UNIVERSITY OF SOUTH CAROLINA

Brain changes in response to faces in the first year

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Wanze Xie, & Jane E. Roberts

ICIS, 2016

http://jerlab.psych.sc.edu/jerpdf/icis2016facesbrain.pdf

Guy, M.W., Zieber, N., & Richards, J.E. (in press). The cortical development of specialized face processing in infancy. Child Development. (Friday morning poster)

Guy, M.W., Richards, J.E., Tonnsen, B., & Roberts, J.E. (submitted; concurrent poster). Neural correlates of face processing associated with risk of autism spectrum disorders in infancy

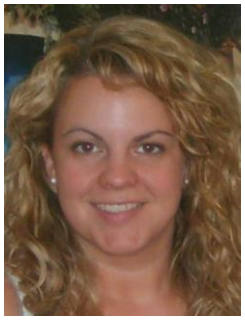
Xie, W., & Richards, J.E. (2016). Effects of interstimulus intervals on behavioral, heart rate, and event-related potential indices of infant engagement and sustained attention. Psychophysiology

Abstract:

Young infants in the first year have dramatic changes in their processing of faces, going from simple perceptual sensitivity through recognition and preference for familiar faces. It is likely that these changes are caused by, or accompanied by, changes in the brain areas known in adults to be involved in face processing. We report data from infants from 3 through 12 months of age that shows the development of scalp-recorded event-related-potentials in response to faces and objects, in the brain areas supporting these ERP components, and in the effect of attention on the face processing / brain development. This work quantifies the specialization of brain areas for face processing in the infant.

Acknowledgements

Maggie Guy (faces, FXS and S-ASD)



Nicki Zieber (faces)

Jane Roberts
(TD vx FXS vs S-ASD)

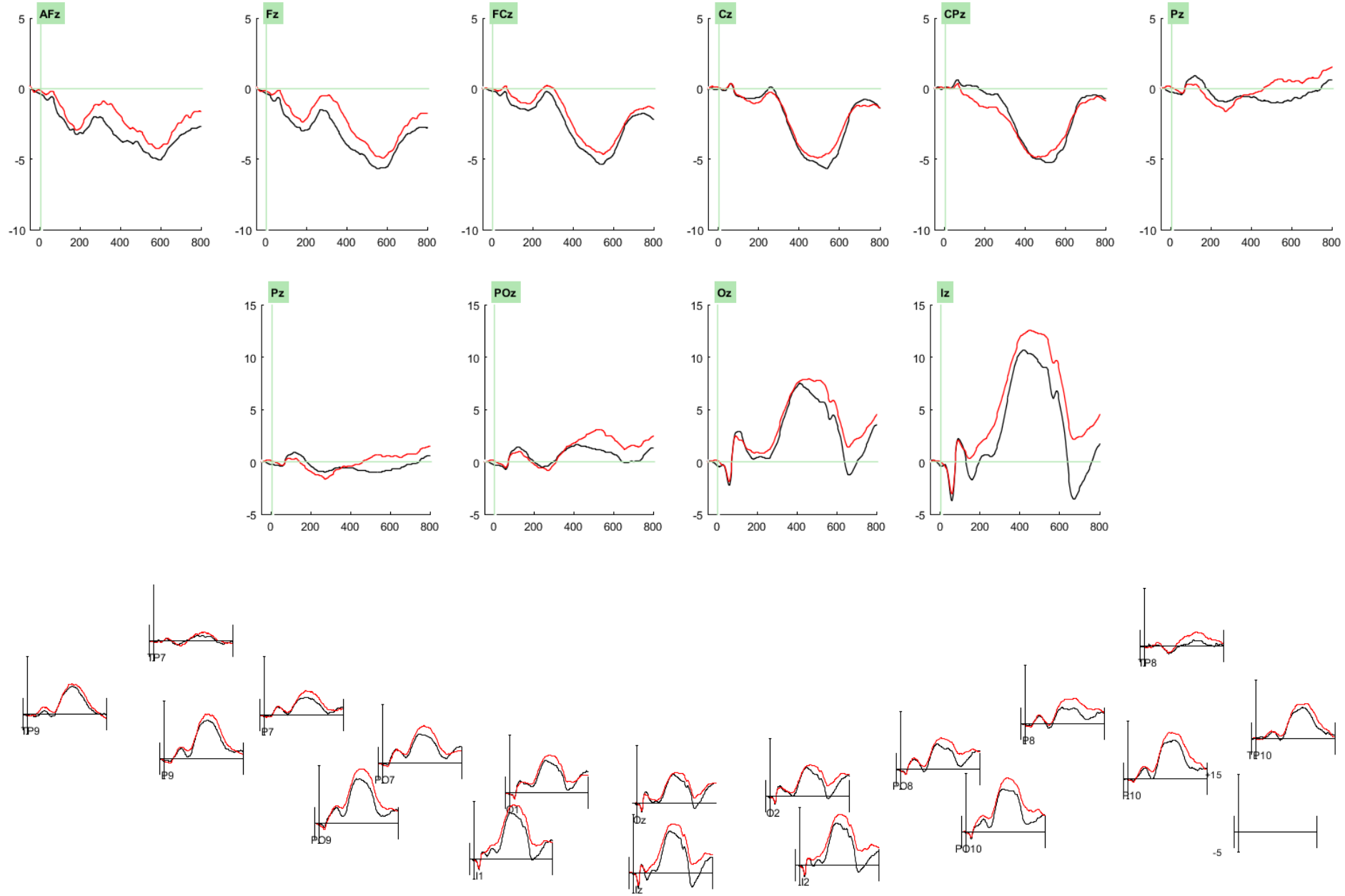
Wanze Xie (faces)

Michael Stevens—RA who does all my MRI scans (infants, children, adolescents and adults), applies EGI cap, and otherwise runs the lab infrastructure

Lisa Freund, NICHD

NIH, NICHD R37-18942

“The development of sustained attention”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Fz
FCz
Cz
CPz
Pz
Pz
POz
Oz
Iz
TP9
TP7
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P7
PO9
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O1
Oz
O2
PO8
P8
TP8
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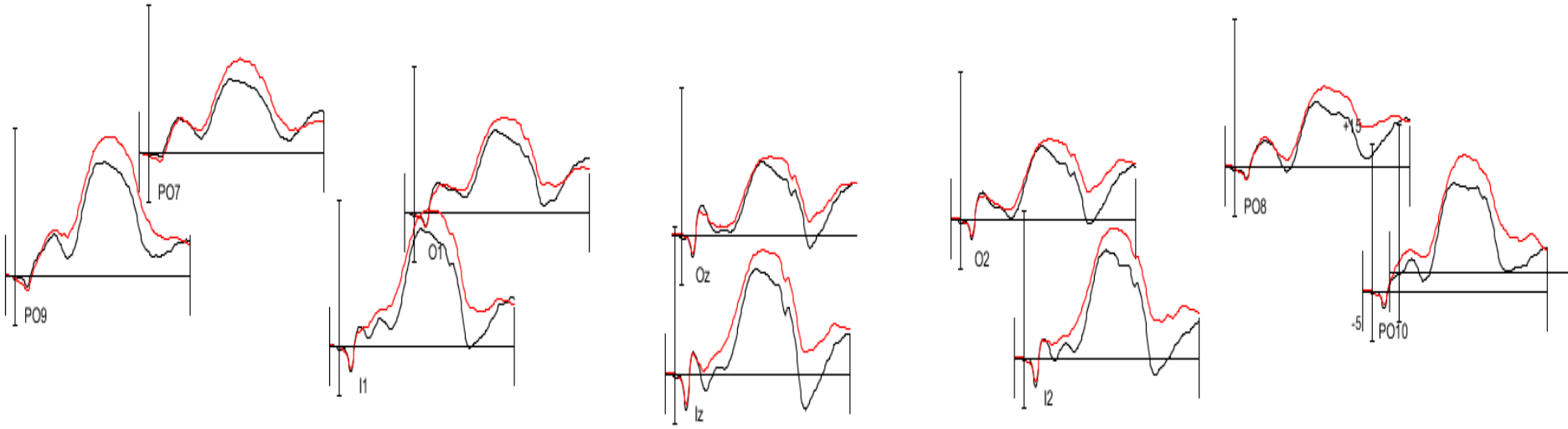
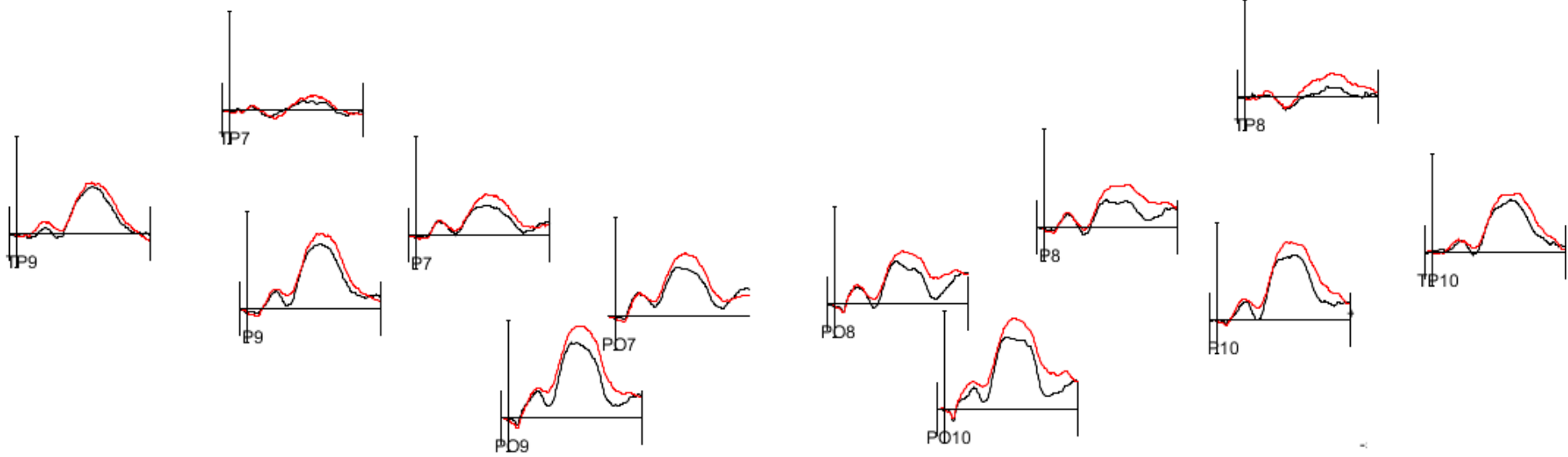
-5
-10
15
10
0
200
400
600
800


PO9
PO7
O1
I1
Oz
Iz
O2
I2
PO8
+15
-5
PO10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P8
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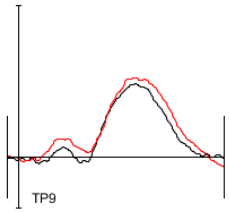
TP10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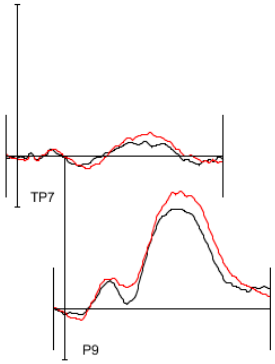
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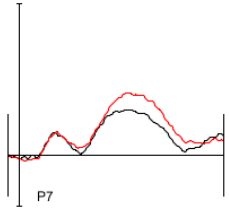
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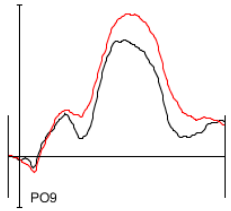
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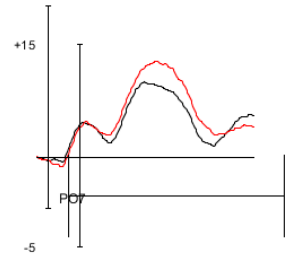
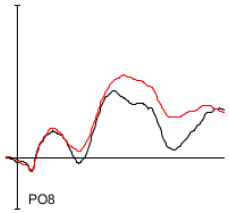

+15
PO7
-5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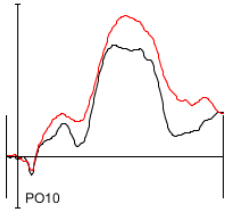
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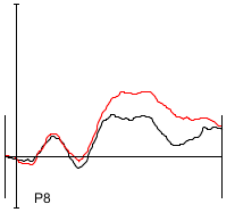
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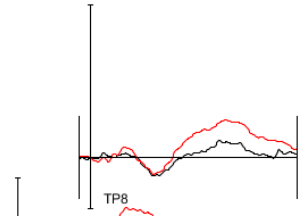
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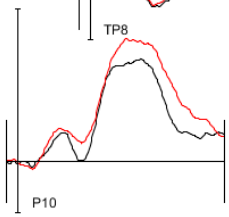
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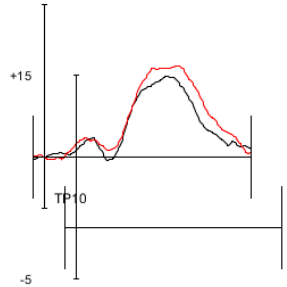
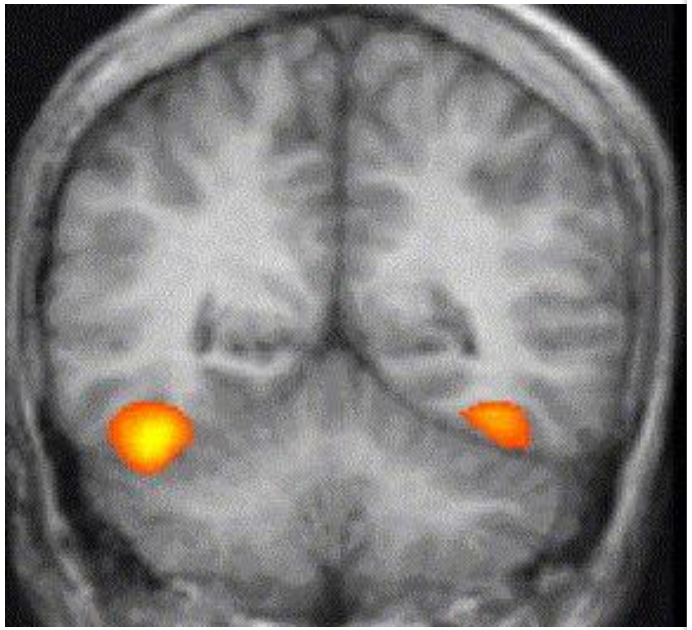
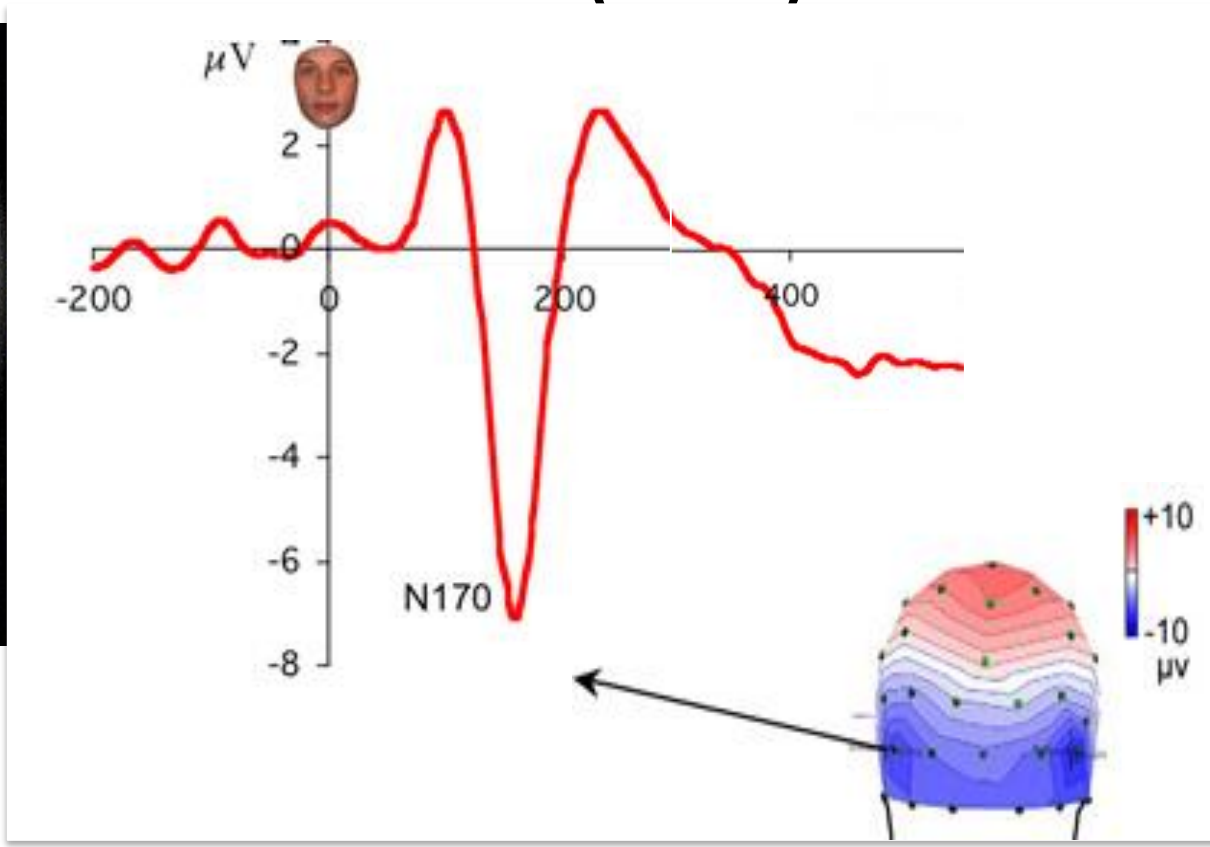

+15
TP10
-5

Adult fMRI, and N290 source analysis, show FFG and other areas active during face processing.

"Fusiform face area" (MRI)

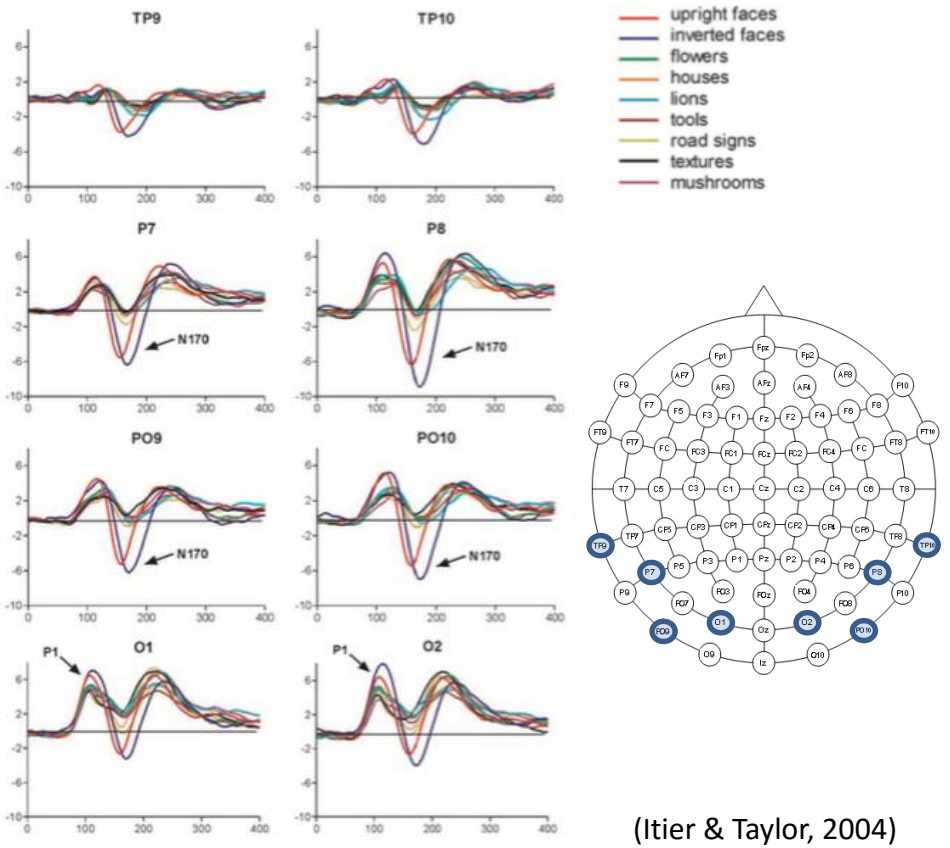


N170 Component (ERP)



Face Processing in Adulthood

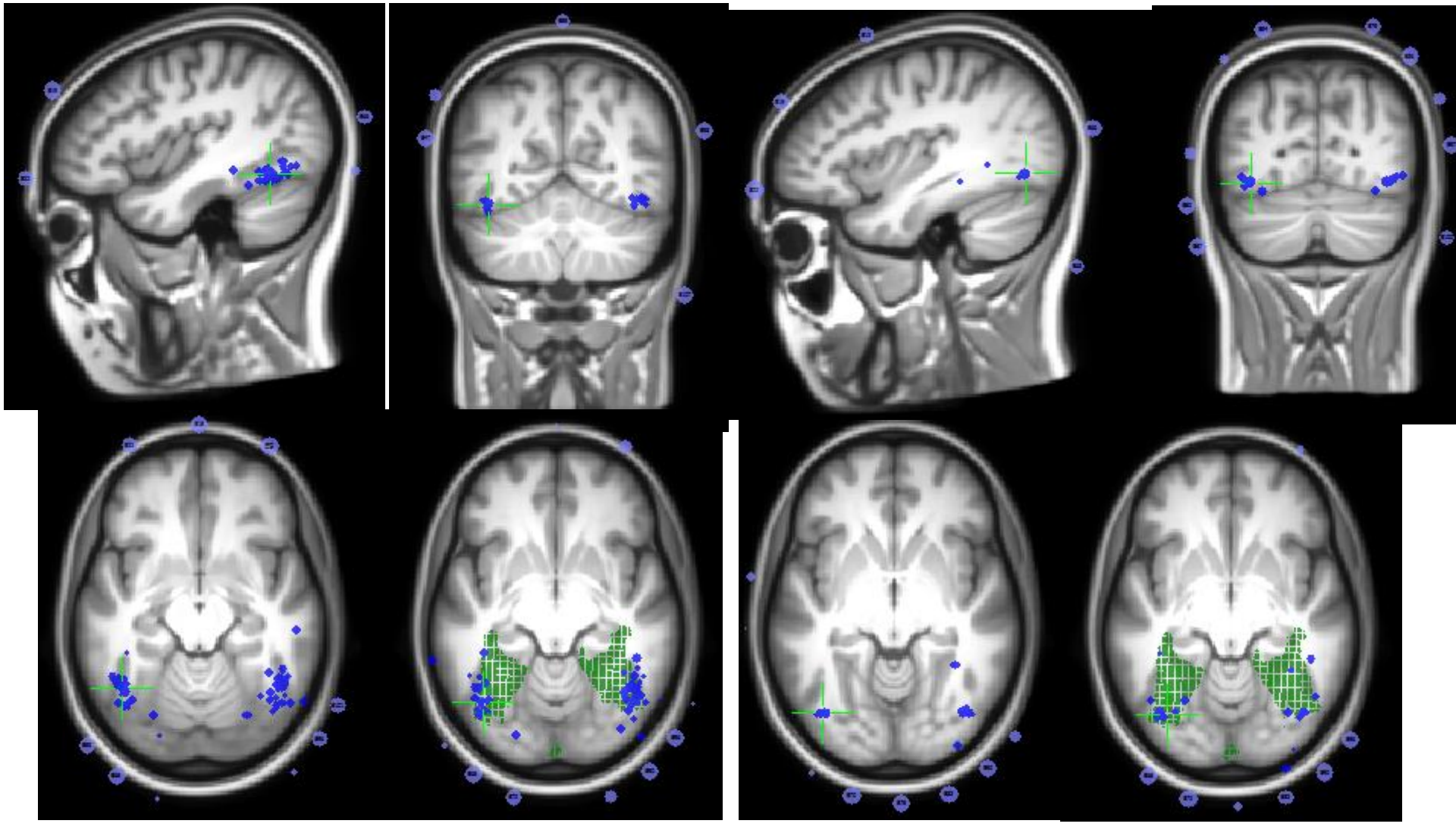
- Show face specific ERP responses
- N170
  - Negative peak over posterior scalp regions
  - ~170 ms after stimulus onset
  - Right lateralized
  - Greater amplitude & shorter latency to faces than objects (e.g., Bentin et al., 1996; Eimer, 1998; Rossion et al., 2000)



(Itier & Taylor, 2004)

Fusiform Face Area localization

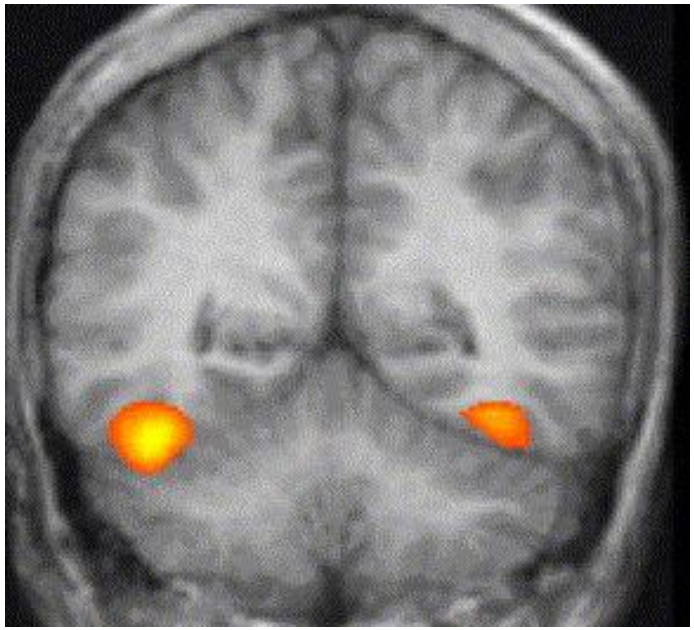
N170 source localization

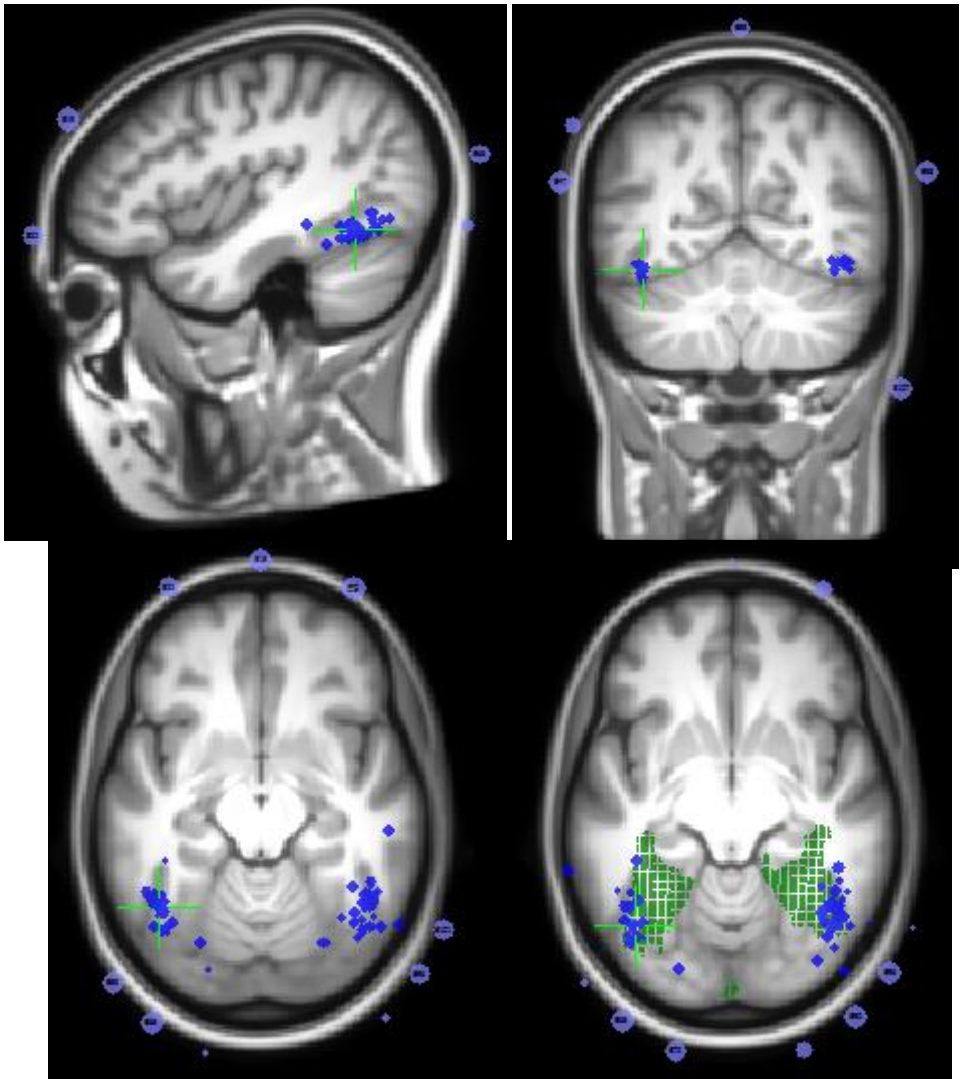


Face-sensitive areas in the adult brain

Fusiform face area

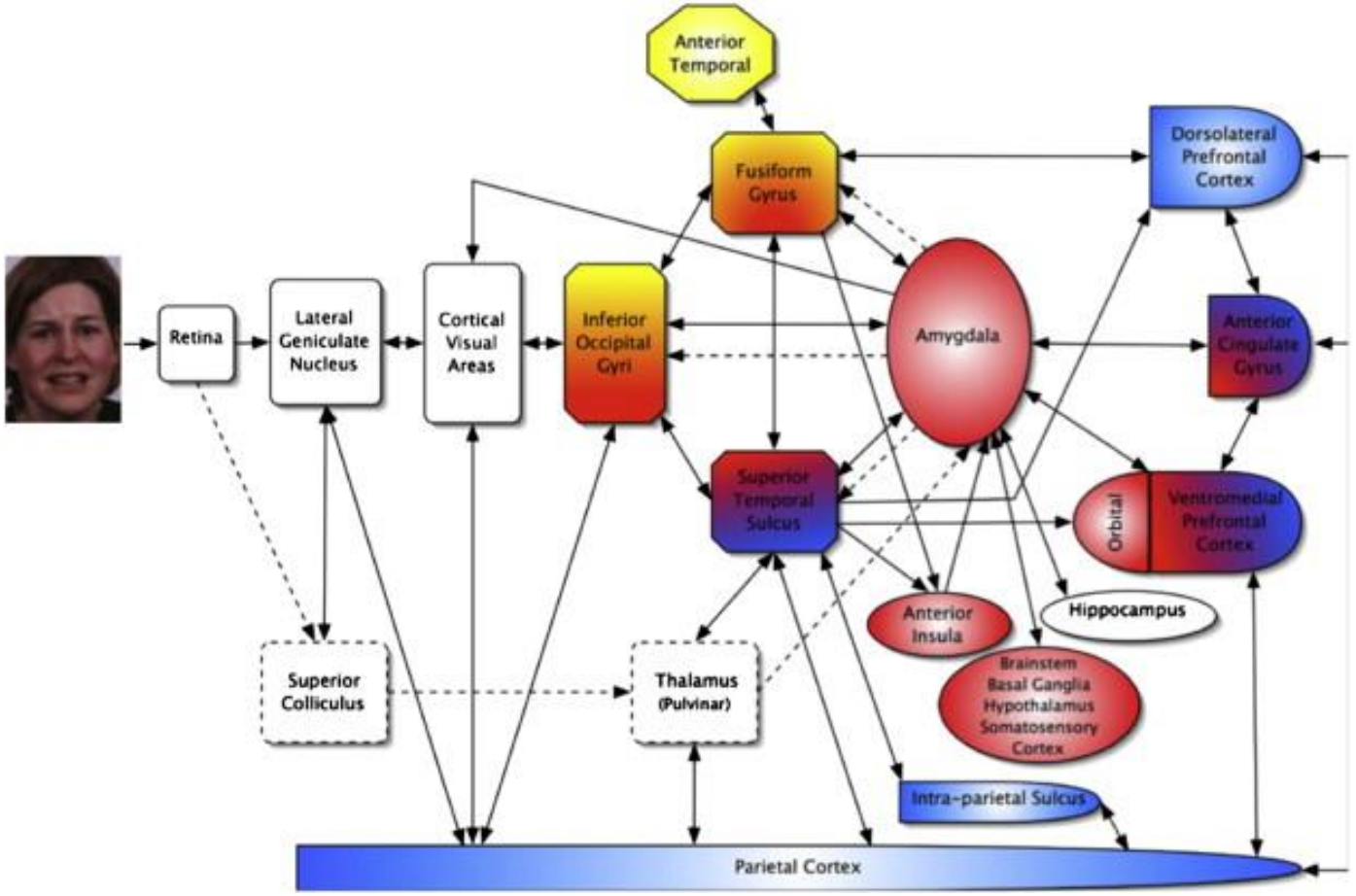
Kanwisher, McDermott, & Chun, 1997



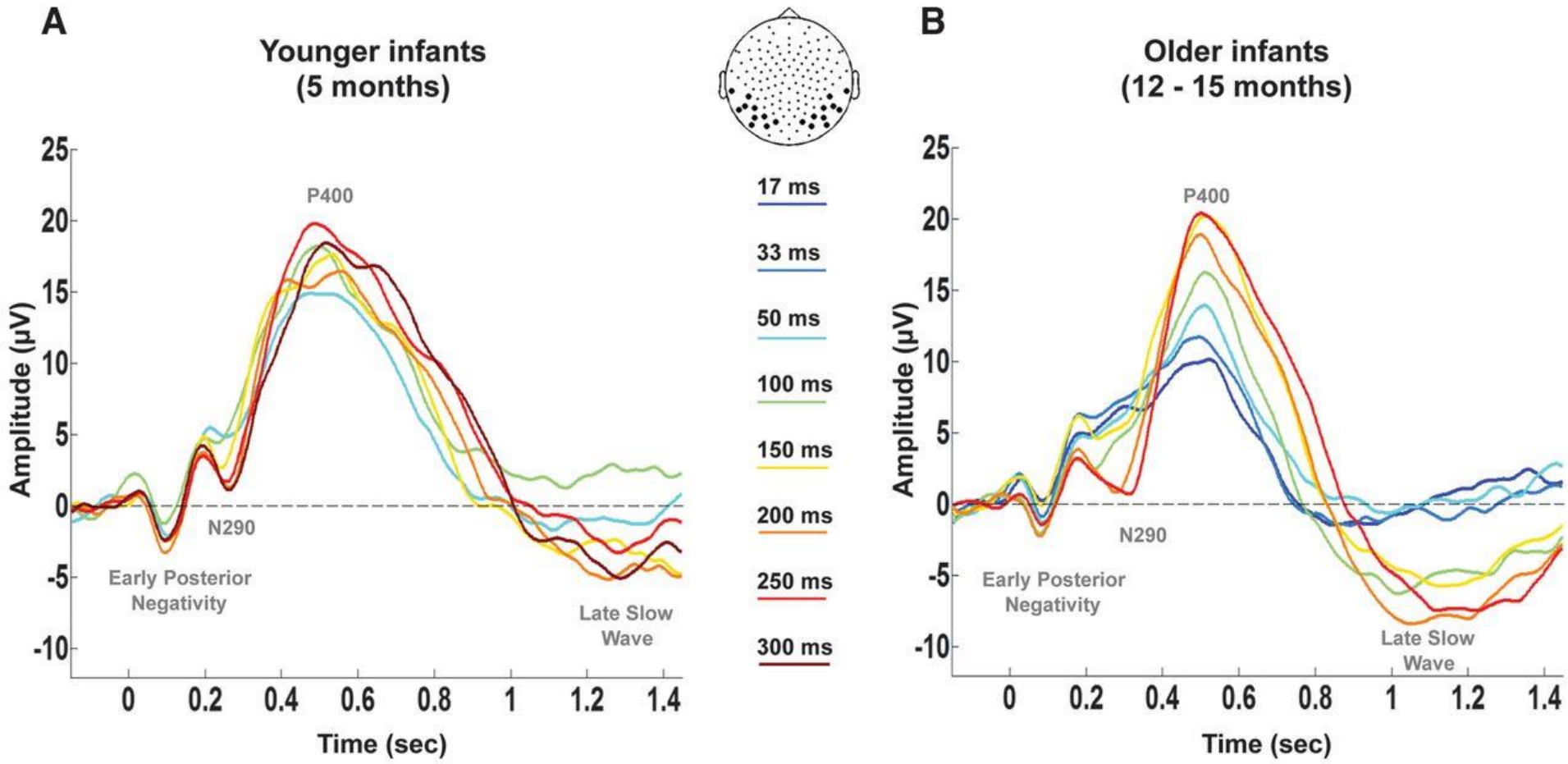


Face Processing

- Subcortical system
- Core system
- Extended system



Infant Face-Sensitive ERP Components?



The goal of this study:
What are the cortical sources of these infant ERP components?

Method

- Procedure
  - ECG recording & high-density EEG recording
    - EGI 128 channel recording
    - Referenced to the vertex
    - 250 Hz sampling rate
    - Bandpass filters .1~100 Hz
    - 100kΩ impedence

Method

- Procedure
  - Infant is seated on mother's lap in darkened room
  - A video camera records infant's looking
  - Experimenter controls stimulus presentation in an adjacent room

Methods

- Participants:
  - 14 4.5-month-old infants
  - 19 6-month-old infants
  - 15 7.5-month-old infants
- EEG recording:
  - Used a high-density EGI 128-channel HydroCel Geodesic Sensor Net
  - Recorded 124 channels of EEG, 2 channels of EOG, & 2 channels of ECG

Methods

Present faces and toys

Record EEG and compute average ERP components

Realistic head model from structural MRI of infants

Electrodes, atlas, lead field, realistic cortical sources

Current density reconstruction for each ERP slice

Participants

- Typical development (months)
- 4.5 (N = 25, Guy et al., Xie & Richards)
- 6.0 (N = 26, Guy et al., Xie & Richards)
- 7.5 (N = 19, Guy et al., Richards unpublished)
- 9 (N = 10, Richards, unpublished)
- 12 (N = 24, Guy et al., submitted; Richards, unpublished)

Methods

- Stimuli & Procedure
  - Infant is seated on mother's lap in darkened room
  - A video camera records infant's looking
  - Experimenter controls stimulus presentation in an adjacent room
  - A series of brief stimulus presentations (500 ms) and paired comparison trials (4
    - Mother's face
    - Unfamiliar female's face
    - Own toy
    - Unfamiliar toy

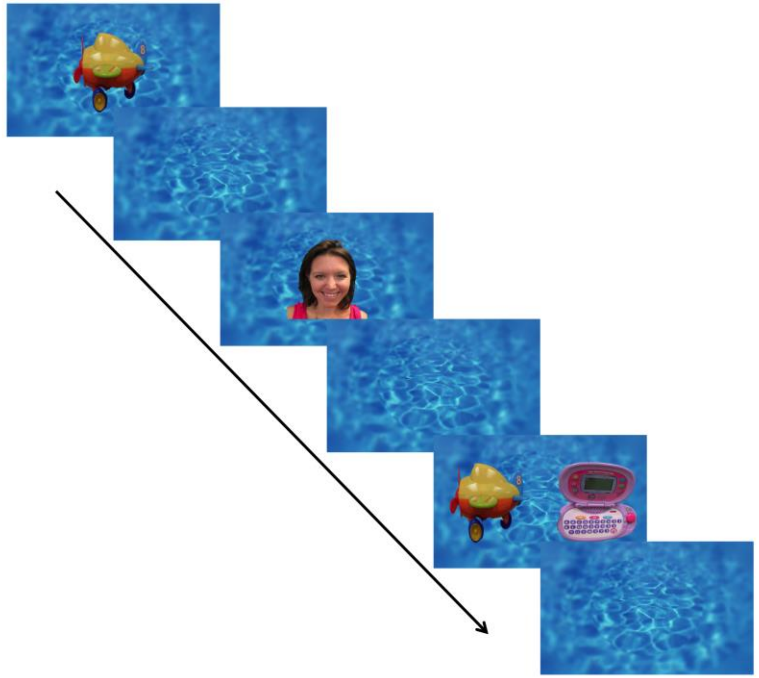
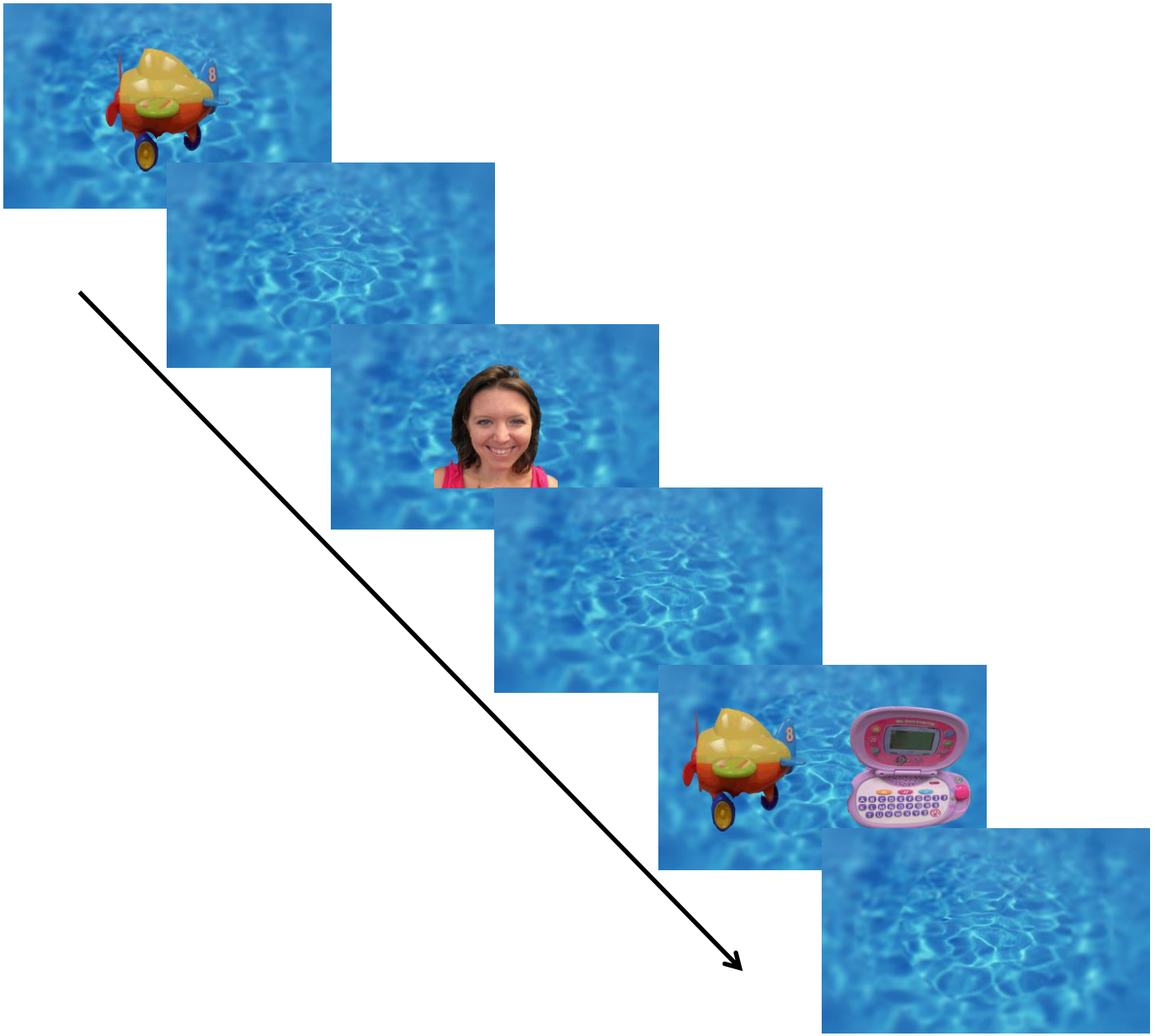
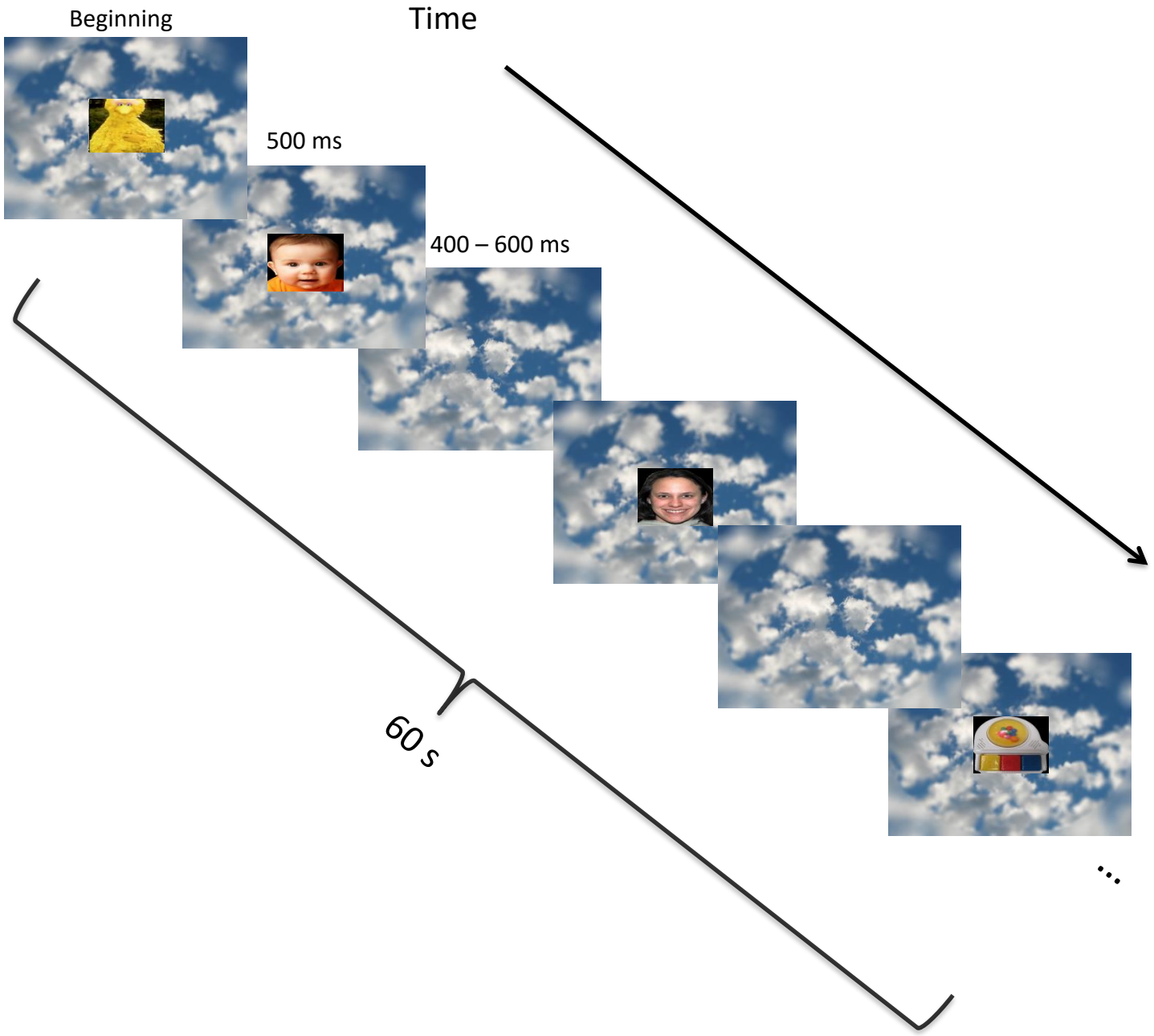
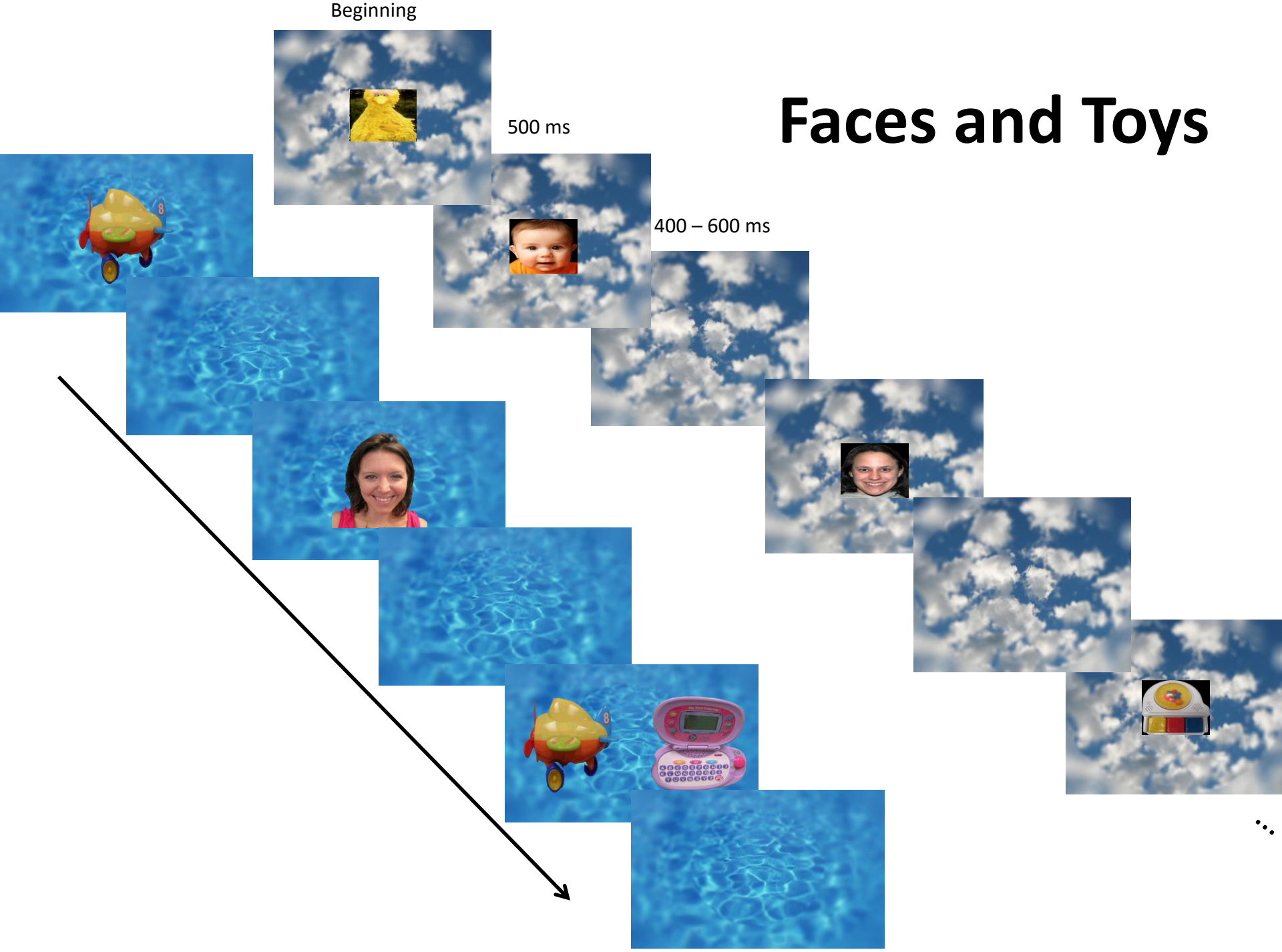


Fig. 1. Sample stimulus presentations in a trial block. Each block included two 4 s visual paired comparisons (faces, toys) and two 500 ms brief presentations of each of the face (mother's, stranger's) and toy (familiar, novel) stimuli. There was a variable inter-trial interval of 500-1500 ms between each slide.




Beginning
Time
500 ms
400 – 600 ms
60 s

Faces and Toys



High-Density Scalp-Recorded EEG

Figure 1. *Grand average ERP activity across HGSN Electrodes and virtual 10-10 electrode clusters*

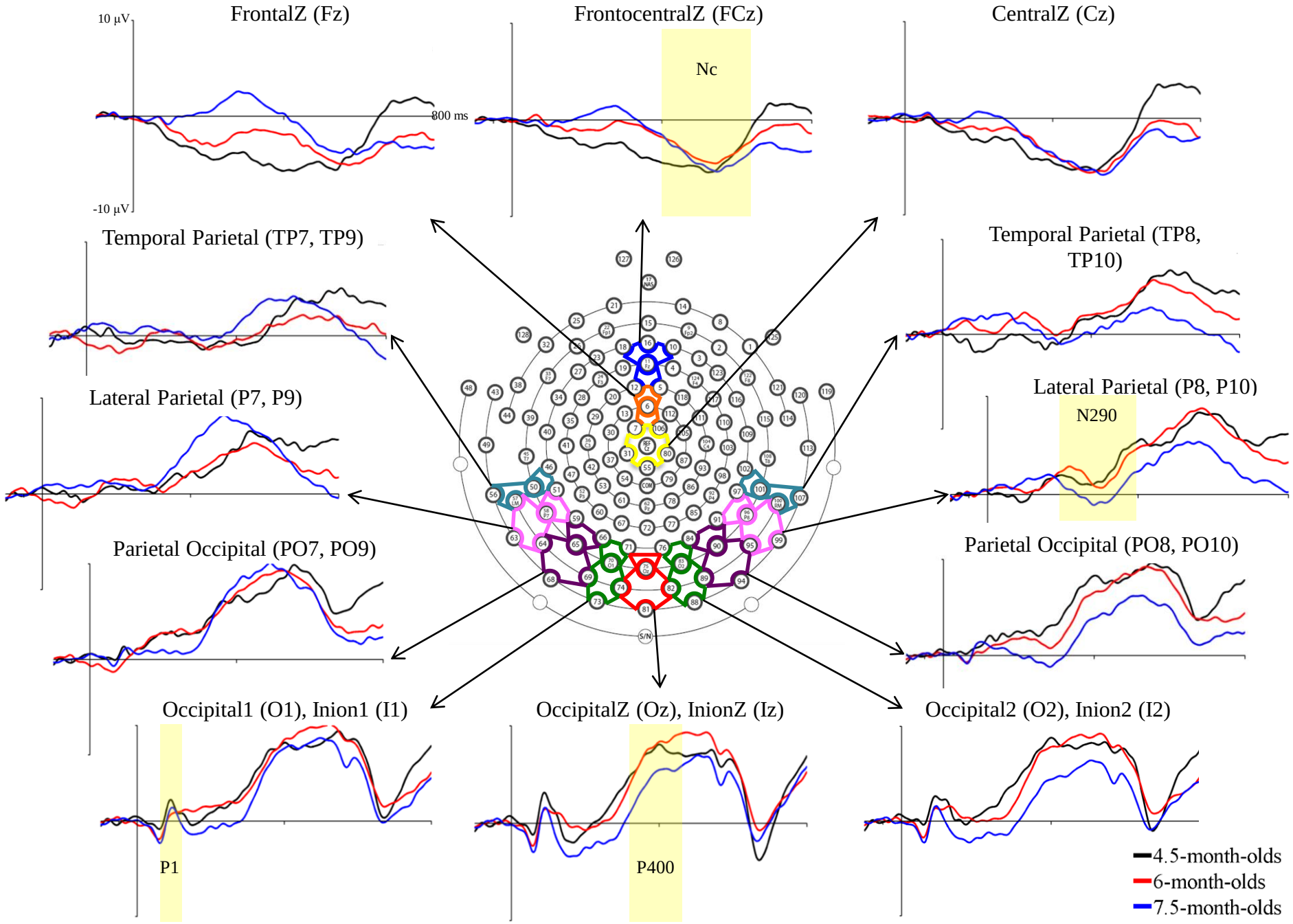
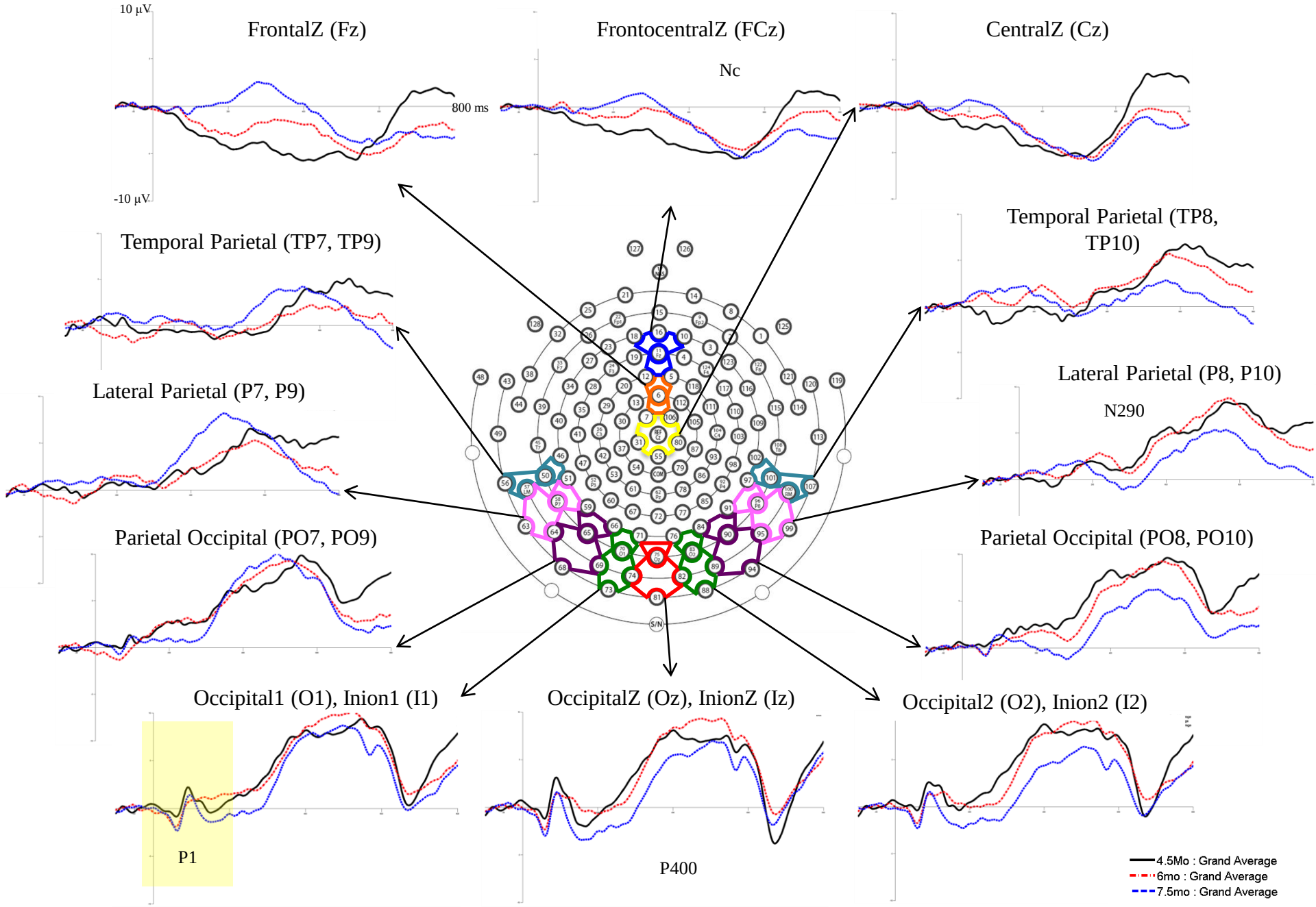
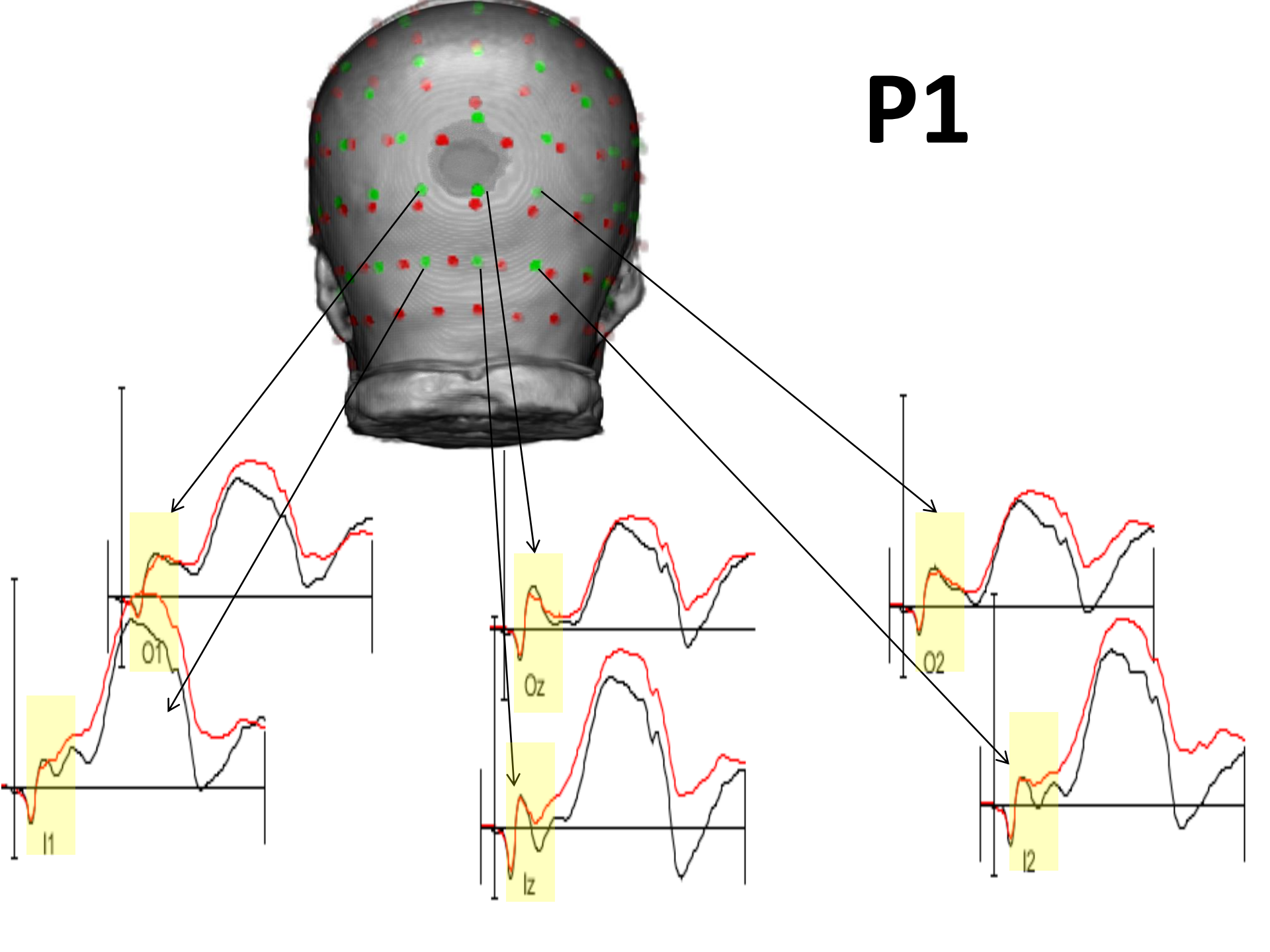


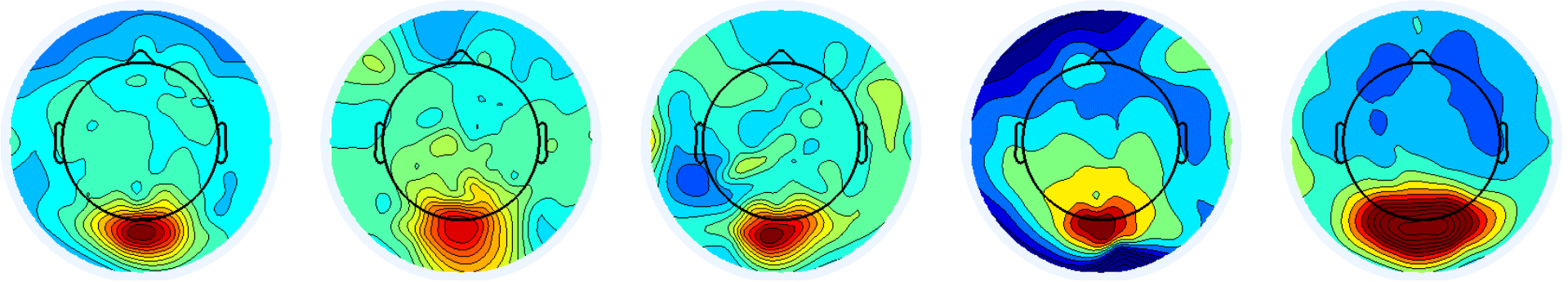
Figure 1. *Grand average ERP activity across HGSN Electrodes and virtual 10-10 electrode clusters*



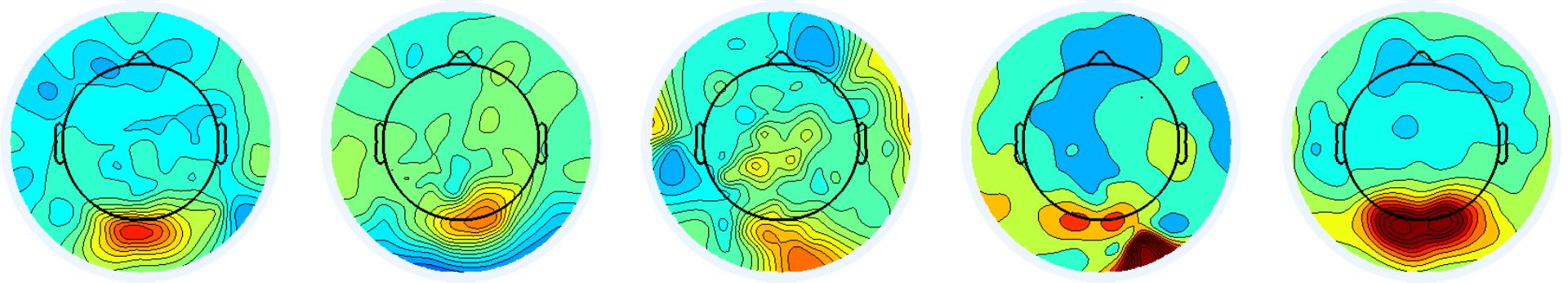

P1
O1
Oz
O2
I1
Iz
I2

Topographical Scalp Potential Maps, Peak P1 +/- 20 ms

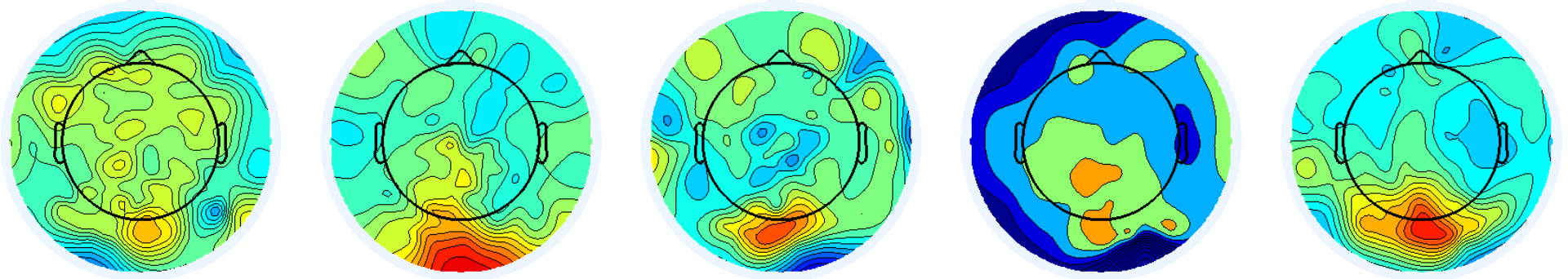
Faces



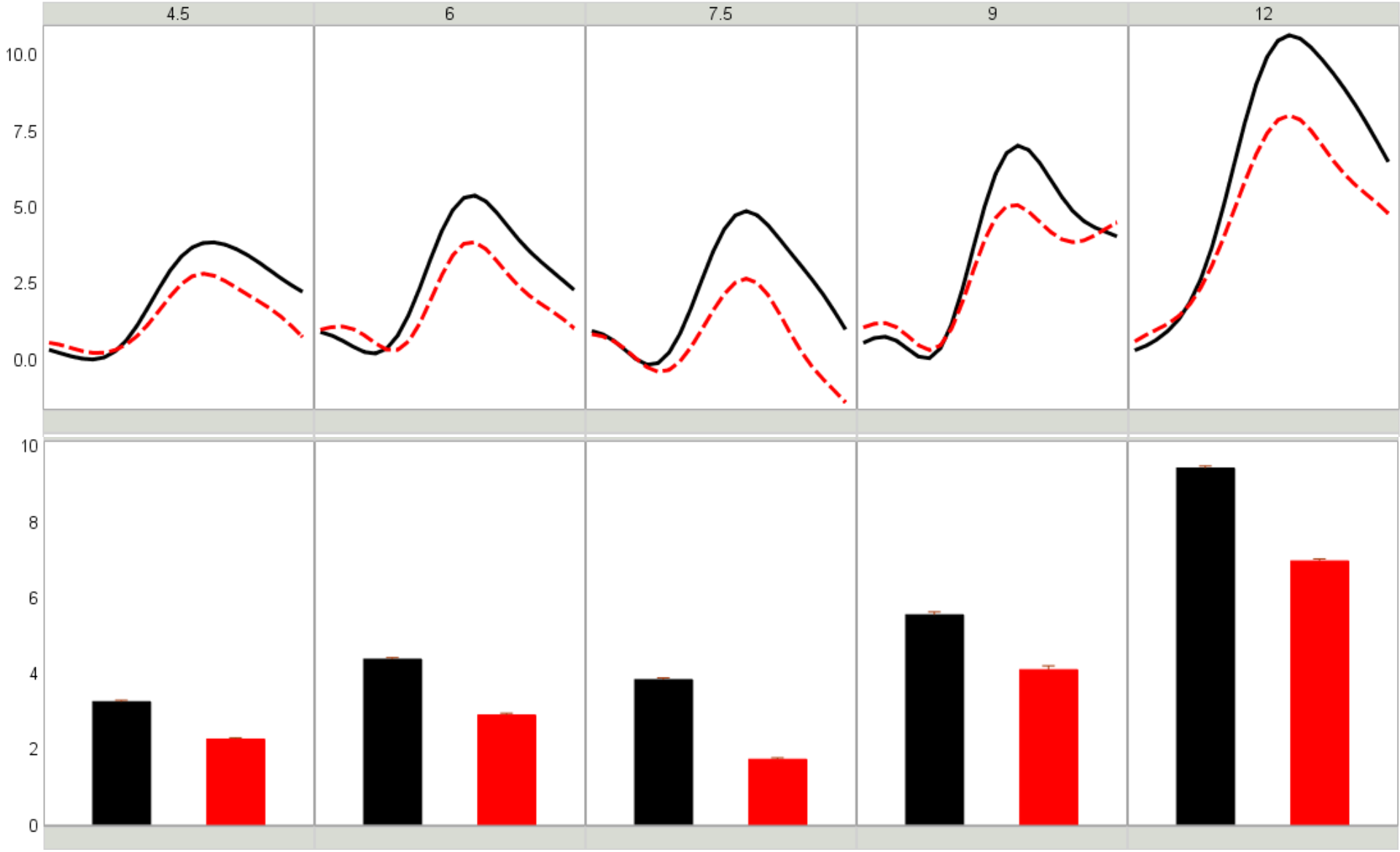
Toys



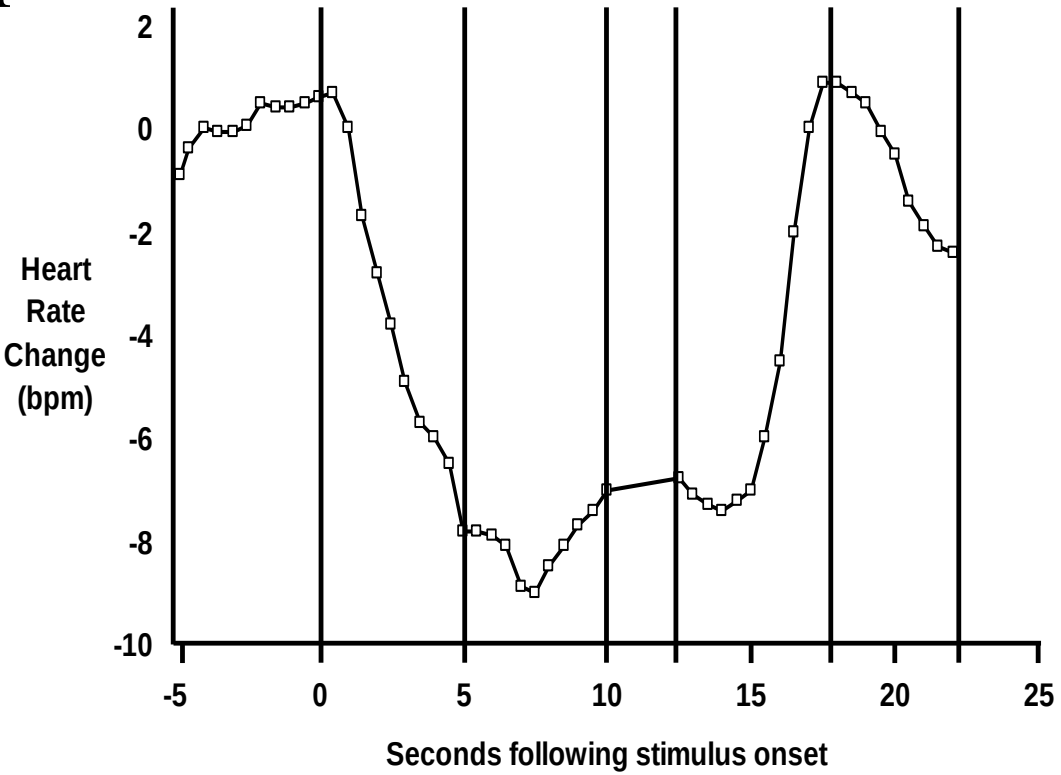
Faces minus Tovs

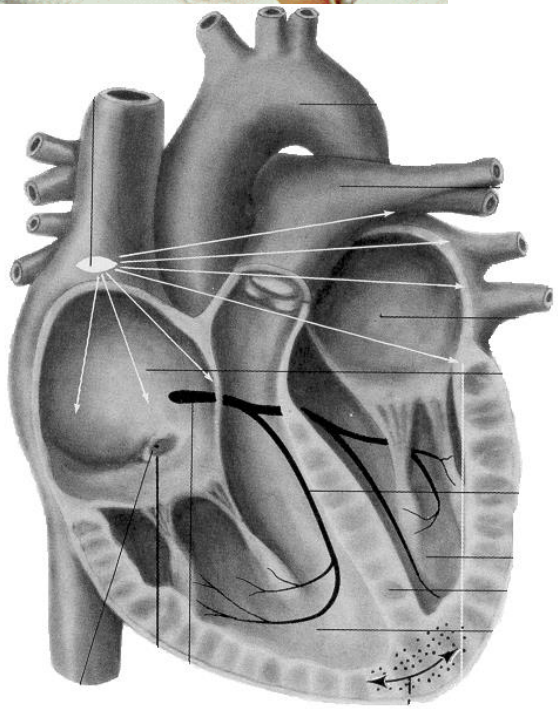


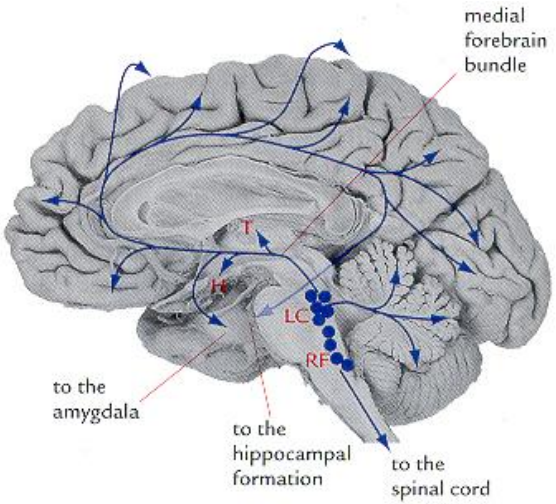
ERP at Peak P1, +/- 40 ms, Faces and Toys

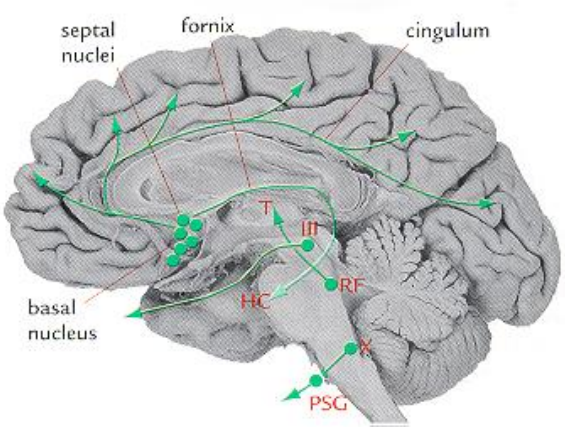


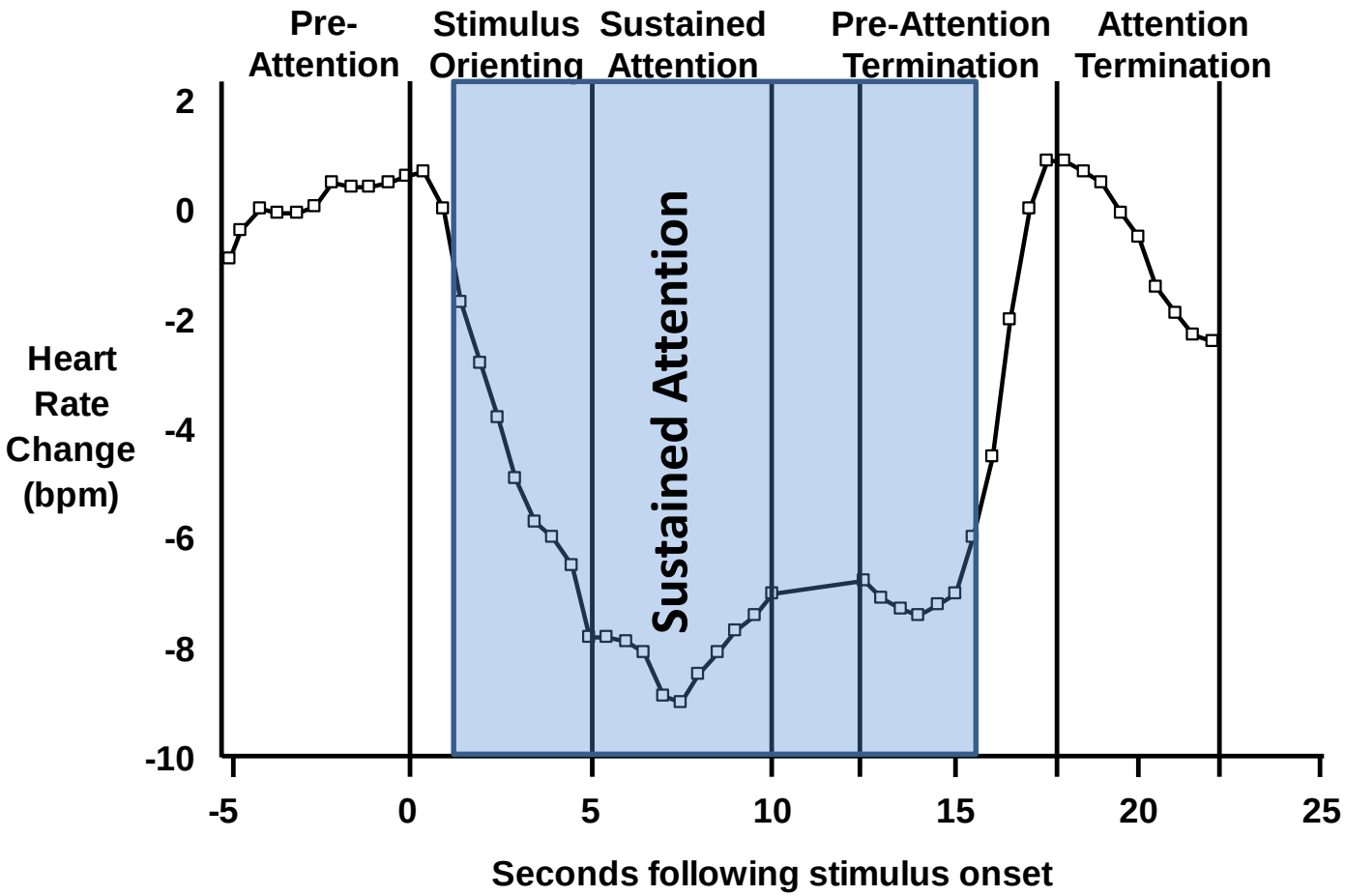
“Model Preparation” for attention










Pre-Attention
Stimulus Orienting
Sustained Attention
Pre-Attention Termination
Attention Termination
Sustained Attention
Heart Rate Change (bpm)
2
0
-2
-4
-6
-8
-10
-5
0
5
10
15
20
25
Seconds following stimulus onset

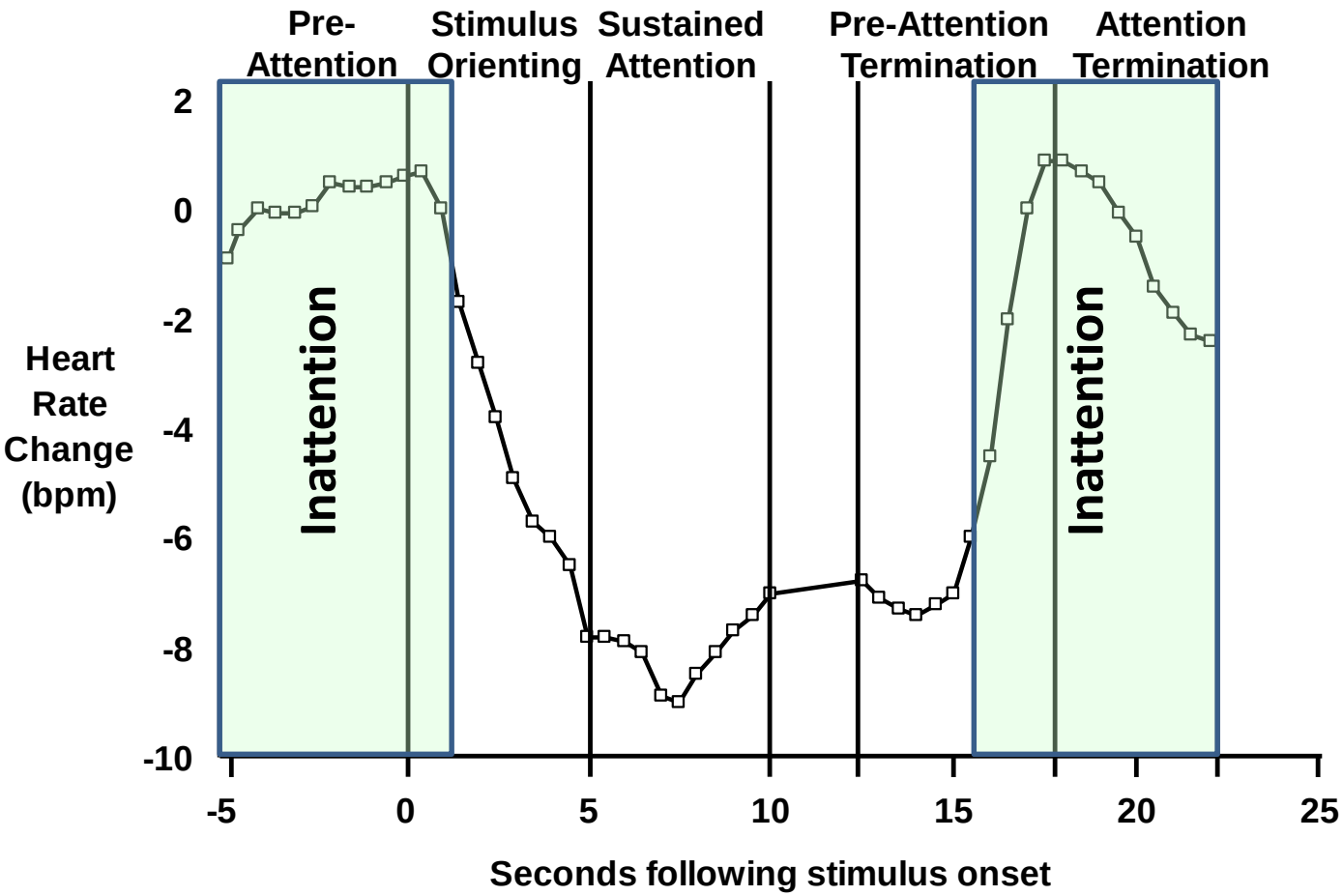

Pre-Attention
Stimulus Orienting
Sustained Attention
Pre-Attention Termination
Attention Termination
Inattention
Inattention
Heart Rate Change (bpm)
2
0
-2
-4
-6
-8
-10
-5
0
5
10
15
20
25
Seconds following stimulus onset

Figure 3a—Topographical scalp potential maps for peak of P1 (-20 to +20 ms), for attention effects, separate for ages

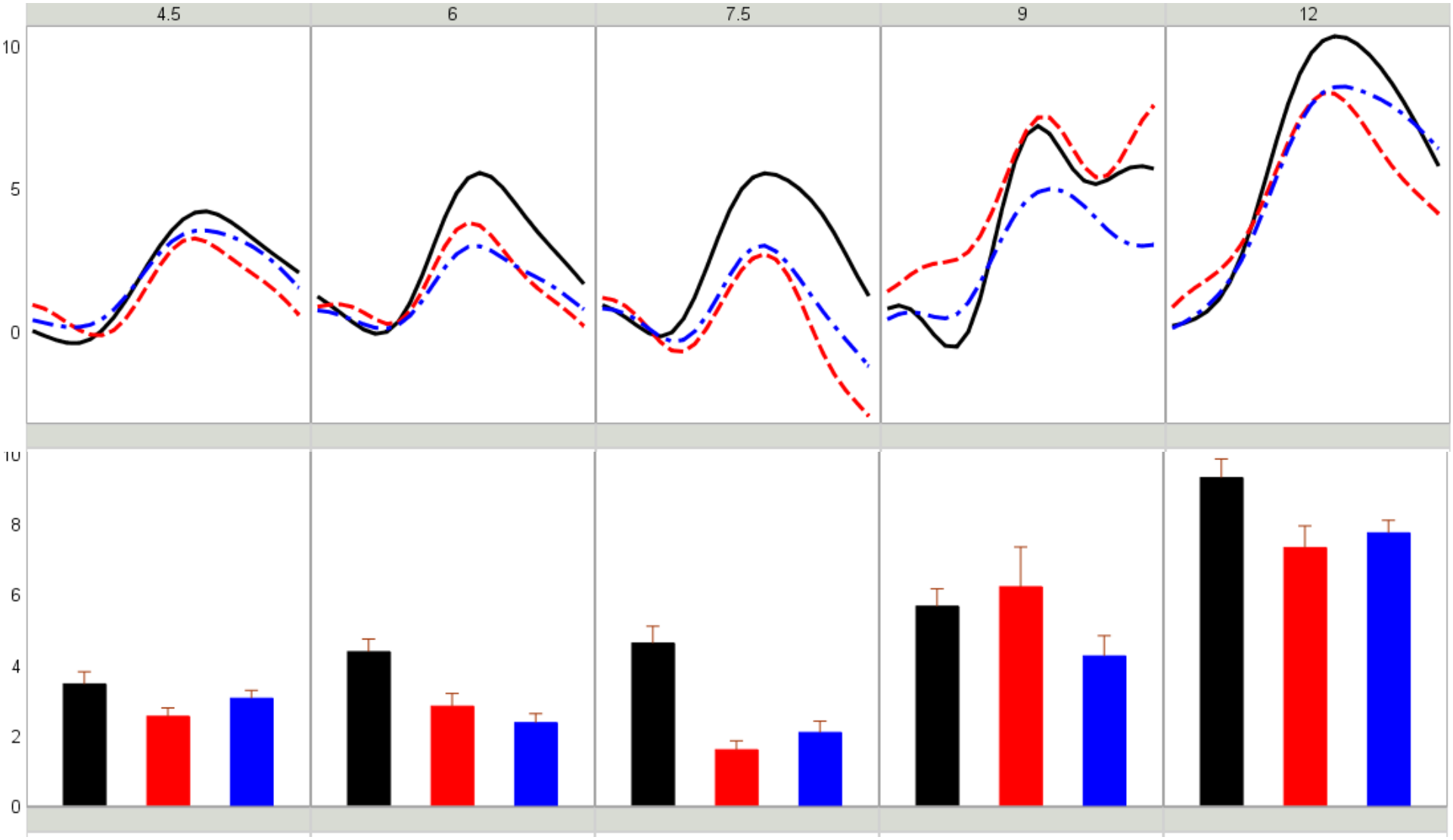
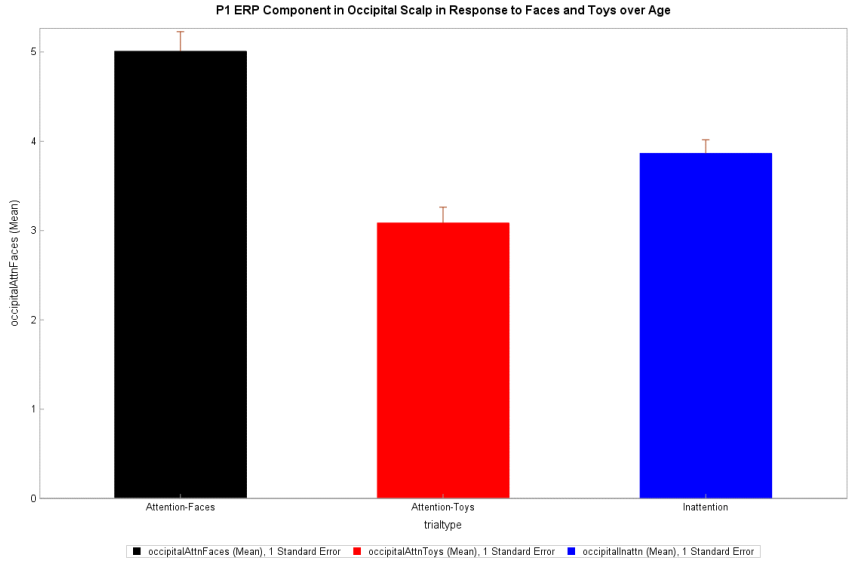


Figure 3a—Topographical scalp potential maps for peak of P1 (-20 to +20 ms), for attention effects, averaged over age



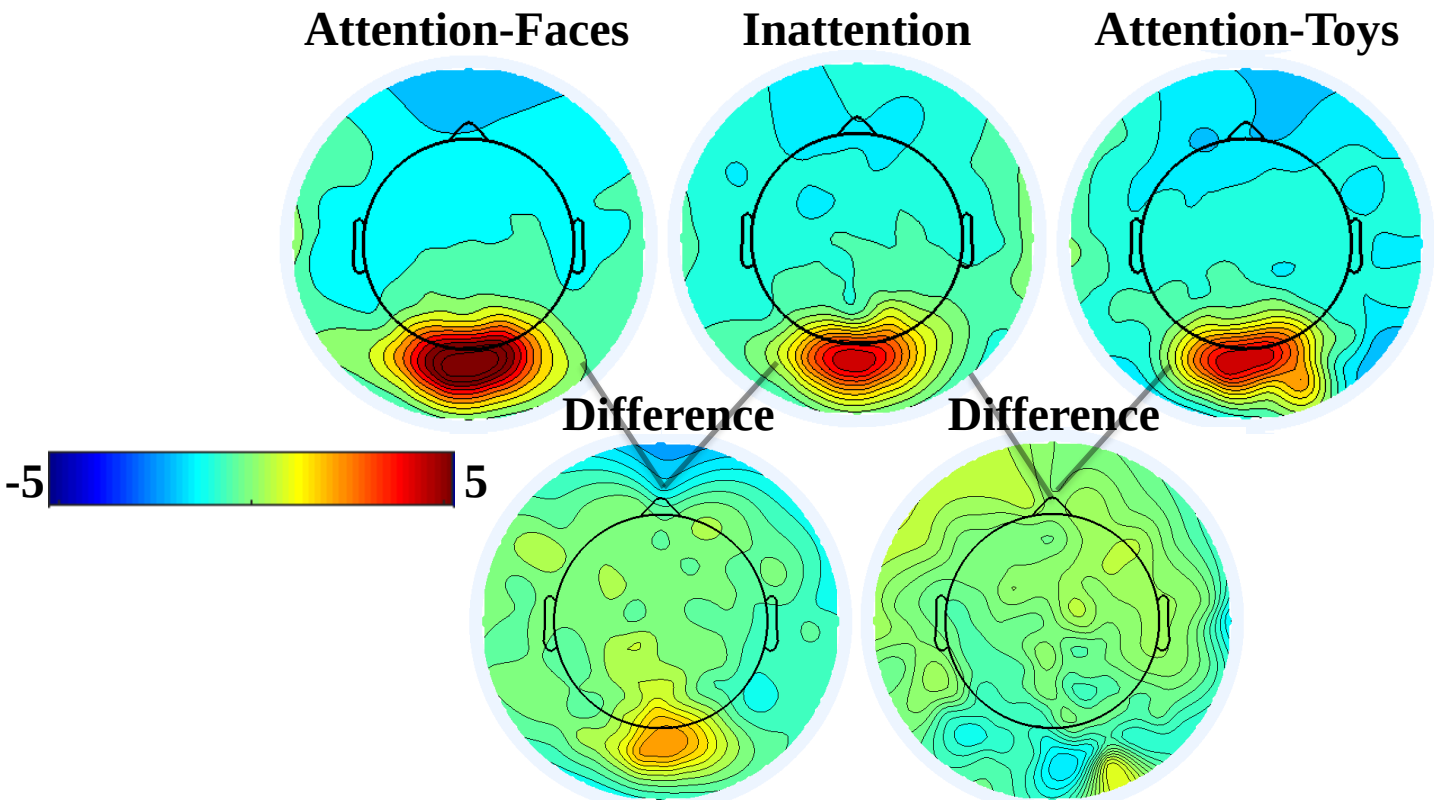
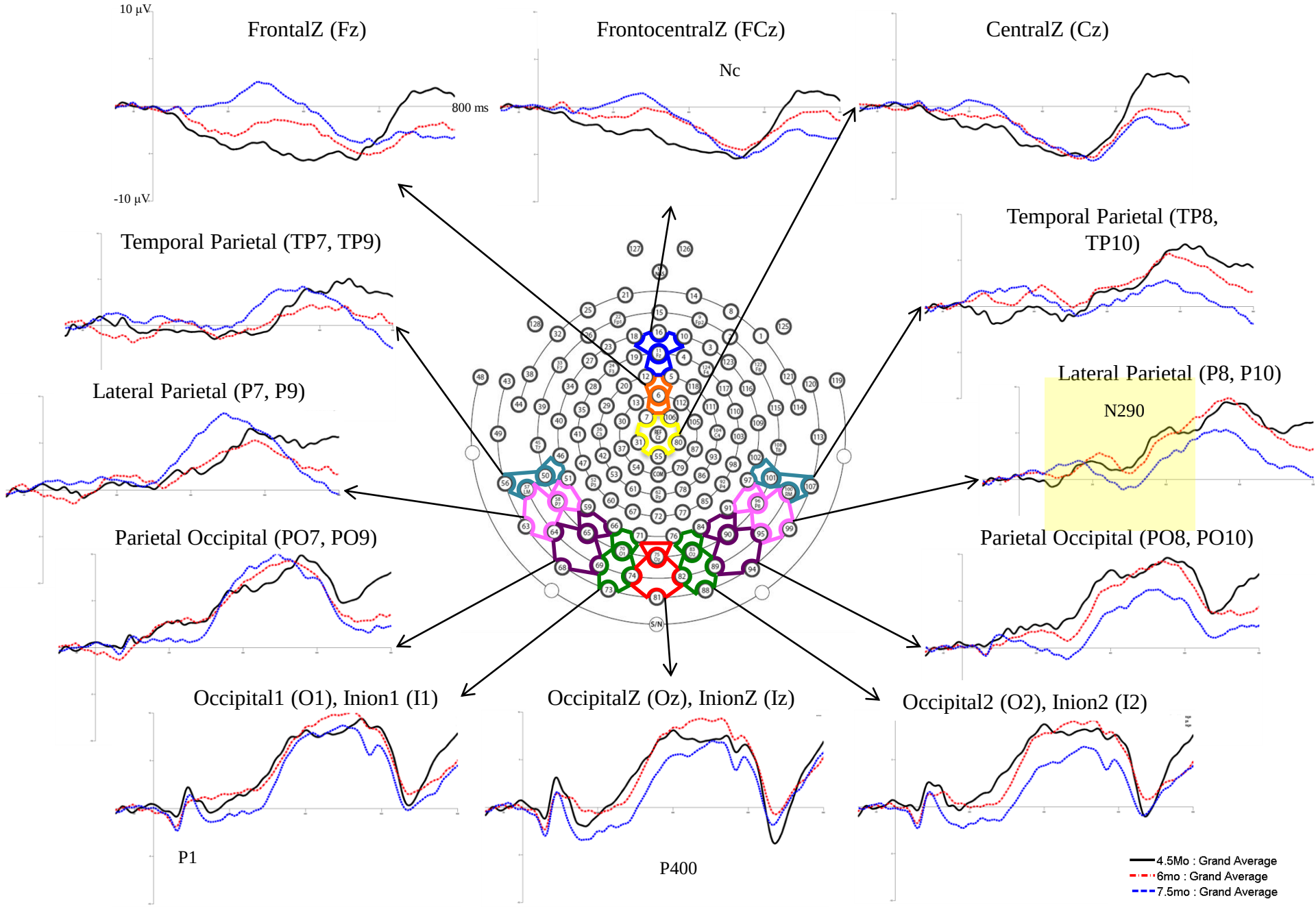
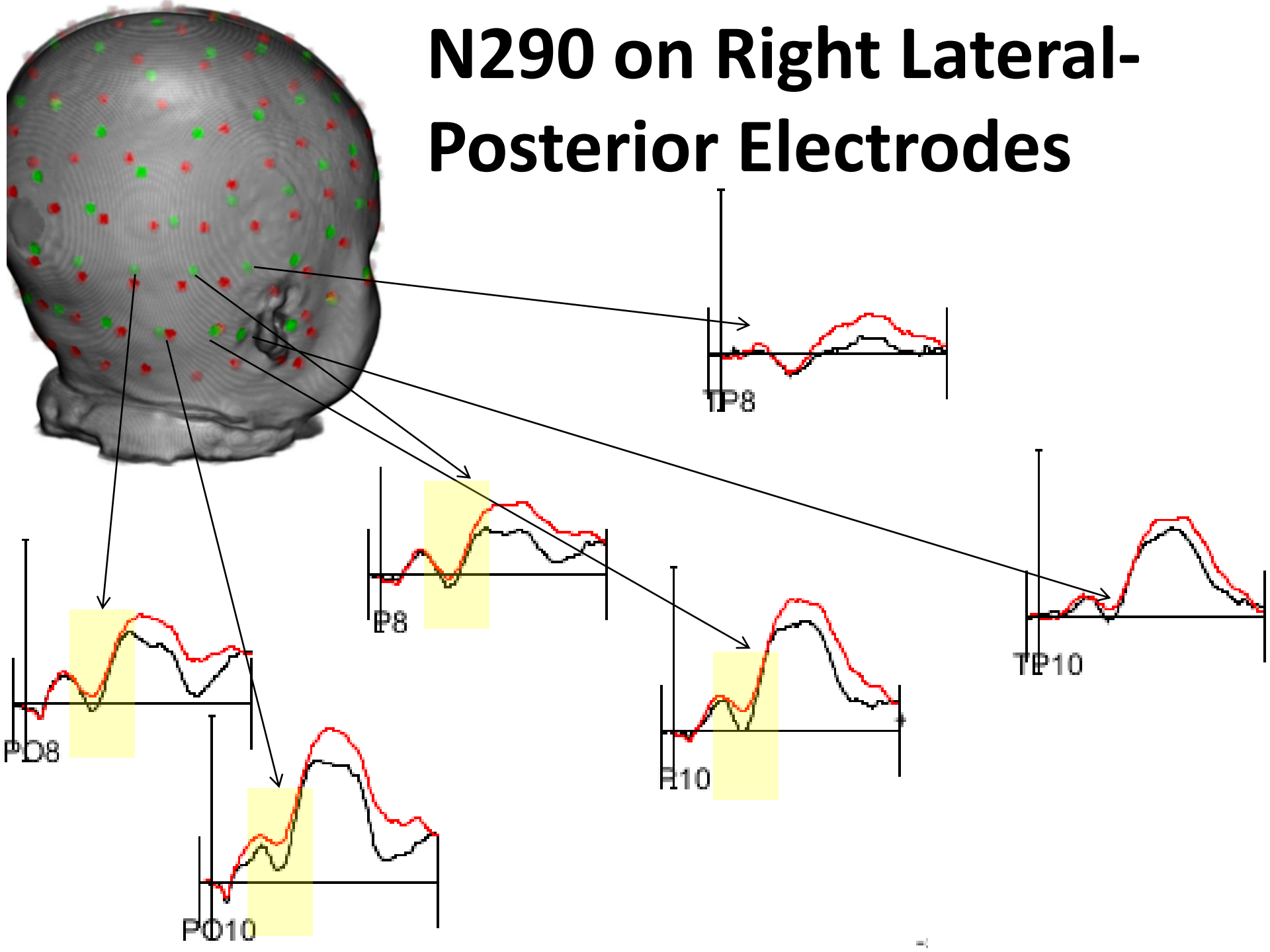


Figure 1. *Grand average ERP activity across HGSN Electrodes and virtual 10-10 electrode clusters*

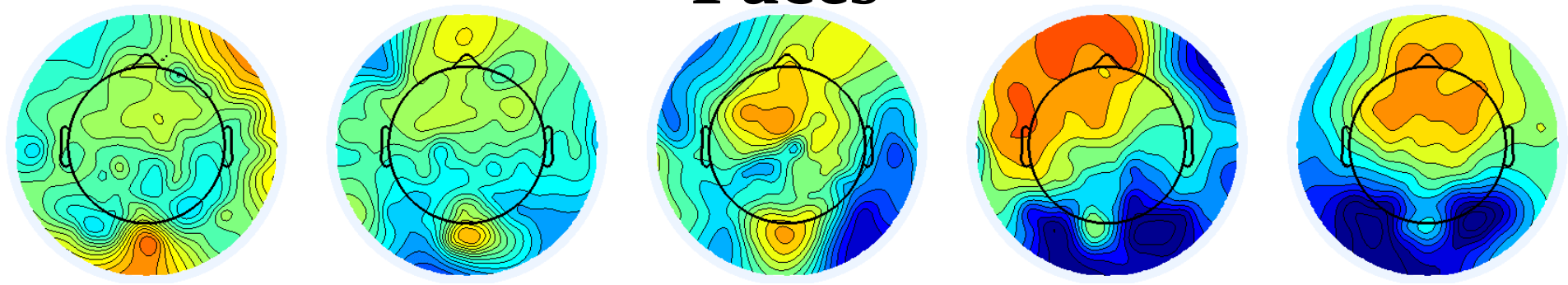


N290 on Right Lateral-Posterior Electrodes



Topographical Scalp Potential Maps, Peak N290 +/- 20 ms

Faces



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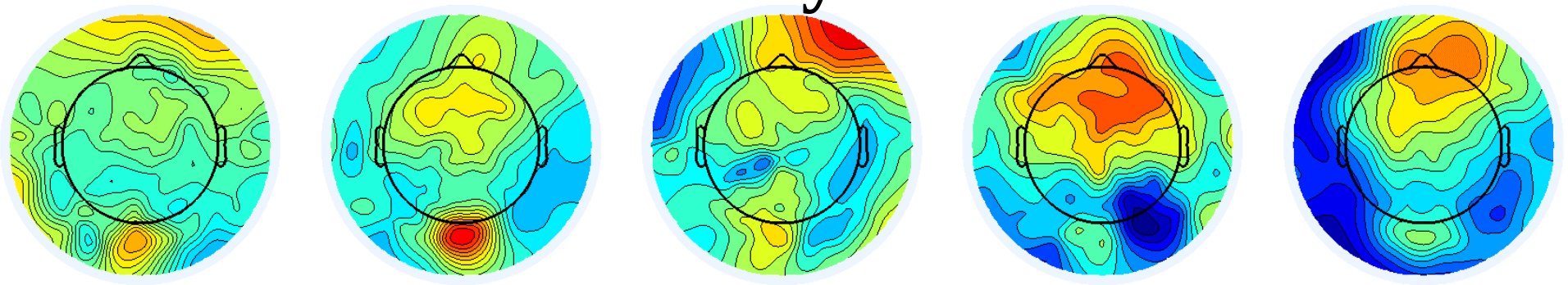
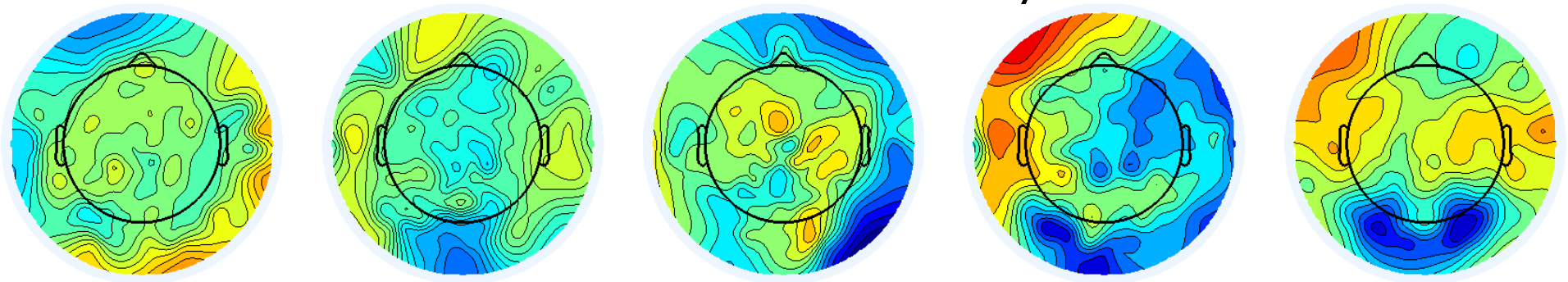
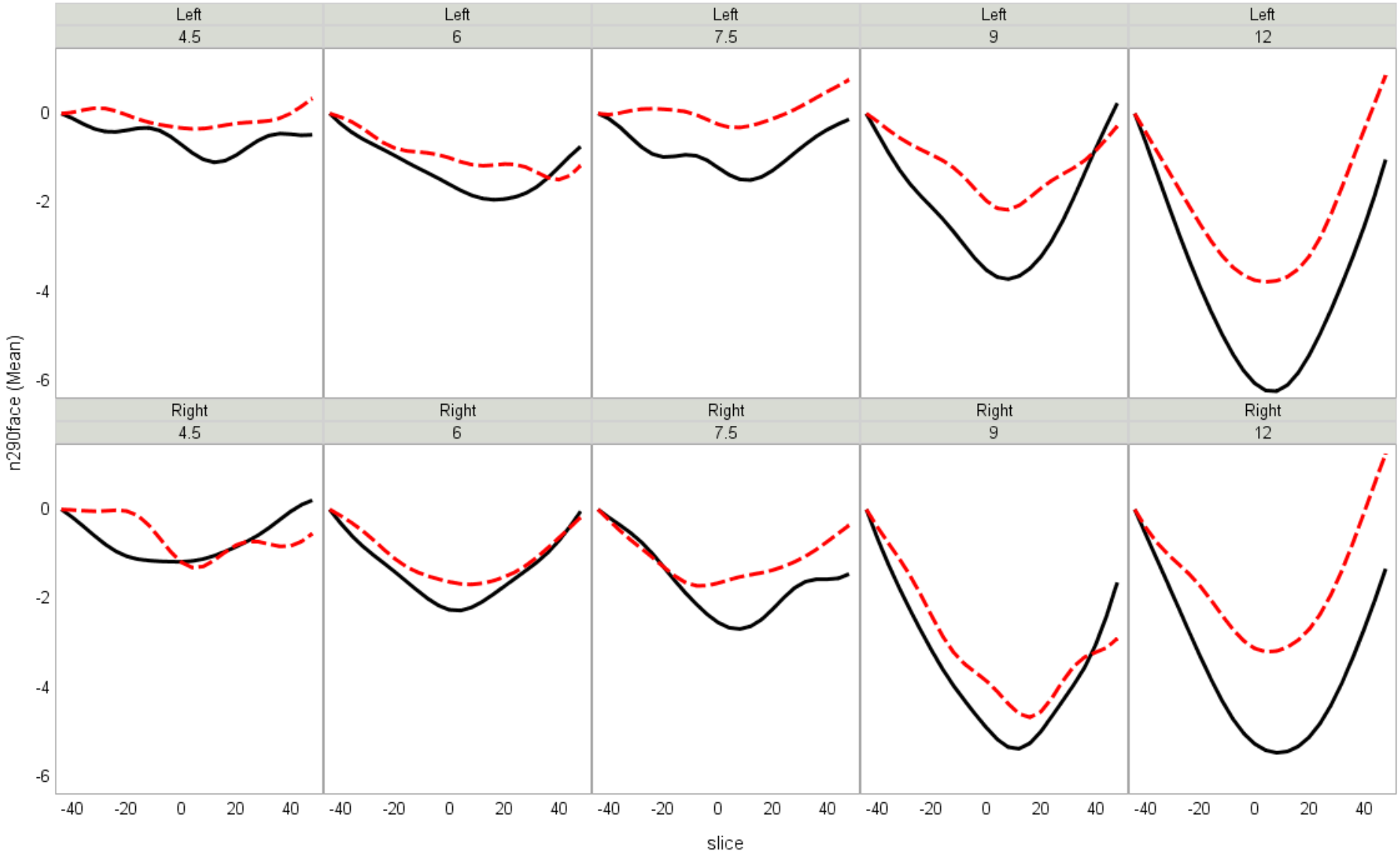
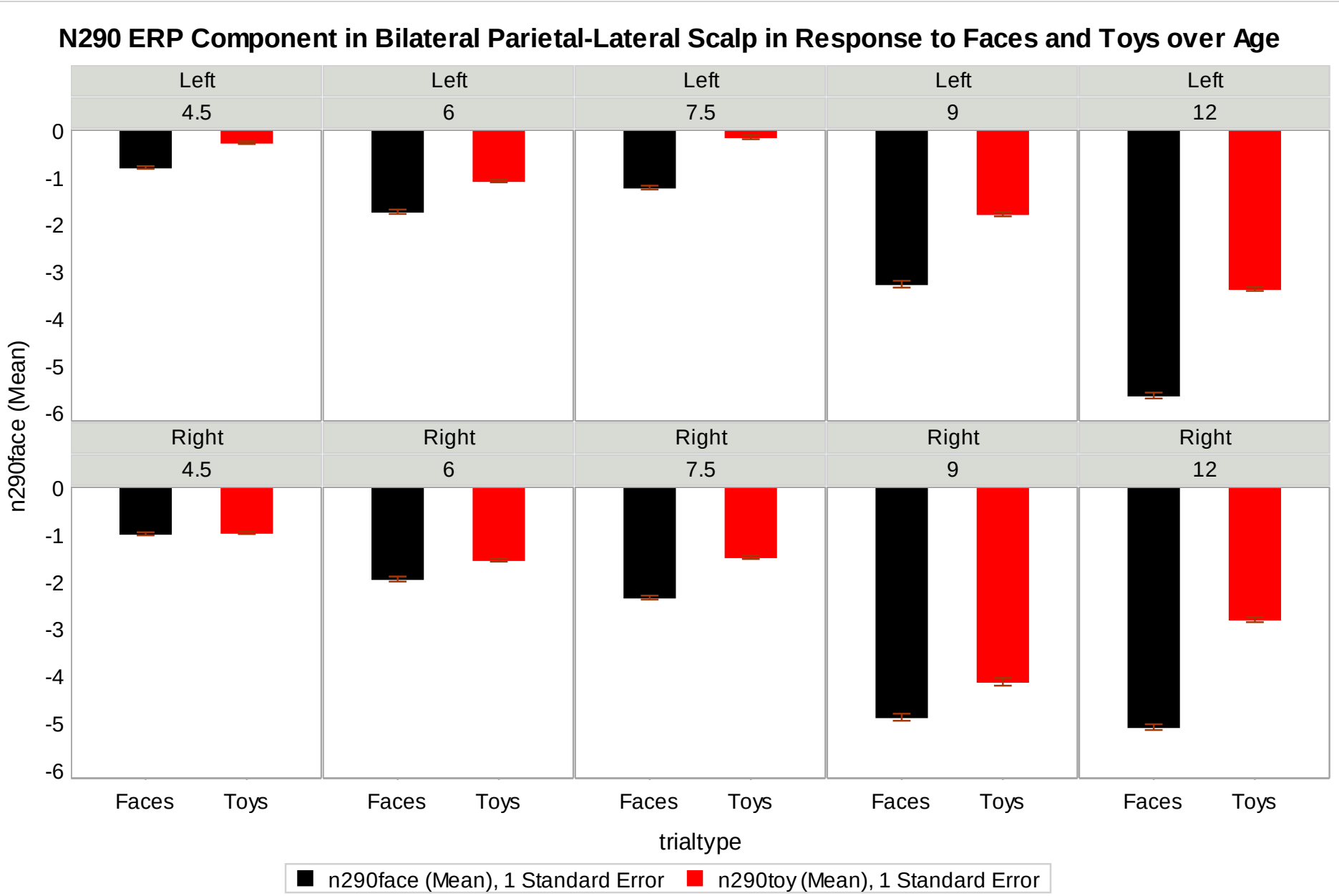


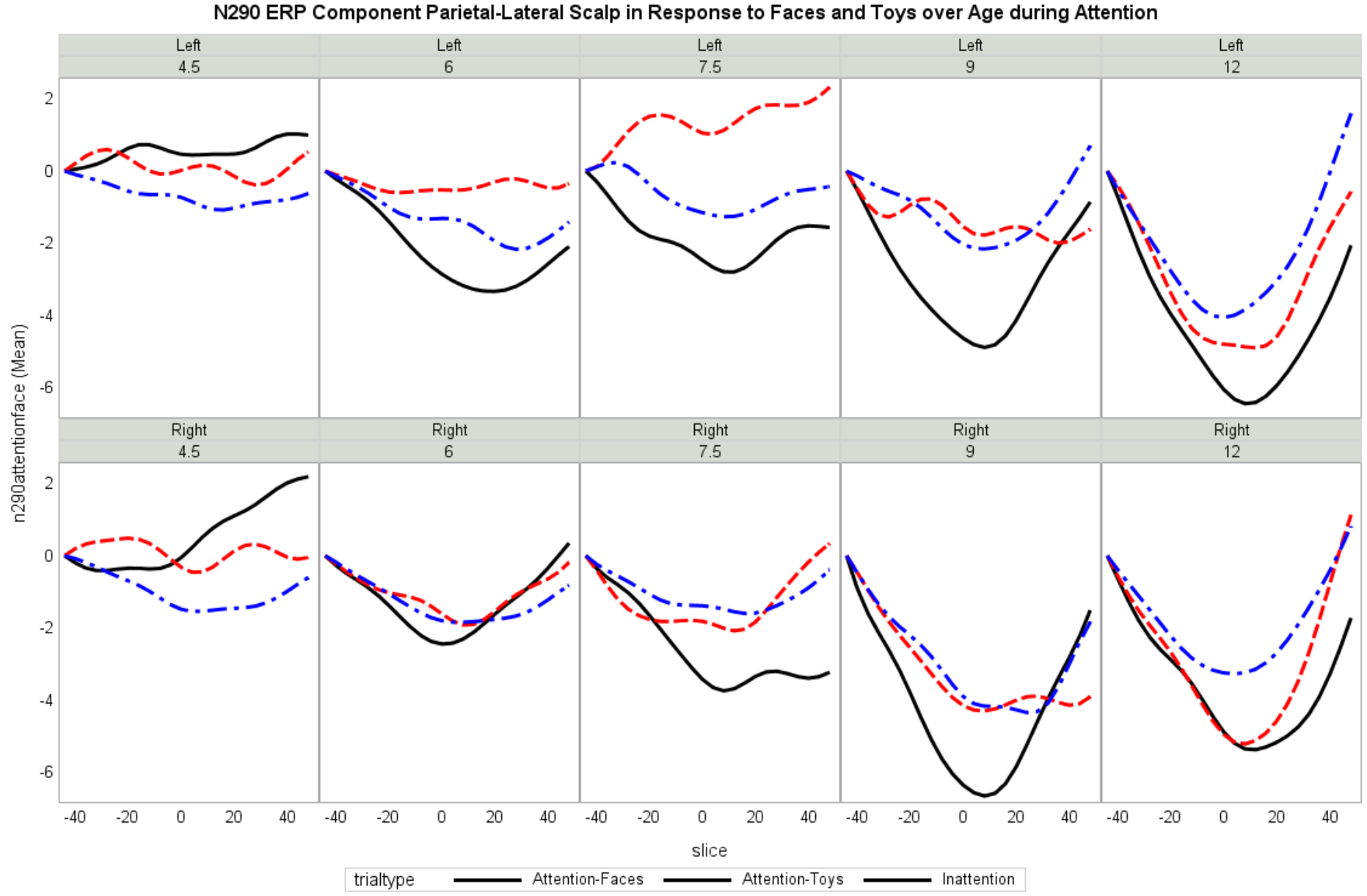
Faces minus Toys



ERP at Peak N290, +/- 40 ms, Faces and Toys




N290 ERP Component in Bilateral Parietal-Lateral Scalp in Response to Faces and Toys over Age
Left
Right
4.5
6
7.5
9
12
n290face (Mean)
0
-1
-2
-3
-4
-5
-6
Faces
Toys
trialtype
n290face (Mean), 1 Standard Error
n290toy (Mean), 1 Standard Error


N290 ERP Component Parietal-Lateral Scalp in Response to Faces and Toys over Age during Attention
Left
4.5
Left
6
Left
7.5
Left
9
Left
12
Right
4.5
Right
6
Right
7.5
Right
9
Right
12
n290attentionface (Mean)
2
0
-2
-4
-6
-40
-20
0
20
40
slice
trialtype
Attention-Faces
Attention-Toys
Inattention

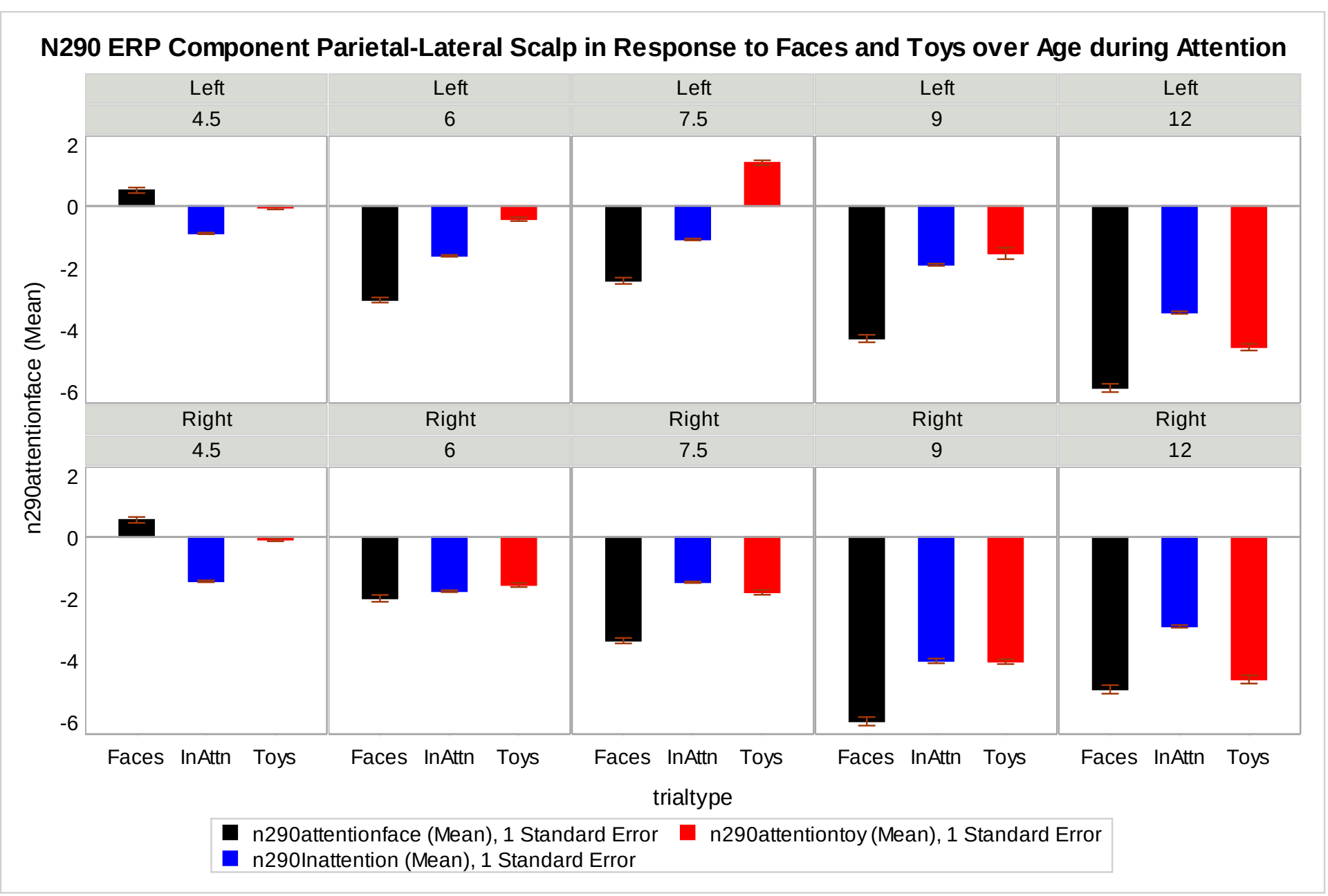
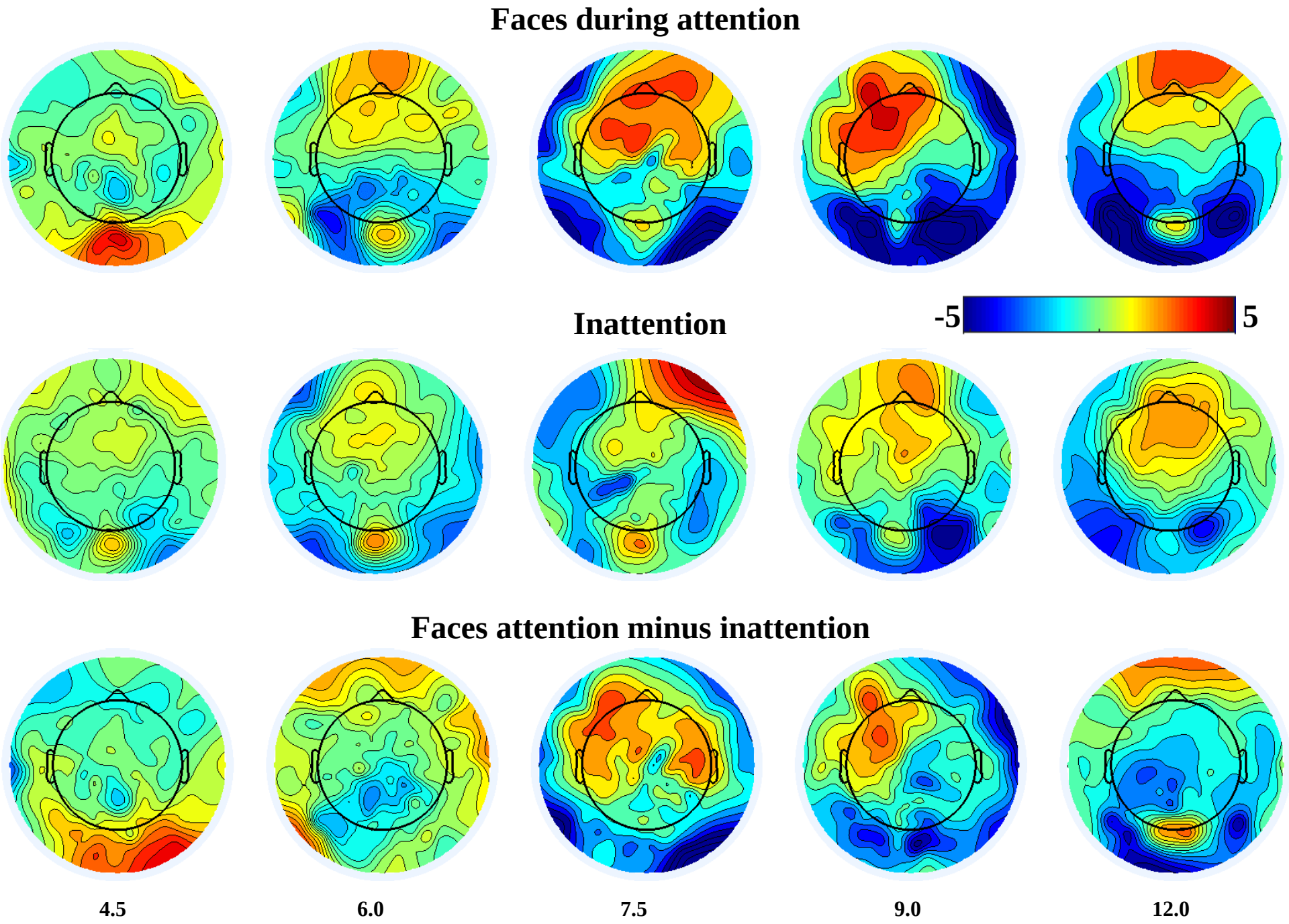
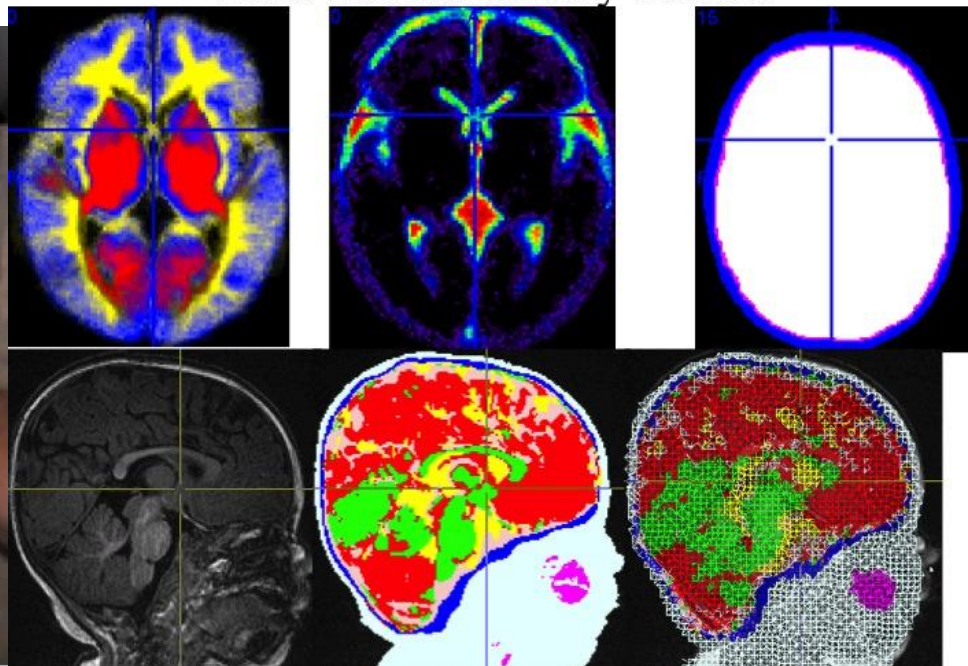

N290 ERP Component Parietal-Lateral Scalp in Response to Faces and Toys over Age during Attention
Left
4.5
6
7.5
9
12
Right
n290attentionface (Mean)
2
0
-2
-4
-6
Faces
InAttn
Toys
trialtype
n290attentionface (Mean), 1 Standard Error
n290attentiontoy (Mean), 1 Standard Error
n290Inattention (Mean), 1 Standard Error

Figure nna—Topographical scalp potential maps for peak of N290 (-20 to +20 ms), for attention faces, inattention, and difference

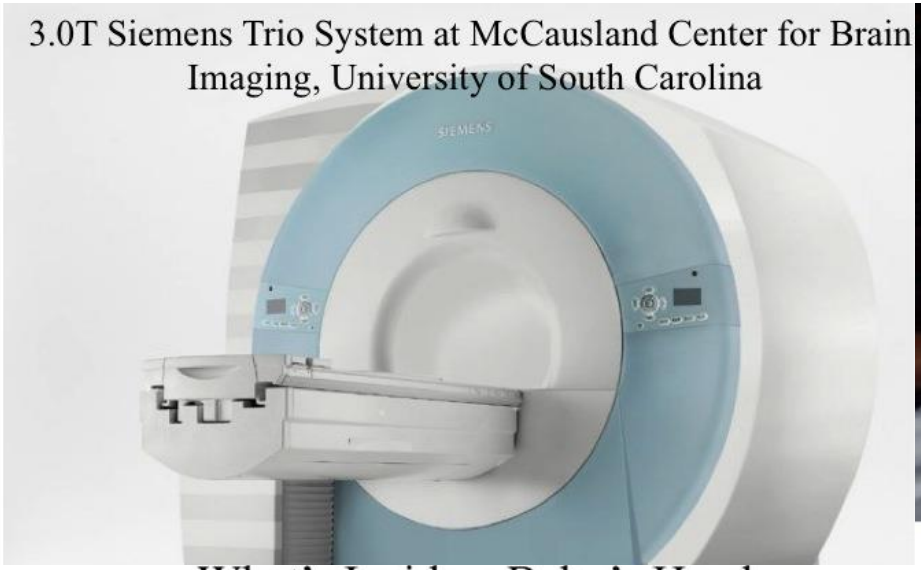


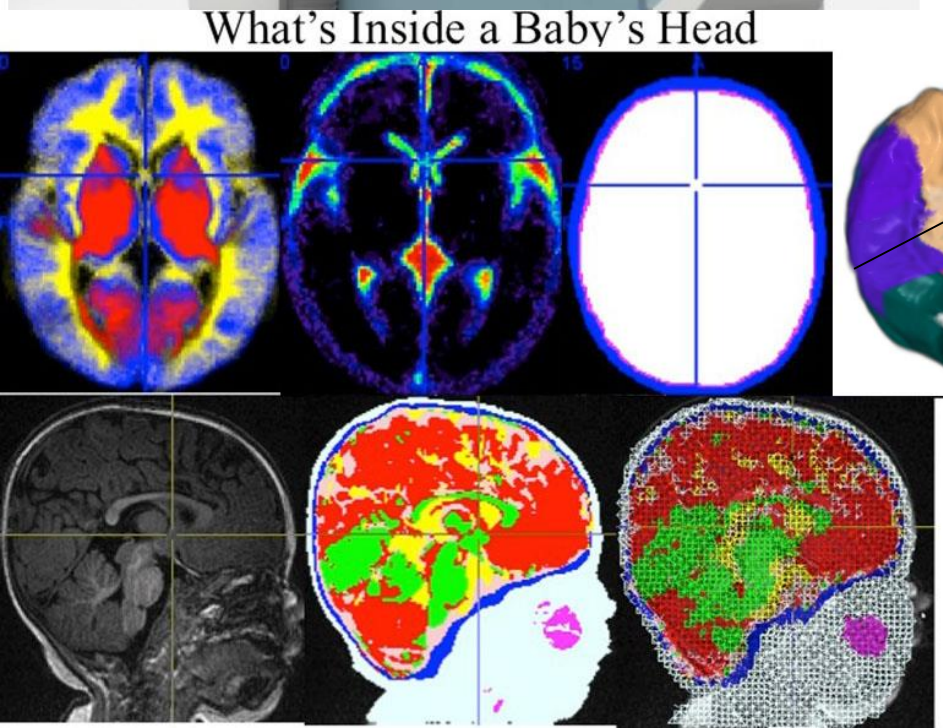
Individual Structural MRI and Source Model

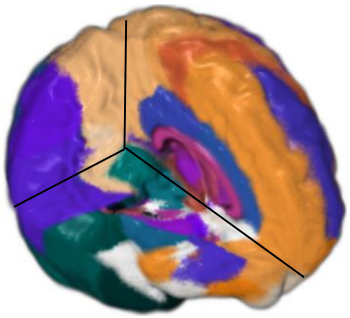
What's Inside a Baby's Head

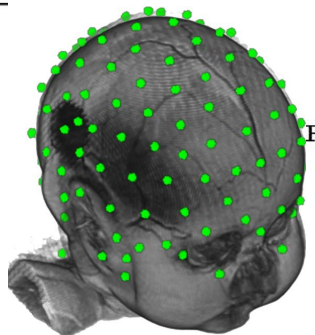


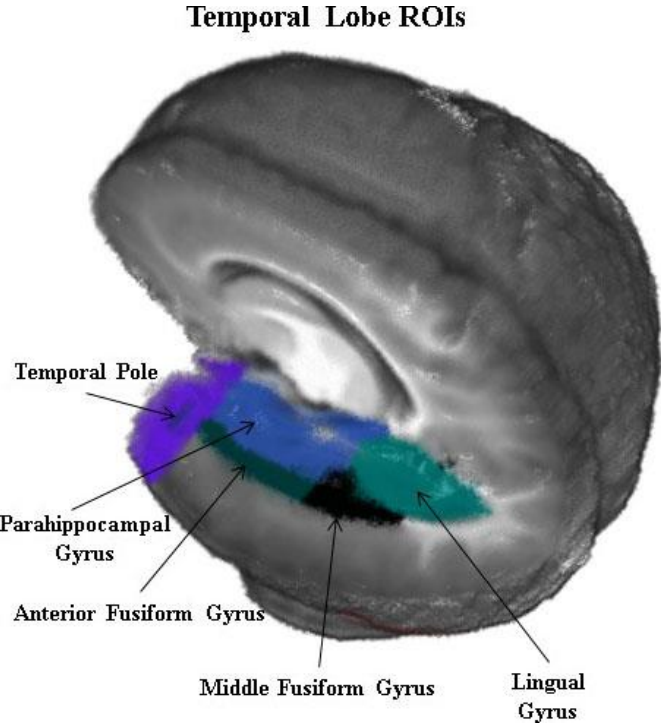
Individual Structural MRI and Source Model











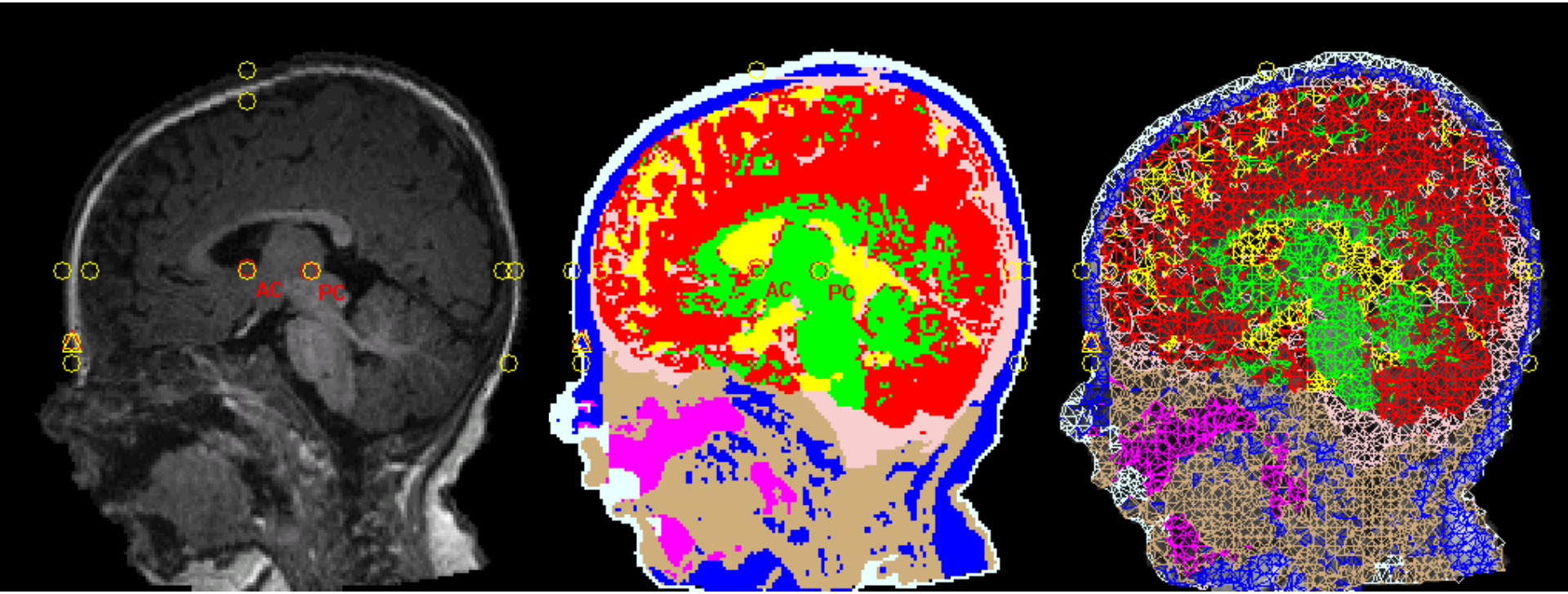
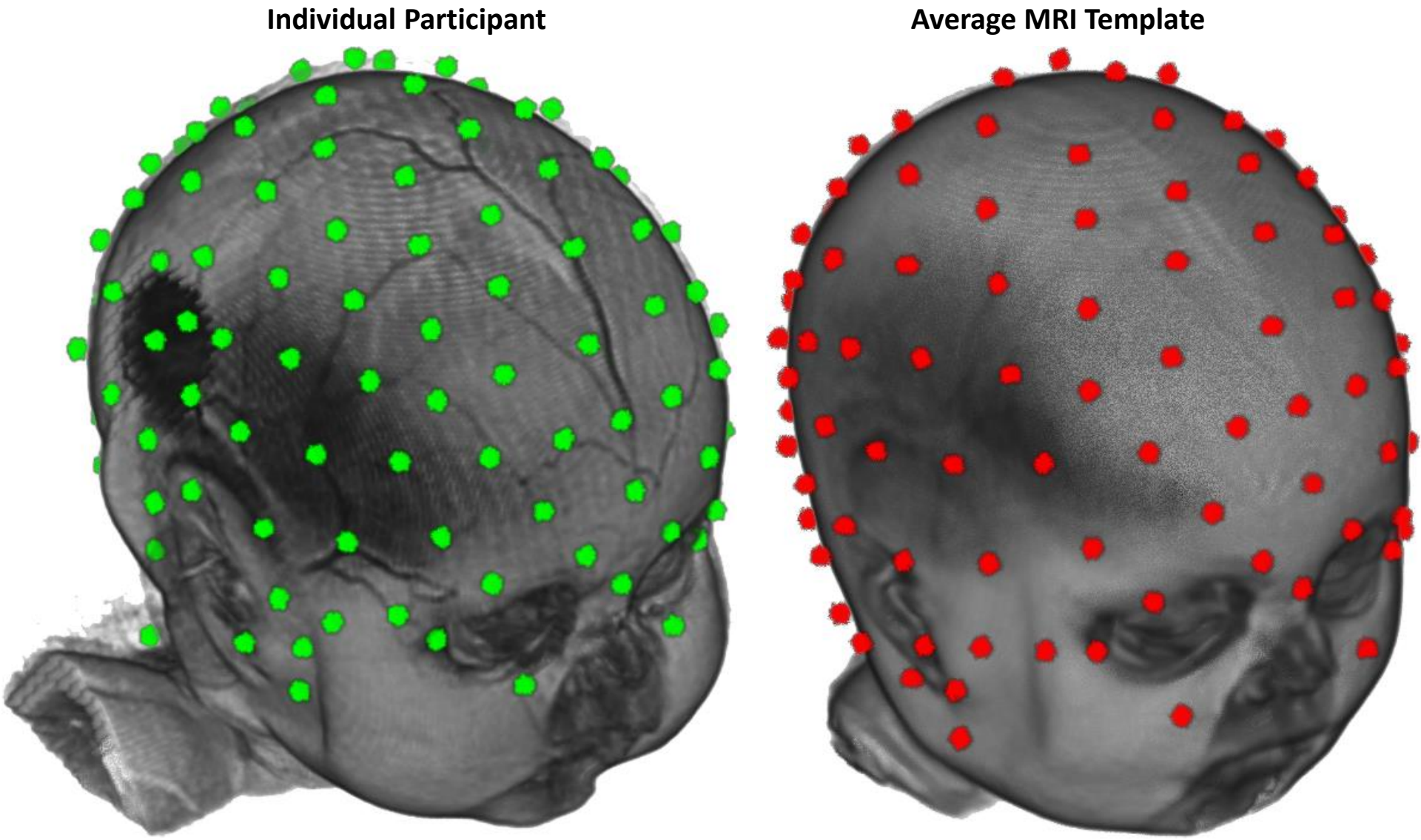
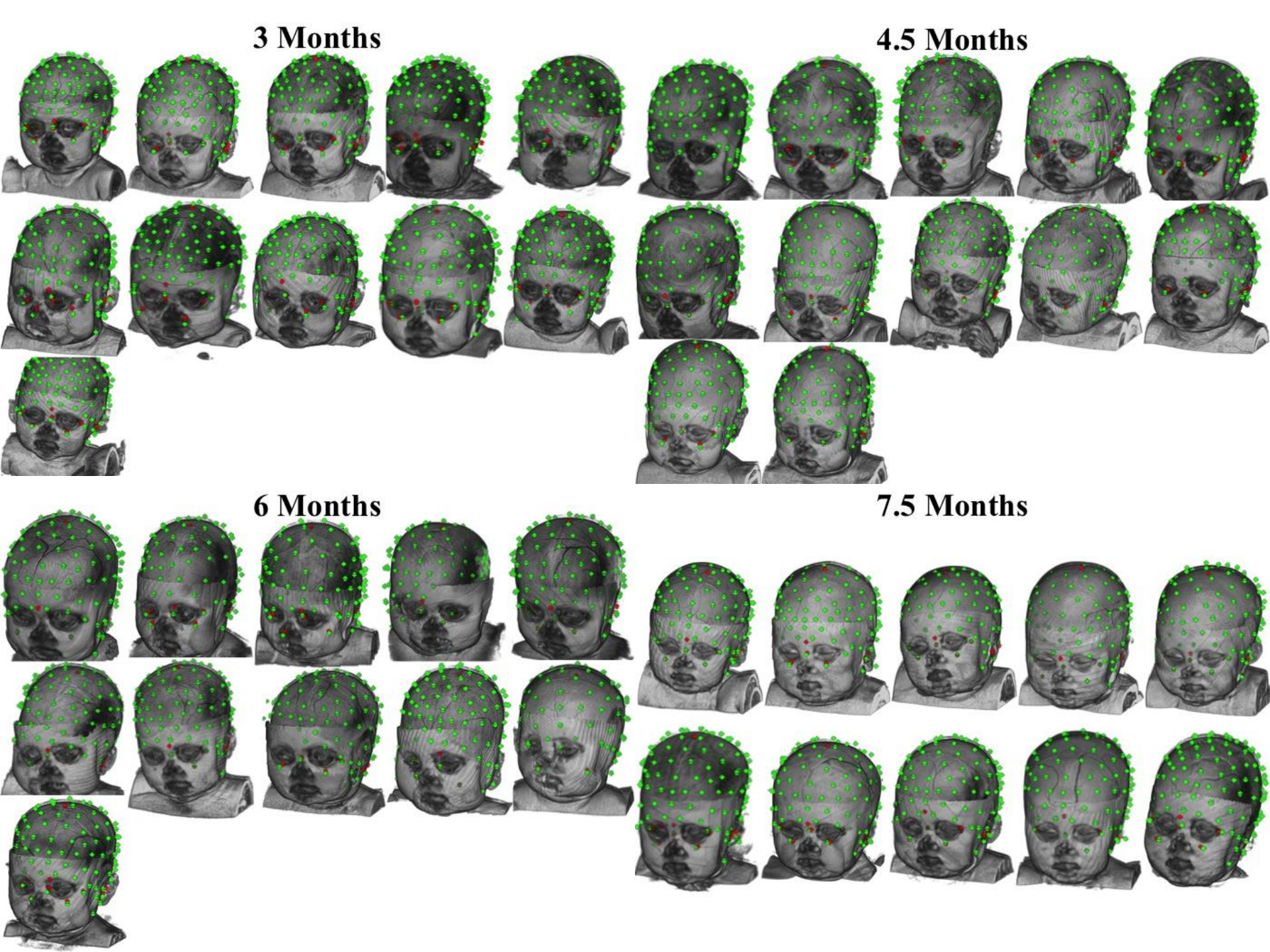

AC
PC
AC
PC
AC
PC

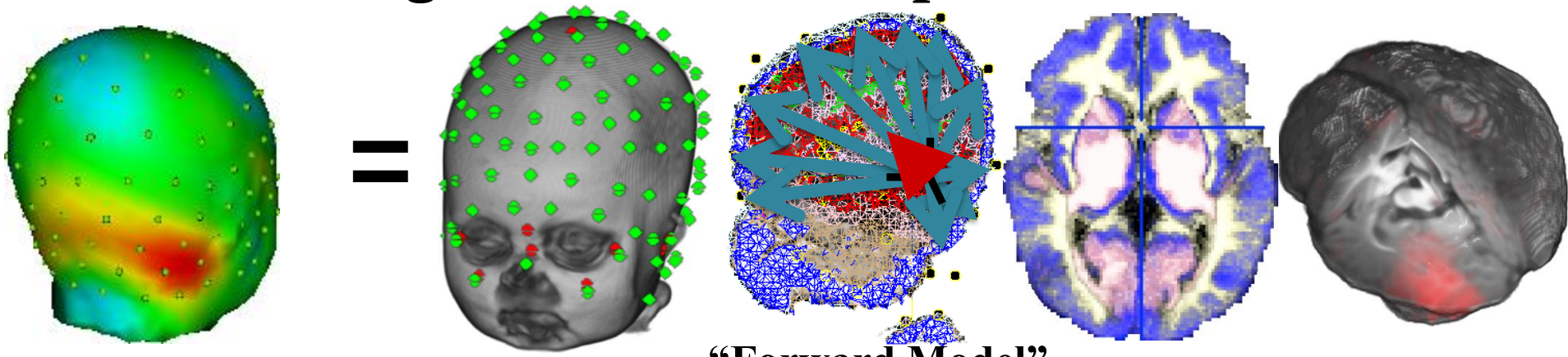
Figure 1. Electrode placement for a six-month old infant, and the 6-month-old average MRI template




3 Months
4.5 Months
6 Months
7.5 Months

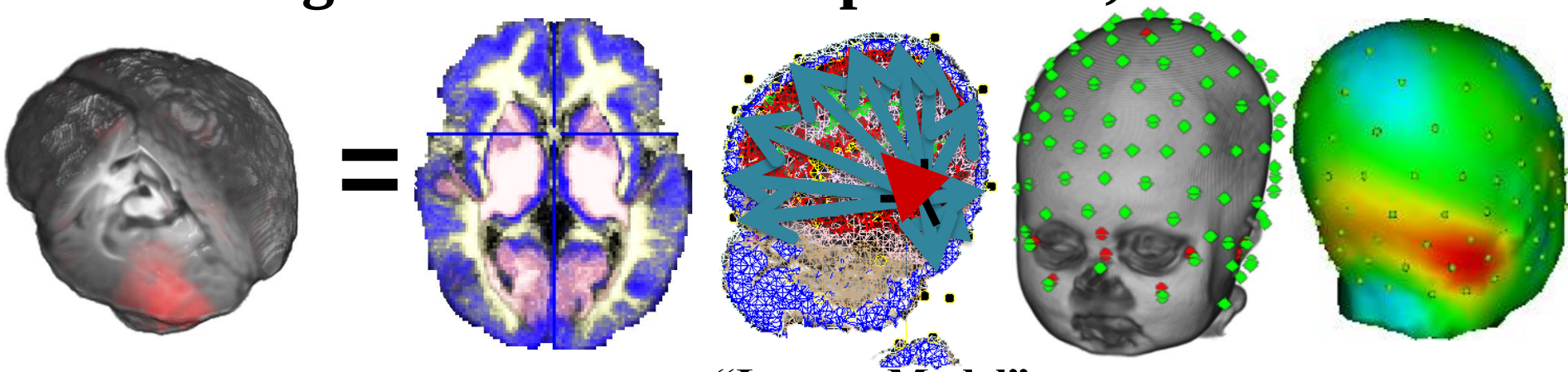
ERP Source Analysis

Current generation on scalp, forward model



"Forward Model"

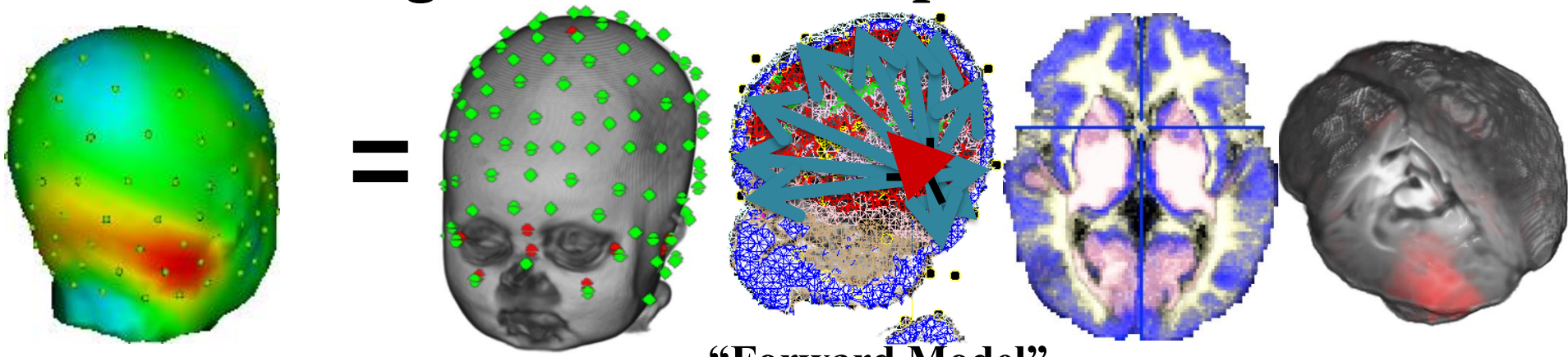
Recovering sources from scalp current, inverse model



"Inverse Model"

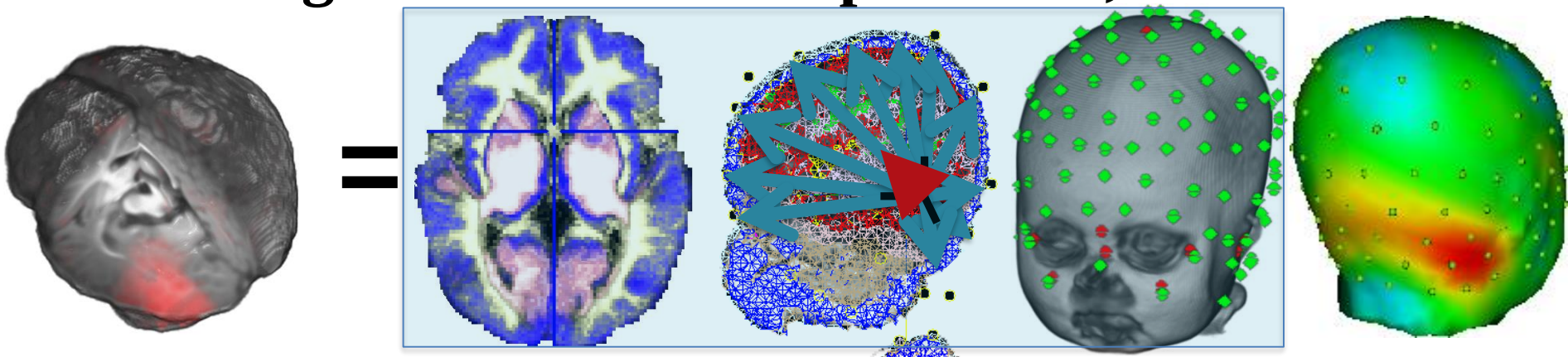
ERP Source Analysis

Current generation on scalp, forward model



"Forward Model"

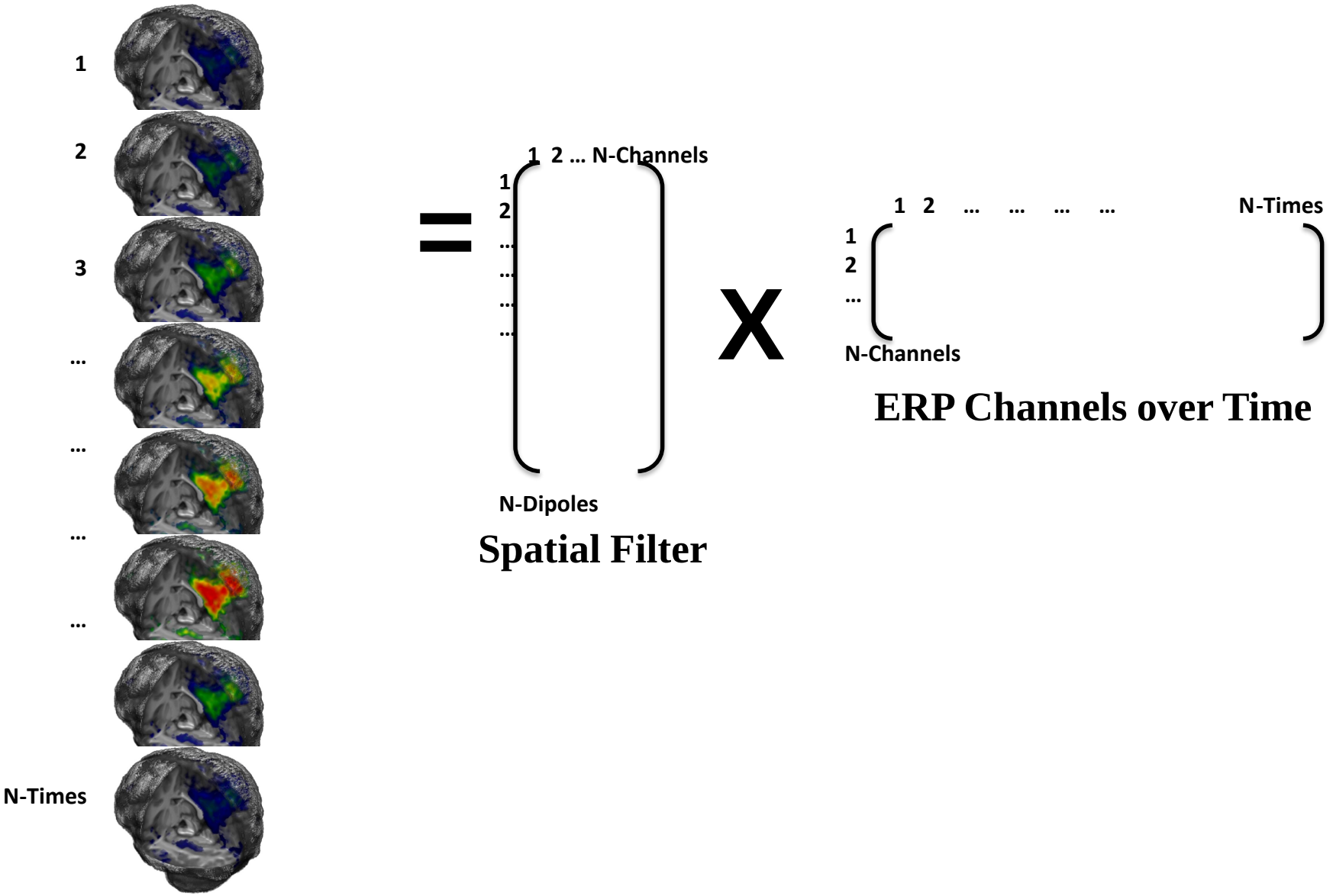
Recovering sources from scalp current, inverse model



"Spatial Filter"

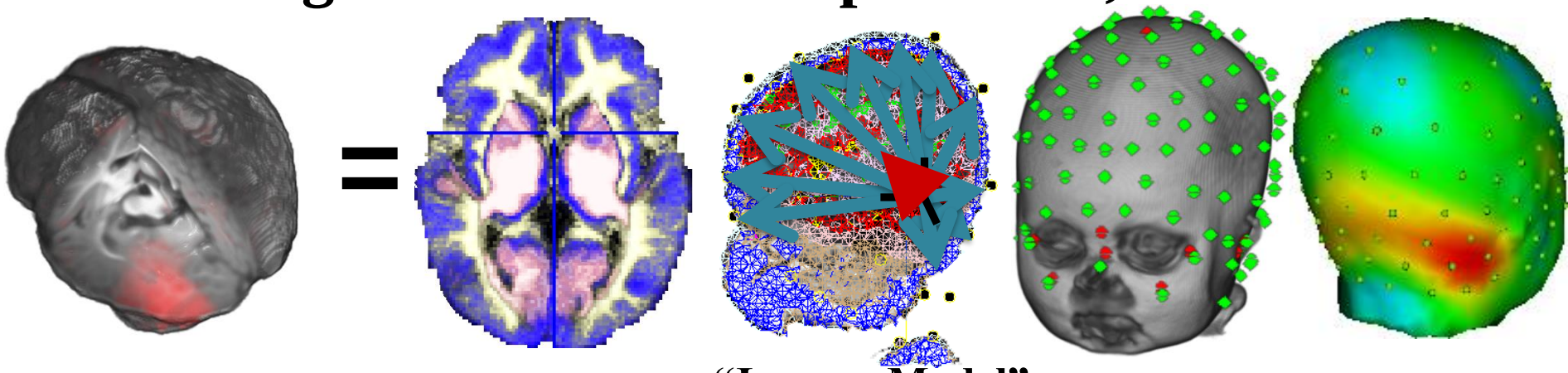
ERP Source Analysis

Spatio-Temporal Electrical Functional Neuroimaging



ERP Source Analysis

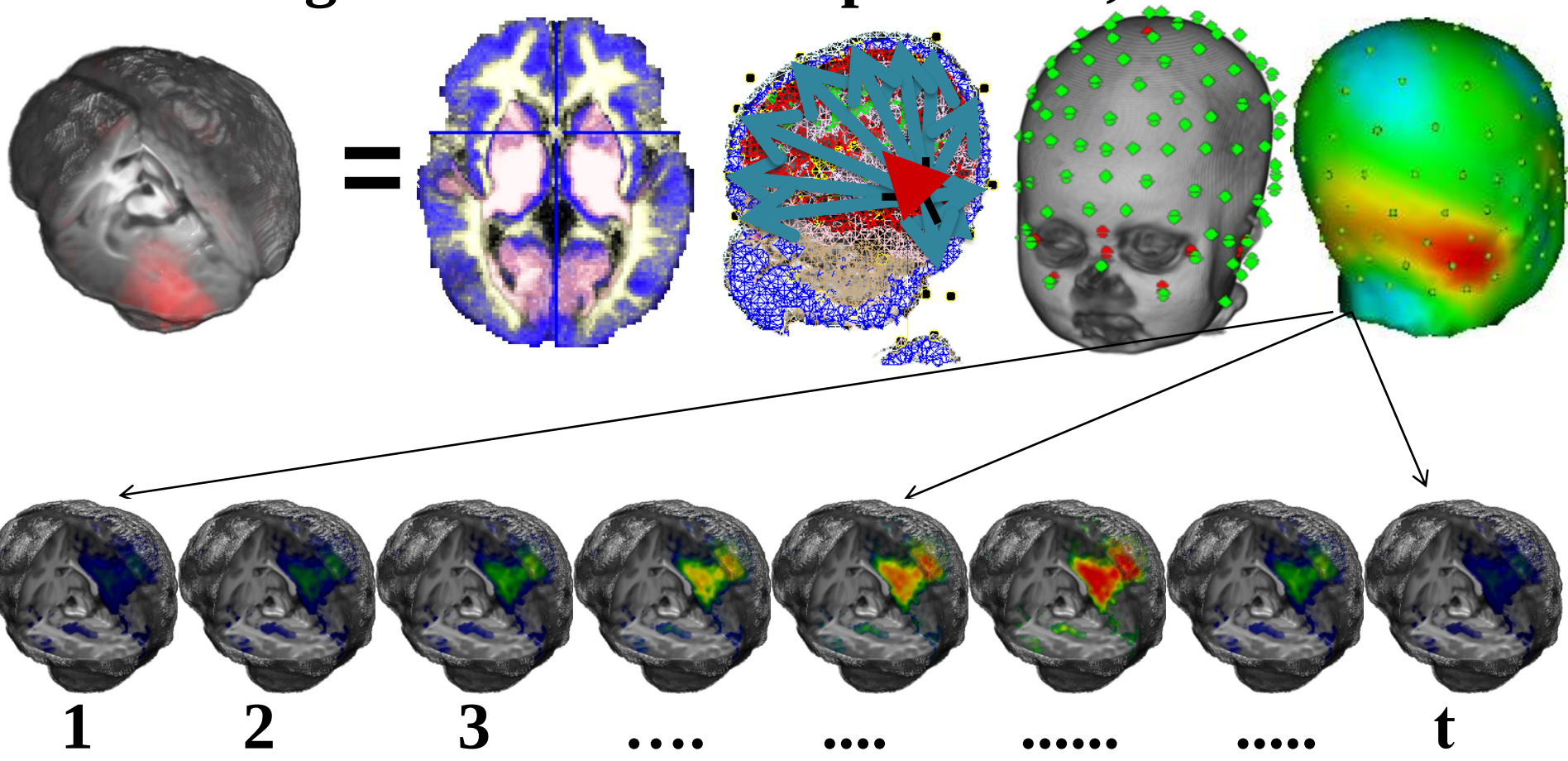
Recovering sources from scalp current, inverse model



"Inverse Model"

ERP Source Analysis

Recovering sources from scalp current, inverse model



1 2 3 …. …. .... t

Spatio-temporal functional electrical neuroimaging

ERP Source Analysis

Spatio-Temporal Electrical Functional Neuroimaging

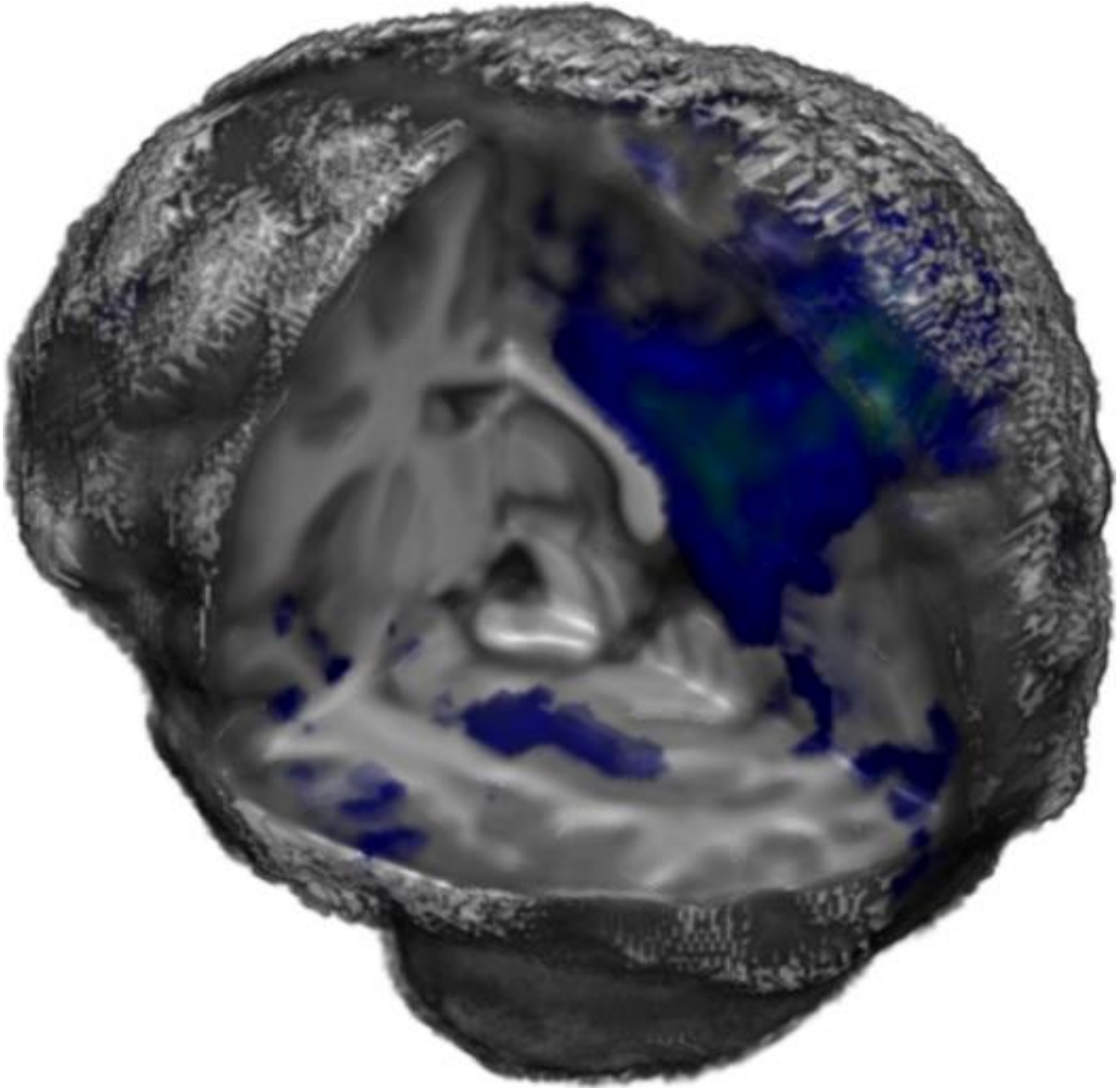
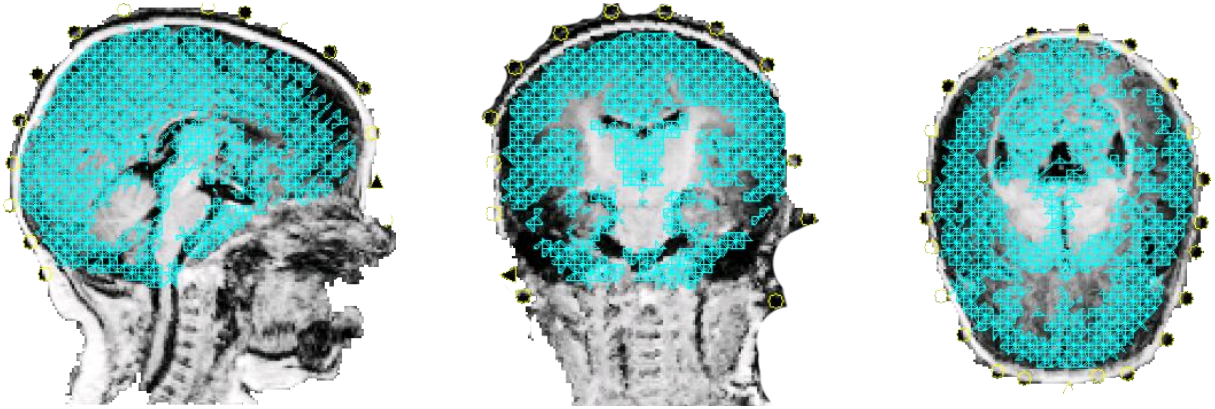


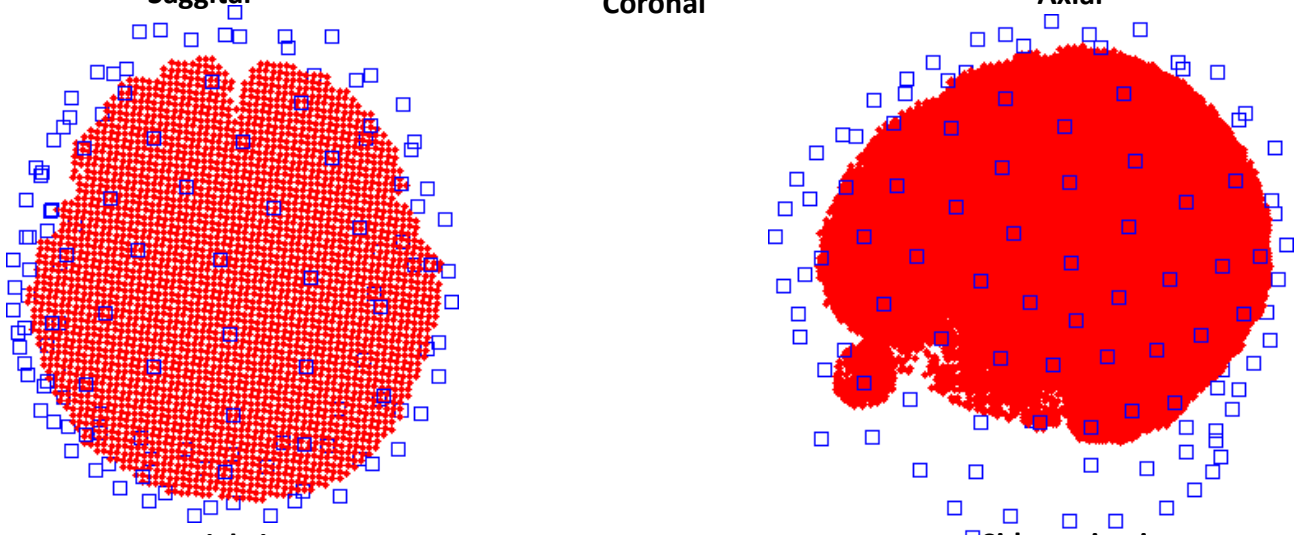
Figure 4. The EMSE and Fieldtrip source models, with HGSN128 electrodes

EMSE tetrahedral source model



Saggital Coronal Axial

Fieldtrip 2mm grid source model



Axial view Side projection

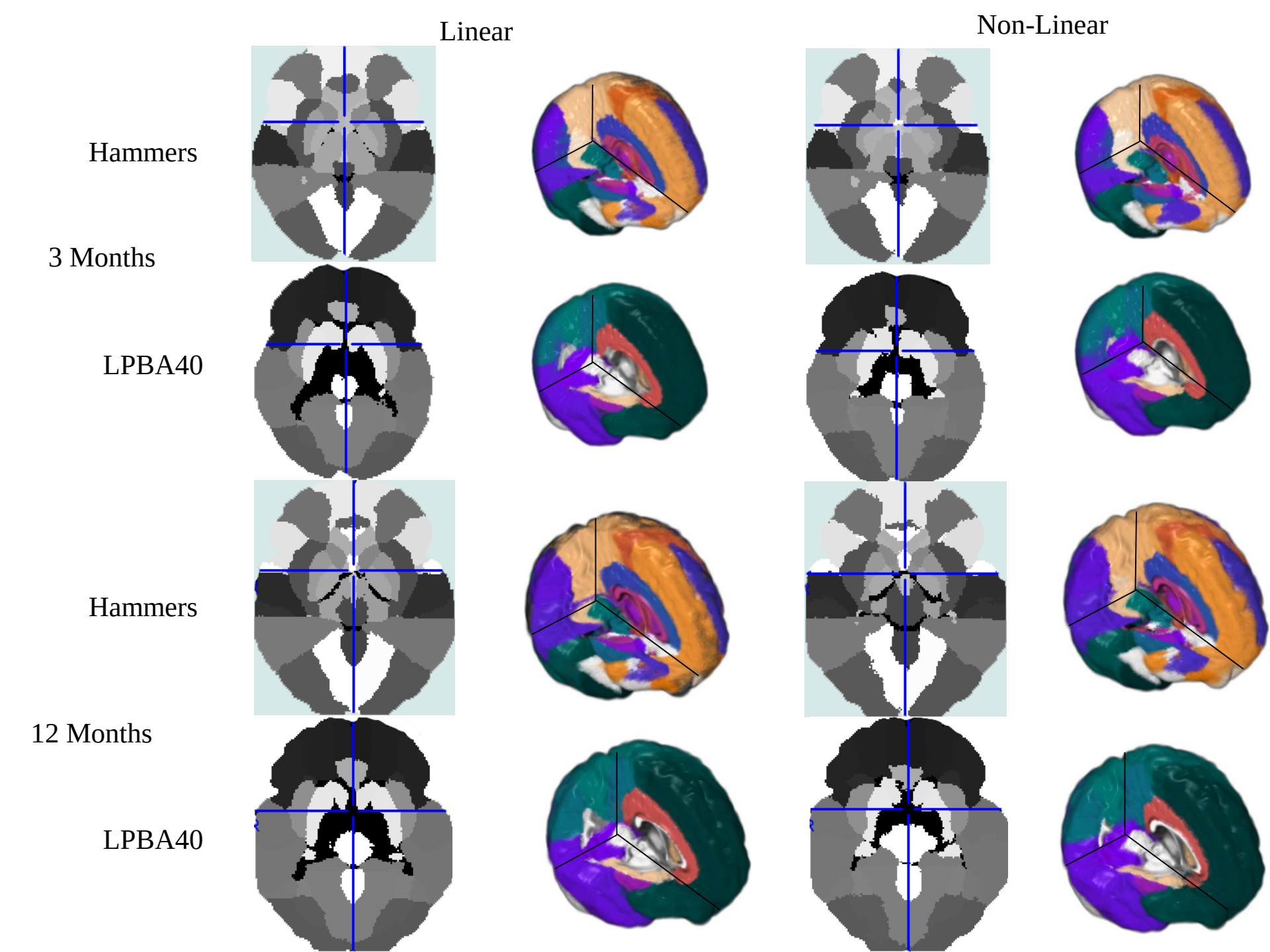
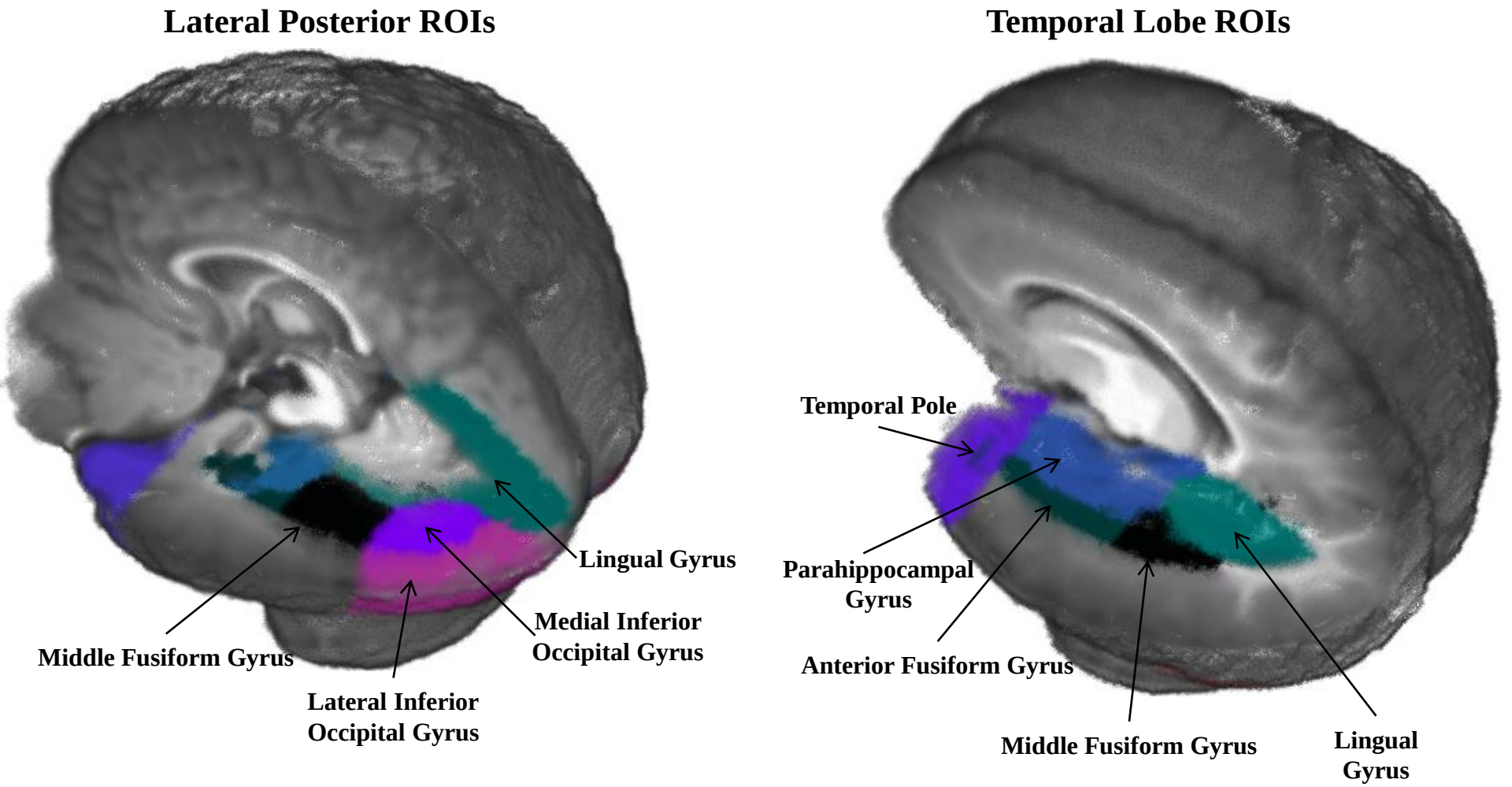
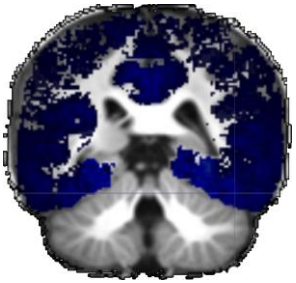
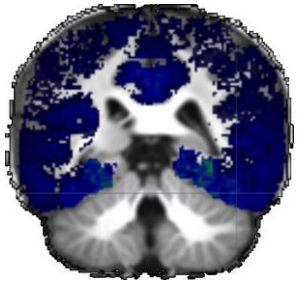

Linear
Non-Linear
Hammers
3 Months
LPBA40
Hammers
12 Months
LPBA40

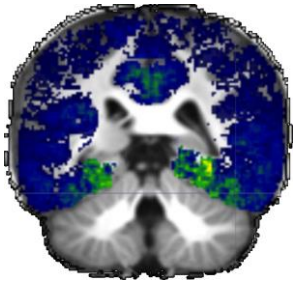
Figure 2. Regions of interests (ROIs) shown on the 6-month-old average age-appropriate template.

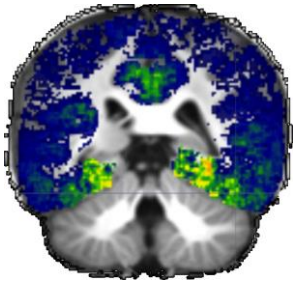


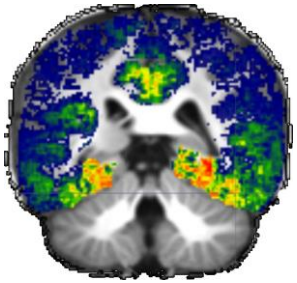
CDR Peak N290 Latency from -40 ms to peak to +40 ms

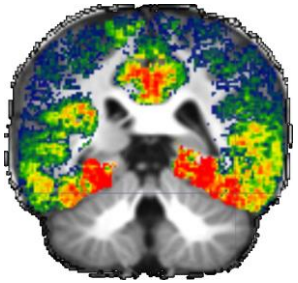

-40

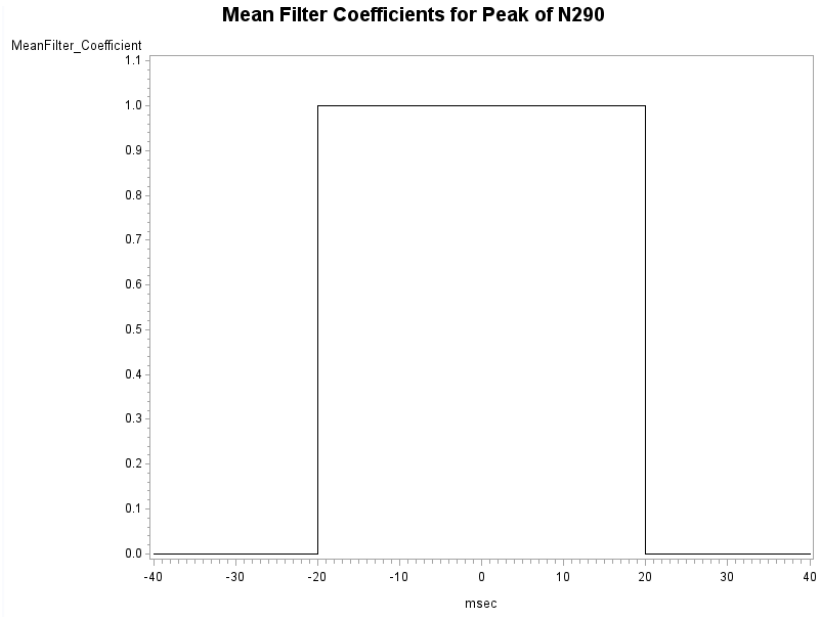

-32


-24

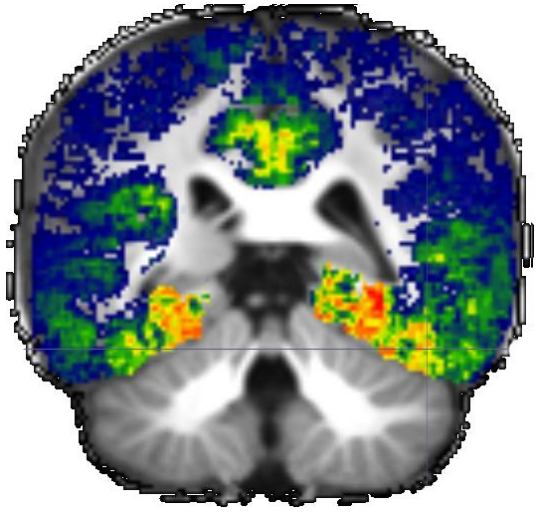

-16


-8

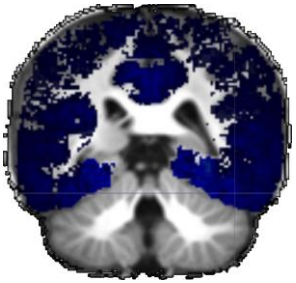

Peak



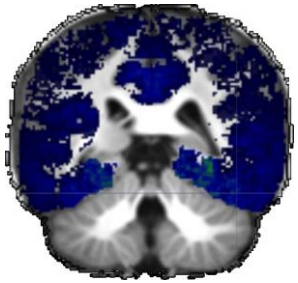
Average CDR at Peak Latency



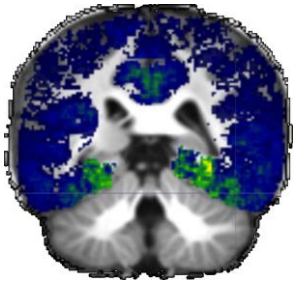
CDR Peak N290 Latency from -40 ms to peak to +40 ms



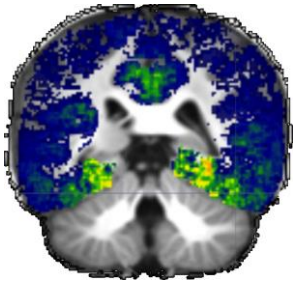
-40



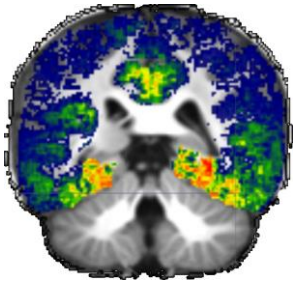
-32



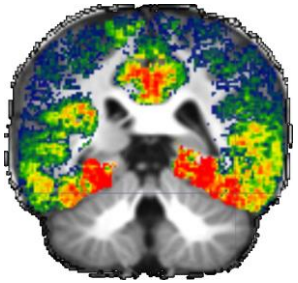
-24



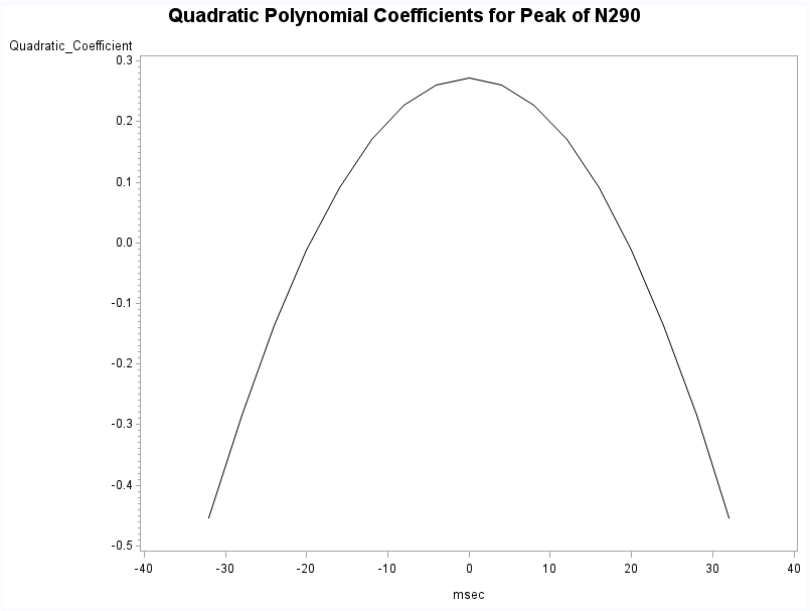
-16



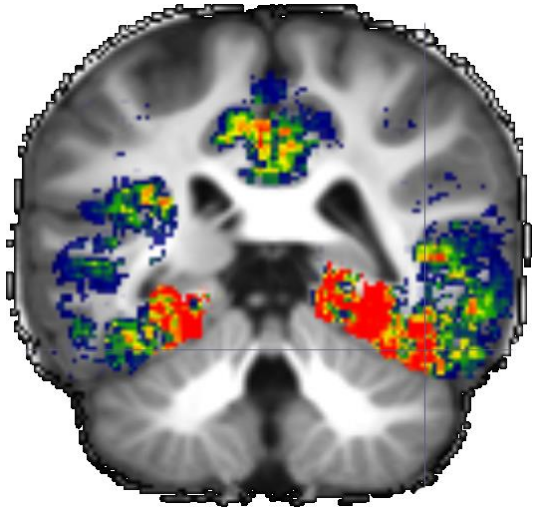
-8



Peak



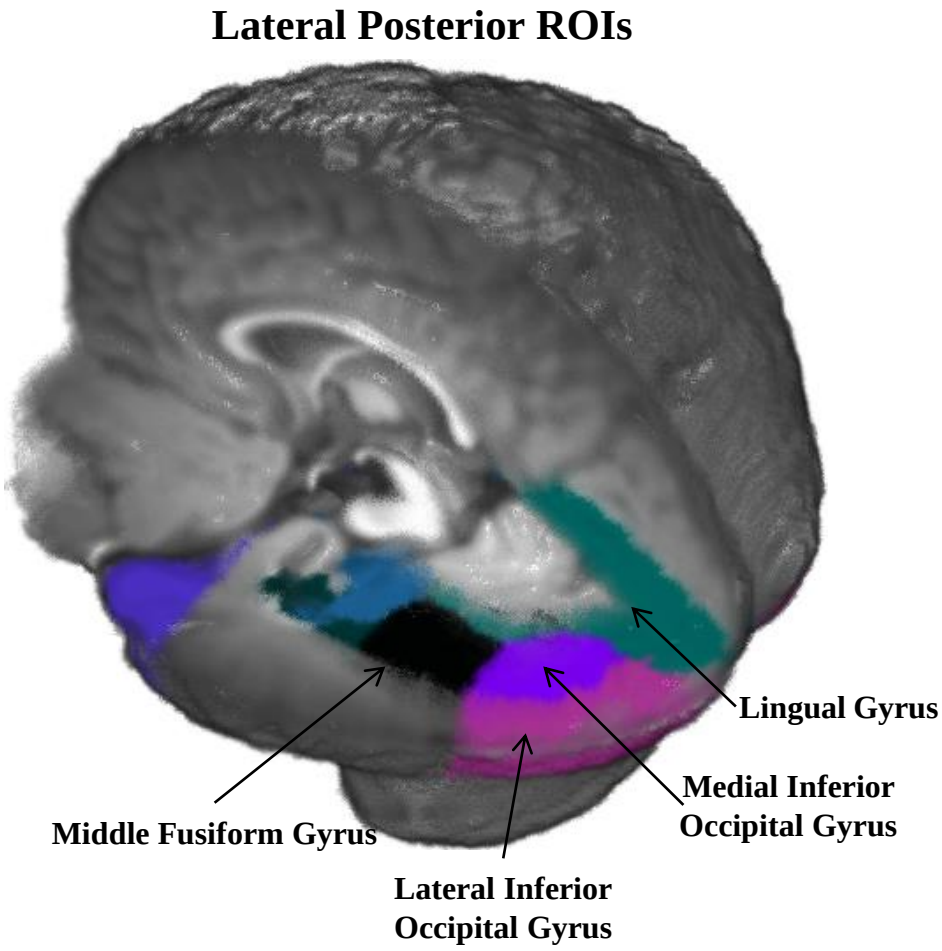
Quadratic CDR at Peak Latency

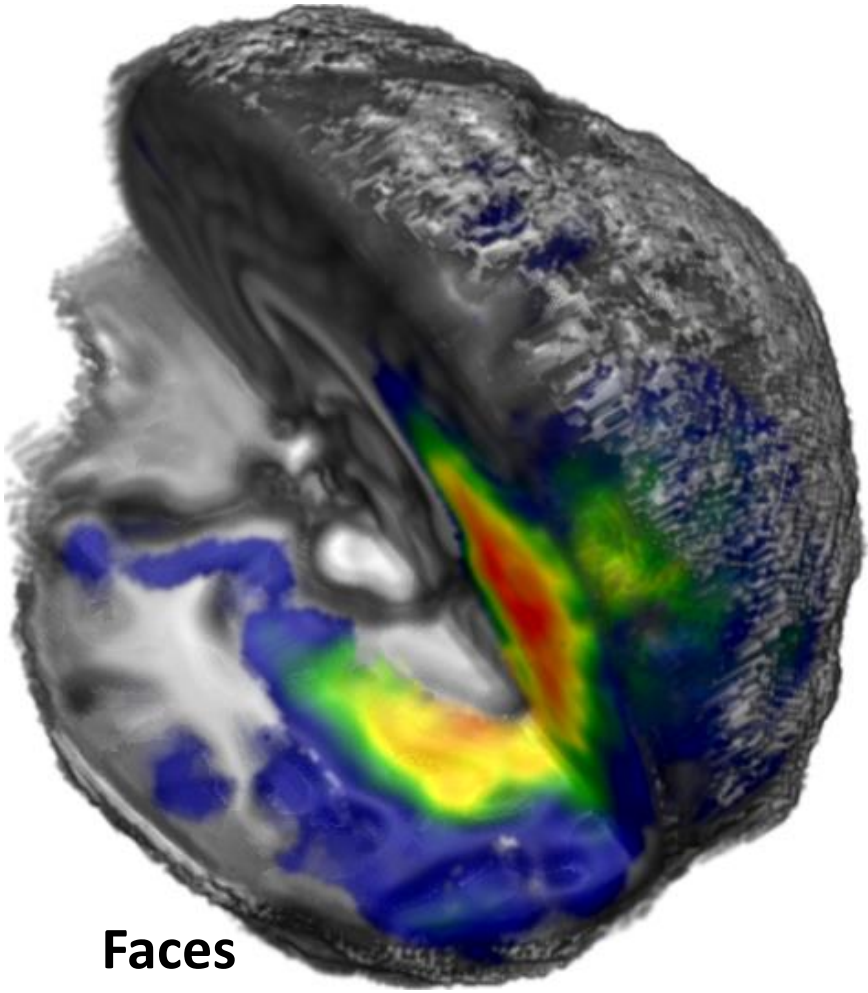


P1 source localization

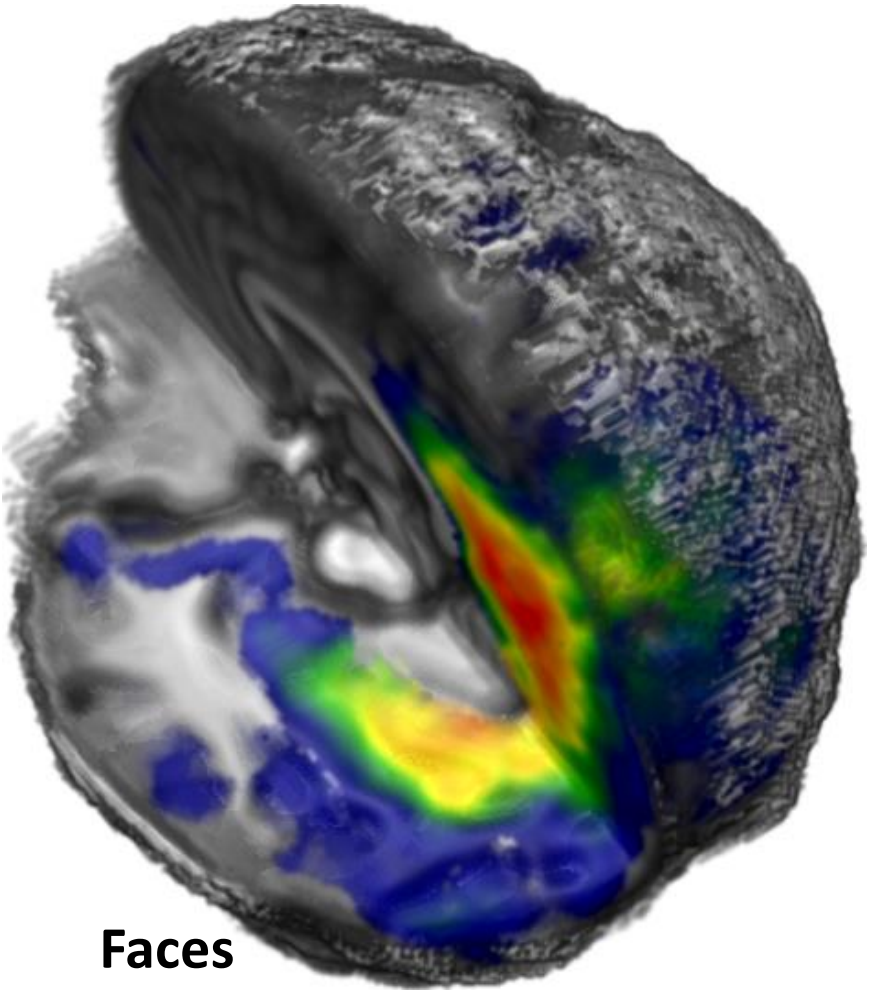
- **Lingual gyrus, and other bilateral areas, has peak consistent with P1, larger to faces than toys at two older ages (quadratic effects)**
- **Other areas show face-toy differences, especially at older ages, but no peak (no quadratic effects).**
- **The posterior cingulate area shows enhanced activity and face-toy difference at peak for 12 month olds.**

Lingual Gyrus CDR Activity at Peak P1 Faces, 12 months

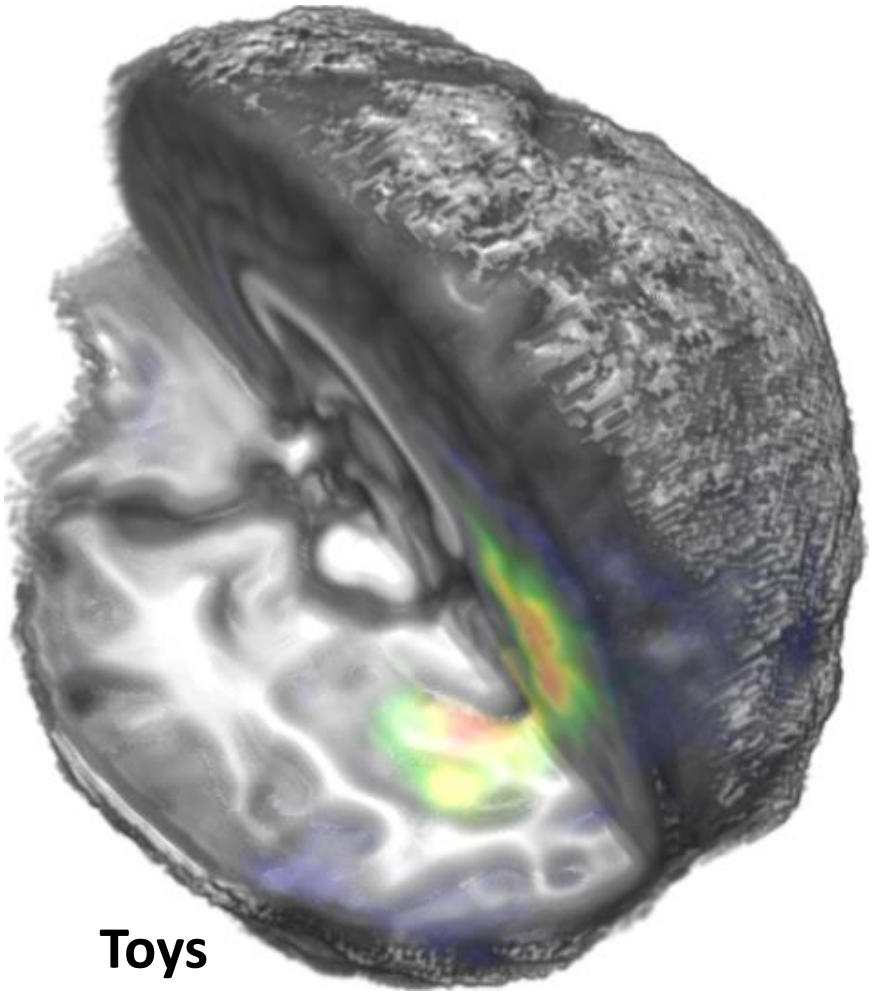




Lingual Gyrus CDR at P1 Peak, Faces and Toys

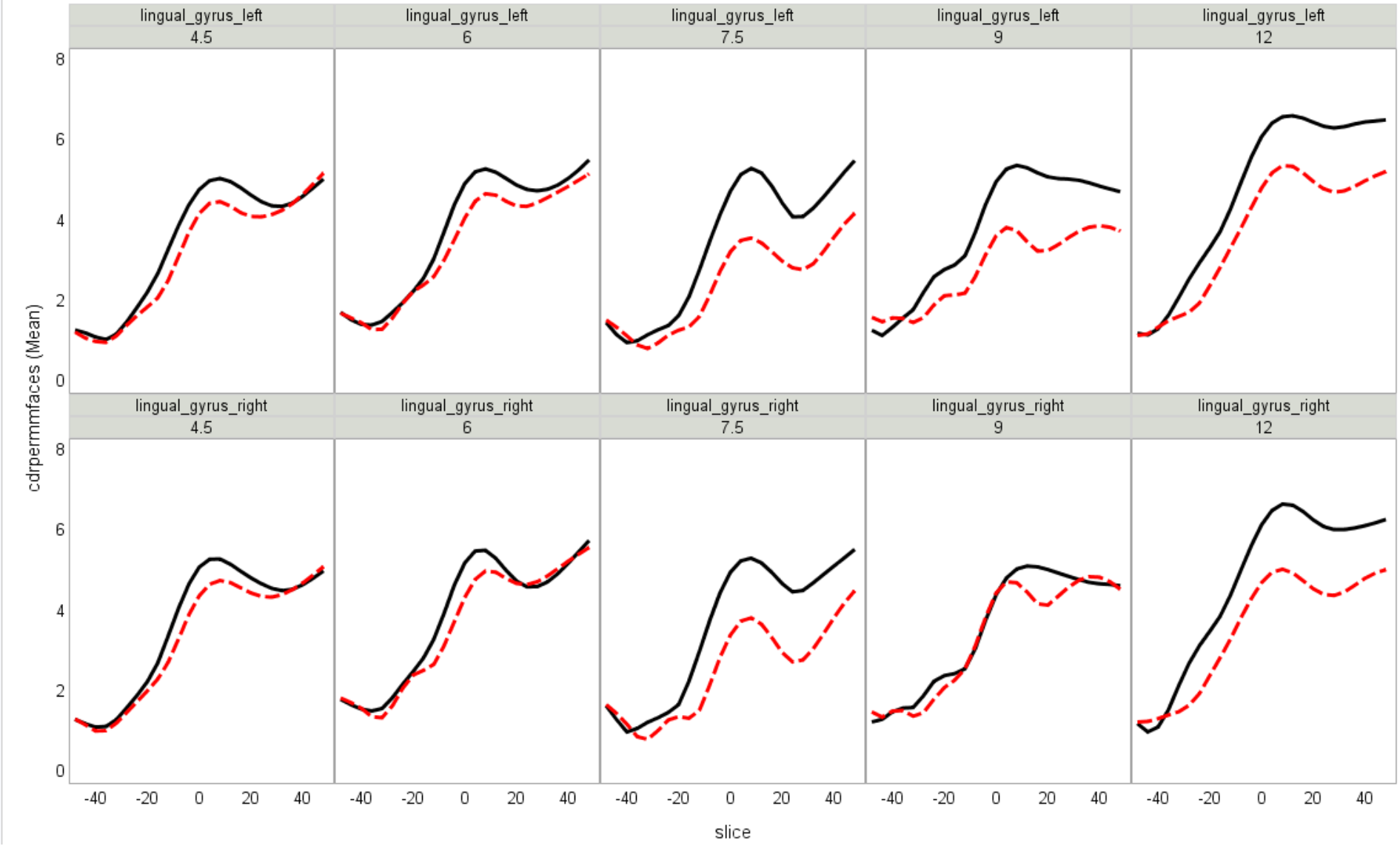


Faces

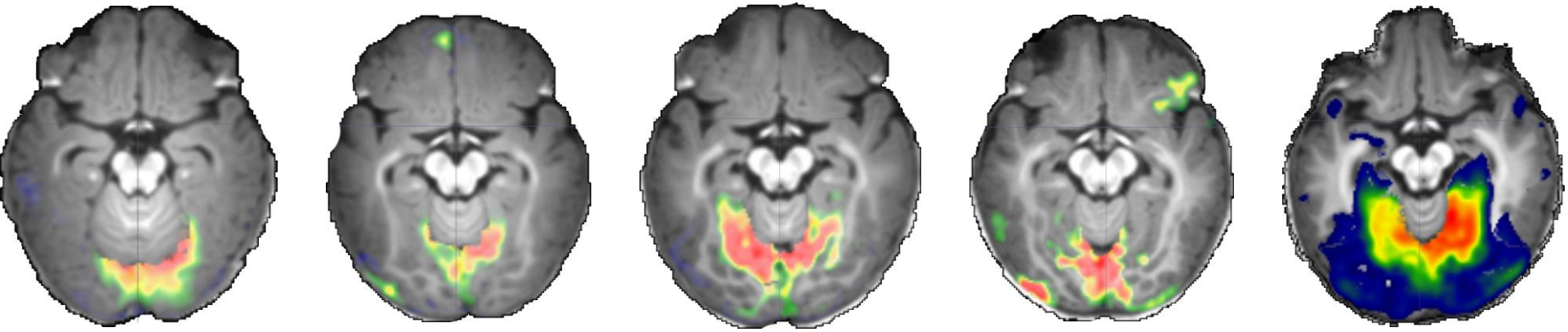


Toys

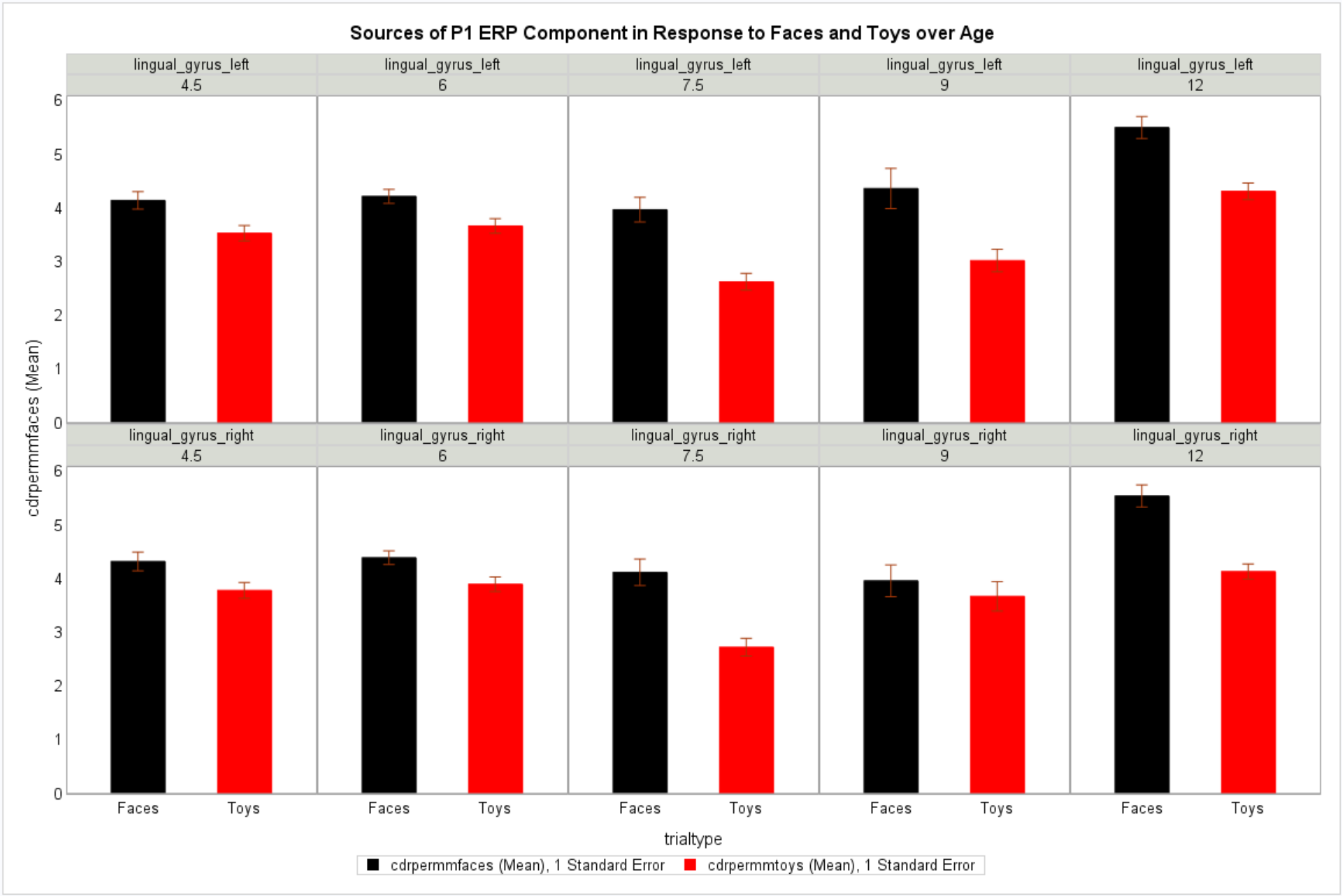
Lingual Gyrus, ROI over Time at Peak P1

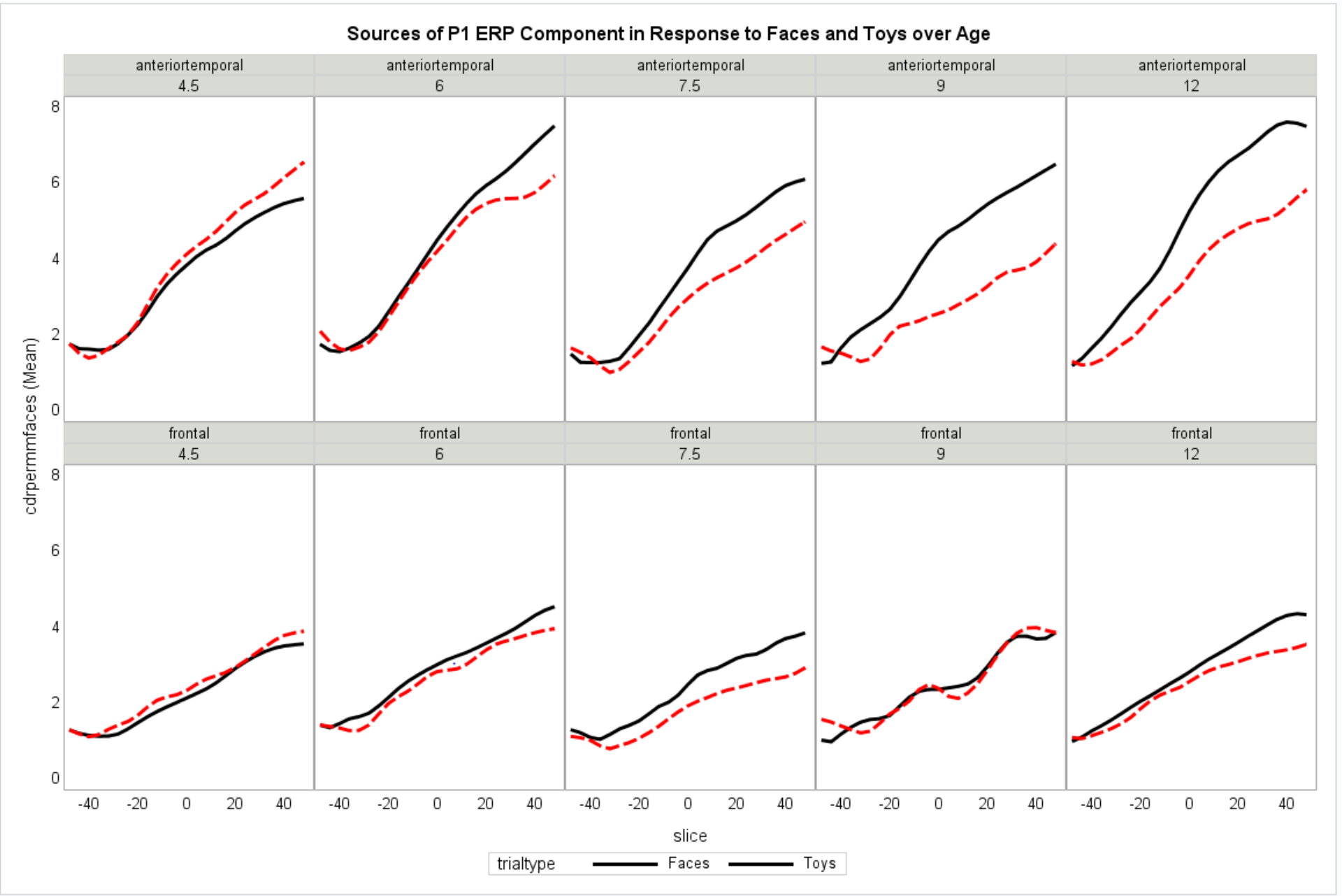


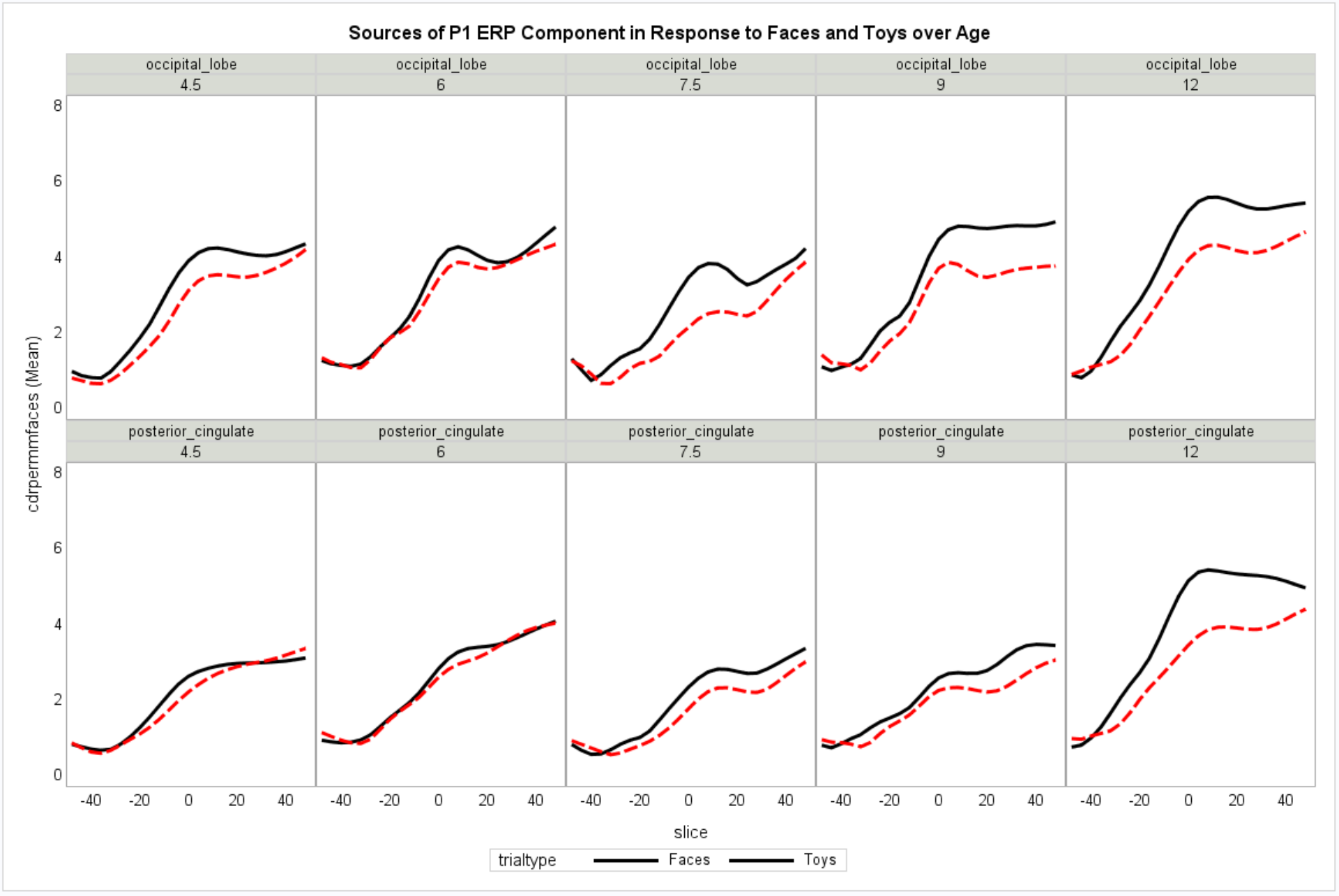
Activity at P1 Latency to Faces, 4.5 to 12 Months



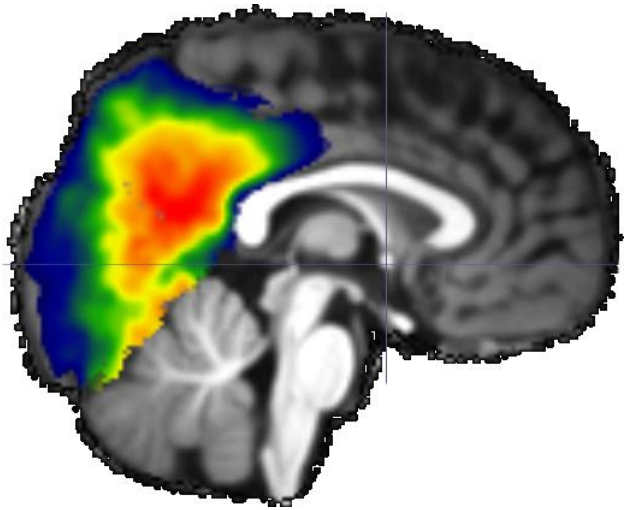
4.5 6.0 7.5 9.0 12.0


Sources of P1 ERP Component in Response to Faces and Toys over Age
lingual_gyrus_left
4.5
lingual_gyrus_left
6
lingual_gyrus_left
7.5
lingual_gyrus_left
9
lingual_gyrus_left
12
lingual_gyrus_right
4.5
lingual_gyrus_right
6
lingual_gyrus_right
7.5
lingual_gyrus_right
9
lingual_gyrus_right
12
cdrpermmfaces (Mean)
0
1
2
3
4
5
6
Faces
Toys
trialtype
cdrpermmfaces (Mean), 1 Standard Error
cdrpermmtoys (Mean), 1 Standard Error

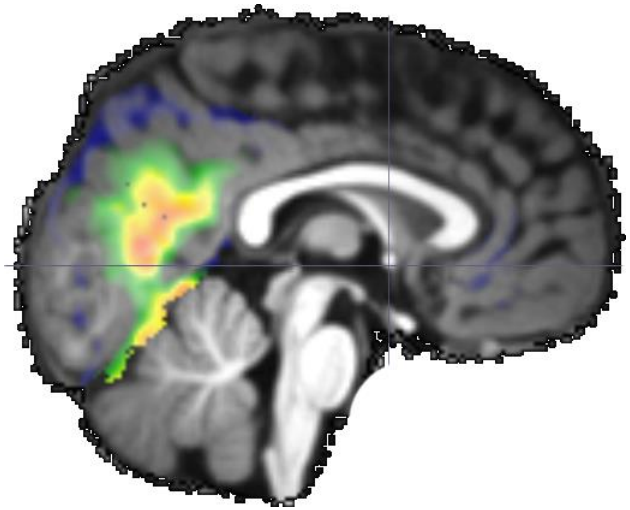

Sources of P1 ERP Component in Response to Faces and Toys over Age
anteriortemporal
4.5
anteriortemporal
6
anteriortemporal
7.5
anteriortemporal
9
anteriortemporal
12
frontal
4.5
frontal
6
frontal
7.5
frontal
9
frontal
12
cdrpermmfaces (Mean)
0
2
4
6
8
-40
-20
0
20
40
slice
trialtype
Faces
Toys


Sources of P1 ERP Component in Response to Faces and Toys over Age
occipital_lobe
4.5
occipital_lobe
6
occipital_lobe
7.5
occipital_lobe
9
occipital_lobe
12
posterior_cingulate
4.5
posterior_cingulate
6
posterior_cingulate
7.5
posterior_cingulate
9
posterior_cingulate
12
cdrpermmfaces (Mean)
0
2
4
6
8
-40
-20
0
20
40
slice
trialtype
Faces
Toys

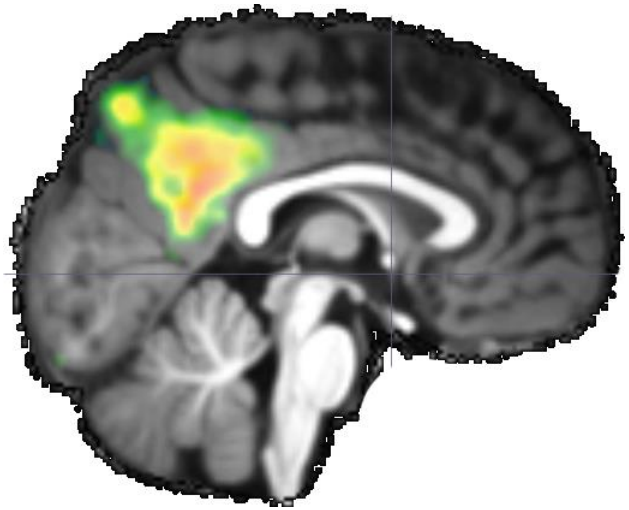
Activity in Posterior Cingulate Gyrus at P1 Latency, 12 Months



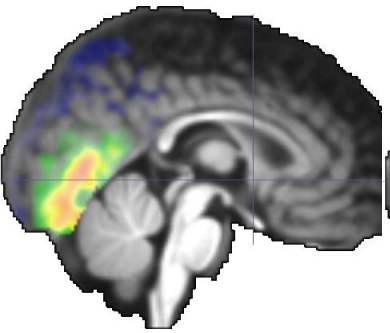
Faces



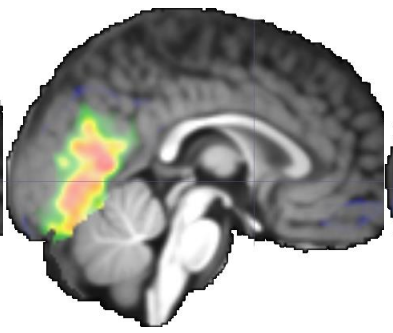
Toys



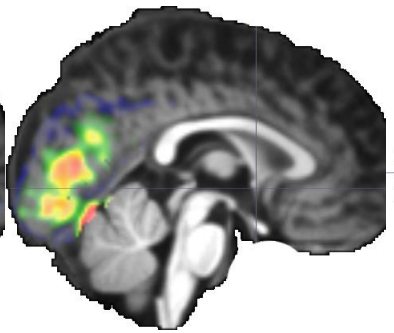
Faces Minus Toys



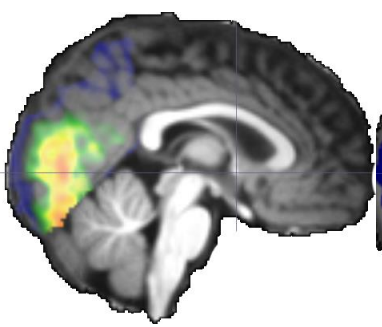
4.5



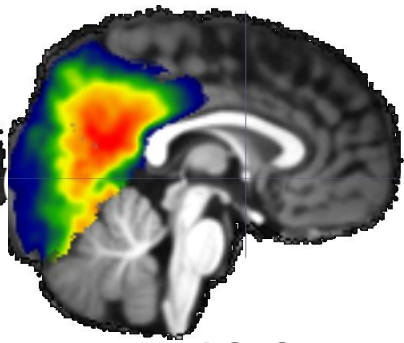
6.0



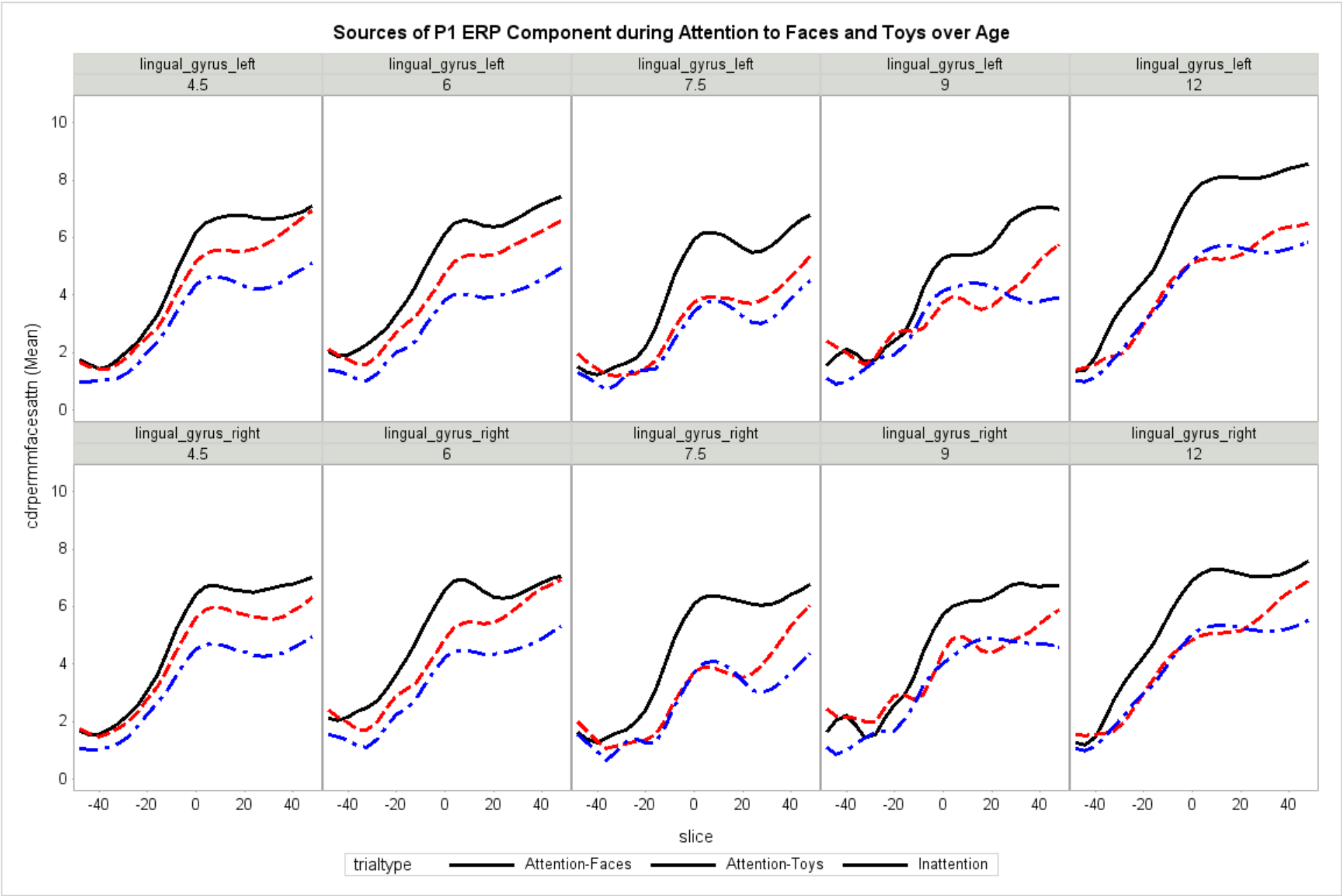
7.5

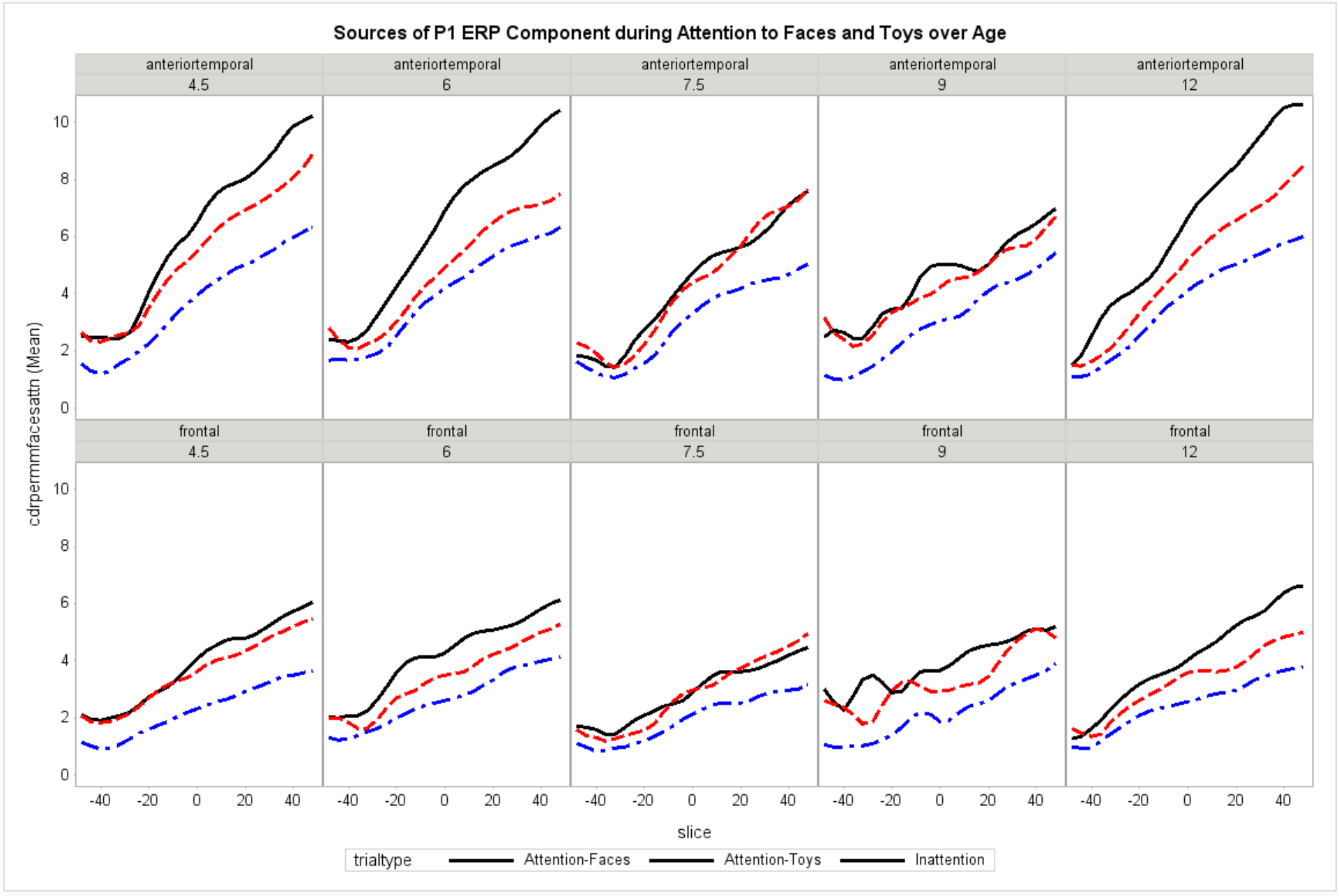


9.0



12.0

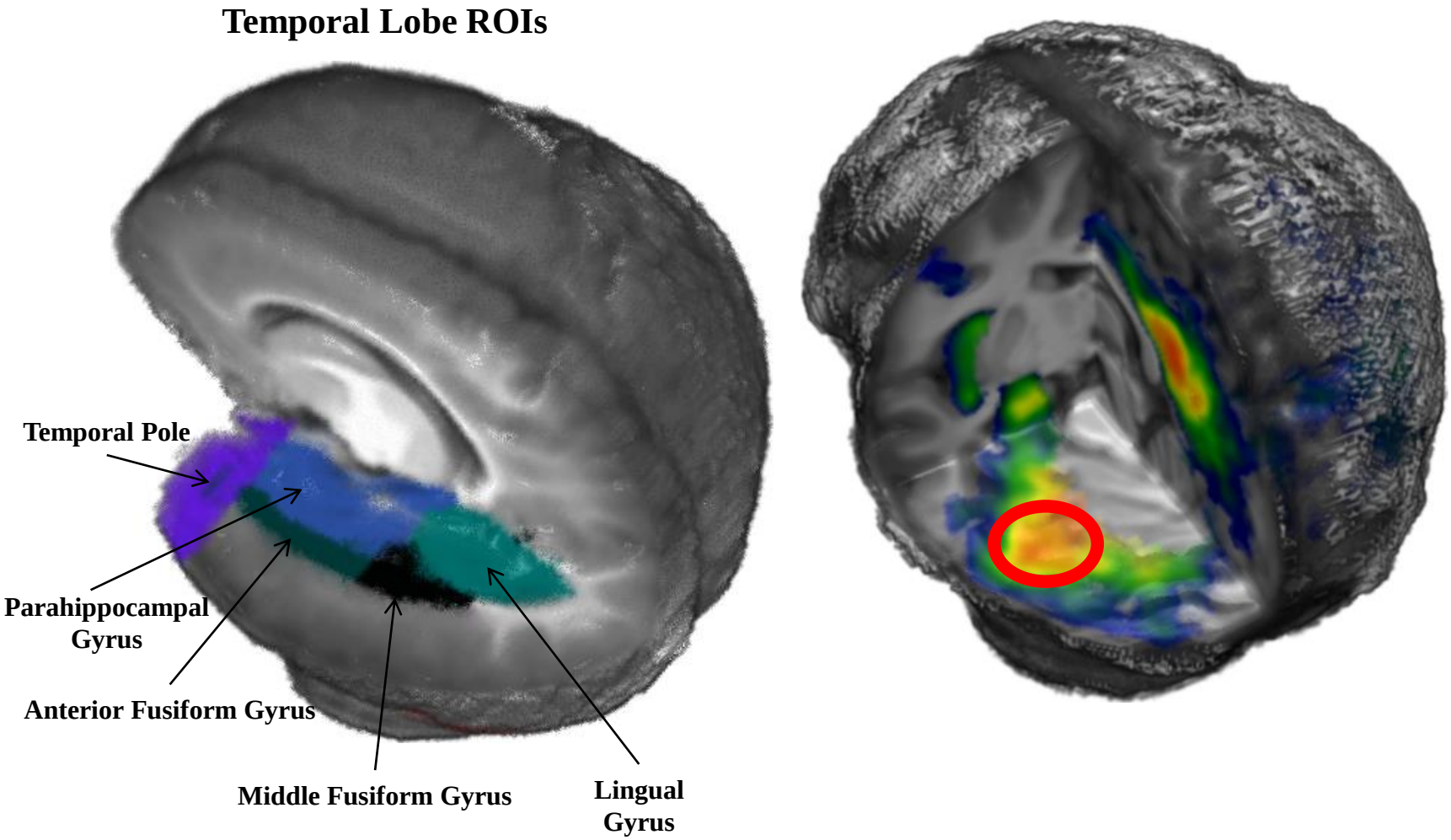

Sources of P1 ERP Component during Attention to Faces and Toys over Age
lingual_gyrus_left
4.5
lingual_gyrus_left
6
lingual_gyrus_left
7.5
lingual_gyrus_left
9
lingual_gyrus_left
12
lingual_gyrus_right
4.5
lingual_gyrus_right
6
lingual_gyrus_right
7.5
lingual_gyrus_right
9
lingual_gyrus_right
12
cdrpermmfacesattn (Mean)
0
2
4
6
8
10
-40
-20
0
20
40
slice
trialtype
Attention-Faces
Attention-Toys
Inattention


Sources of P1 ERP Component during Attention to Faces and Toys over Age
anteriortemporal
4.5
anteriortemporal
6
anteriortemporal
7.5
anteriortemporal
9
anteriortemporal
12
frontal
4.5
frontal
6
frontal
7.5
frontal
9
frontal
12
cdrpermmfacesattn (Mean)
0
2
4
6
8
10
-40
-20
0
20
40
slice
trialtype
Attention-Faces
Attention-Toys
Inattention

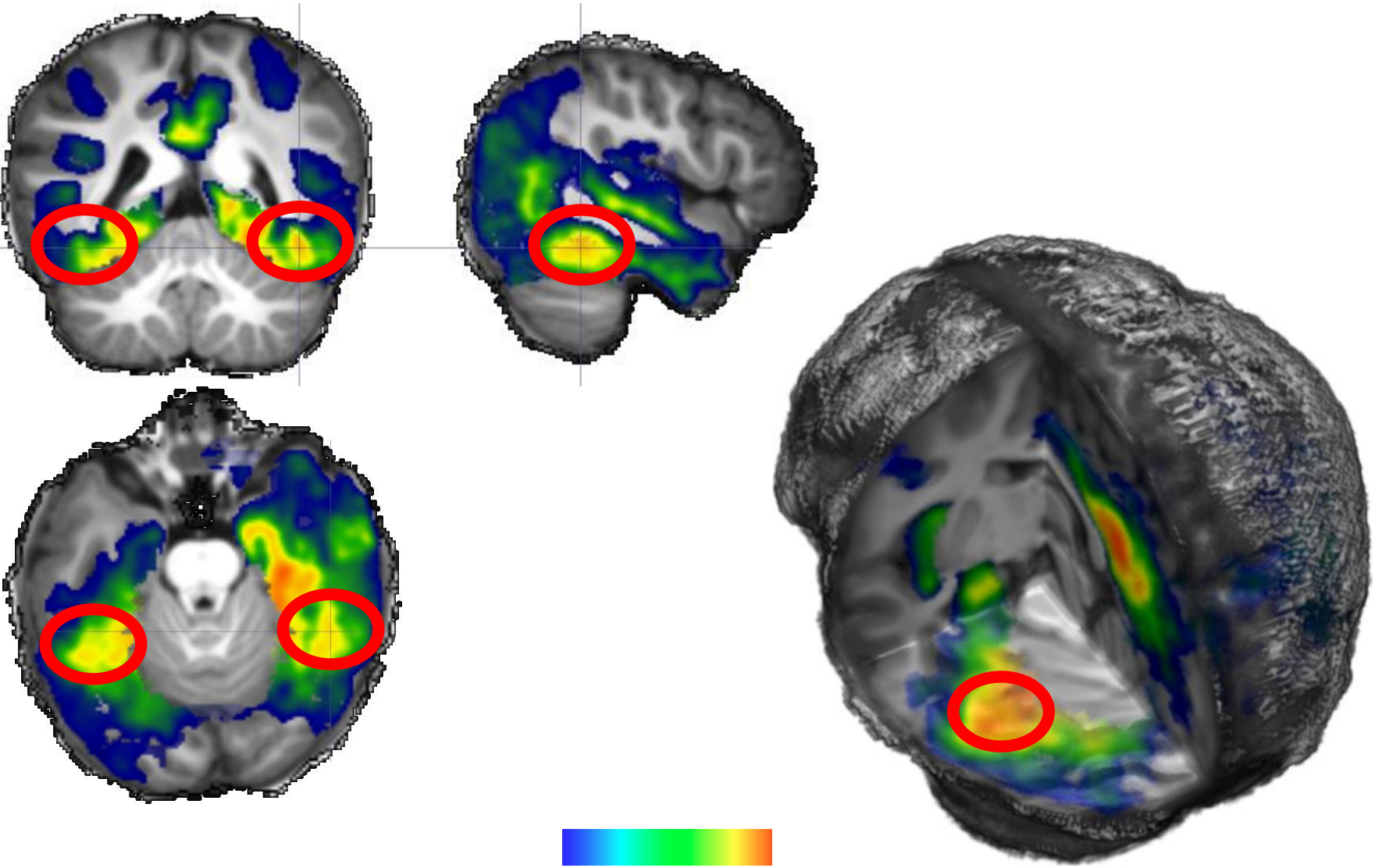
N290 source localization

- **“Middle” fusiform gyrus, larger to faces than toys in older infants, and has peak consistent with the source area for the N290**
- **Some other areas show face-toy difference (e.g., lateral-posterior), but amplitude is not as large and peak is less pronounced or absent, or is smaller with no peak (frontal)**
- **Effects in anterior temporal area (temporal pole, anterior fusiform gyrus, parahippocampal gyrus) appear to be a precursor to extended ERP activity in P400 and Nc**

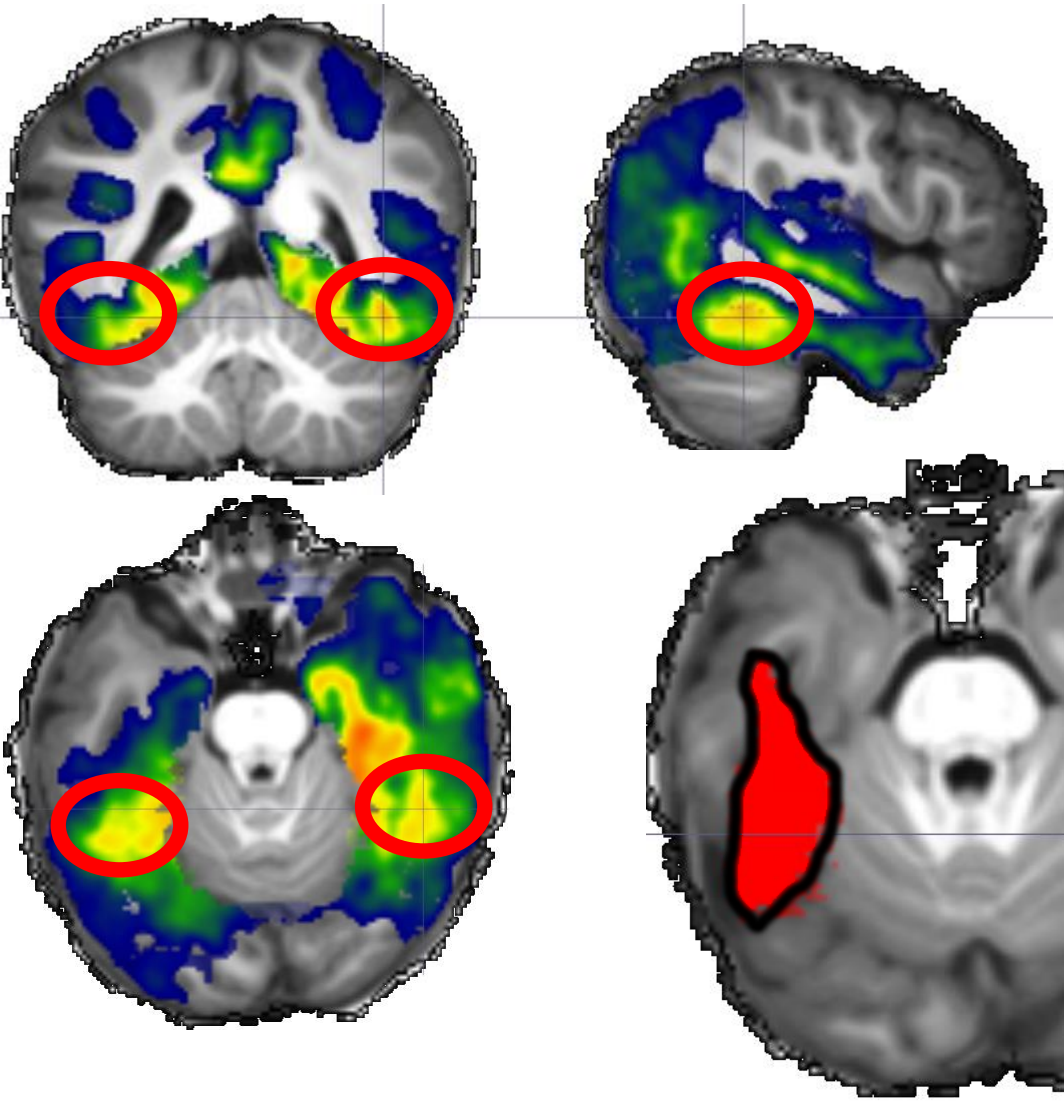
Middle Fusiform Gyrus CDR Activity at Peak N290 Latency, Faces, 12 months



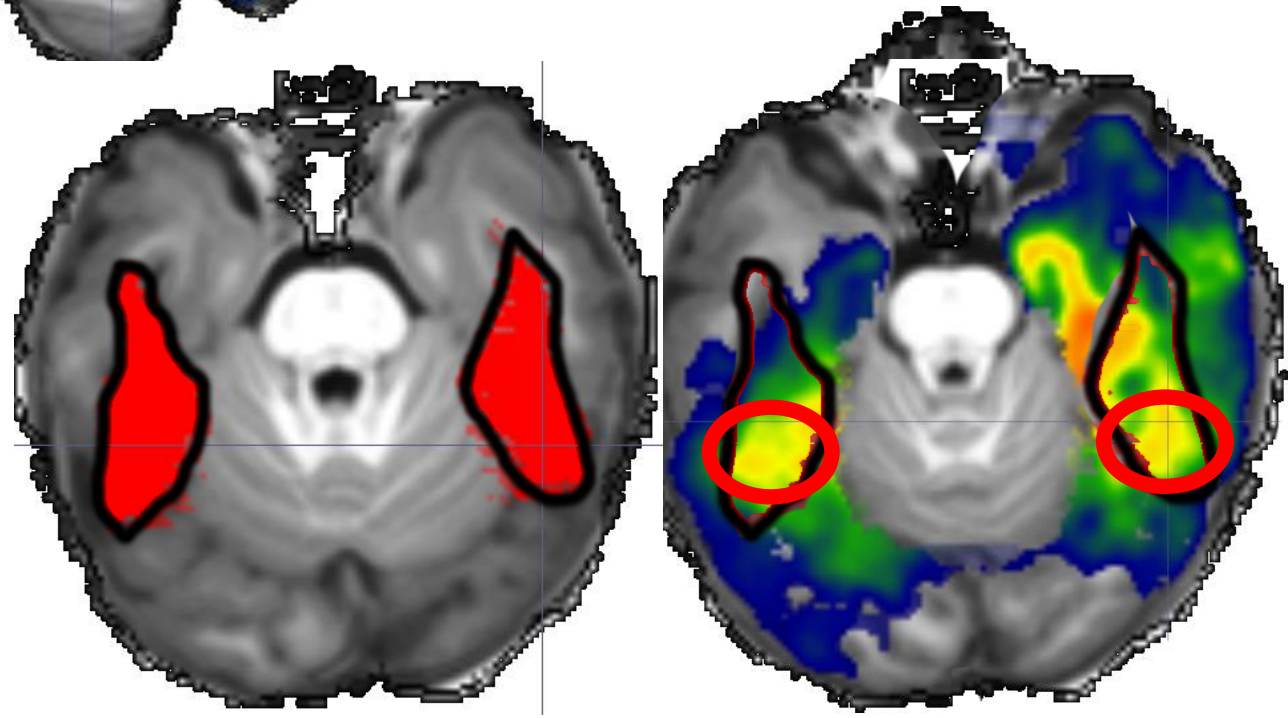
Middle Fusiform Gyrus CDR Activity at Peak N290 Latency, Faces, 12 months



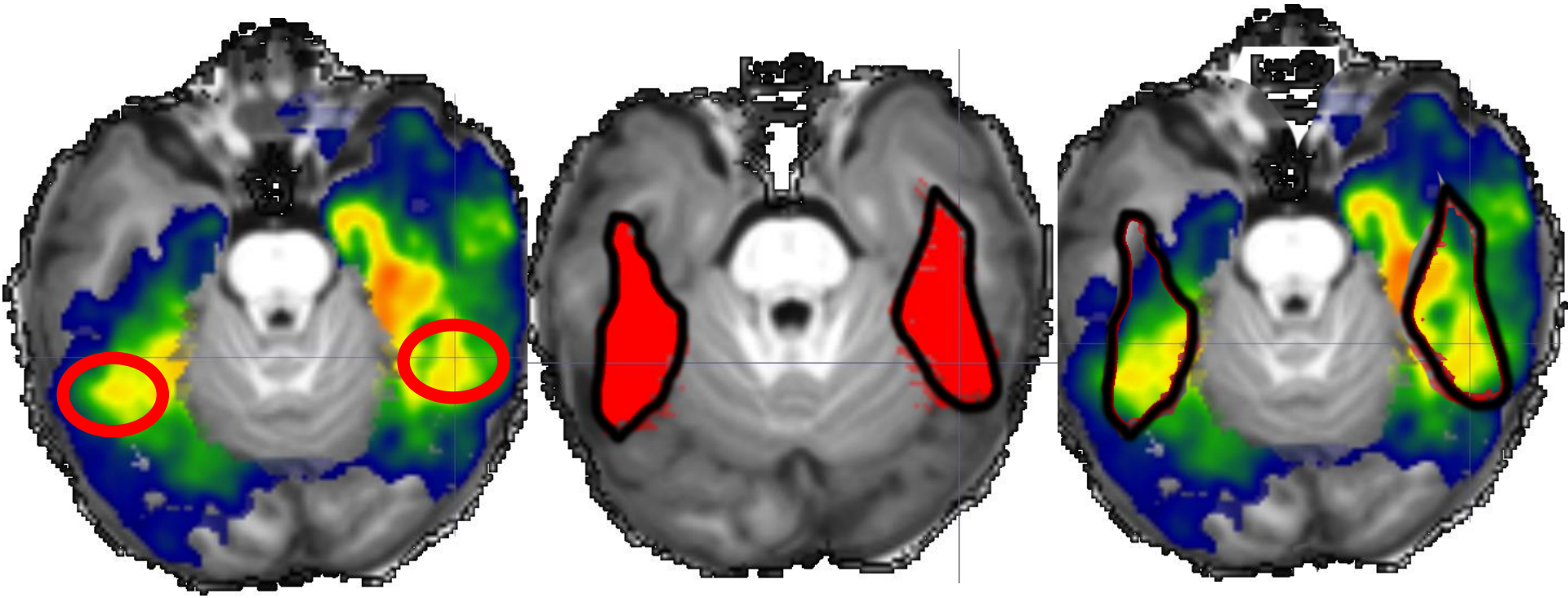
Middle Fusiform Gyrus CDR Activity at Peak N290 Latency, Faces, 12 months



FFG, Atlas ROI



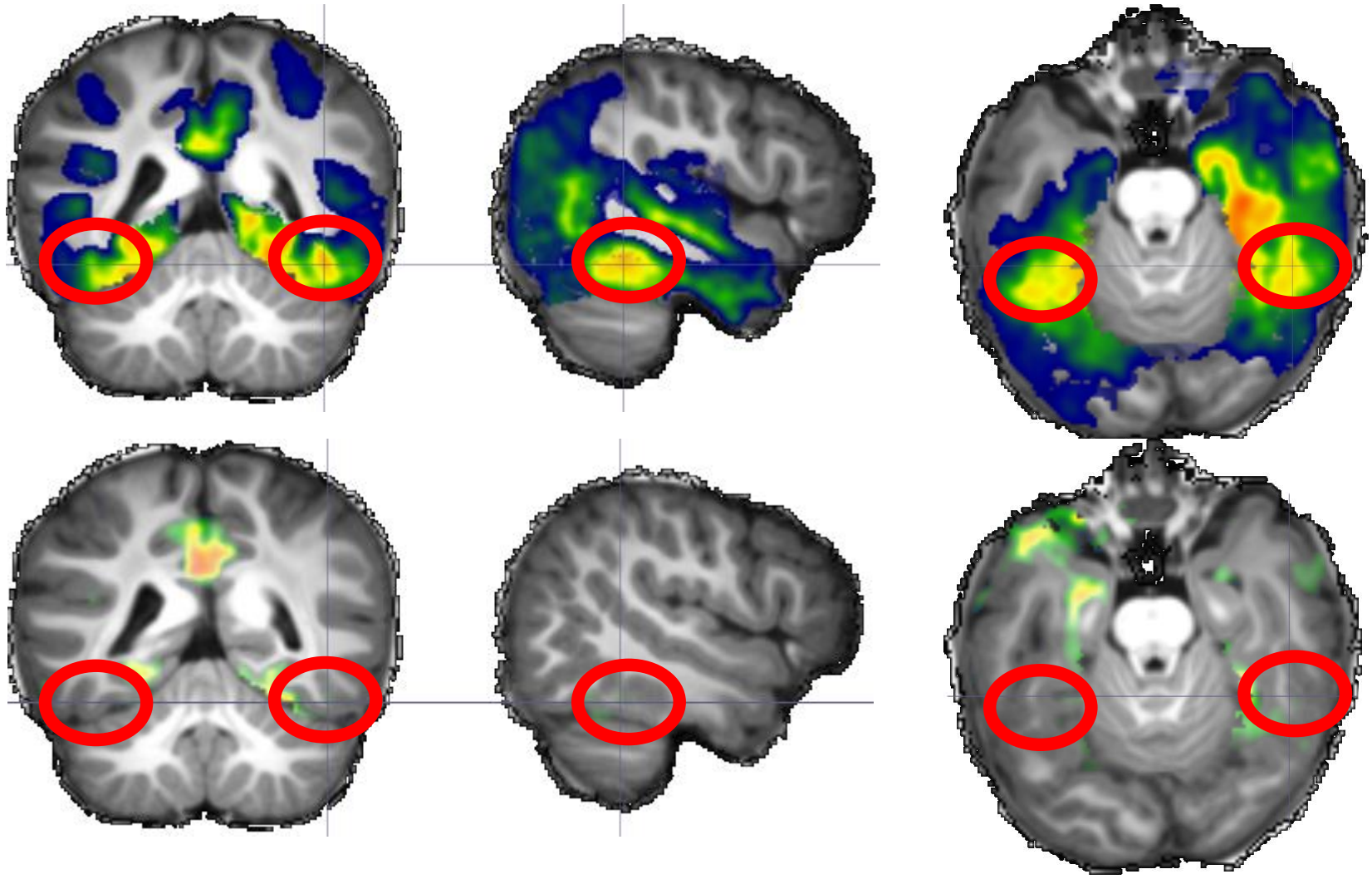
Activity in Middle Fusiform Gyrus at N290 Latency, 12 Months
Comparison with “Fusiform Gyrus” Atlas ROI



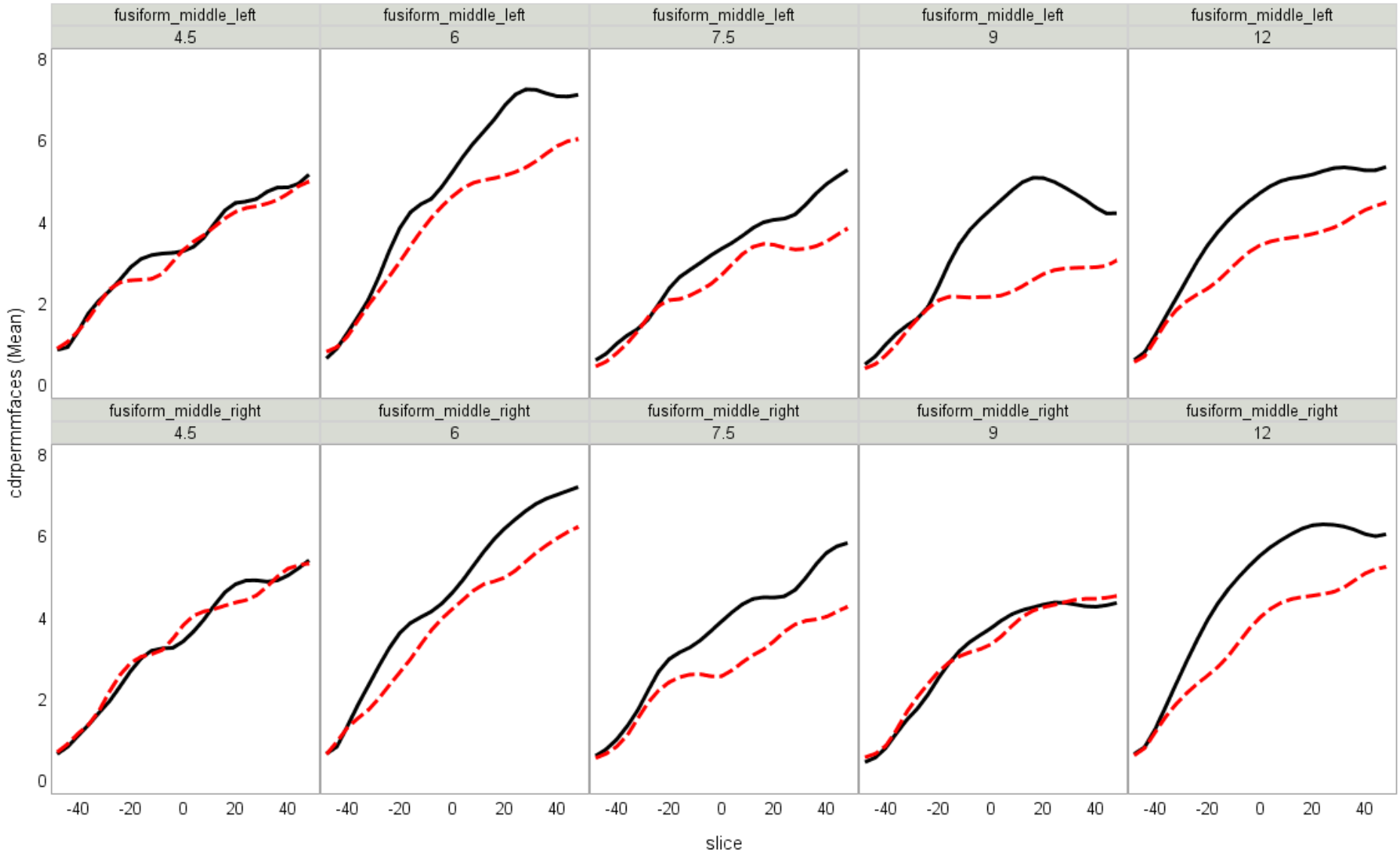
Face- and Toy-Related Activity, Middle FFG, N290 Latency, 12 Months

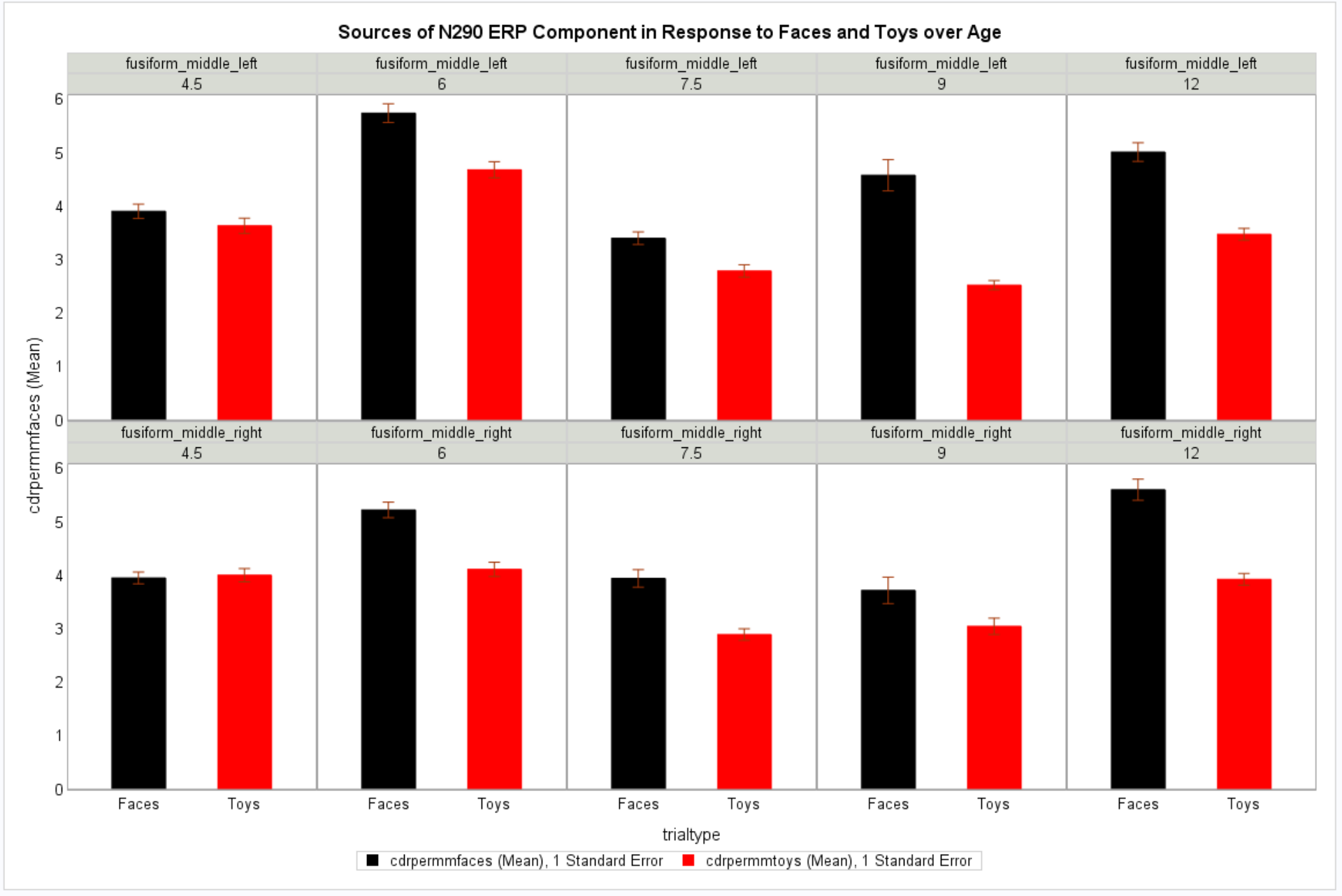
Faces

Toys

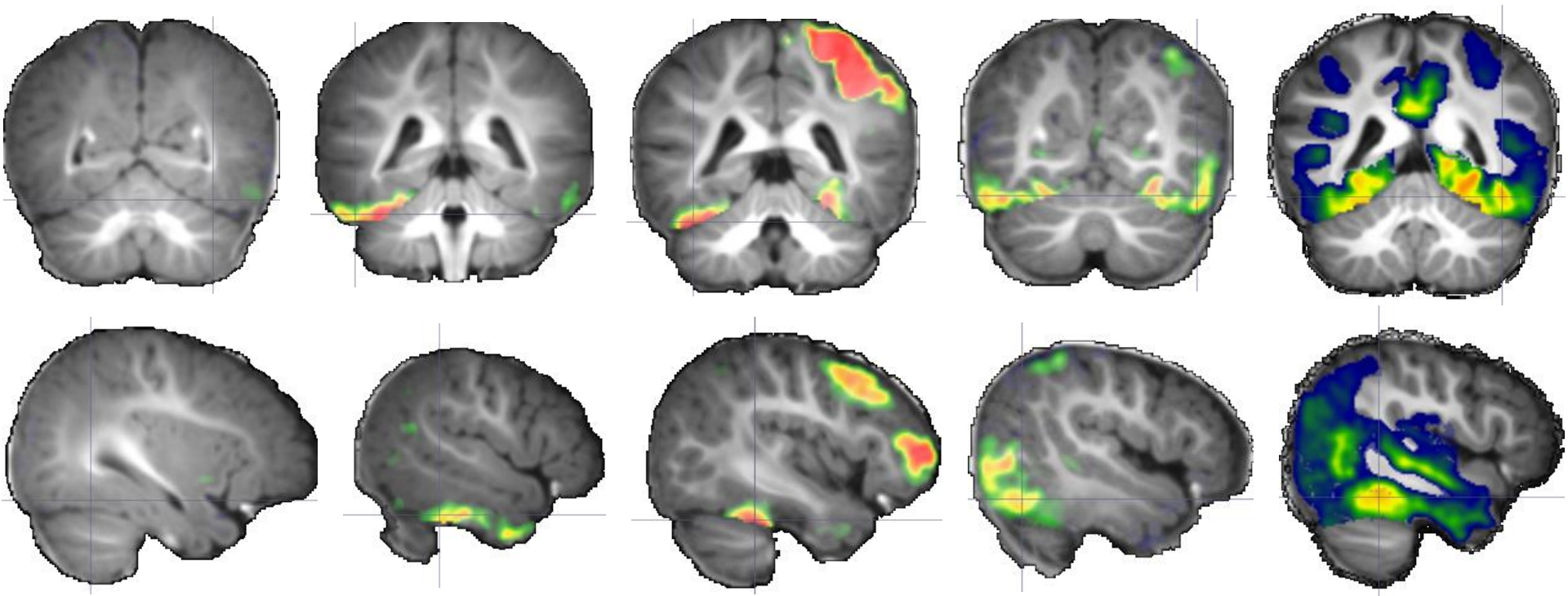


Middle FFG, ROI over Time at Peak N290



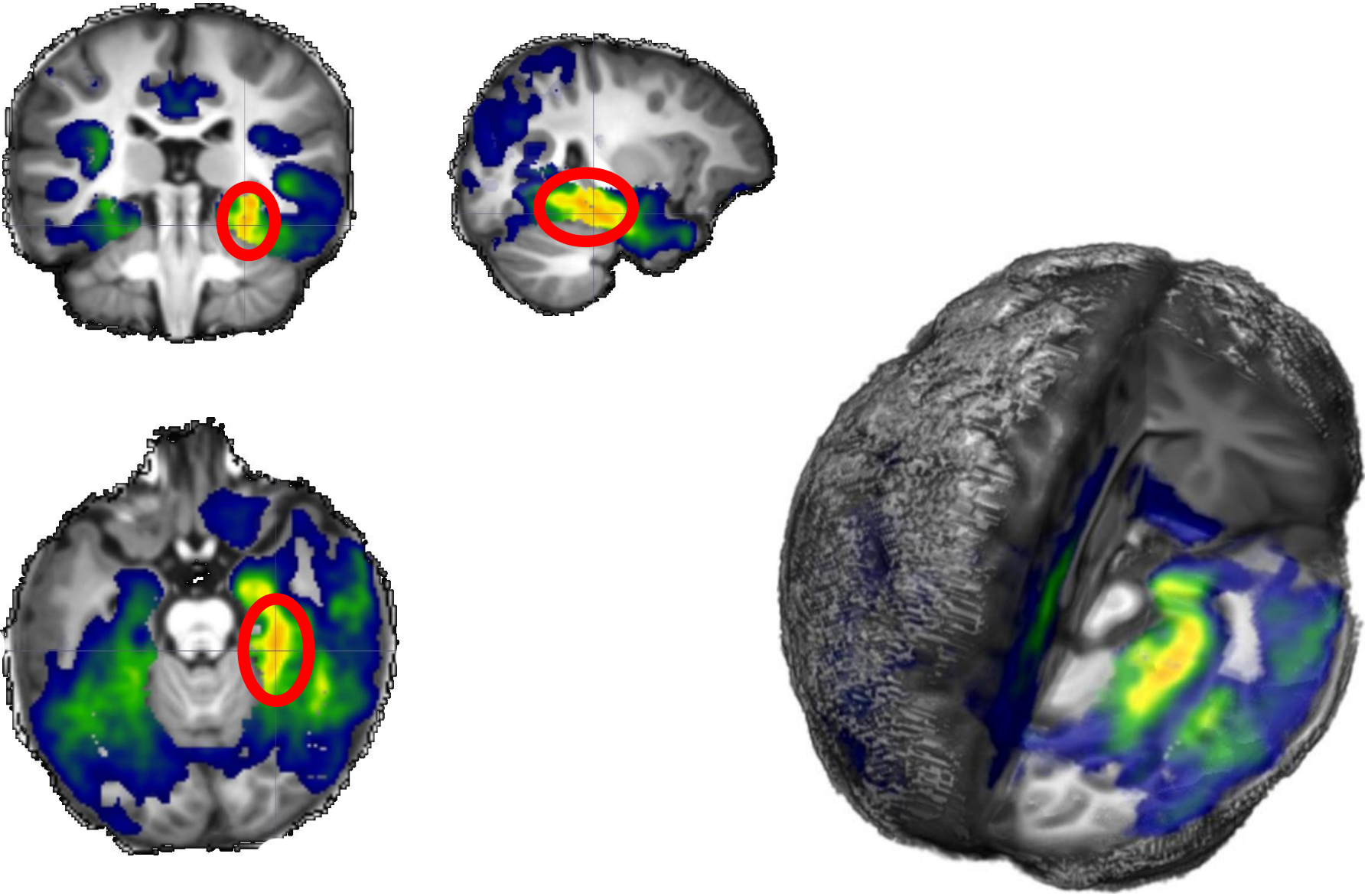

Sources of N290 ERP Component in Response to Faces and Toys over Age
fusiform_middle_left
4.5
fusiform_middle_left
6
fusiform_middle_left
7.5
fusiform_middle_left
9
fusiform_middle_left
12
fusiform_middle_right
4.5
fusiform_middle_right
6
fusiform_middle_right
7.5
fusiform_middle_right
9
fusiform_middle_right
12
cdrpermmfaces (Mean)
0
1
2
3
4
5
6
Faces
Toys
trialtype
cdrpermmfaces (Mean), 1 Standard Error
cdrpermmtoys (Mean), 1 Standard Error

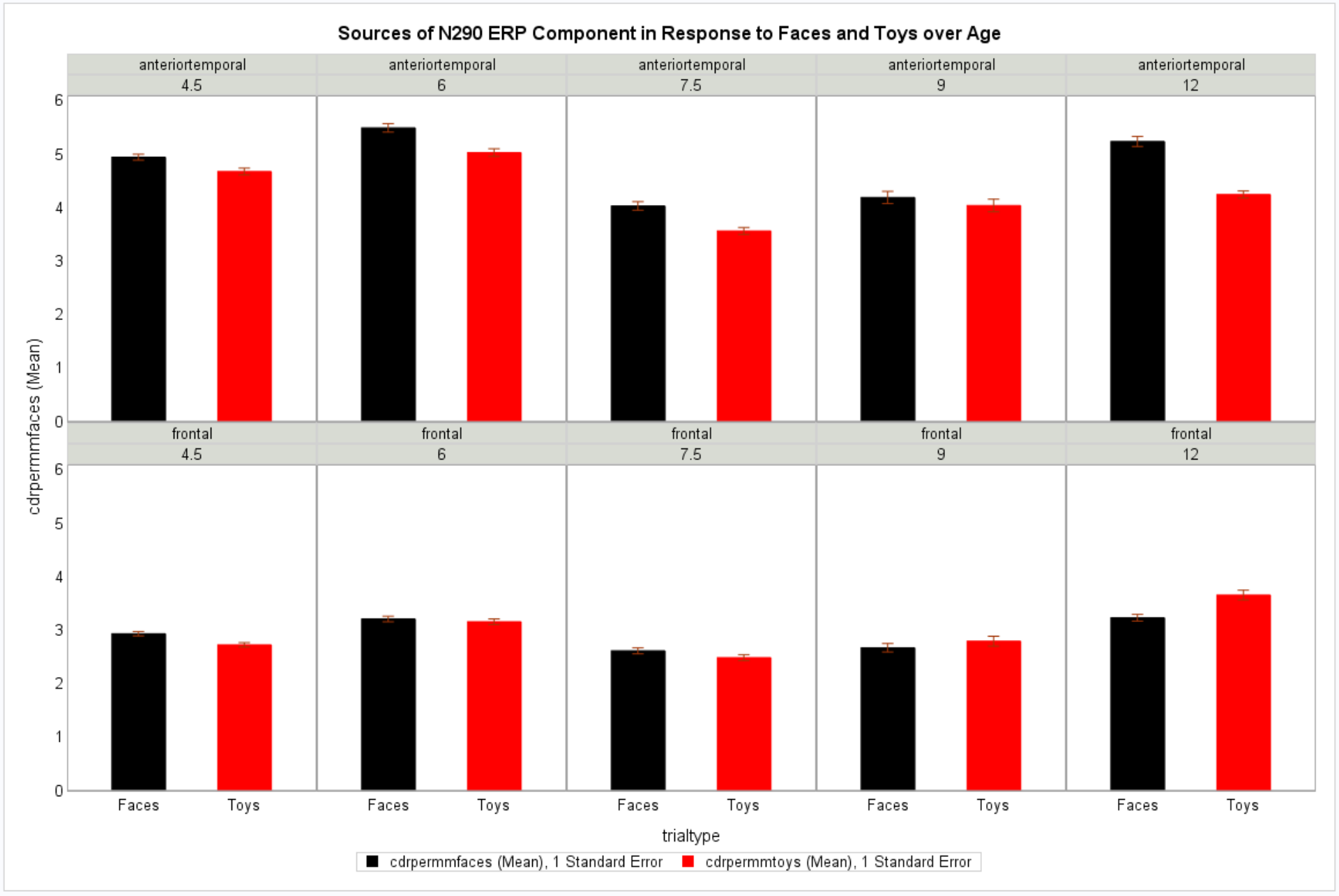
Activity at N290 Latency to Faces, 4.5 to 12 Months

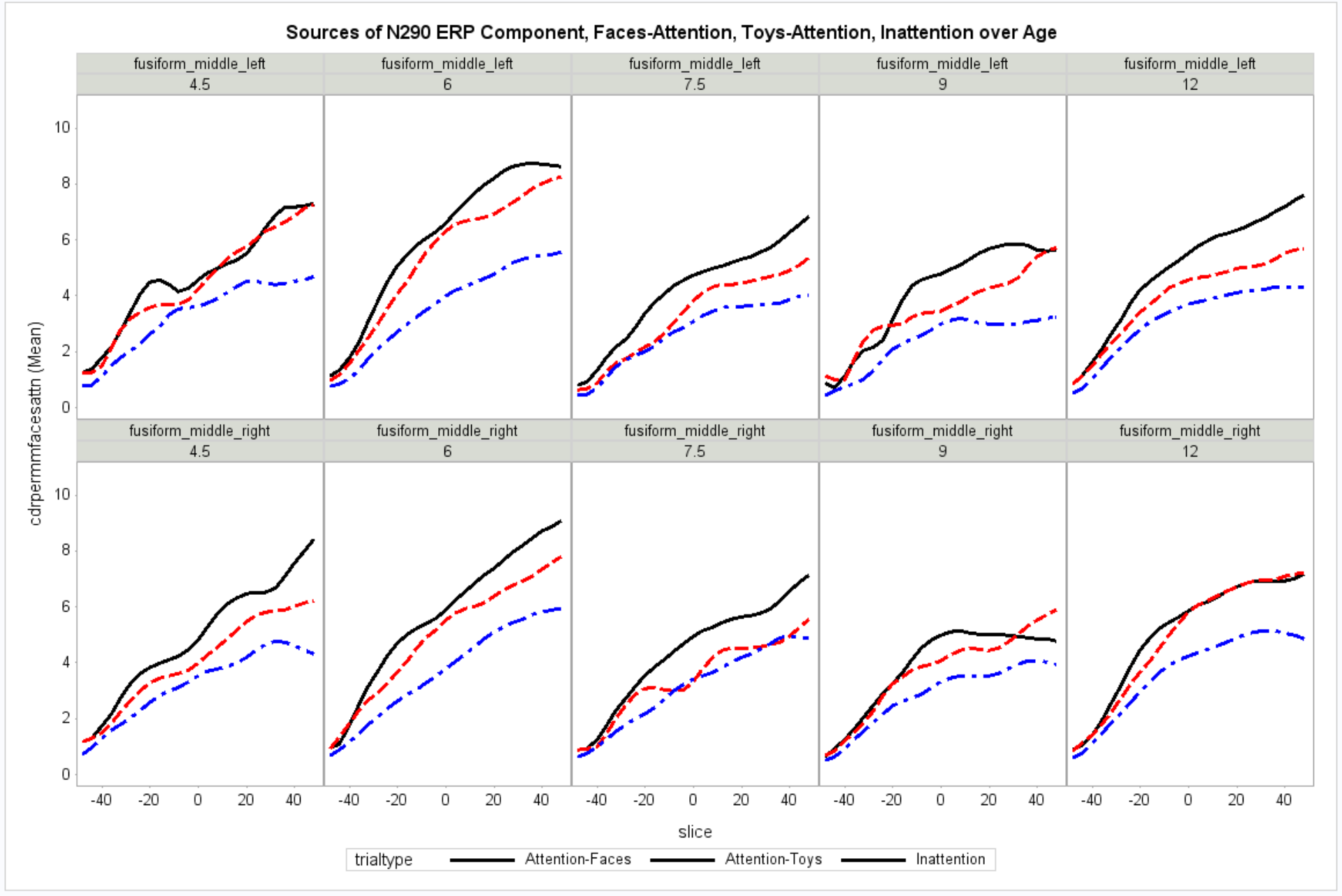


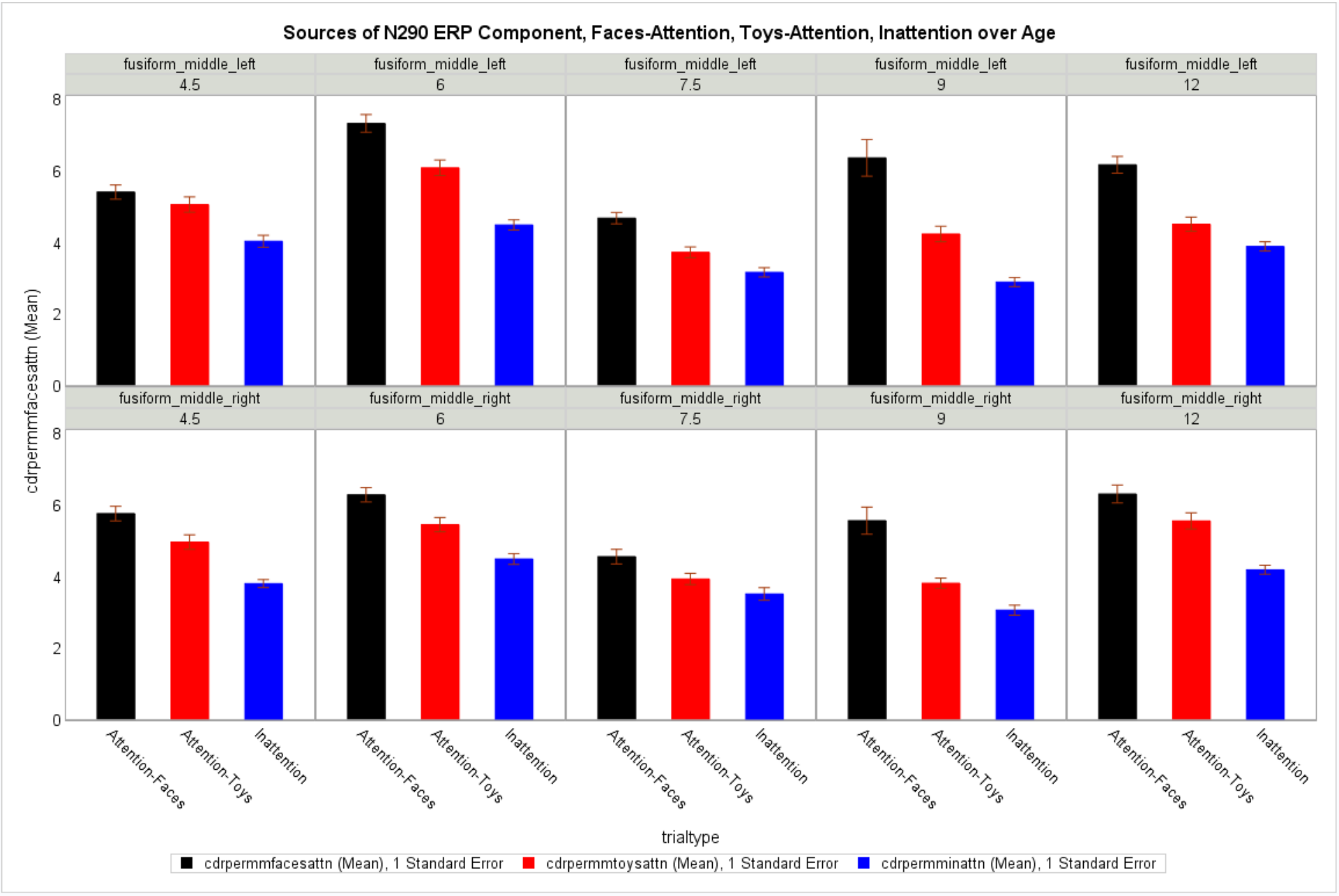
4.5 6.0 7.5 9.0 12.0

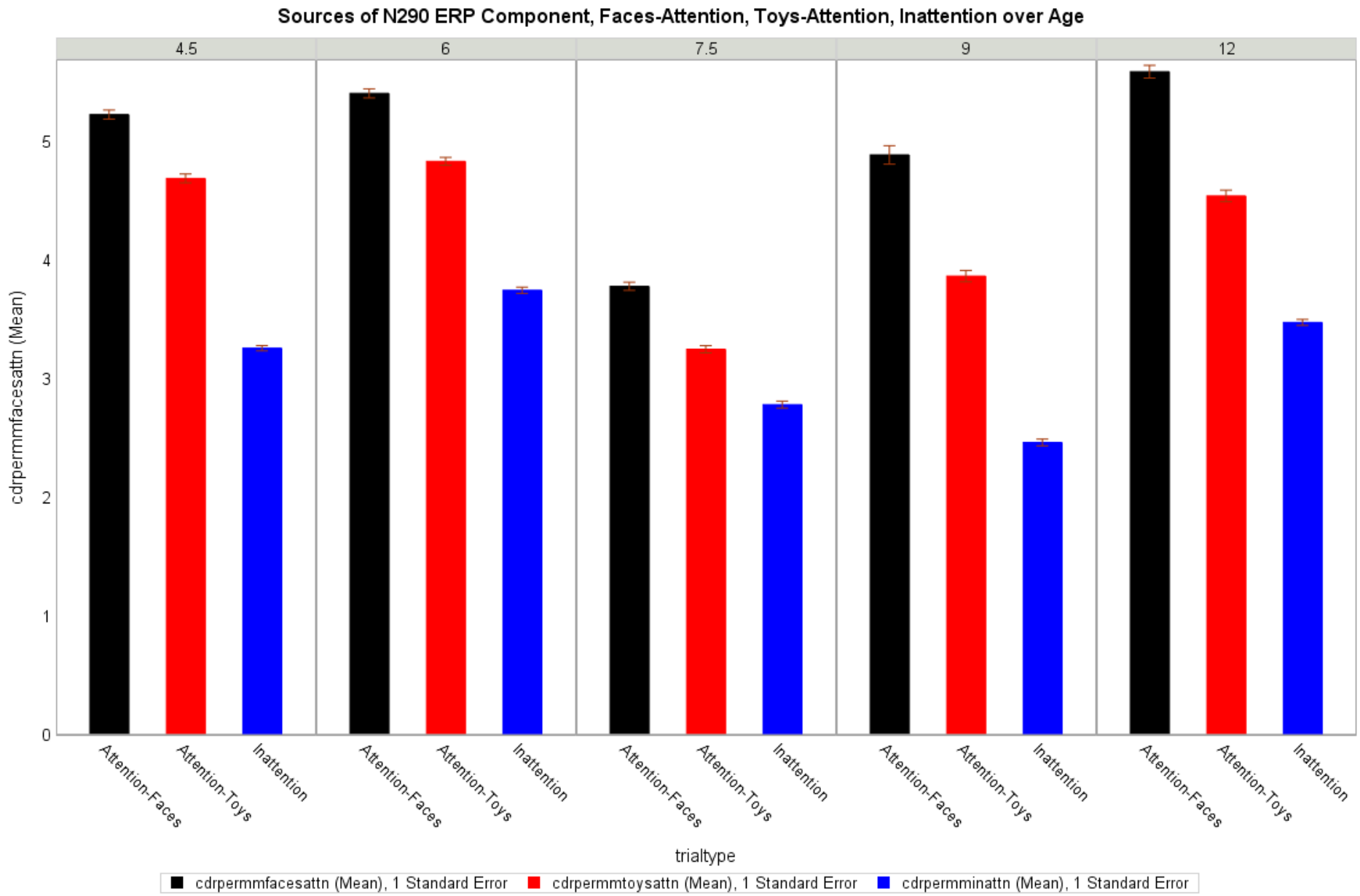
Face-Related Activity in Parahippocampal Gyrus at N290 Latency, 12 Months

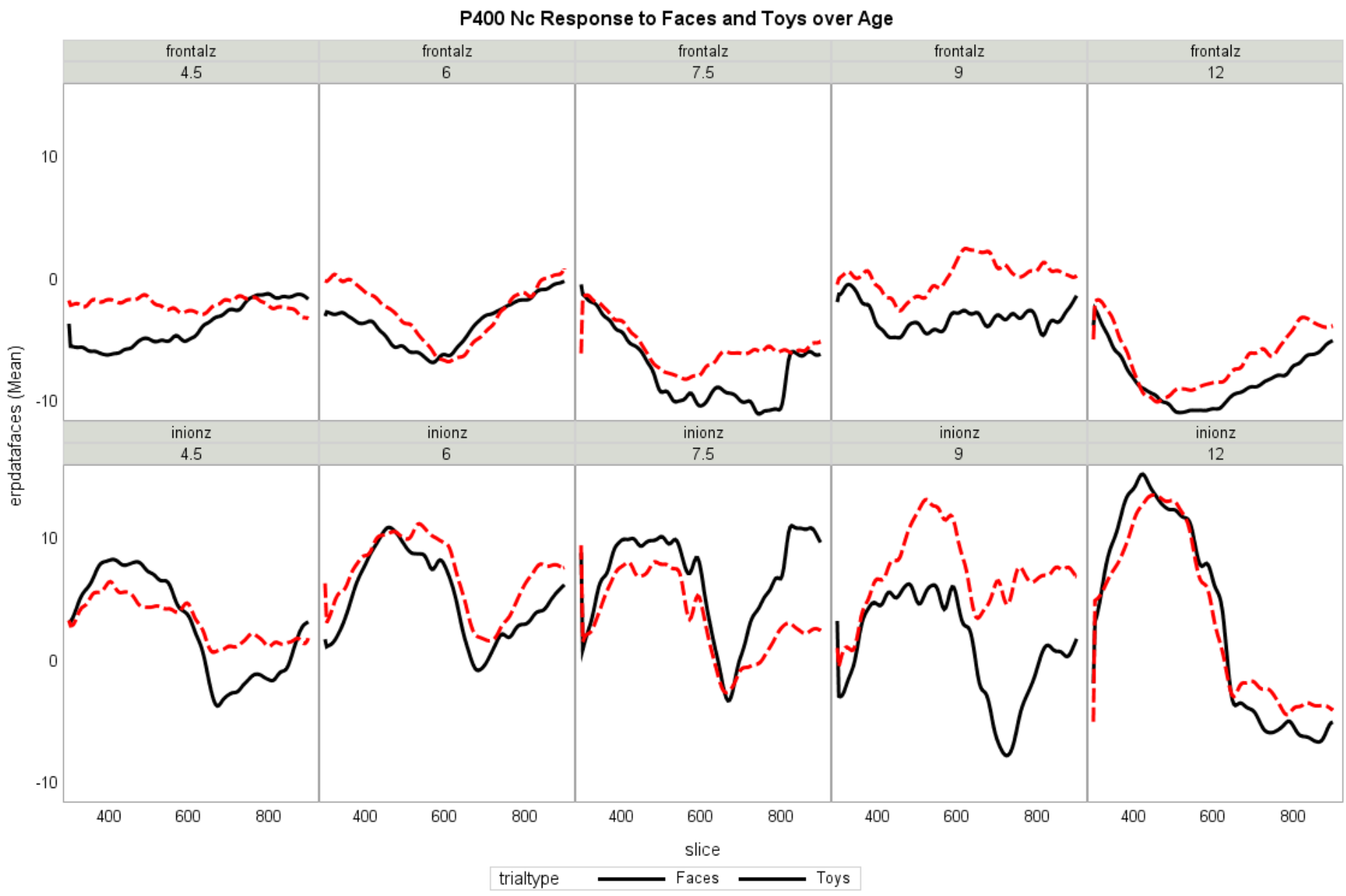


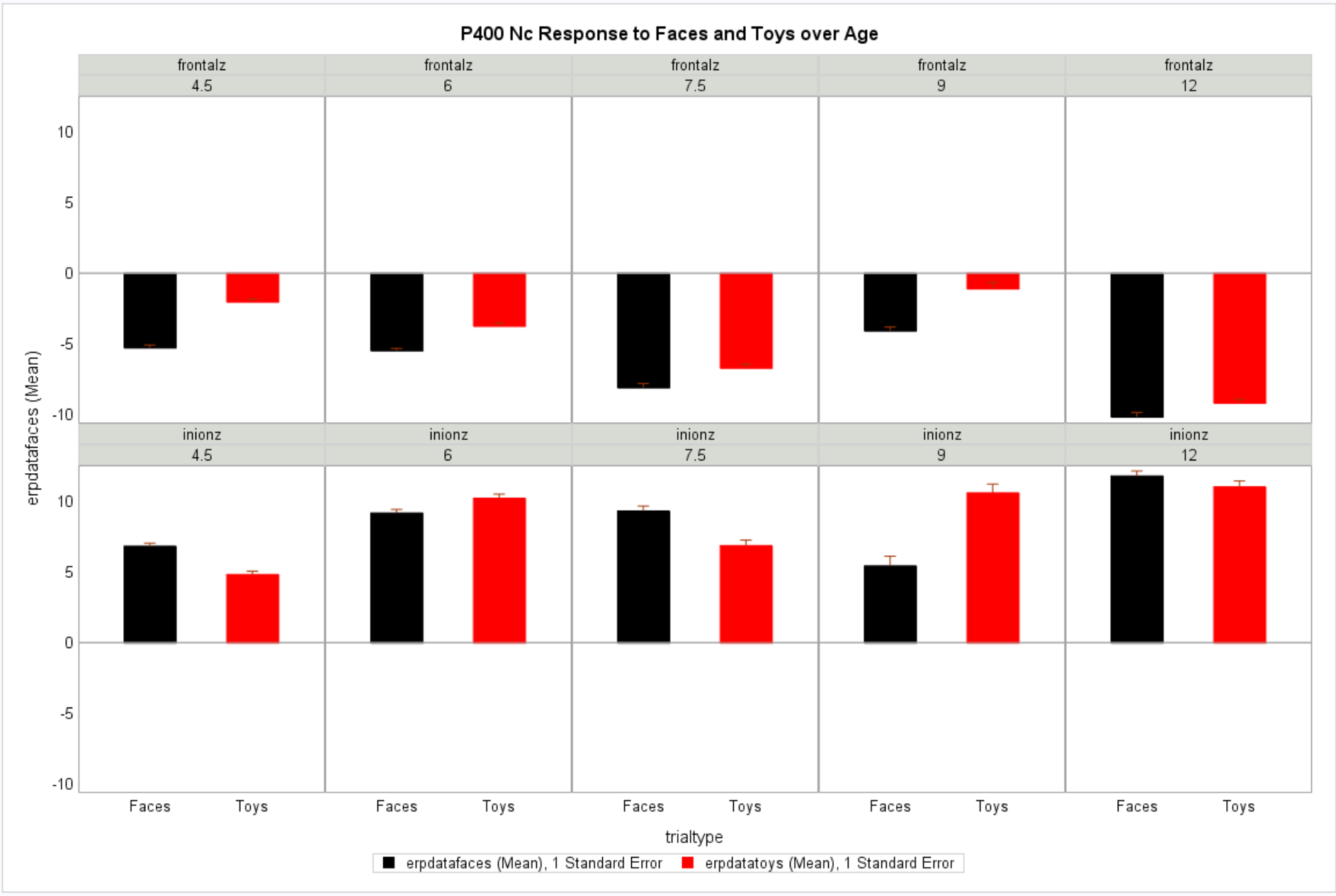

Sources of N290 ERP Component in Response to Faces and Toys over Age
anteriortemporal
4.5
anteriortemporal
6
anteriortemporal
7.5
anteriortemporal
9
anteriortemporal
12
frontal
4.5
frontal
6
frontal
7.5
frontal
9
frontal
12
cdrpermmfaces (Mean)
0
1
2
3
4
5
6
Faces
Toys
trialtype
cdrpermmfaces (Mean), 1 Standard Error
cdrpermmtoys (Mean), 1 Standard Error


Sources of N290 ERP Component, Faces-Attention, Toys-Attention, Inattention over Age
fusiform_middle_left
4.5
fusiform_middle_left
6
fusiform_middle_left
7.5
fusiform_middle_left
9
fusiform_middle_left
12
fusiform_middle_right
4.5
fusiform_middle_right
6
fusiform_middle_right
7.5
fusiform_middle_right
9
fusiform_middle_right
12
cdrpermmfacesattn (Mean)
0
2
4
6
8
10
-40
-20
0
20
40
slice
trialtype
Attention-Faces
Attention-Toys
Inattention

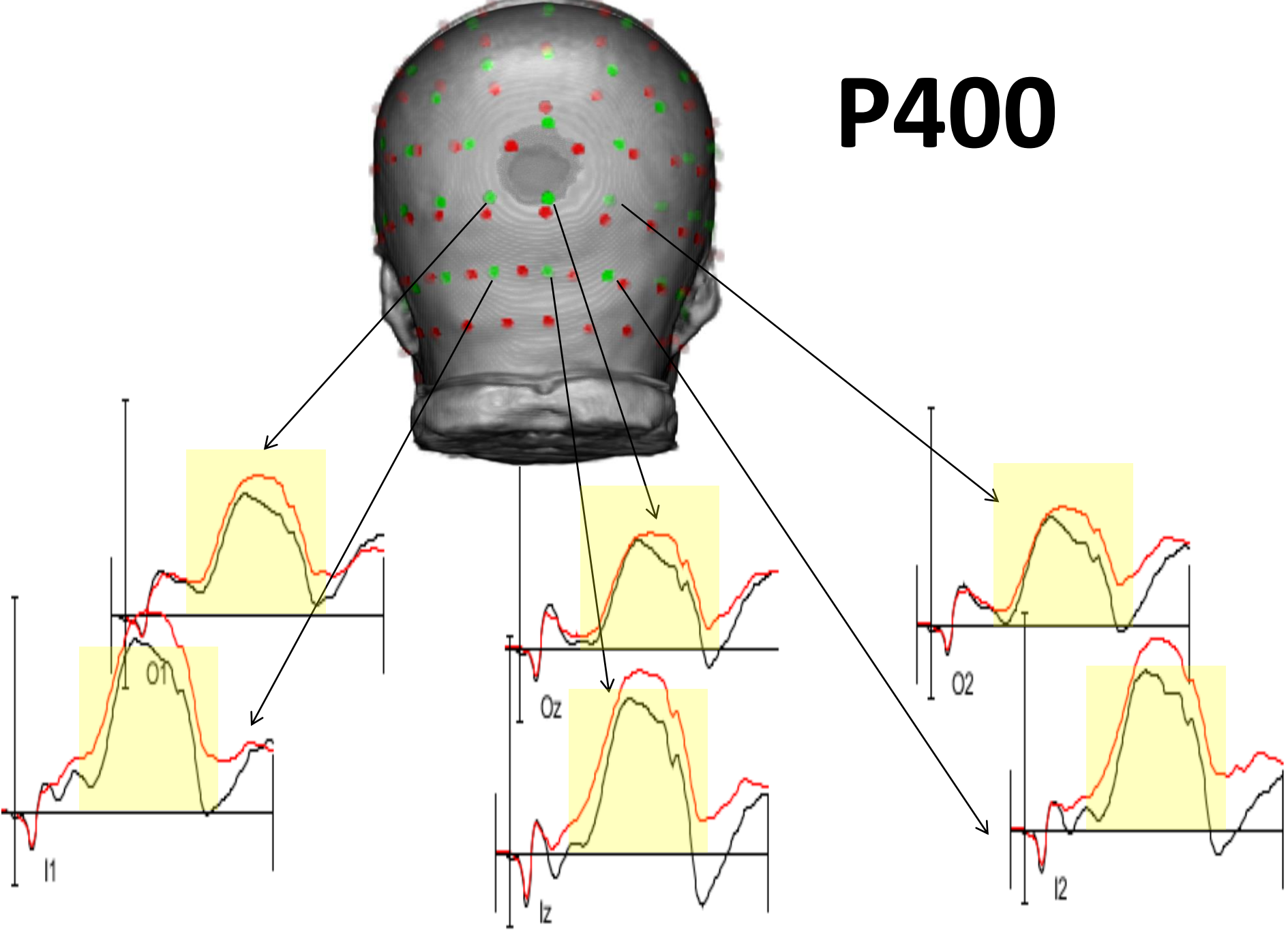

Sources of N290 ERP Component, Faces-Attention, Toys-Attention, Inattention over Age
fusiform_middle_left
4.5
fusiform_middle_left
6
fusiform_middle_left
7.5
fusiform_middle_left
9
fusiform_middle_left
12
fusiform_middle_right
4.5
fusiform_middle_right
6
fusiform_middle_right
7.5
fusiform_middle_right
9
fusiform_middle_right
12
cdrpermmfacesattn (Mean)
0
2
4
6
8
Attention-Faces
Attention-Toys
Inattention
trialtype
cdrpermmfacesattn (Mean), 1 Standard Error
cdrpermmtoysattn (Mean), 1 Standard Error
cdrpermminattn (Mean), 1 Standard Error

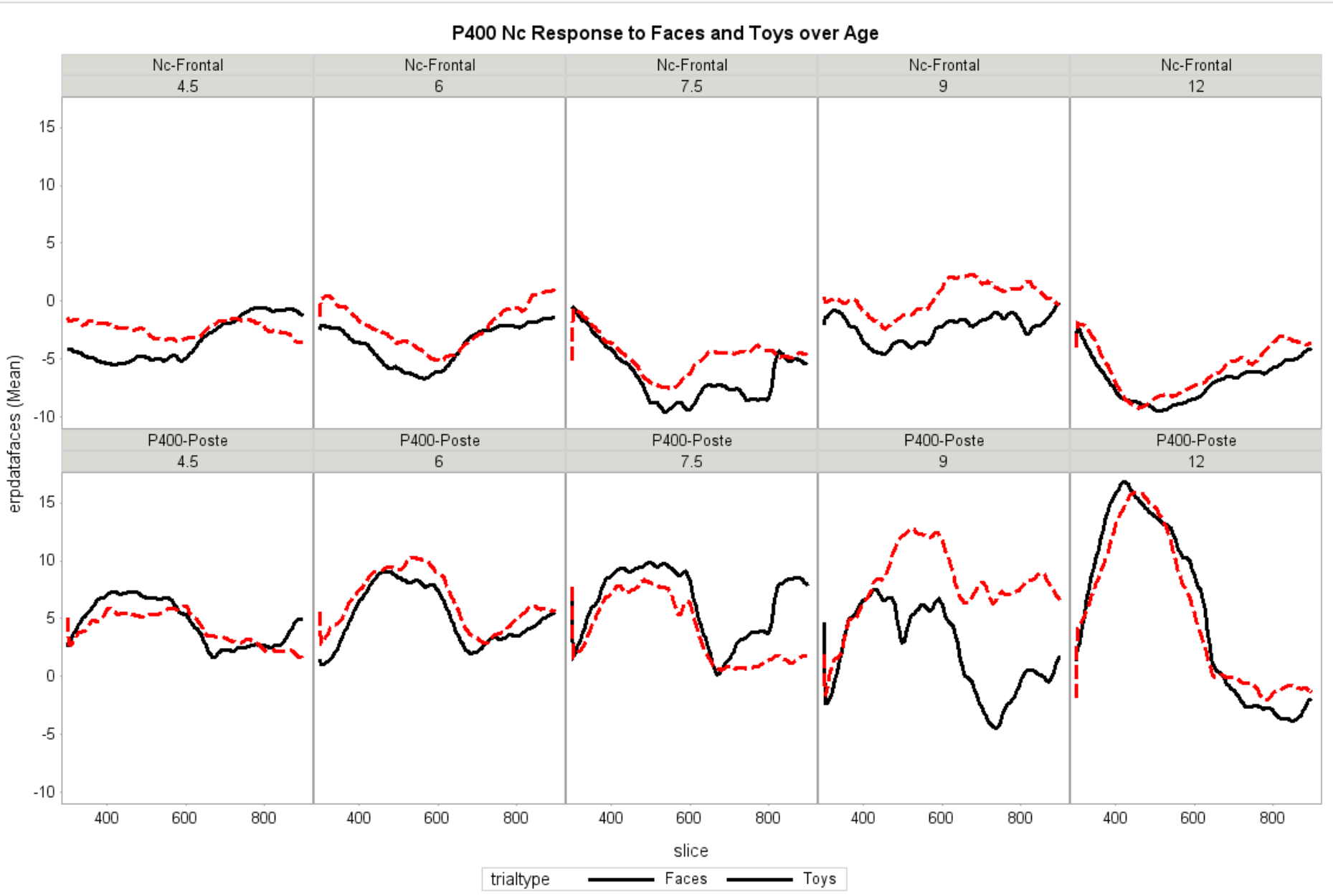

Sources of N290 ERP Component, Faces-Attention, Toys-Attention, Inattention over Age
4.5
6
7.5
9
12
cdrpermmfacesattn (Mean)
0
1
2
3
4
5
Attention-Faces
Attention-Toys
Inattention
trialtype
cdrpermmfacesattn (Mean), 1 Standard Error
cdrpermmtoysattn (Mean), 1 Standard Error
cdrpermminattn (Mean), 1 Standard Error


P400 Nc Response to Faces and Toys over Age
frontalz
4.5
frontalz
6
frontalz
7.5
frontalz
9
frontalz
12
inionz
4.5
inionz
6
inionz
7.5
inionz
9
inionz
12
erpdatafaces (Mean)
10
0
-10
400
600
800
slice
trialtype
Faces
Toys

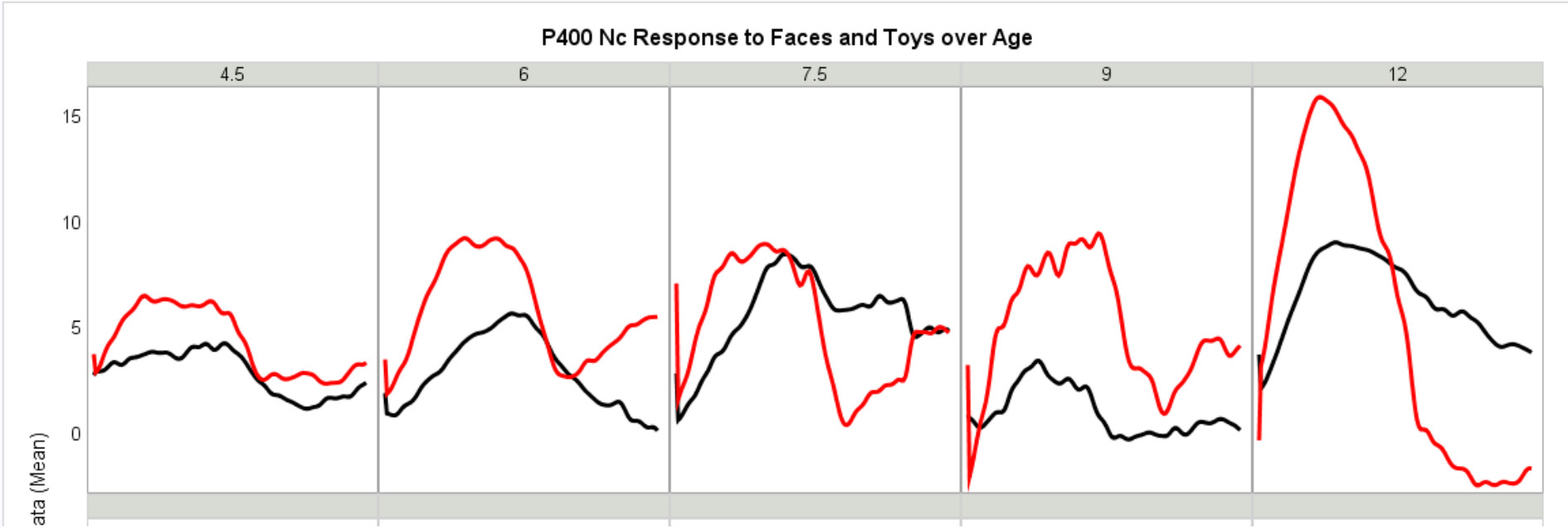

P400 Nc Response to Faces and Toys over Age
frontalz
4.5
6
7.5
9
12
inionz
erpdatafaces (Mean)
10
5
0
-5
-10
Faces
Toys
trialtype
erpdatafaces (Mean), 1 Standard Error
erpdatatoys (Mean), 1 Standard Error

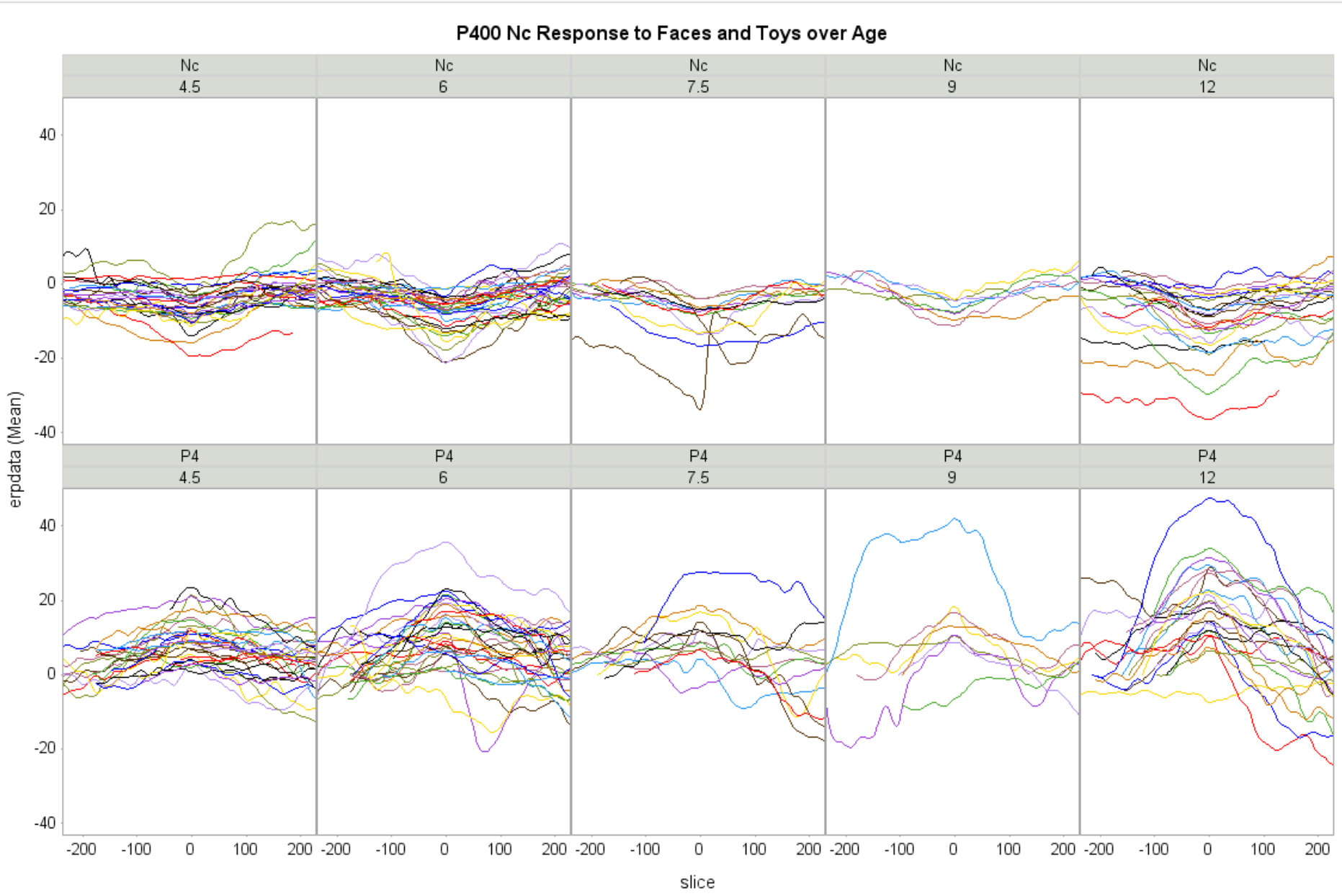
P400



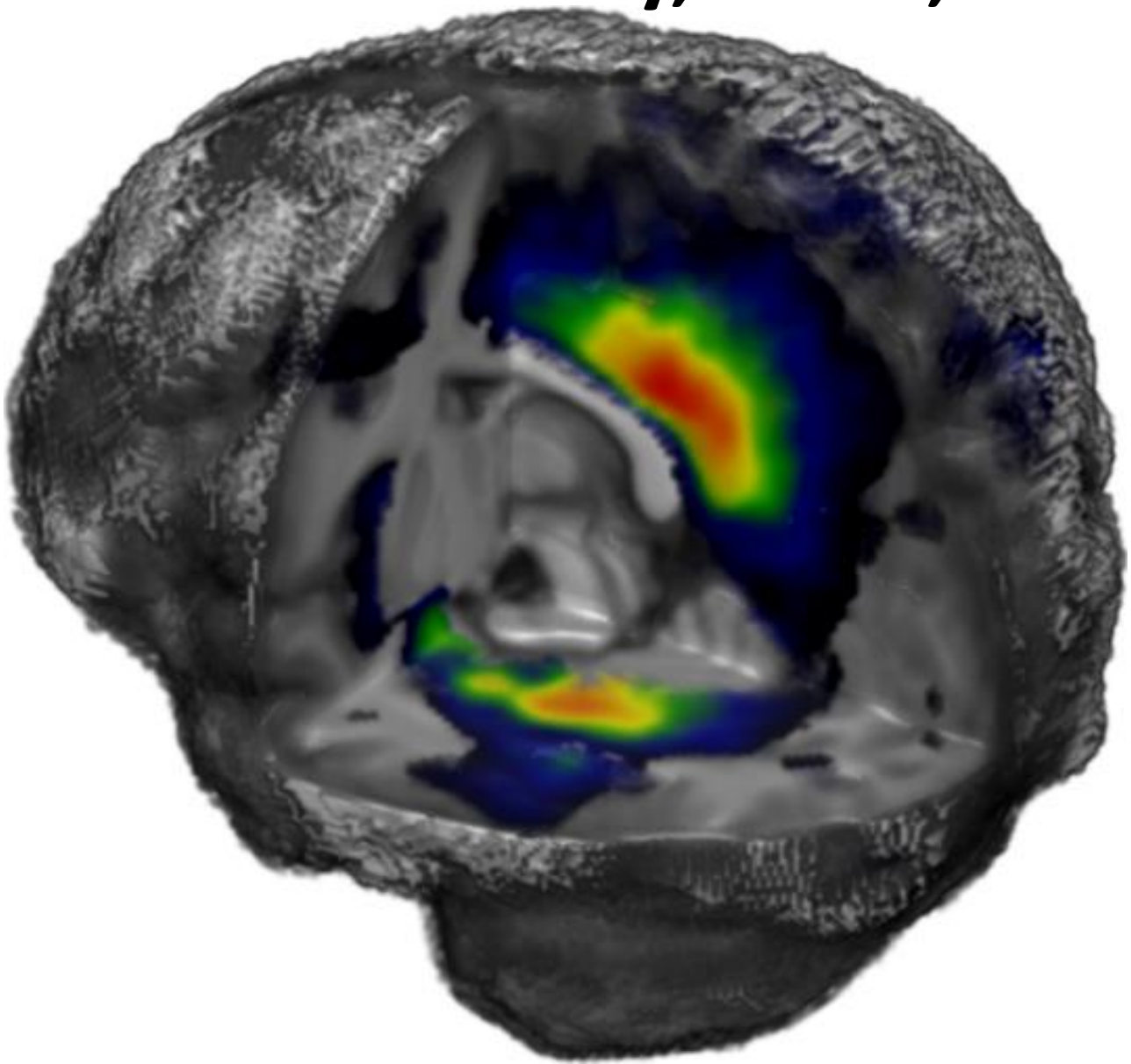

P400 Nc Response to Faces and Toys over Age
Nc-Frontal
4.5
Nc-Frontal
6
Nc-Frontal
7.5
Nc-Frontal
9
Nc-Frontal
12
P400-Poste
4.5
P400-Poste
6
P400-Poste
7.5
P400-Poste
9
P400-Poste
12
erpdatafaces (Mean)
15
10
5
0
-5
-10
400
600
800
slice
trialtype
Faces
Toys

ERP from 350 to 900 ms
Posterior, P400 (Red)
Frontal-Central, Inverted Nc (Black)

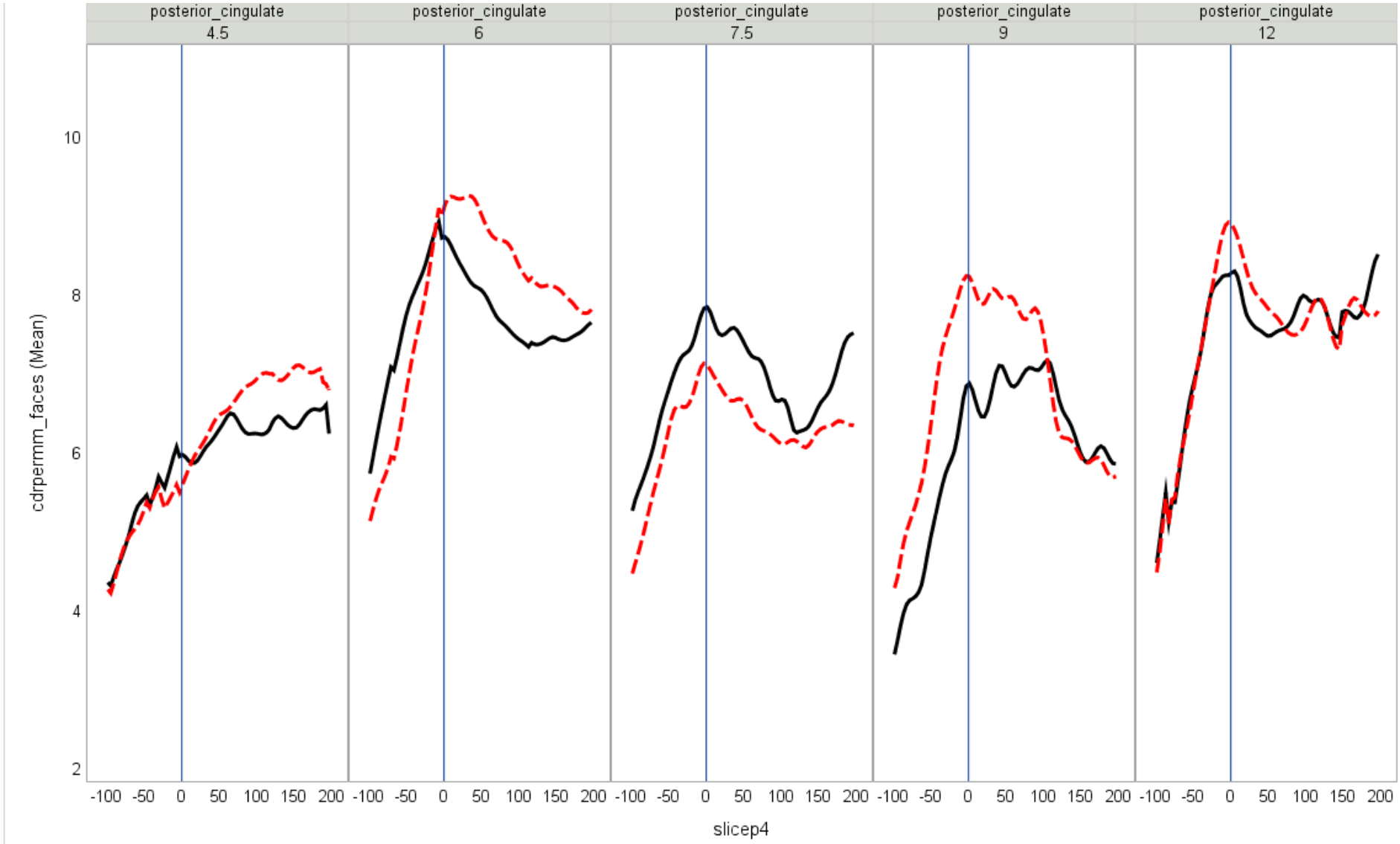



P400 Nc Response to Faces and Toys over Age
Nc
4.5
Nc
6
Nc
7.5
Nc
9
Nc
12
P4
4.5
P4
6
P4
7.5
P4
9
P4
12
erpdata (Mean)
40
20
0
-20
-40
-200
-100
0
100
200
slice

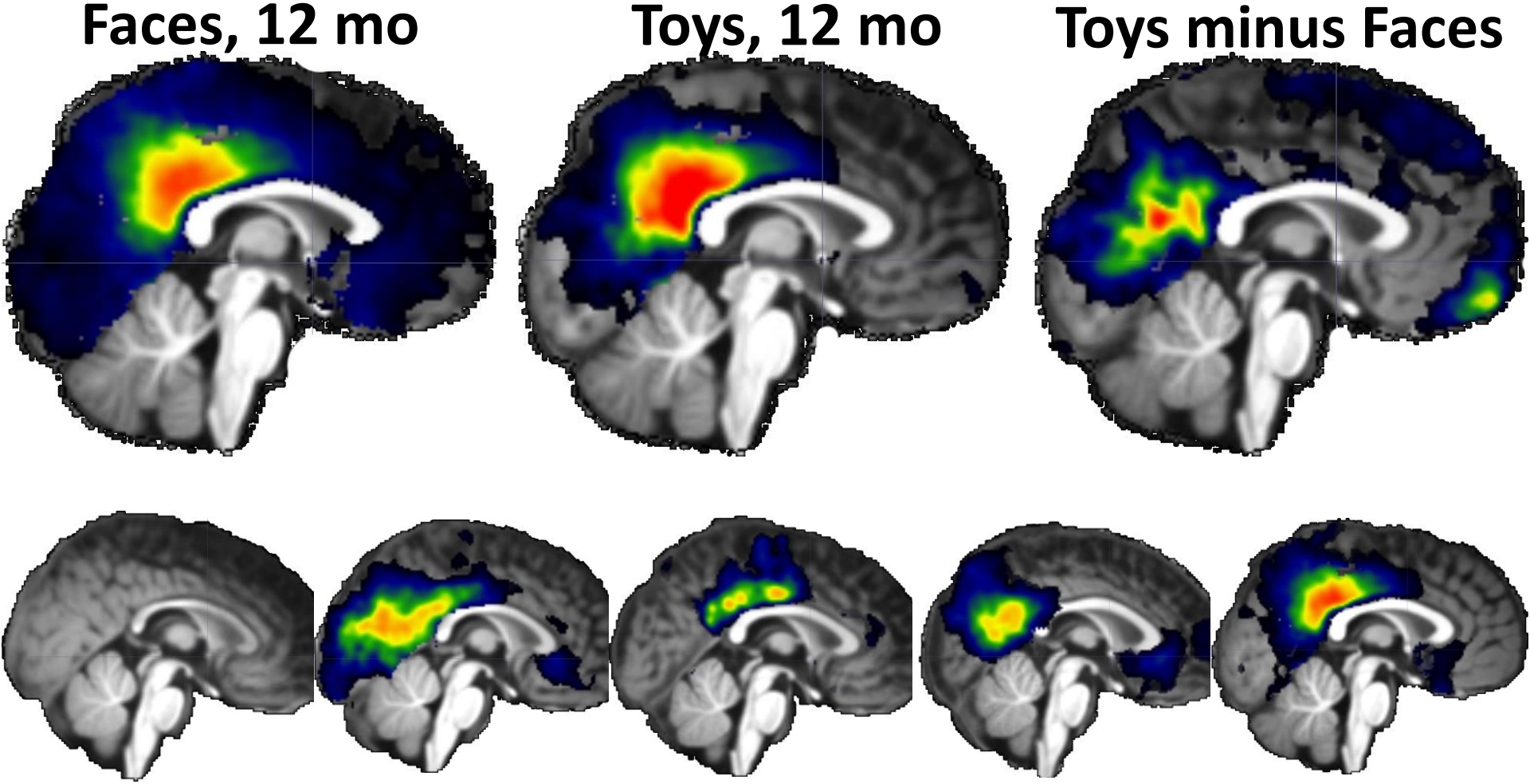
Posterior Cingulate Gyrus CDR Activity at Peak P400 Latency, Faces, 12 months

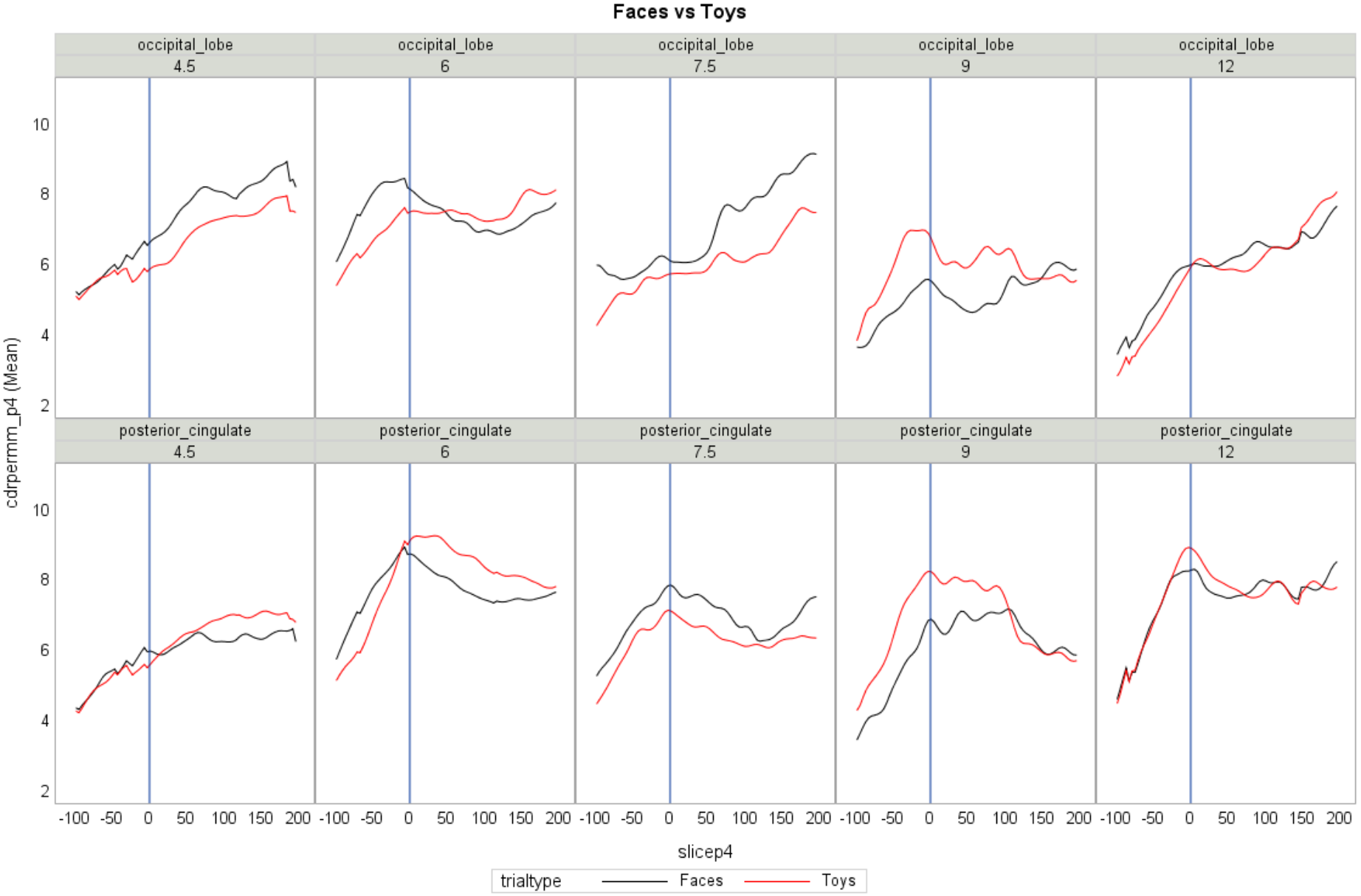


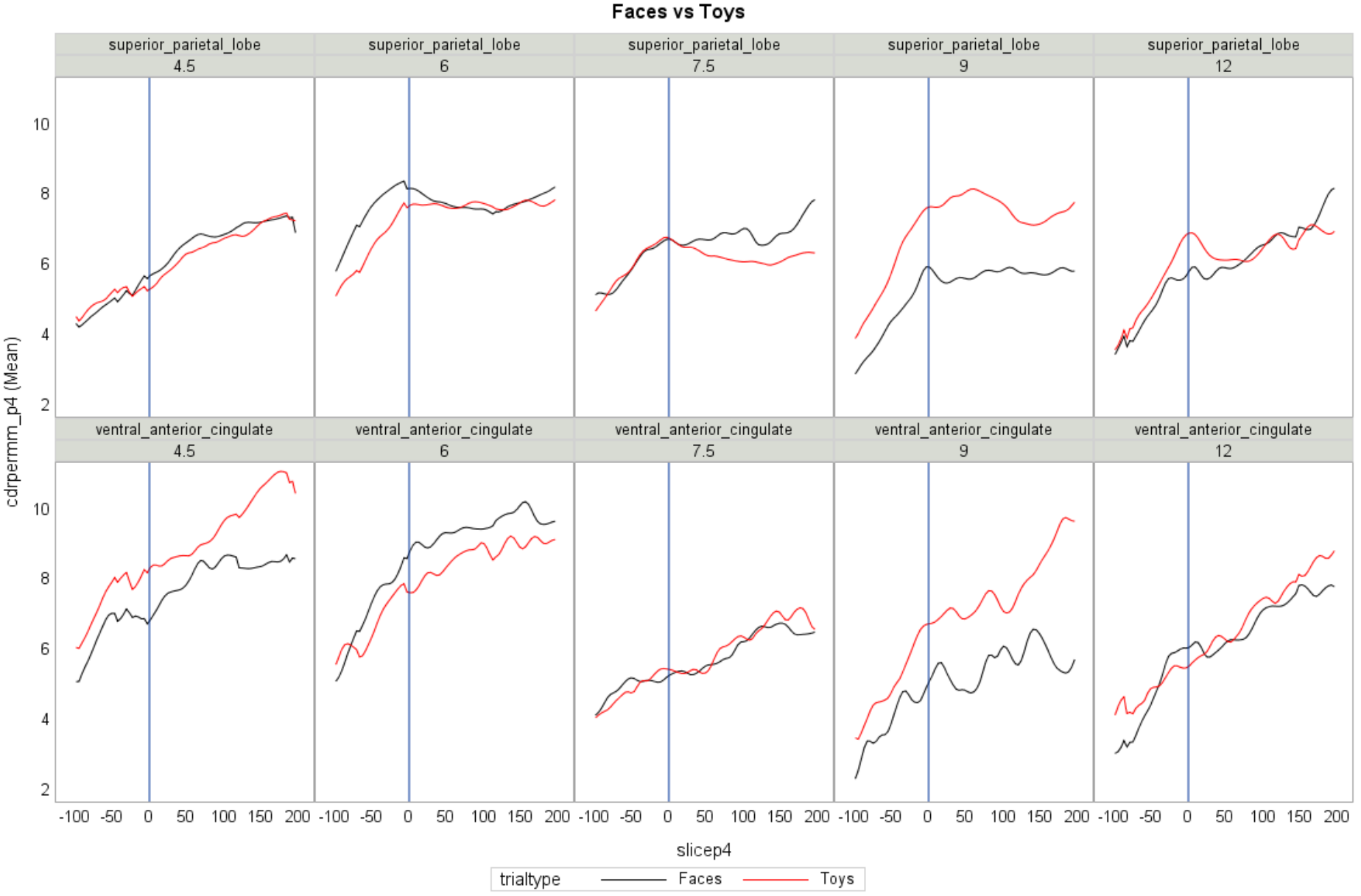
Posterior Cingulate Gyrus, ROI over Time at Peak P400



Posterior Cingulate Gyrus CDR Activity at Peak P400 Latency




Faces vs Toys
occipital_lobe
4.5
occipital_lobe
6
occipital_lobe
7.5
occipital_lobe
9
occipital_lobe
12
posterior_cingulate
4.5
posterior_cingulate
6
posterior_cingulate
7.5
posterior_cingulate
9
posterior_cingulate
12
cdrpermm_p4 (Mean)
2
4
6
8
10
-100 -50 0 50 100 150 200
slicep4
trialtype
Faces
Toys


Faces vs Toys
superior_parietal_lobe
4.5
superior_parietal_lobe
6
superior_parietal_lobe
7.5
superior_parietal_lobe
9
superior_parietal_lobe
12
ventral_anterior_cingulate
4.5
ventral_anterior_cingulate
6
ventral_anterior_cingulate
7.5
ventral_anterior_cingulate
9
ventral_anterior_cingulate
12
cdrpermm_p4 (Mean)
2
4
6
8
10
-100 -50 0 50 100 150 200
slicep4
trialtype
Faces
Toys

P1 source localization

- **Lingual gyrus, and other bilateral areas, has peak consistent with P1, larger to faces than toys at two older ages (quadratic effects)**
- **Other areas show face-toy differences, especially at older ages, but no peak (no quadratic effects).**
- **The posterior cingulate area shows enhanced activity and face-toy difference at peak for 12 month olds.**

N290 source localization

- **“Middle” fusiform gyrus, larger to faces than toys in older infants, and has peak consistent with the source area for the N290**
- **Some other areas show face-toy difference (e.g., lateral-posterior), but amplitude is not as large and peak is less pronounced or absent, or is smaller with no peak (frontal)**
- **Effects in anterior temporal area (temporal pole, anterior fusiform gyrus, parahippocampal gyrus) appear to be a precursor to extended ERP activity in P400 and Nc**

P400 source localization

- Posterior cingulate gyrus, larger to toys than to faces, has peak consistent with the peak for the P400
- Distinct timing and sources for the Nc:
- Anterior temporal areas
  (temporal pole, anterior fusiform gyrus, parahippocampal gyrus)
- Prefronal areas
  (subcallosal gyrus, ventral AC)

Results Summary

- **P1: Lingual gyrus, and other bilateral areas, has peak consistent with P1, larger to faces than toys at two older ages**
- **N290: “Middle” fusiform gyrus, larger to faces than toys in older infants, and has peak consistent with the source area for the N290. Other areas show activity, possibly precursor to later components**
- **P400: Posterior cingulate gyrus, larger to toys than to faces, has peak consistent with the peak for the P400**

Summary

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