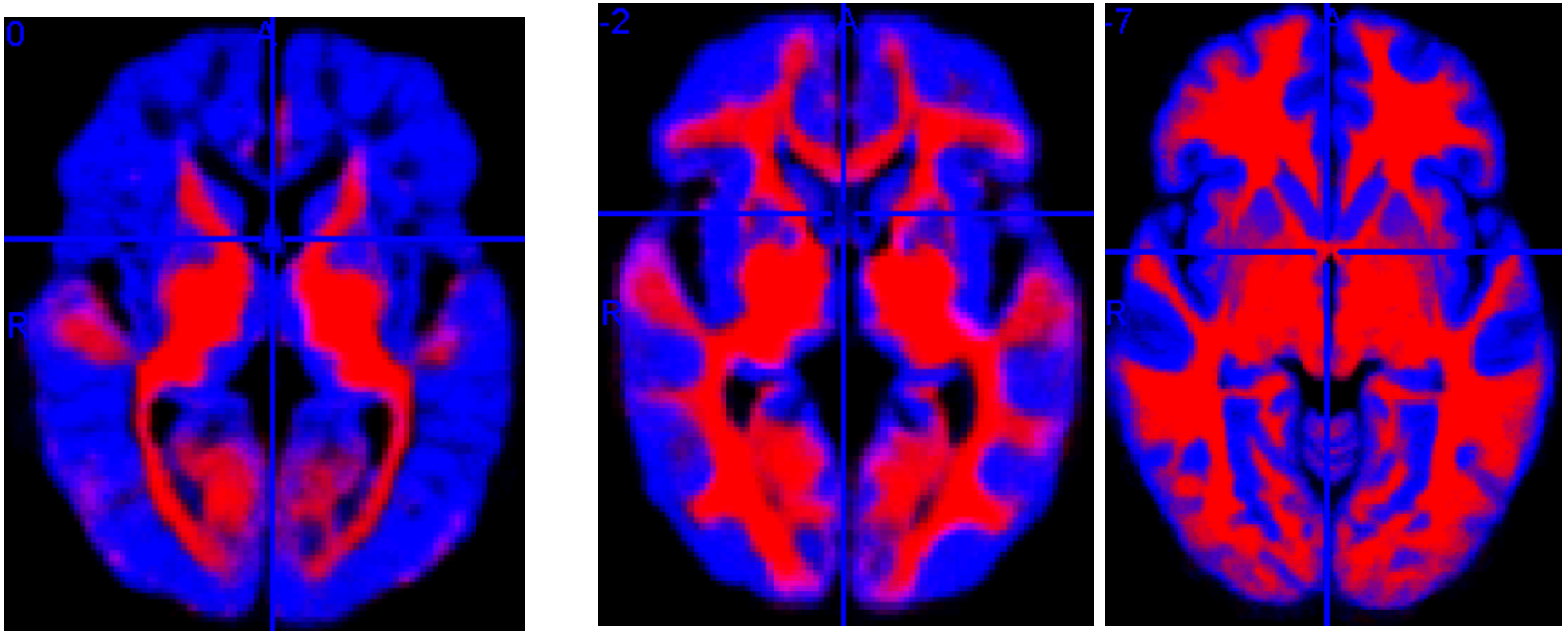
3-0 mos



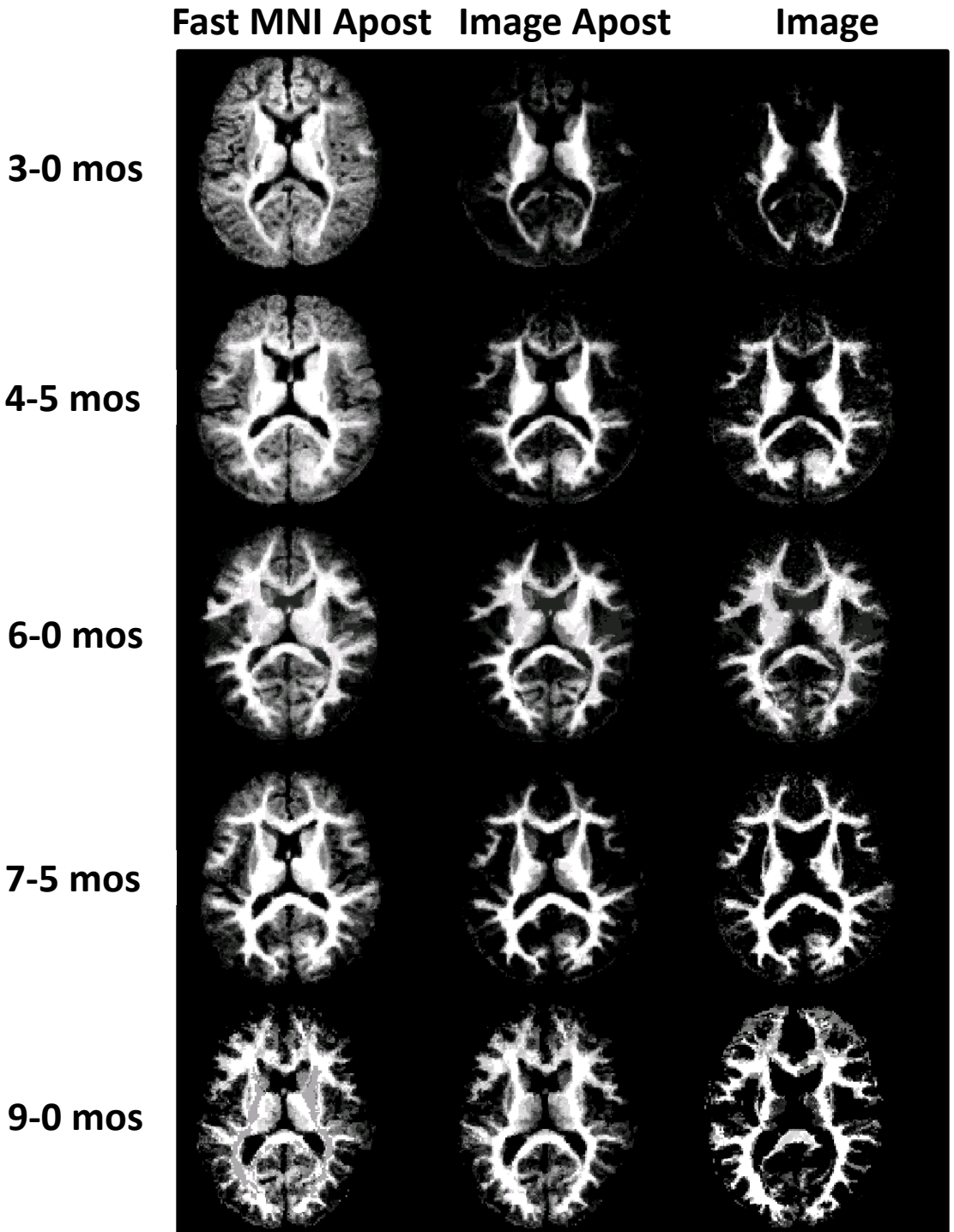
6-0 mos

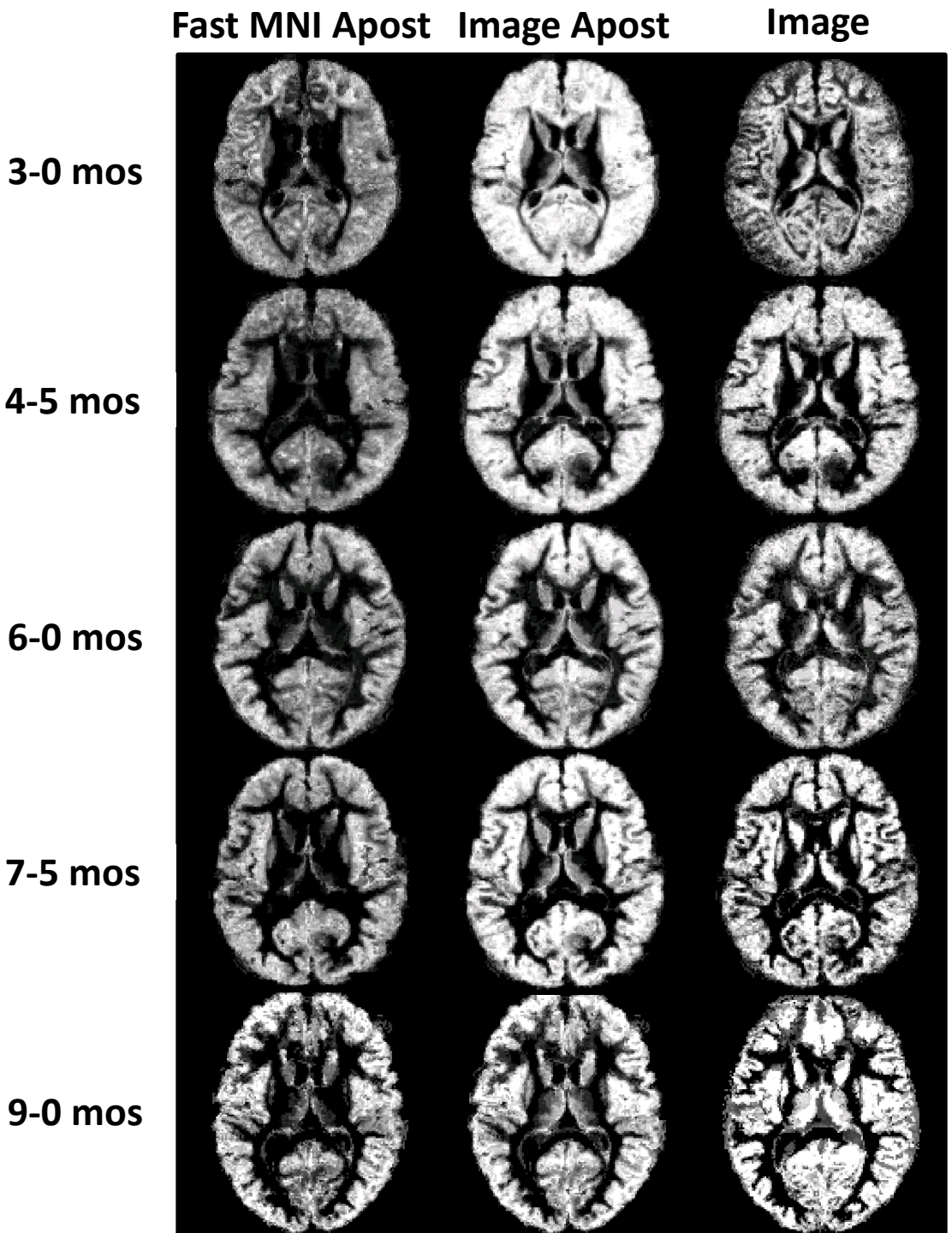


GM and WM PVE (3, 6 mo, adult)

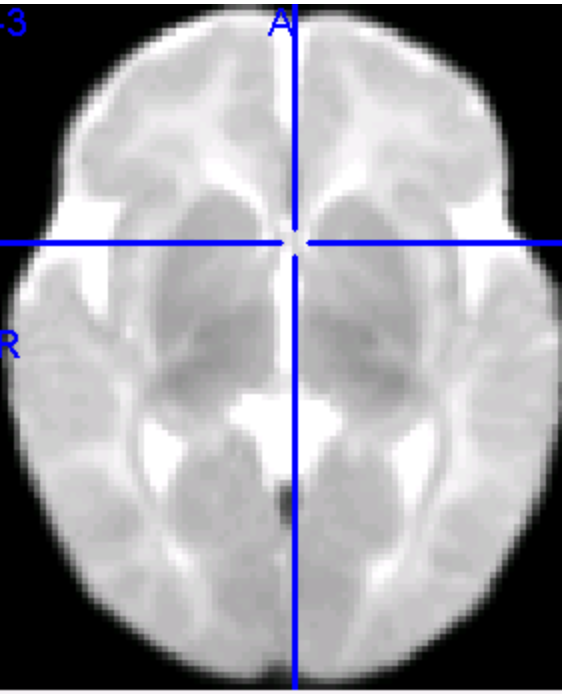


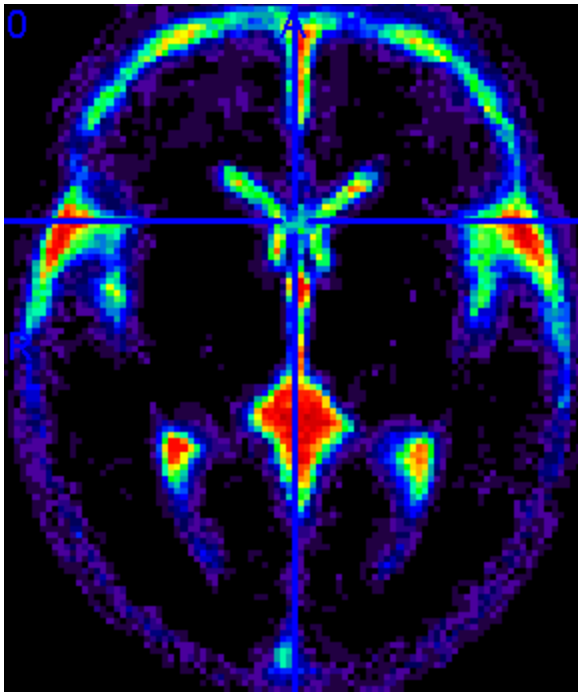
(Note the WM in PFC / InferiorPFC / Temporal)

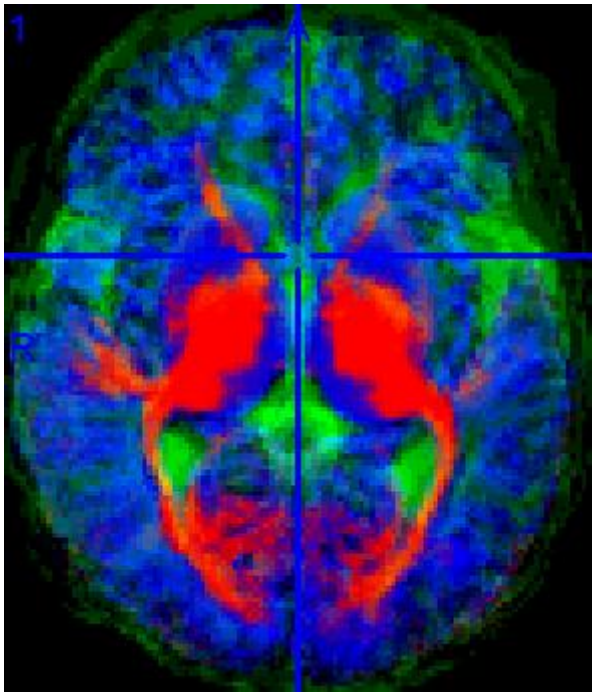

Fast MNI Apost
Image Apost
Image
3-0 mos
4-5 mos
6-0 mos
7-5 mos
9-0 mos


Fast MNI Apost
Image Apost
Image
3-0 mos
4-5 mos
6-0 mos
7-5 mos
9-0 mos

3-0 Months T2W CSF GM/WM/CSF

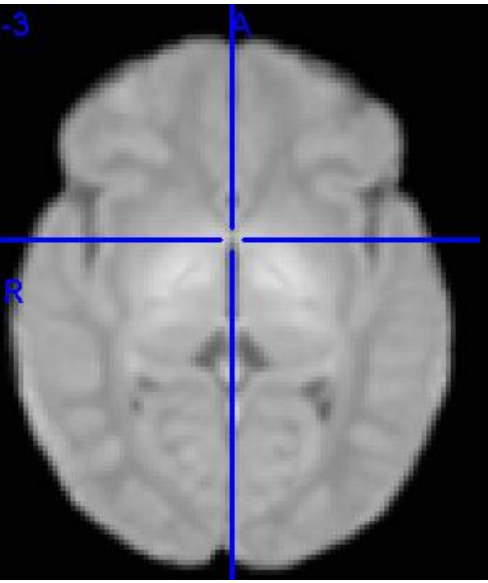






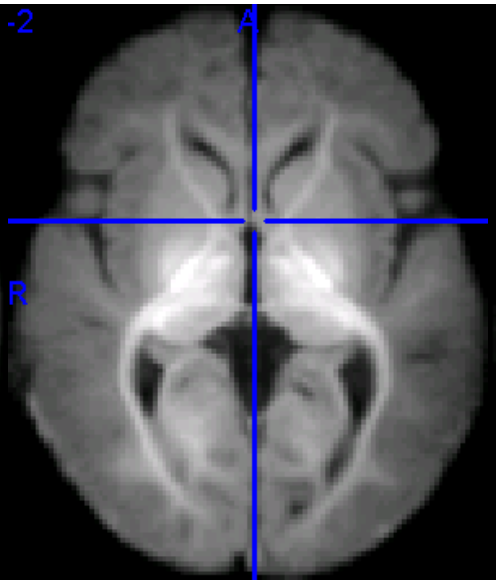
T1W in First Year

1-0Mo (1.5T 2D)



3-0Mo

4-5Mo

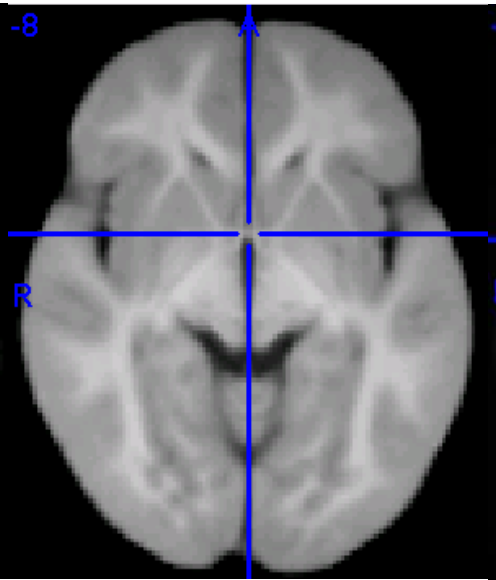


6-0Mo

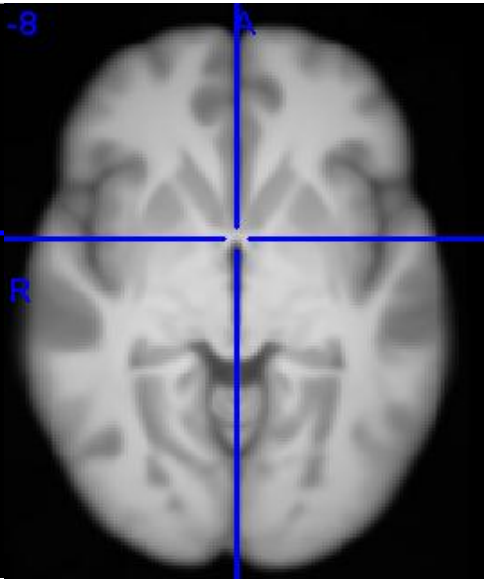
7-5Mo

9-0Mo

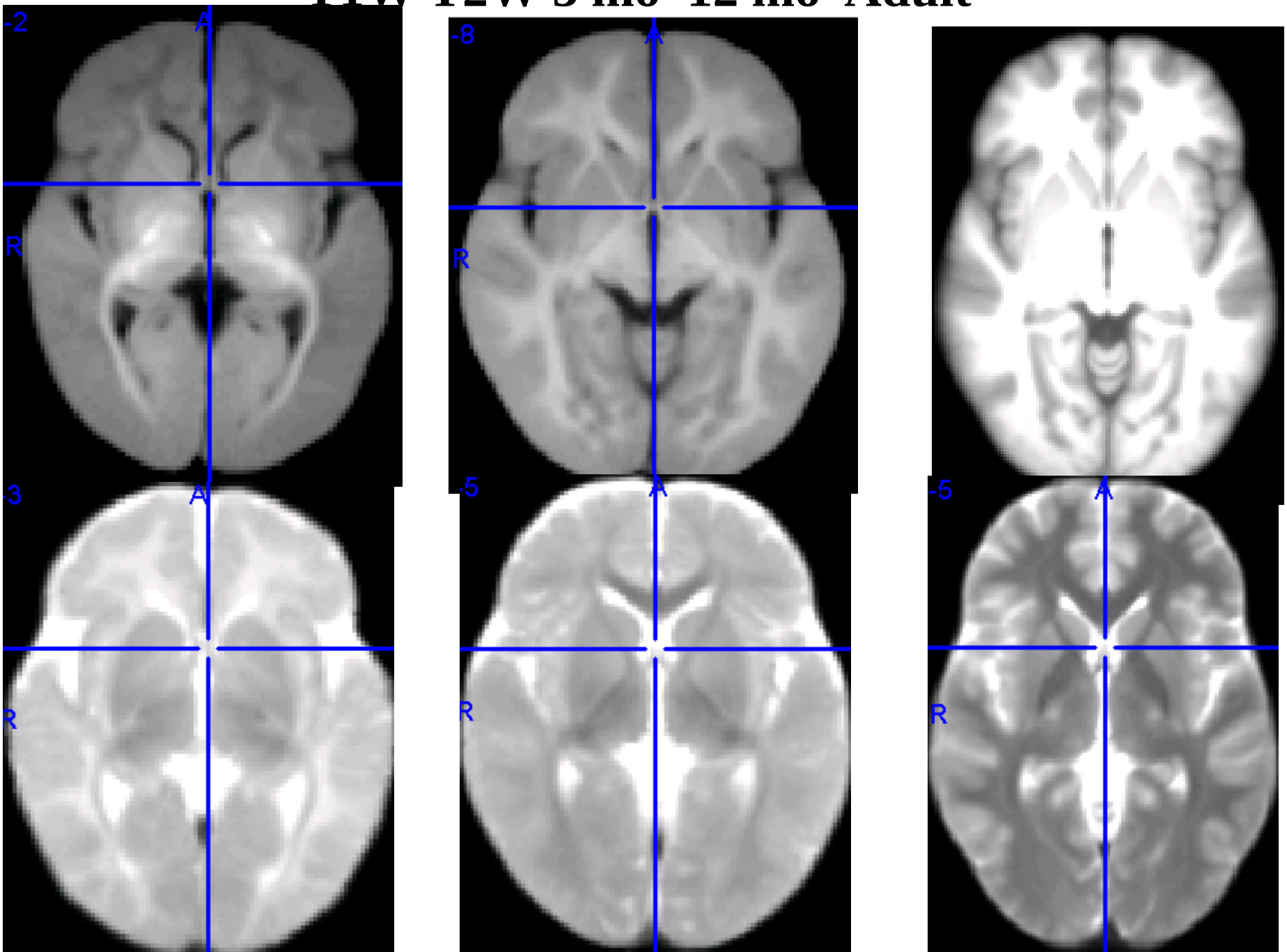
12-0Mo (1.5T 2D)



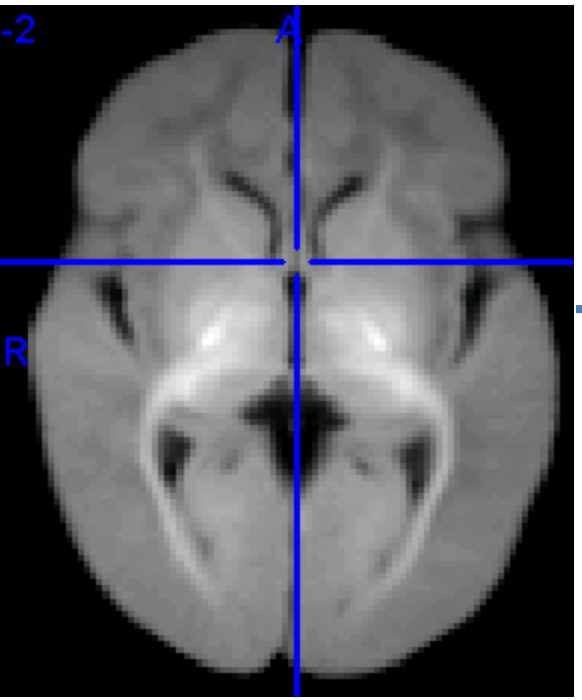
20-24Yrs

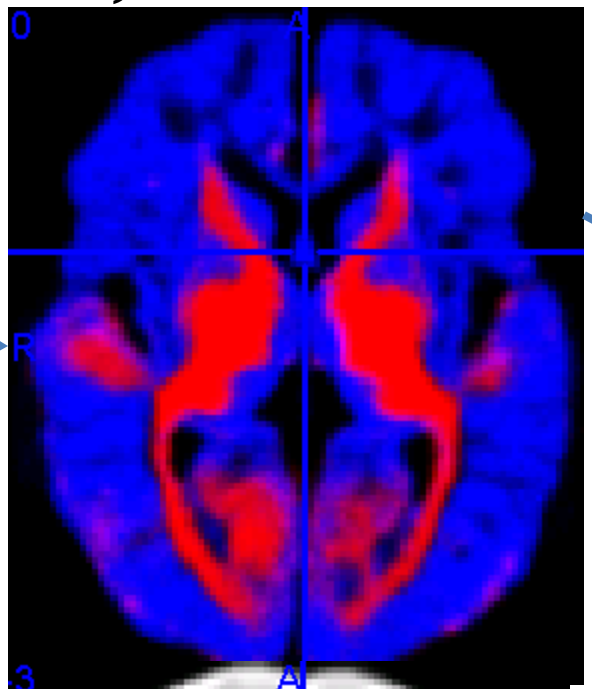


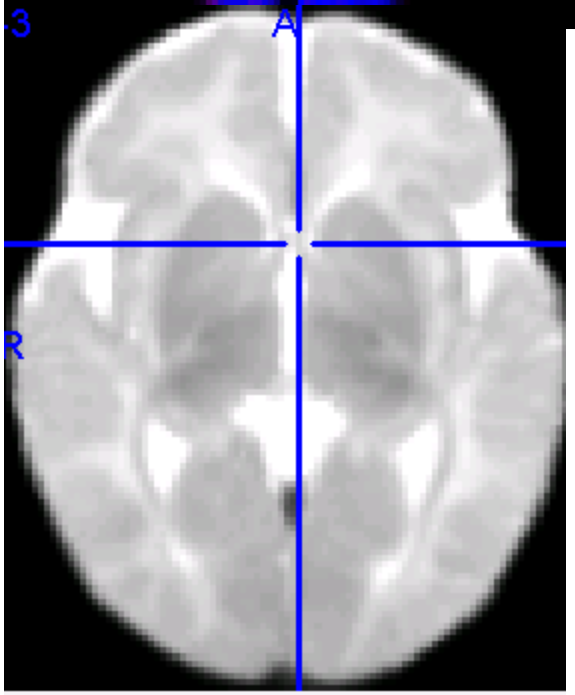
T1W T2W 3 mo 12 mo Adult

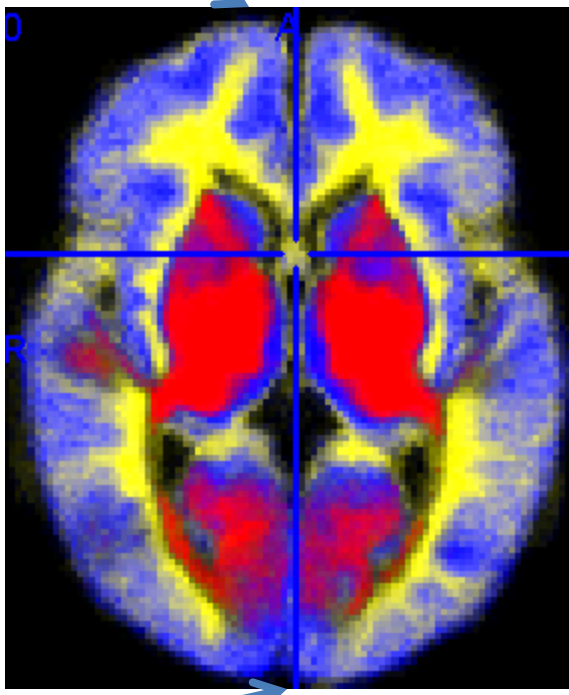


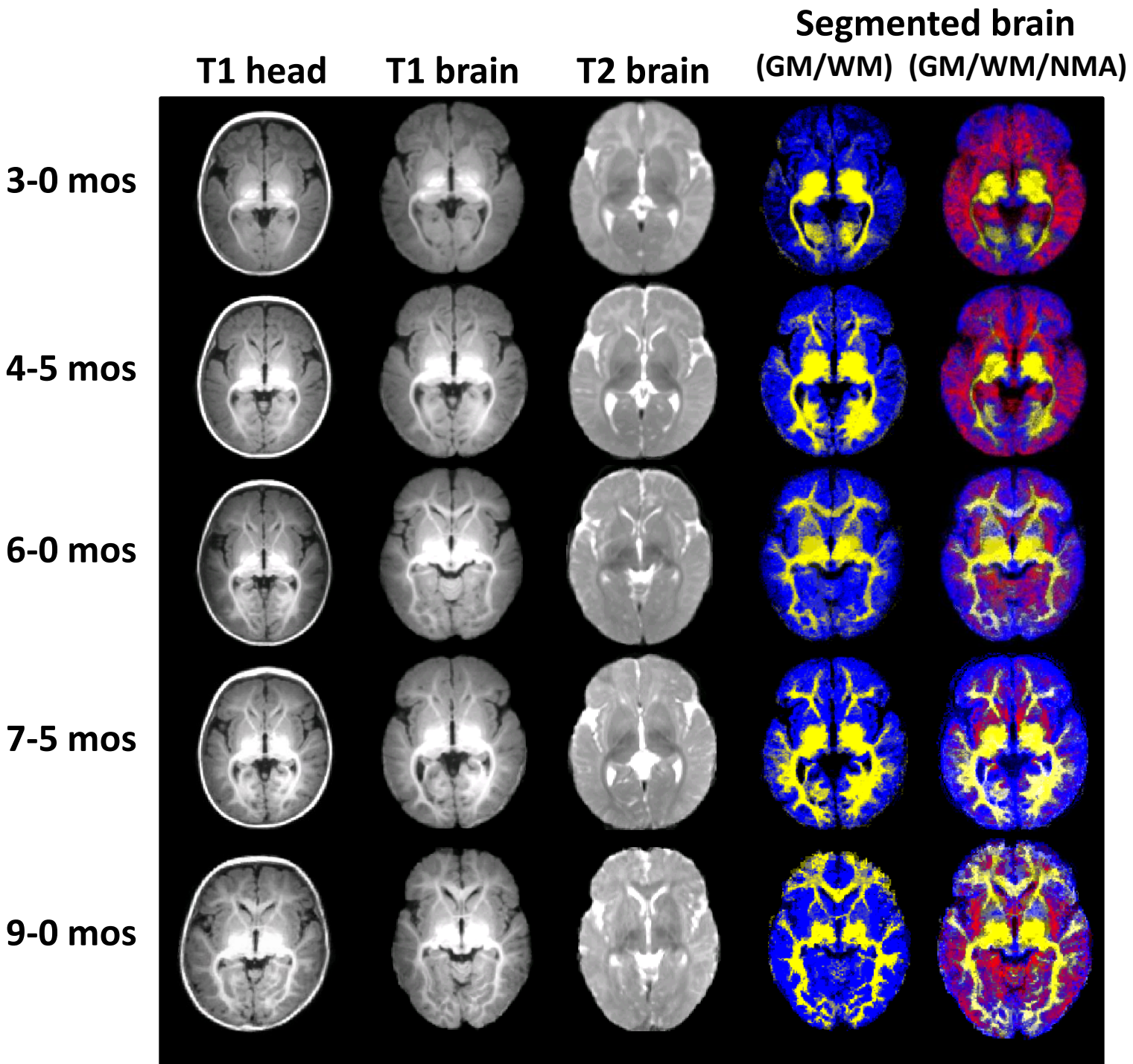
T1W, GM/WM; T2W, GM/WM/NMA 3-0Months










T1 head
T1 brain
T2 brain
Segmented brain
(GM/WM)
(GM/WM/NMA)
3-0 mos
4-5 mos
6-0 mos
7-5 mos
9-0 mos

http://jerlab.psych.sc.edu/NeurodevelopmentalMRI/index.html

JERLab Neurodevelopmental MRI Da...

Description | Citations | Access | Details | Ages Table

Neurodevelopmental MRI Database

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Department of Psychology
University of South Carolina

This is a database of MRIs from birth through age 89 years. The database provides average MRI templates for 3-month, 6-month, year, and 5-year intervals for various ages. The data came from the NIH MRI Study of Normal Brain Development, from the McCausland Center for Brain Imaging (University of South Carolina), and the Information Exchange from Images (IXI) database. The data consists of templates for infants, children, adolescents, and adults. The MRIs are average templates of the head and brain (T1W and T2W), segmented GM-WM-CSF probability maps, and neuroanatomical atlases. This data are intended to be used for structural and functional MRI analyses, but may be the basis for neurodevelopmental studies of brain development.

Citations: The citations page has the publication citations that should be included when using this data for publication

Access: The access page describes how the data may be accessed. Permission must be obtained from John E. Richards to use the data.

Updates: The templates are "in progress". The first wave will provide templates from 4-5 years through 24 years; the second wave will be from birth through 4 years; the third wave will be adults. This program of research is "in progress" and there will be updates as changes occur. People registered to use the database will be notified of updates.

WWW Sites
McCausland Center for Brain Imaging
NIHPD Information
Information Exchange from Images MRI Database

Undone: (To Do)

Atlas (Harvard-Oxford; AAL)

DTI

Changes in NMA/WM over age in infants

Methods for individual estimates

Neurodevelopmental MRI Database

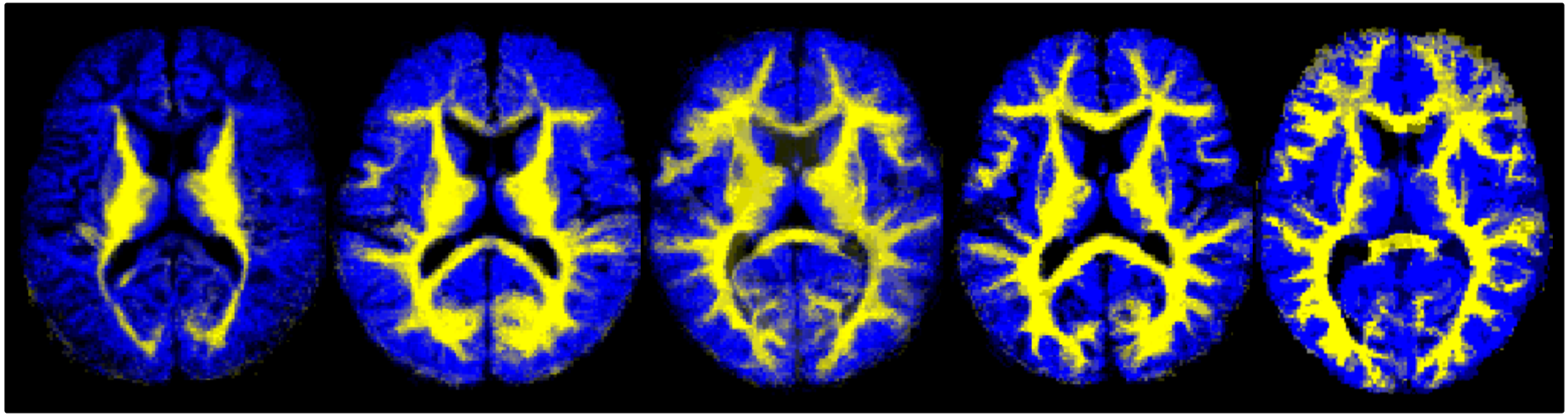
Example Uses

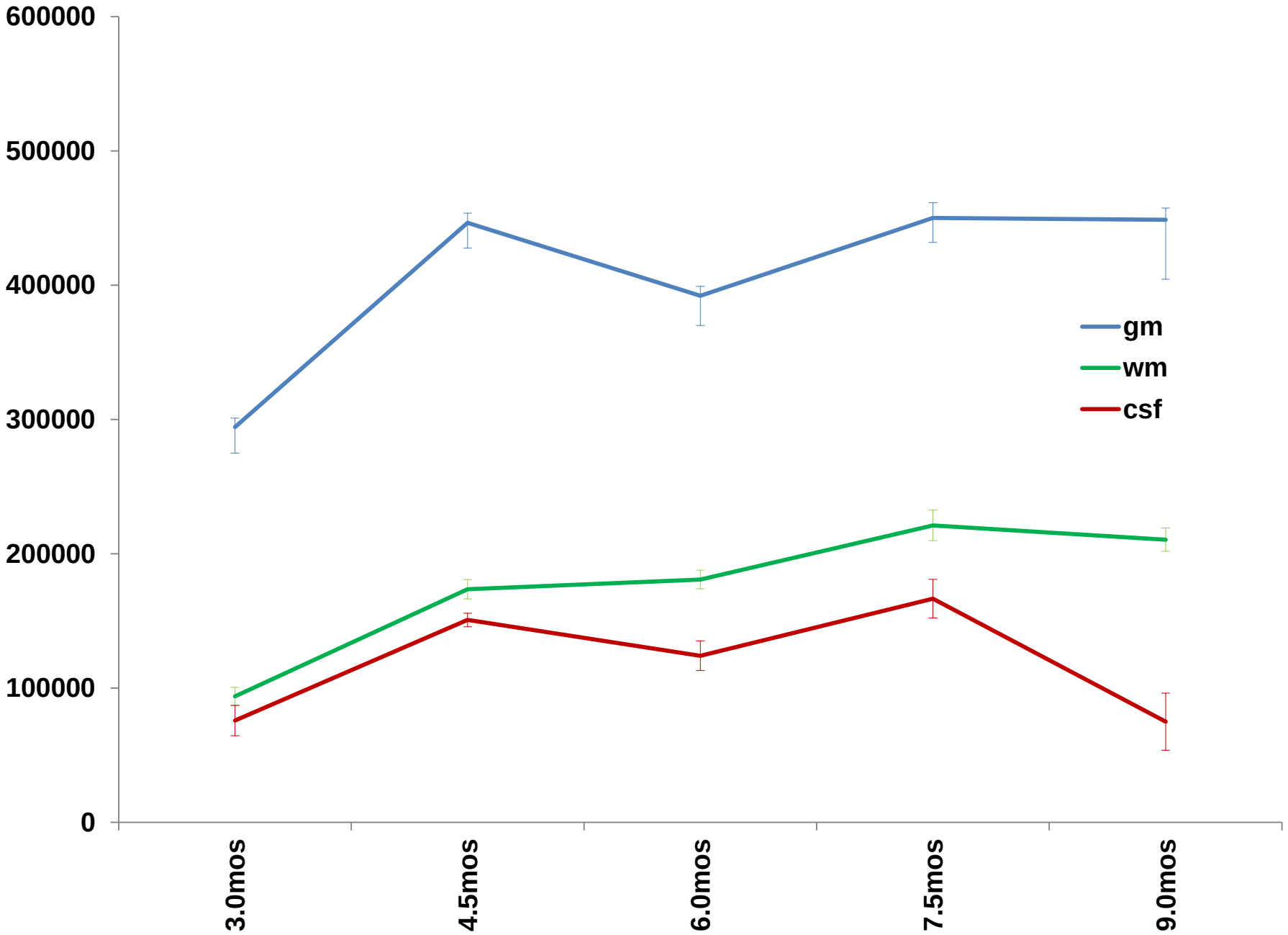
Functional brain development and attention

Example structural development

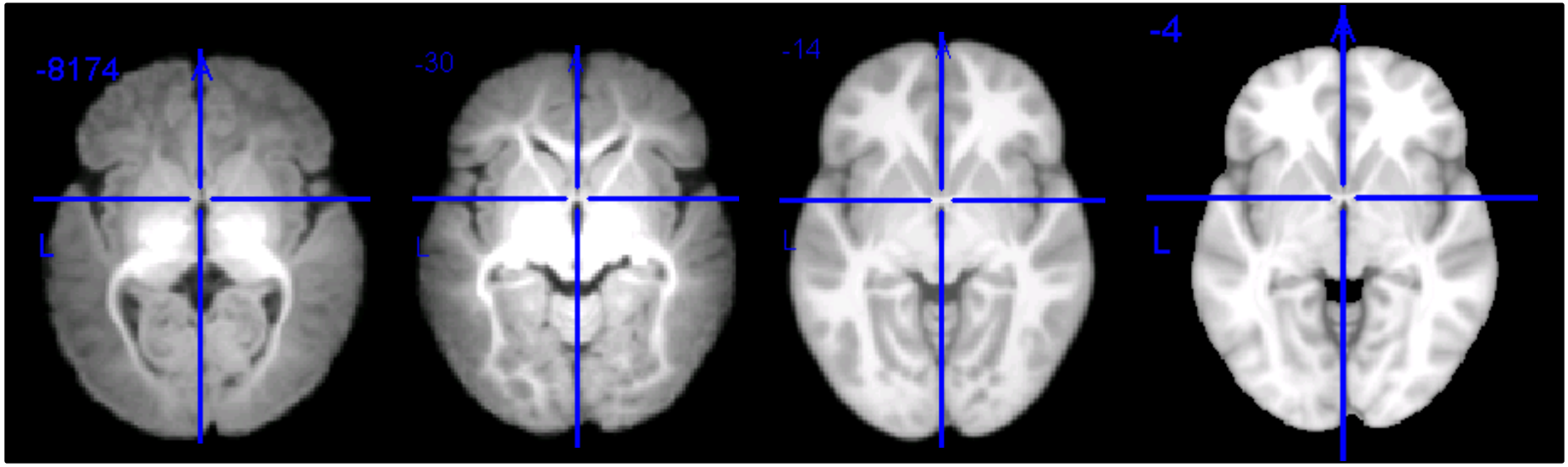
White matter development

3-0 mos 4-5 mos 6-0 mos 7-5 mos 9-0 mos

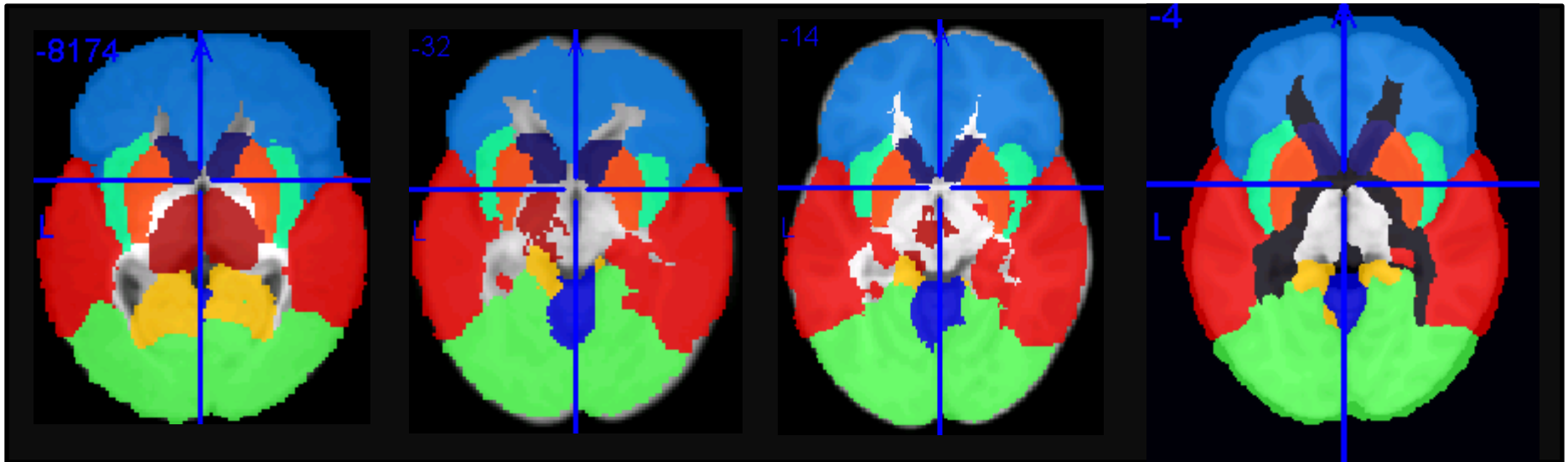


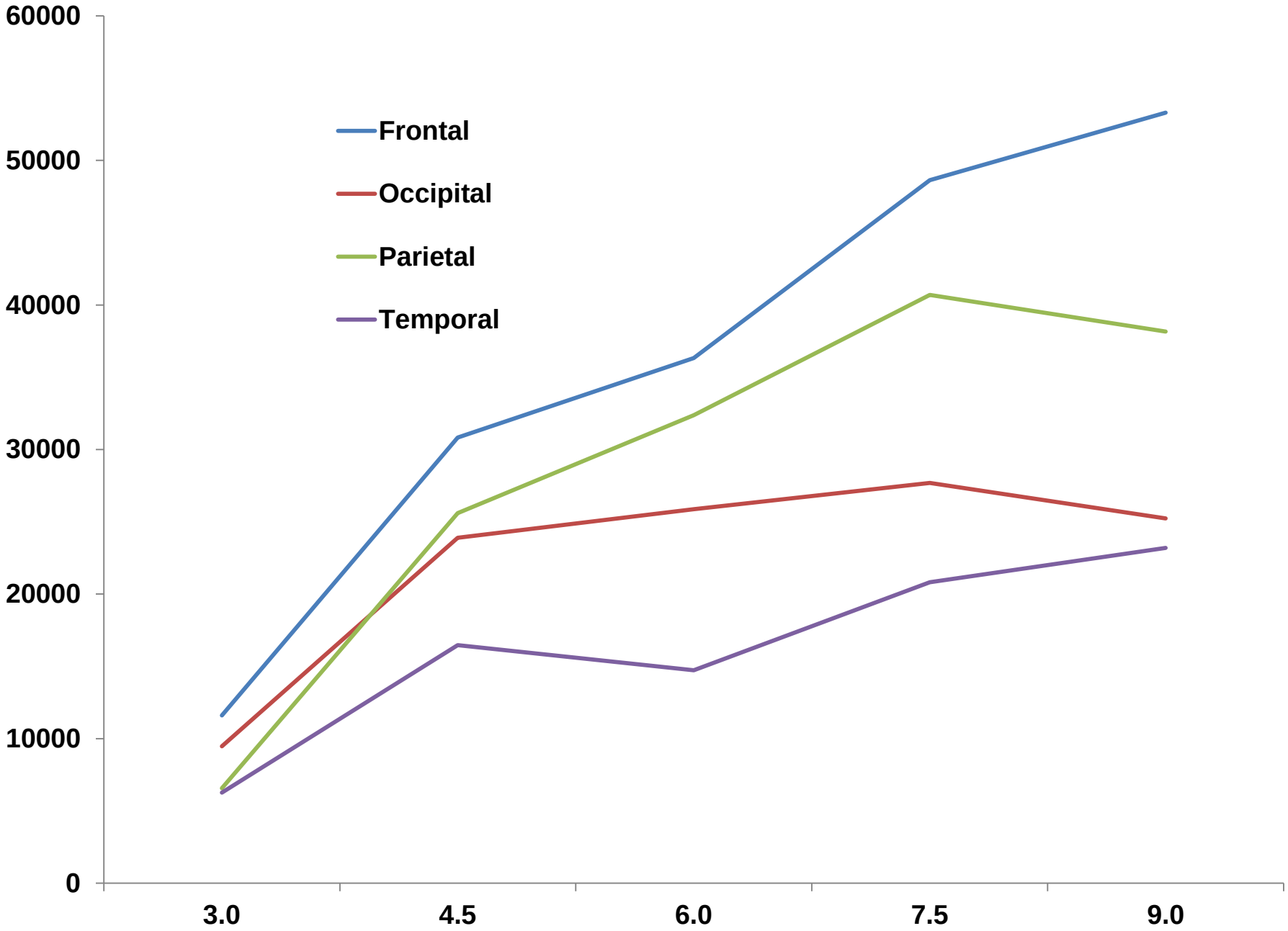

600000
500000
400000
300000
200000
100000
0
3.0mos
4.5mos
6.0mos
7.5mos
9.0mos
gm
wm
csf

Undone task: Common Stereotaxic Atlas



3 mos | 6 mos | 10 years | MNI




60000
50000
40000
30000
20000
10000
0
3.0
4.5
6.0
7.5
9.0
Frontal
Occipital
Parietal
Temporal

Example cortical source analysis

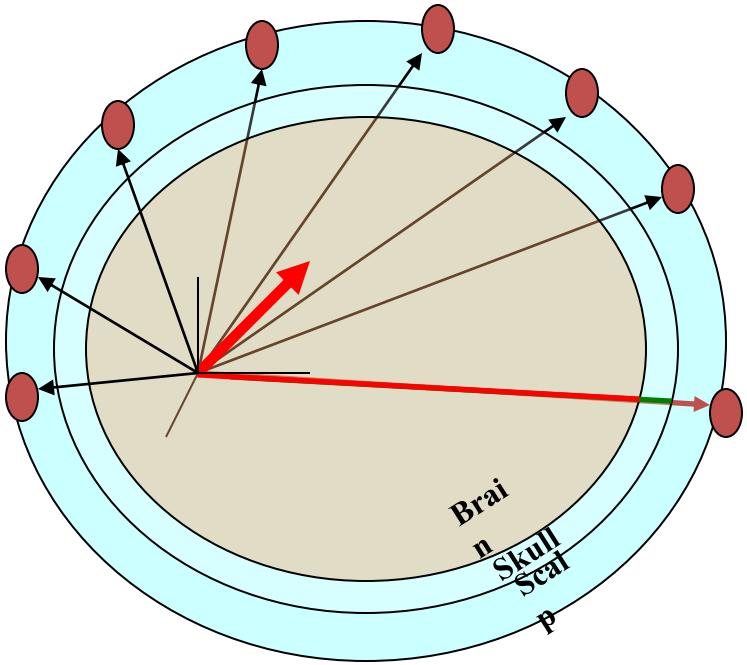
Realistic infant head model

What are cortical sources of ERP?

Reynolds, G.D., & Richards, J.E. (2009). Cortical source localization of infant cognition. ***Developmental Neuropsychology, 3*****, 312-329.**

Greg Reynolds

Equivalent Current Dipole Analysis Multishell Model
Source Location: Inner Shell Resistances: Shell-Media

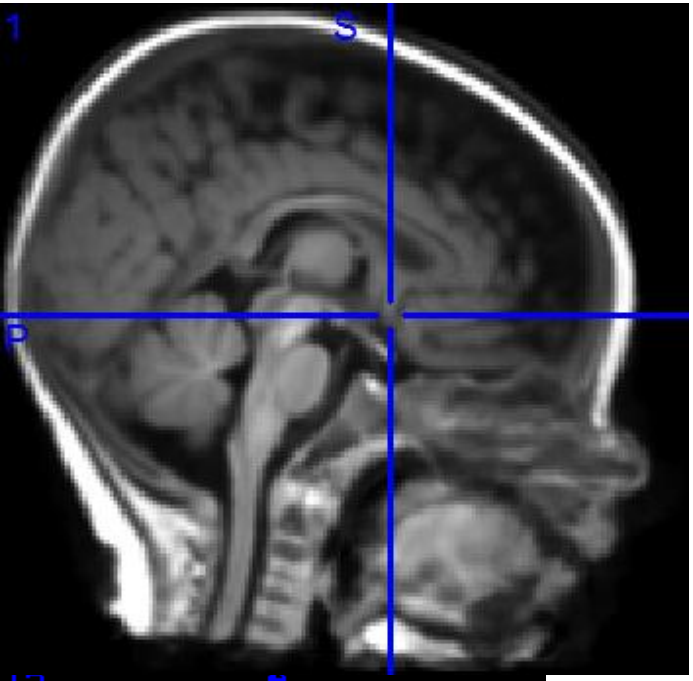


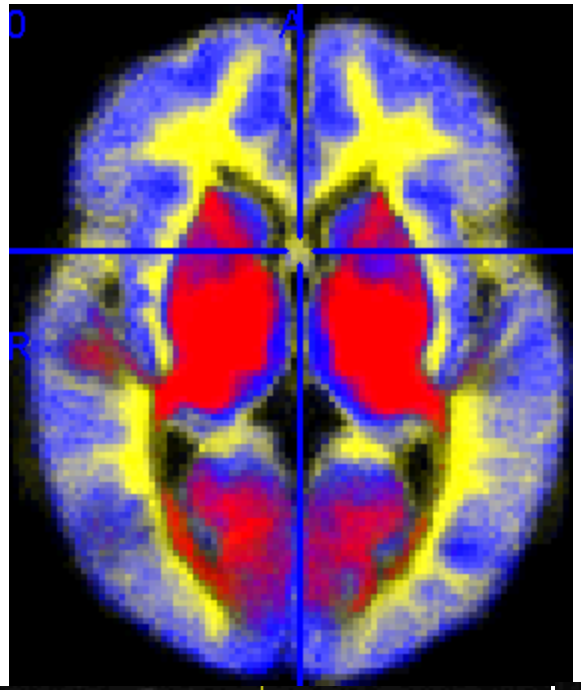
1) Current flow on scalp (EEG / ERP)
2) Hypothesize cortical source
3) Calculate forward solution
4) Compare against scalp current
5) Change source, iterate 3) and 4)

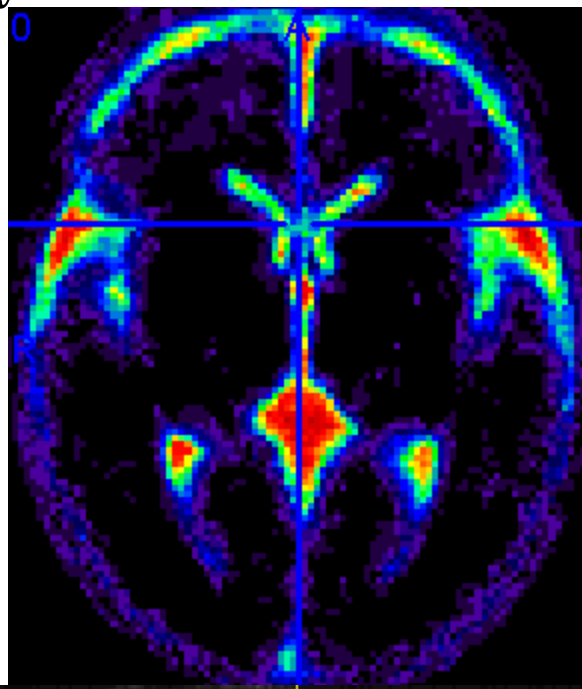
6) $I_{electrode} = I_{dipole} * \cos(\theta) /$

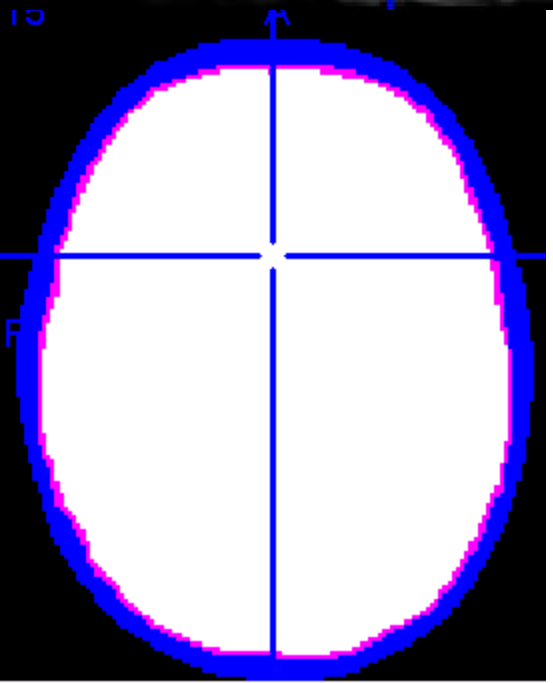
$\Sigma (R_{Brain}*d1 + R_{skull}*d2 + R_{scalp}*d3)$

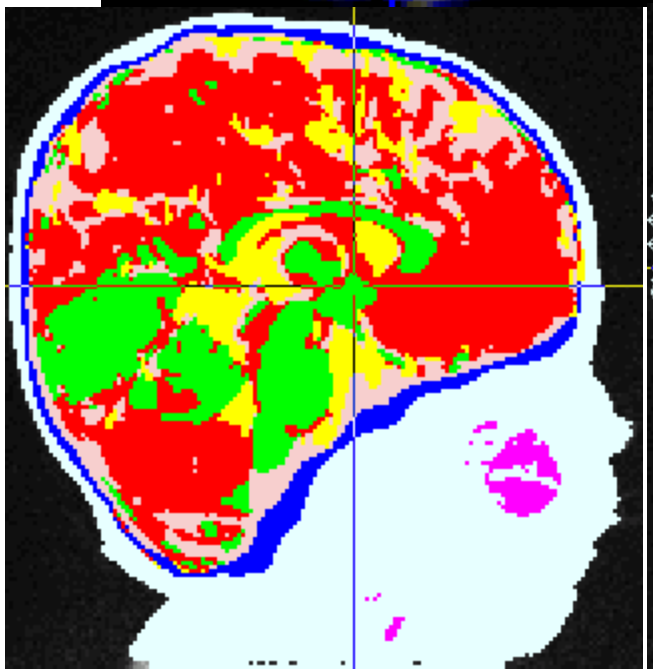
What's Inside an *AVERAGE* Baby's Head?

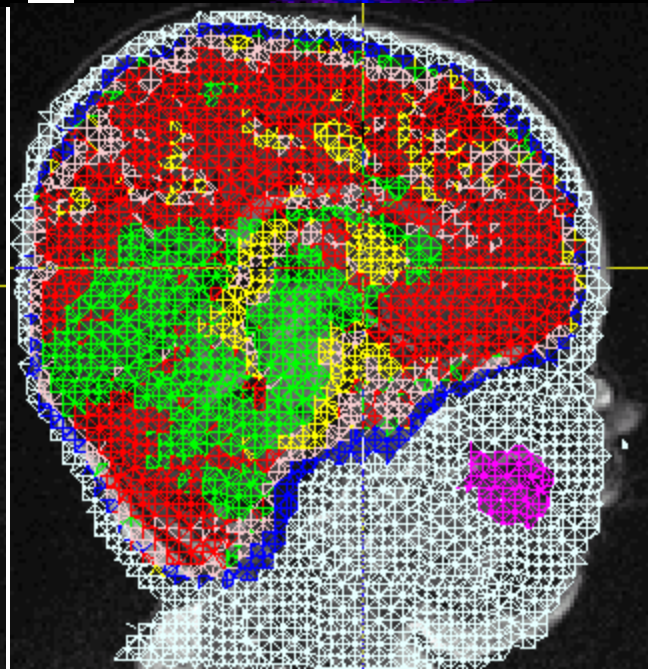






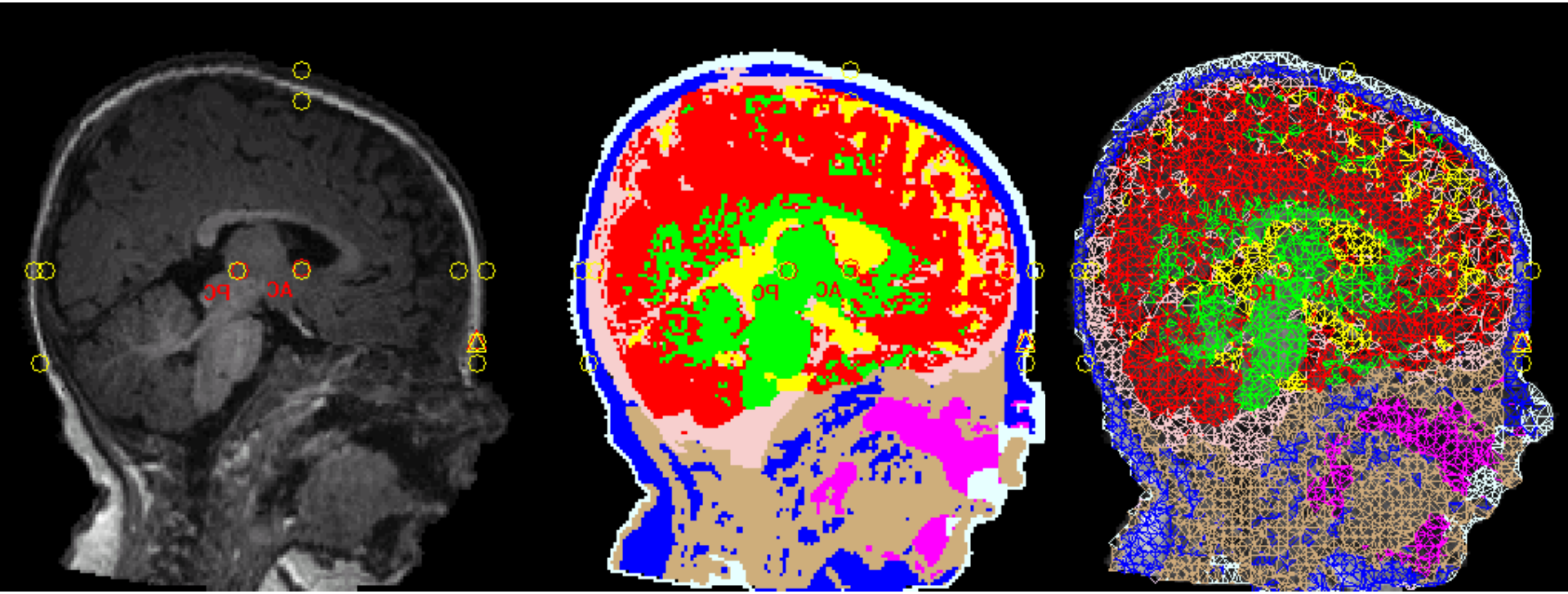







09/21/2006

What's Inside a (an Individual) Baby's Head?



Neurodevelopmental MRI Database

Example Uses

Functional brain development and attention

Functional brain development and attention

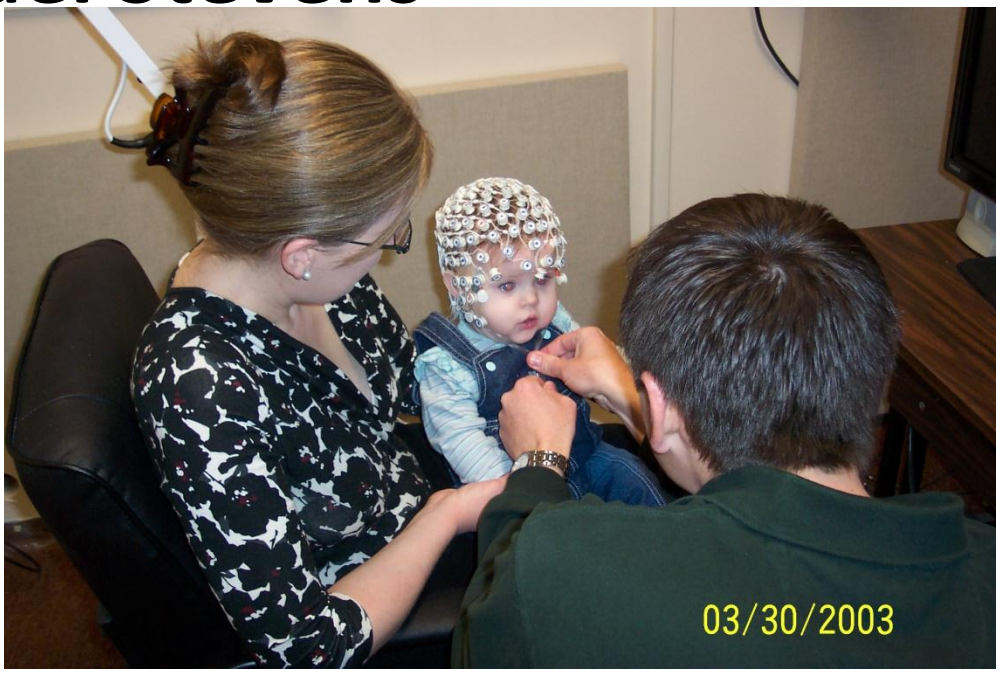
Modified “Oddball” Procedure

Familiarize infant to two stimuli
One familiar picture presented frequently
One familiar picture presented infrequently
Set of novel pictures presented infrequently

Chuck Nelson

Modified “Oddball” Procedure

Michael Stevens



Michael Stevens

Michael Stevens

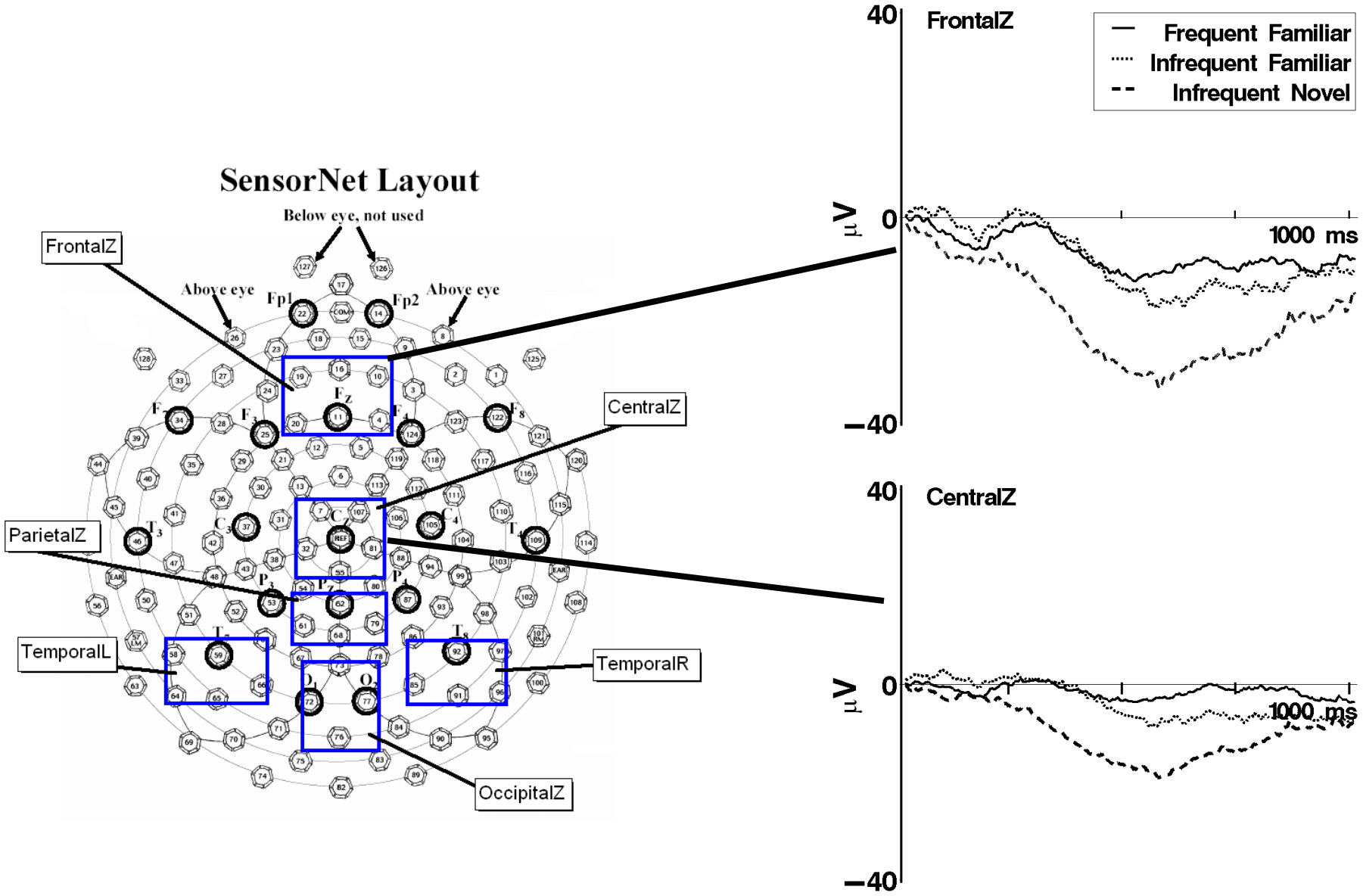
Michael Stevens

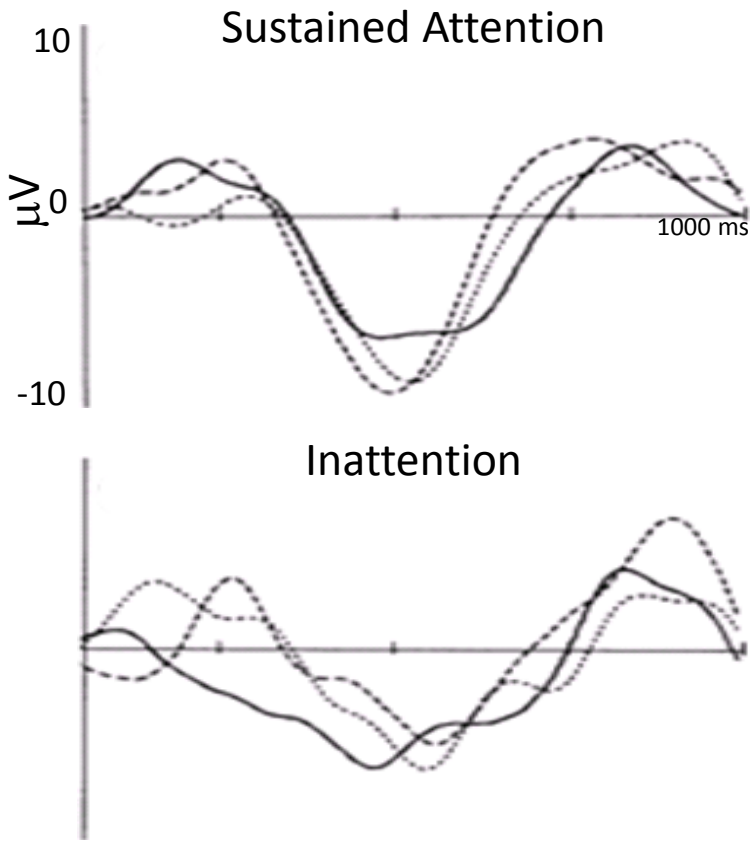
Michael Stevens

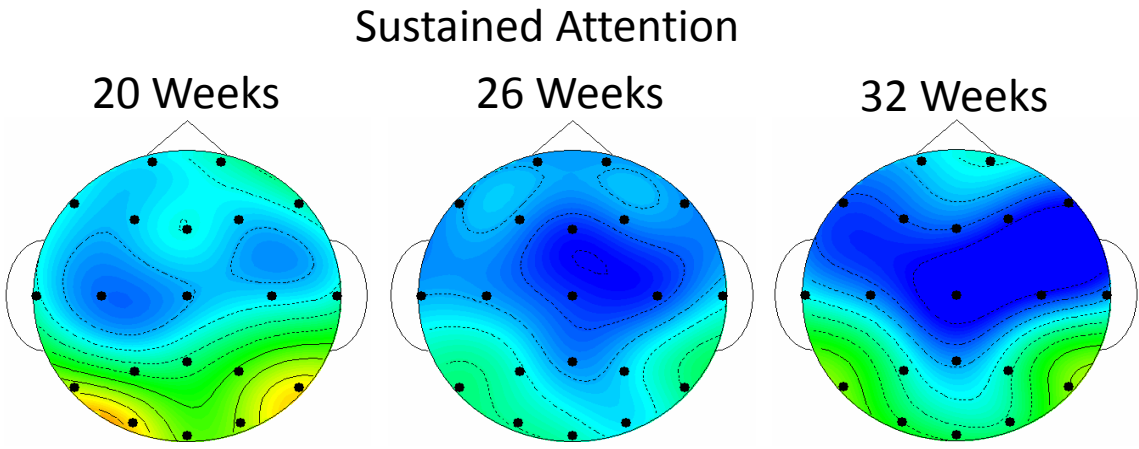
Michael Stevens

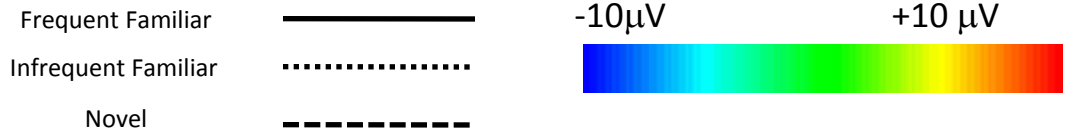
Neuroimaging tool: High-density scalp-recorded ERP

FrontalZ and CentralZ electrodes, "Nc" (Negative central)




Sustained Attention
10
μV
0
-10
1000 ms
Inattention


Sustained Attention
20 Weeks
26 Weeks
32 Weeks

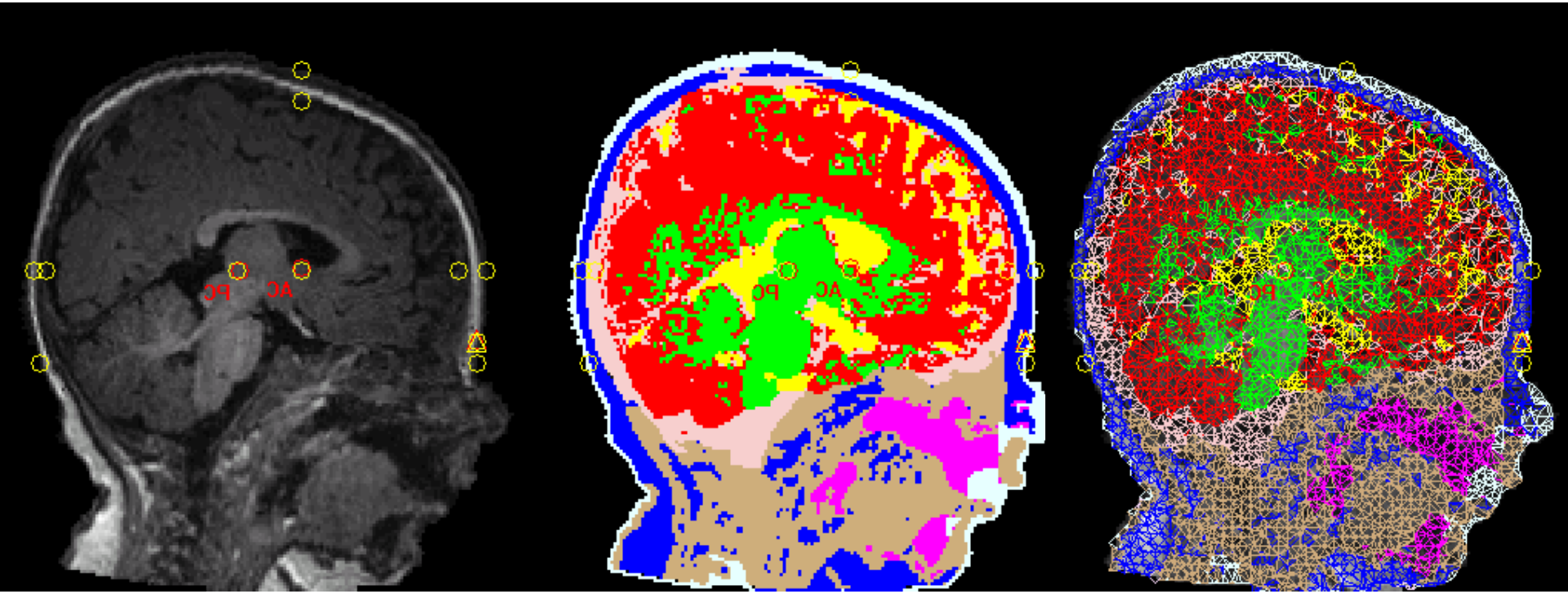

Frequent Familiar
Infrequent Familiar
Novel
-10μV
+10 μV

What are cortical sources of ERP in the modified oddball task?

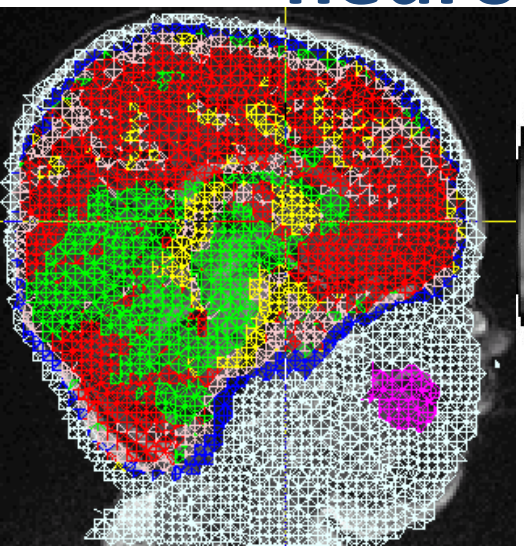
Reynolds, G.D., & Richards, J.E. (2005). Familiarization, attention, and recognition memory in infancy: An ERP and cortical source localization study. *Developmental Psychology, 41*, 598-615.

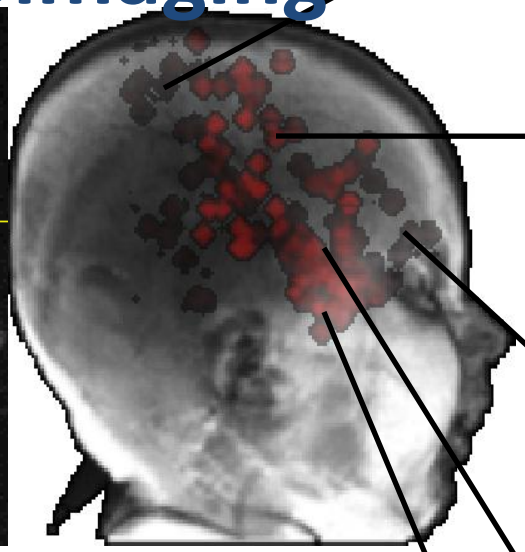
Greg Reynolds

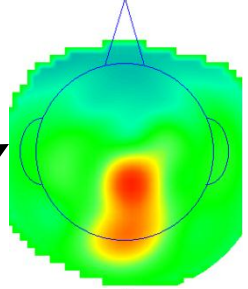
What's Inside a Baby's Head?
(Reminder later, "template" approach)

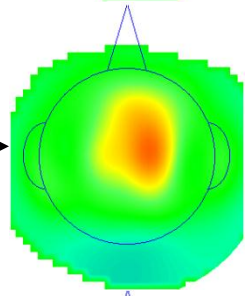


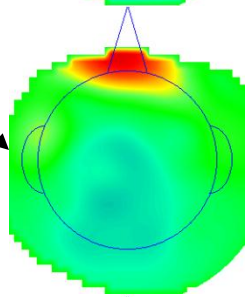
Spatio-temporal functional developmental neuroimaging

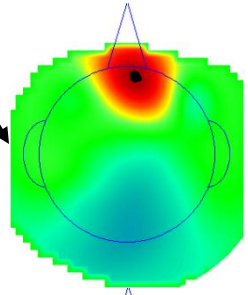


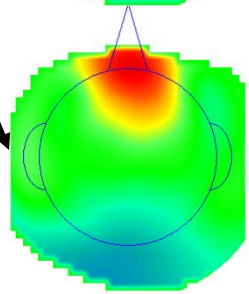


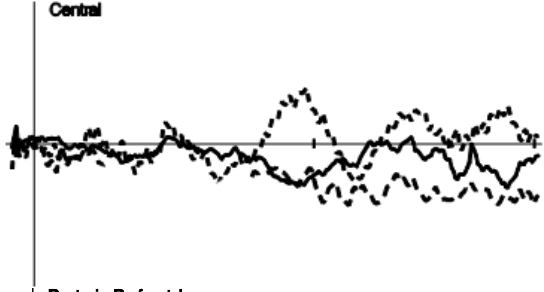


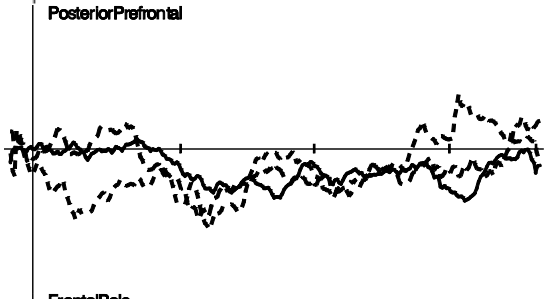


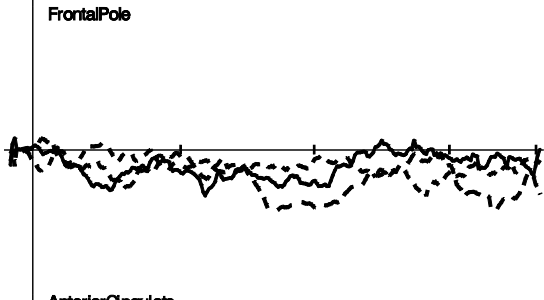


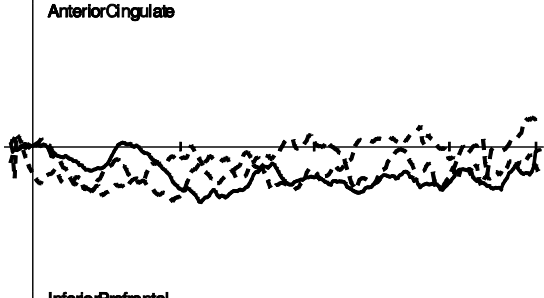


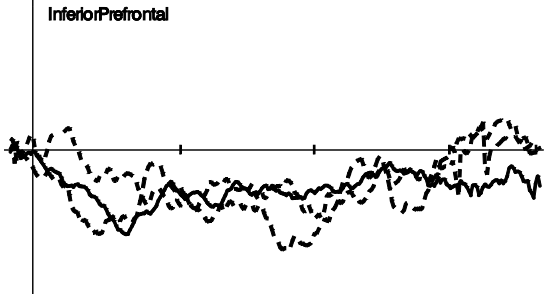




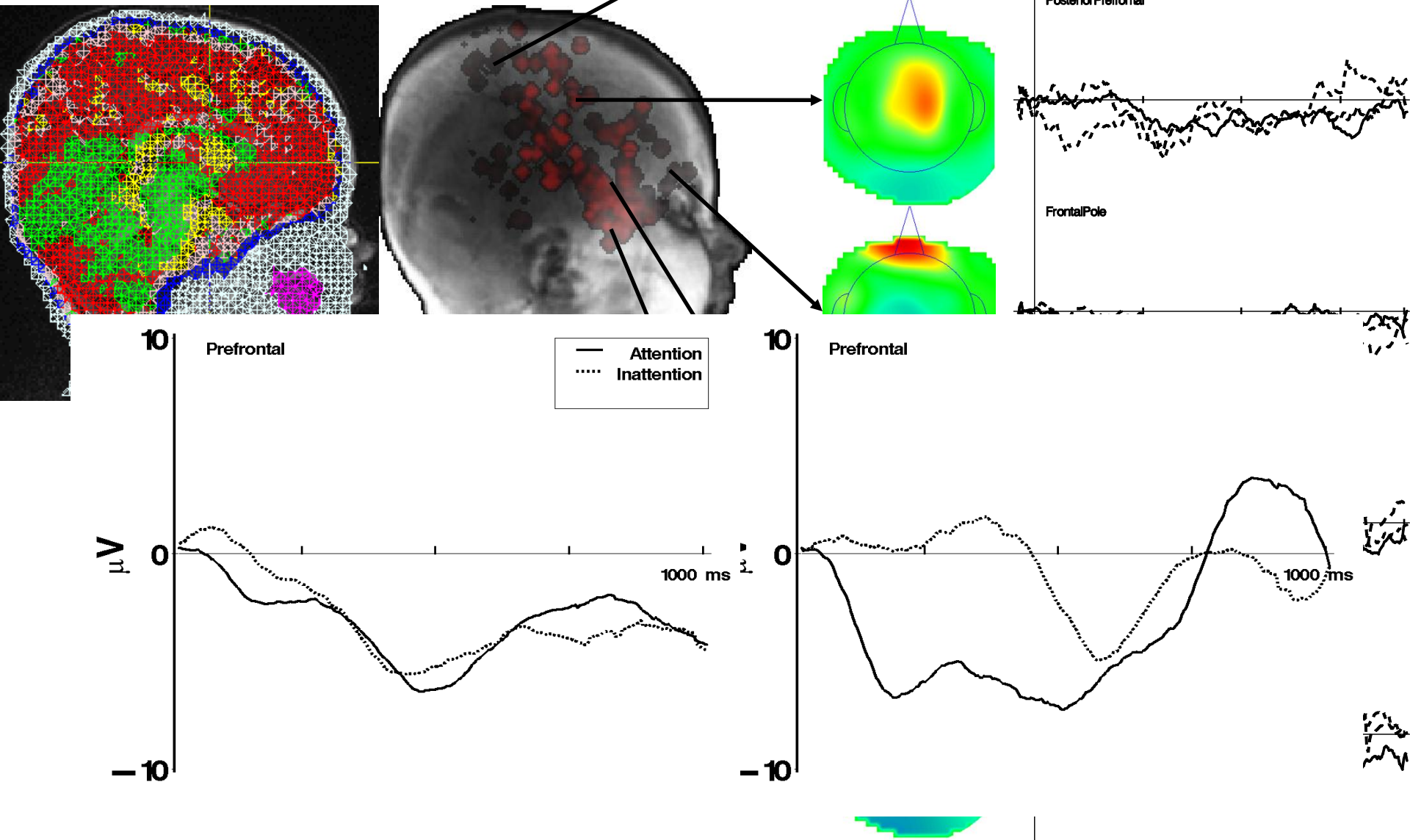








…functional…


Central
PosteriorPrefrontal
FrontalPole
Prefrontal
Attention
Inattention
10
0
−10
μV
1000 ms
Prefrontal
10
0
−10
1000 ms

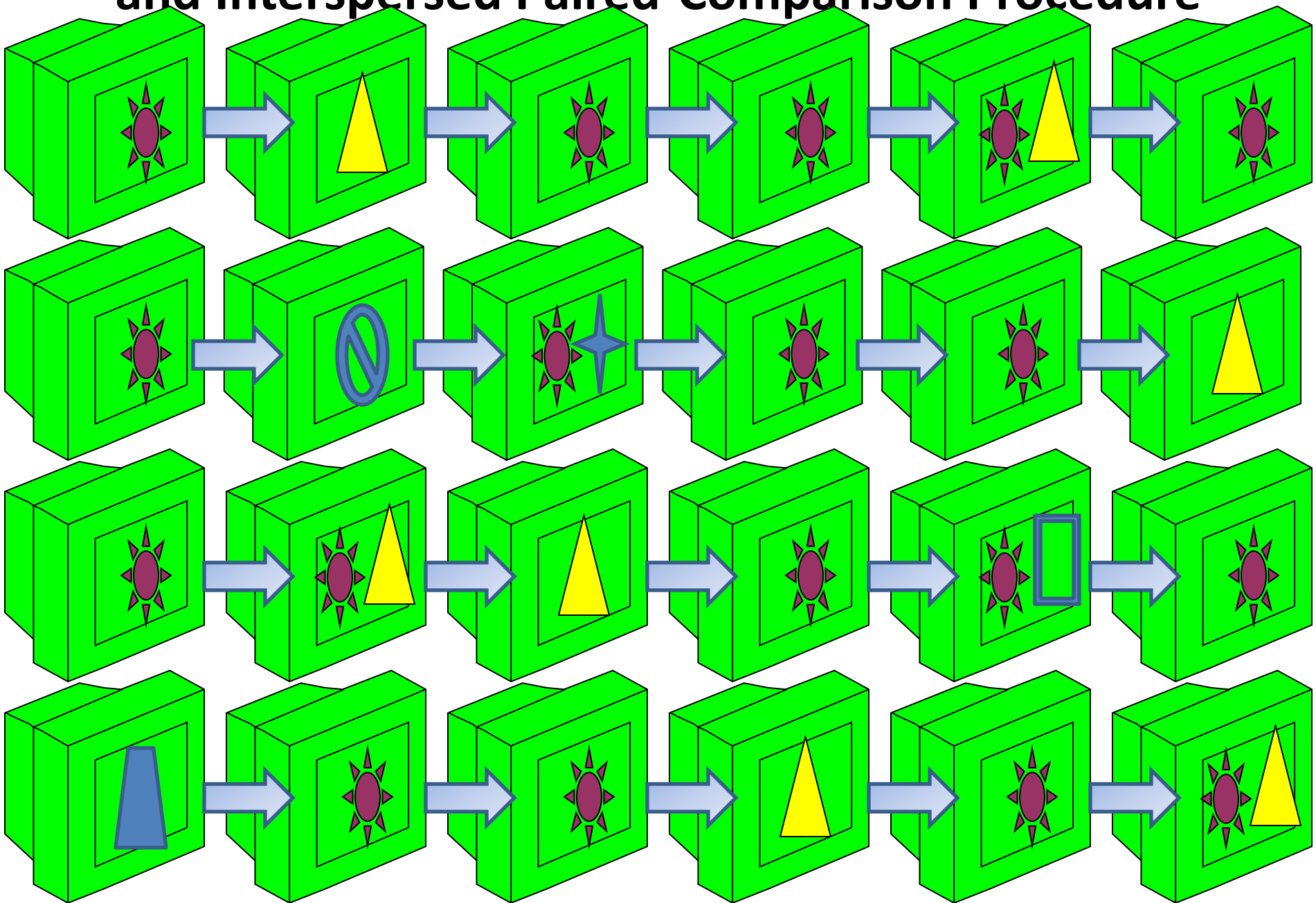
Attention, recognition memory, visual preference, brain

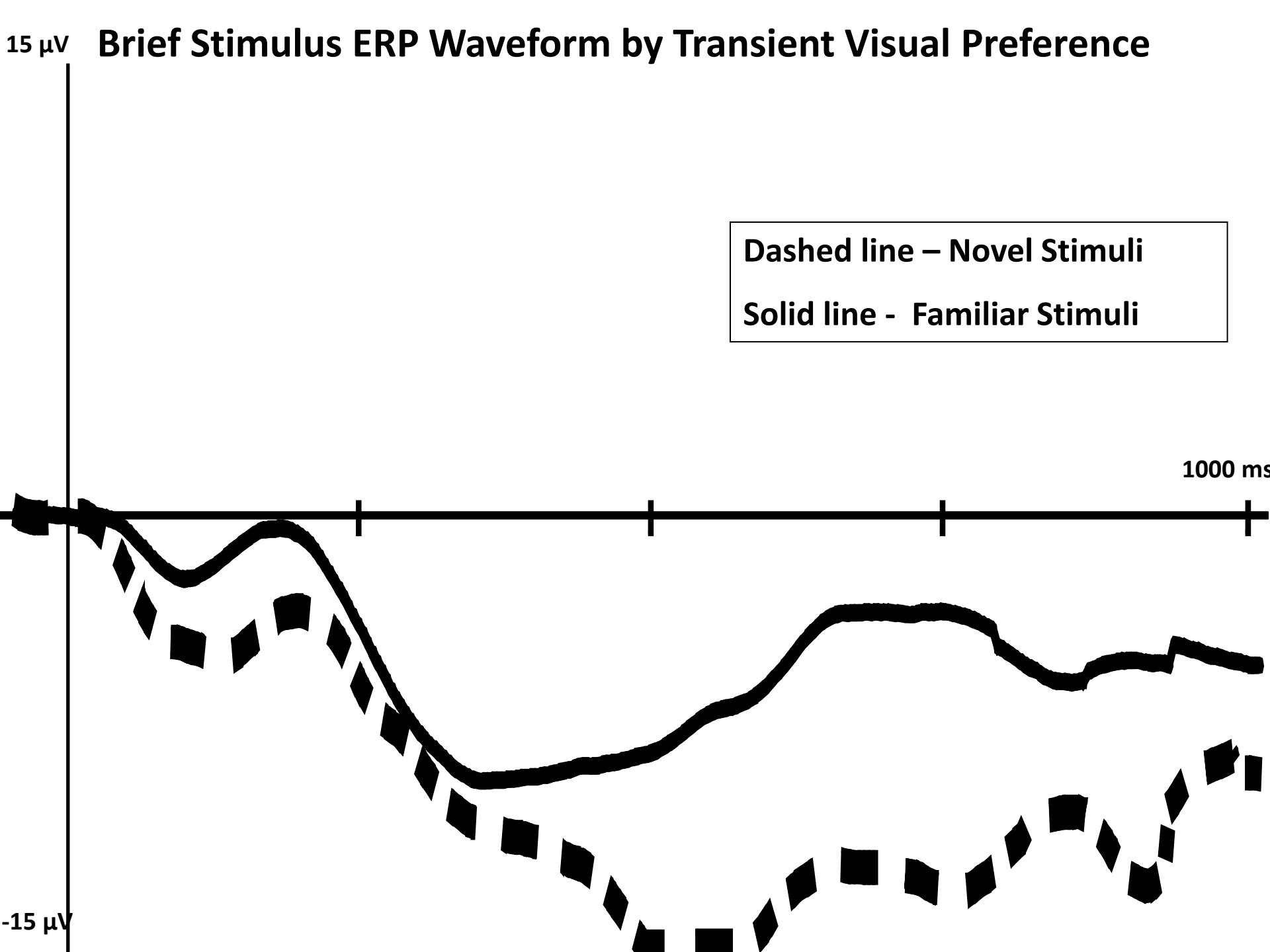
Reynolds, G.D., Courage, M.I., & Richards, J.E. (in press). Infant attention and visual preferences: Converging evidence from behavior, event-related potentials, and cortical source localization. *Developmental Psychology*.

Greg Reynolds

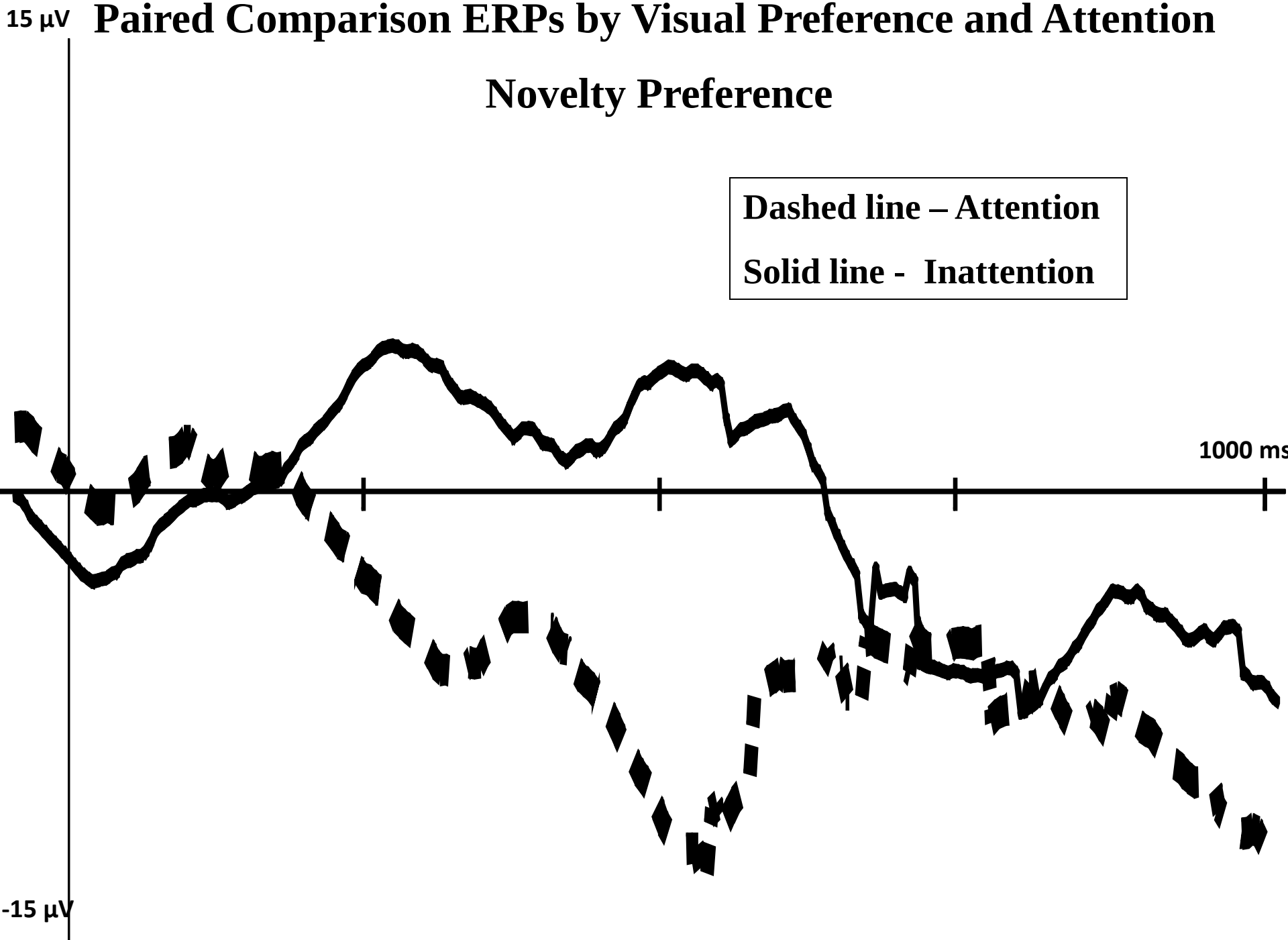
Mary Courage

Modified “Oddball” Procedure and Interspersed Paired-Comparison Procedure

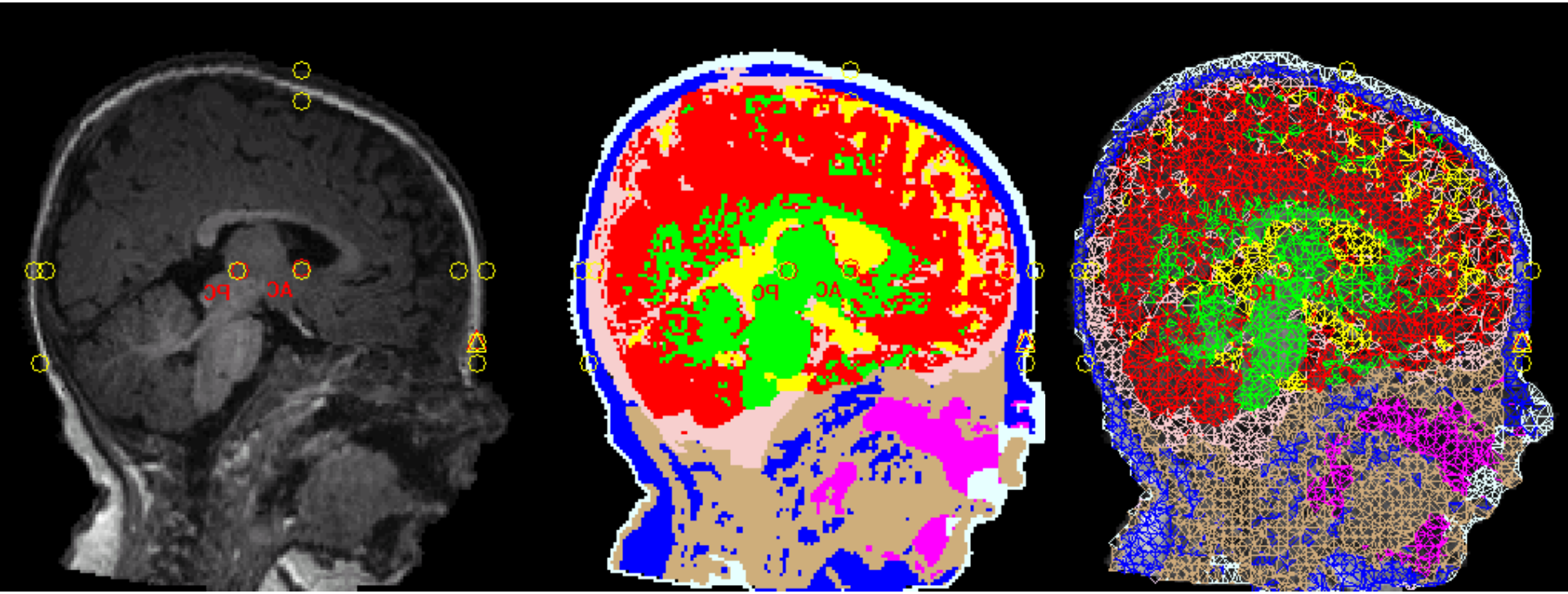



15 µV
Brief Stimulus ERP Waveform by Transient Visual Preference
Dashed line – Novel Stimuli
Solid line - Familiar Stimuli
1000 ms
-15 µV

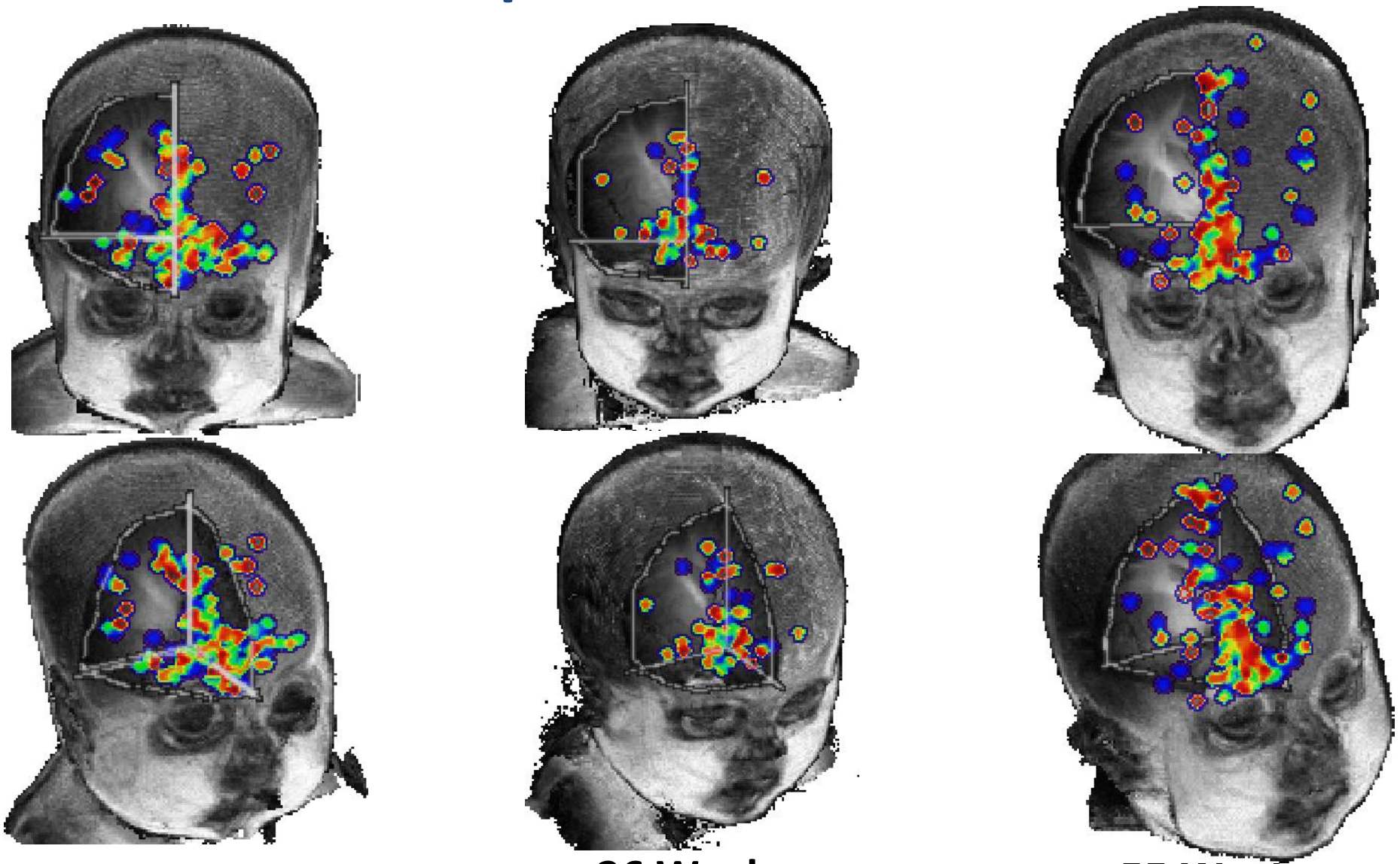
Paired Comparison ERPs by Visual Preference and Attention



What's Inside a Baby's Head?
(Reminder later, "library" approach)



…developmental…



Undone: (To Do)

Atlas identified ROI

Methods for individual estimates

Realistic models (skull thickness-density-impedance; seams; scalp impedance; NMA impedance)

Electrode maps

“Templates” “Library” “Individual”

Relation to brain structure, individuals

USE THESE !!!!

NIRS: Locate structures under sensors

fMRI: Common template space

EEG and ERP: Electrode placement on head

Cortical source analysis: Template library individual

Voxel based morphometry

Structural development in groups

Individual brain and behavior