Sundeep Teki

UCL

The right hemisphere supports but does not replace left hemisphere auditory function in patients with persisting aphasia

Auditory Cognition Group
Wellcome Trust Centre for Neuroimaging

Acknowledgments

Alex Leff

Gareth Barnes

Will Penny

Paul Iverson

Zoe Woodhead

Tim Griffiths

wellcome trust

Take-home message

- Aphasics *do* show robust speech mismatch responses.
- MEG source-space responses indicative of reorganization from left to right hemisphere in aphasics.
- DCM analysis of MEG data suggests distinct speech networks for aphasics vs. controls.
- Speech comprehension deficits in aphasics can be explained by a predictive coding theory of brain function (cf. Friston).
- Left-STG => Right-STG connection strength in aphasics predicts behaviour on phonemic perception tests.

Overview

- **Aphasia** – patient details, literature review
- **Methods** – MMN, stimulus details
- **MEG recordings** – dipole fits, source-space analysis
- **Dynamic Causal Modelling** – predictions and analysis
- **Discussion**

I. INTRODUCTION

Aims of the study

- Characterize speech perception in controls and aphasics using MEG source space data.

- Investigate causal architecture of speech network in both groups using DCM of evoked MEG responses.

- Assess speech perception and recovery in aphasics in terms of connection strengths of underlying connections of the speech network.

Aphasia

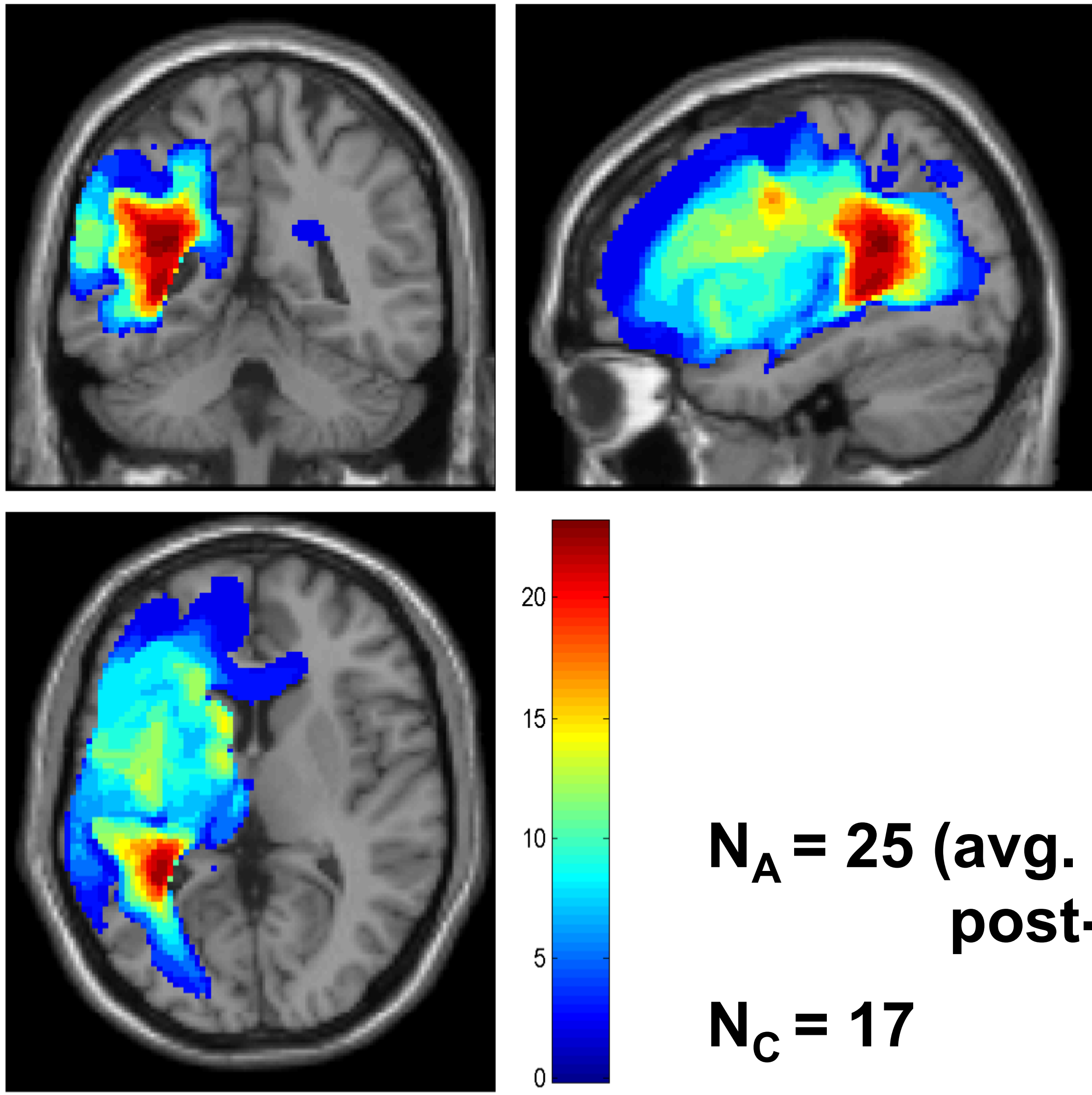
Aphasia is an impairment of language ability following brain damage typically as a result of stroke. This affects talking, reading, understanding and/or writing.

Wernicke's aphasia: patients tend to speak fluently, but their speech often degenerates into seemingly random, very hard to follow "streams of consciousness", which may be peppered with non-words or made up words.

Wernicke's aphasics often fails to provide good answers to questions posed to them, suggesting that they do not really understand the speech of their interviewers.

Lesions to posterior left superior temporal gyrus (STG)

Aphasics



N_A = 25 (avg. 3.6 years post-stroke)

N_C = 17

Table 1. Demographic, stroke and lesion details of the aphasic patients

Patient ID	Age at scan (years)	Time since stroke (years)	Type of stroke	Lesion volume (cm^3)	Fractional lesion volume (%)	
					L A1	L STG
1	69.6	1	I	66.9	73.1	0
2	62.7	1.2	I	37.4	0	8.4
3	63	8.6	I	403.6	86.5	44.7
4	61.5	7.6	I	289.6	86.5	0.2
5	60.5	5.6	I	163.1	83.7	8.5
6	67.8	7.4	H	52.9	0	12.3
7	64.9	1.2	I	147.2	35.4	6.5
8	72.8	4.3	I	59.5	15.4	19.3
9	50.6	3.5	I	399.3	76.0	47.6
10	66.5	5.3	I	197.9	84.1	17.2
11	61.5	3.4	Multi-lacune	40.4	0	0
12	63.3	0.6	I	65.2	0	24.4
13	43.5	1.3	I	65.4	0	17.5
14	35.8	6.2	I	246.5	85.6	60.1
15	46.3	0.7	I	27.9	0	29.3
16	71.1	5.1	I	143.8	56.5	19.5
17	62.4	3.7	I	155.1	85.4	0.6
18	68	4.6	I	62.3	0	8.5
19	54	1.9	I	81.8	0	18.0
20	60.9	3	H	128.8	27.5	5.0
21	74.7	0.6	I	45.8	7.3	0
22	45.4	2.1	I	61.6	0	9.5
23	90.3	3.7	I	24.2	0	0.1
24	62.7	4.9	I	124.2	48.6	28.7
25	62.5	3.3	I	116.5	9.6	74.9
Mean	61.7	3.6	22:2:1	128.3	18.4	34.4

Table 2. Behavioural details of the aphasic patients.

Patient ID	Comprehension		Object Naming	Reading	Writing	Formant Threshold (ERB)	Vowel Threshold (ERB)
	Spoken comp.	Vowel ID					
1	61	27	6	19	76	0.558	0.590
2	56	38	38	50	70	0.525	0.494
3	52	17	22	6	28	0.754	0.672
4	52	16	12	32	51	0.666	0.352
5	61	34	27	34	64	0.785	0.449
6	54	37	30	35	58	0.933	0.514
7	52	38	33	33	48	0.628	0.647
8	61	34	21	13	28	1.012	0.697
9	51	39	0	0	33	0.533	0.514
10	38	13	12	18	50	0.797	0.810
11	56	40	36	18	17	0.672	0.590
12	33	12	0	12	49	0.735	0.603
13	35	17	14	0	9	0.359	0.609
14	39	38	37	26	41	0.660	0.685
15	39	26	41	47	58	0.754	0.501
16	37	7	0	2	48	0.772	0.603
17	35	21	0	7	9	0.577	0.494
18	40	31	26	44	44	0.647	0.545
19	41	24	6	18	31	0.482	0.449
20	54	40	30	34	71	0.647	0.384
21	51	24	14	37	29	0.957	1.037
22	52	39	18	66	76	0.378	0.475
23	51	40	43	6	62	0.660	0.533
24	40	24	41	53	62	0.685	0.514
25	36	16	16	42	29	0.651	0.533
Mean	47	28	21	26	46	0.674	0.573

II. MMN

Mismatch Negativity (MMN)

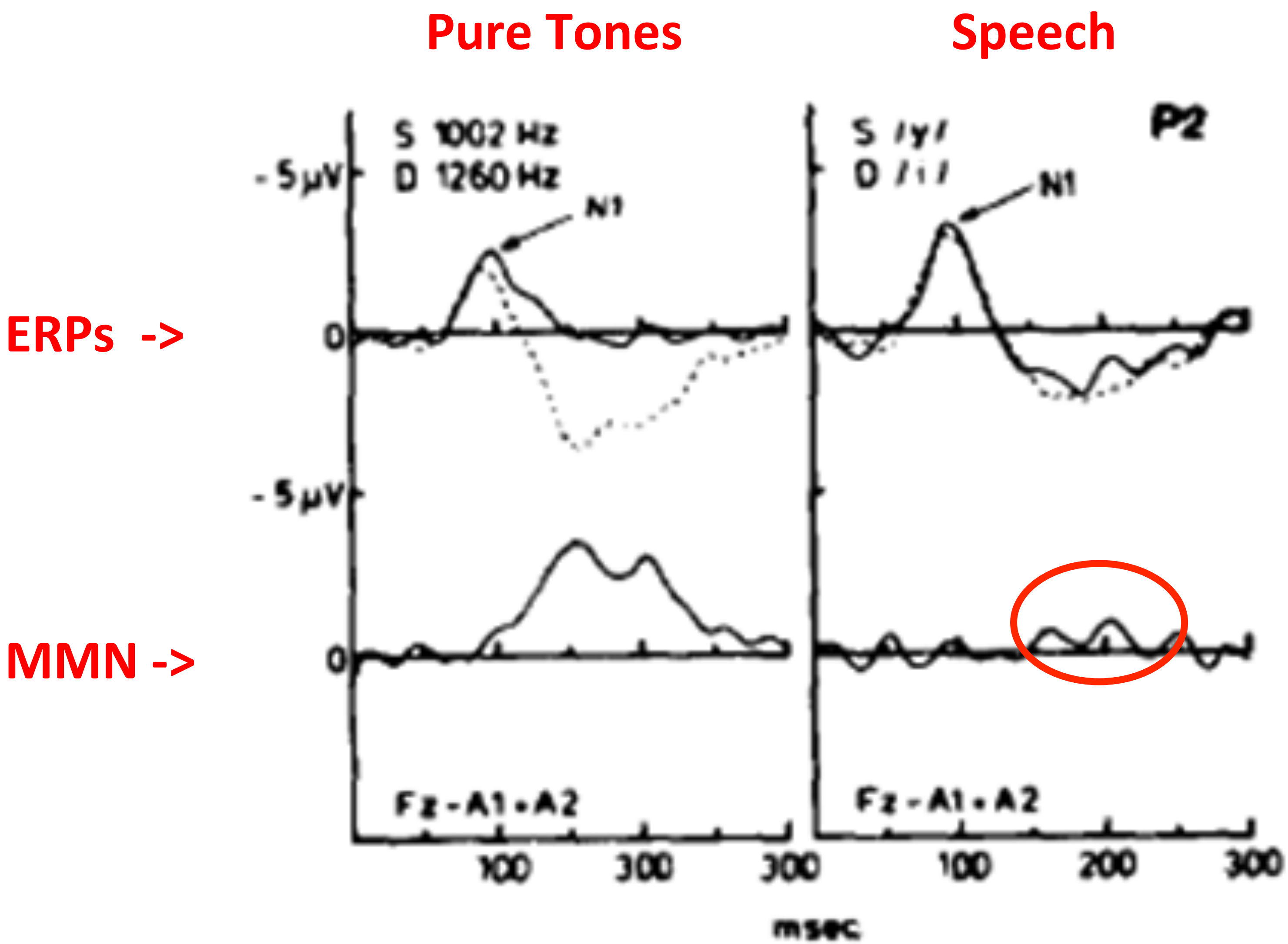
MMN is a negative peak that occurs after an unpredictable change in the acoustic environment, e.g. when deviant sounds are embedded in a stream of repeating sounds, or standards. Näätänen et al., 2007

Latency: 150-250 ms after change onset.

Sources: interactive fronto-temporal network including primary and secondary auditory cortex and right inferior frontal gyrus. Alho, 1995; Opitz et al., 2002

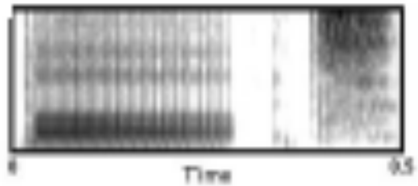
Interpretation: MMN is though to reflect updating of an internal model of the acoustic input: register change & update

Aphasia & MMN



Aaltonen et al., 1993

MMN stimuli

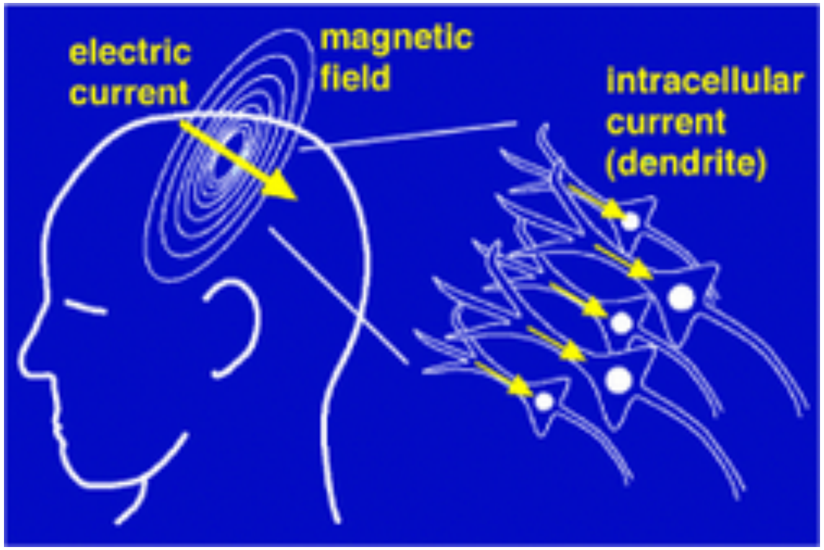
Vowel Stimulus	Percept	Vowels	Formant Frequencies F1 (Hz)	F2 (Hz)	Distance from Standard (ERB)
STD	“Bart”		628	1014	0
D1	“Bart”		565	1144	1.16
D2	“Burt”		507	1287	2.32
D3	“Beat”		237	2522	9.30

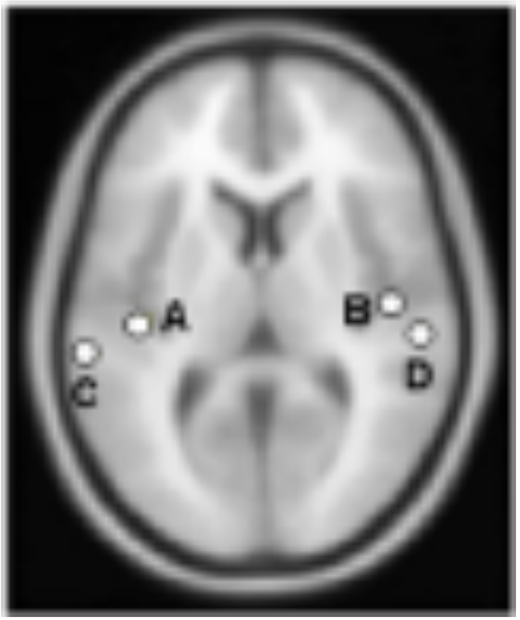
D1: acoustic deviant (same vowel category)
D2 & D3: phonemic deviants (different vowel type)

D2&D3 vs. D1: phonemic contrast

III. MEG

MEG





- 274 channel MEG (CTF)
- Fs = 480 Hz
- ISI = 1.08s
- STD:DEV = 4:1, ~60dbSPL
- # Deviants = 120 x 3
- Concurrent visual task

- Best model: 4 sources

  bilateral A1 & STG

- Aphasics sources constrained by lesion topography

Kiebel et al., 2008

MEG Source localization

- **Variational-Bayes Equivalent Current Dipole** (Kiebel et al., 2008).

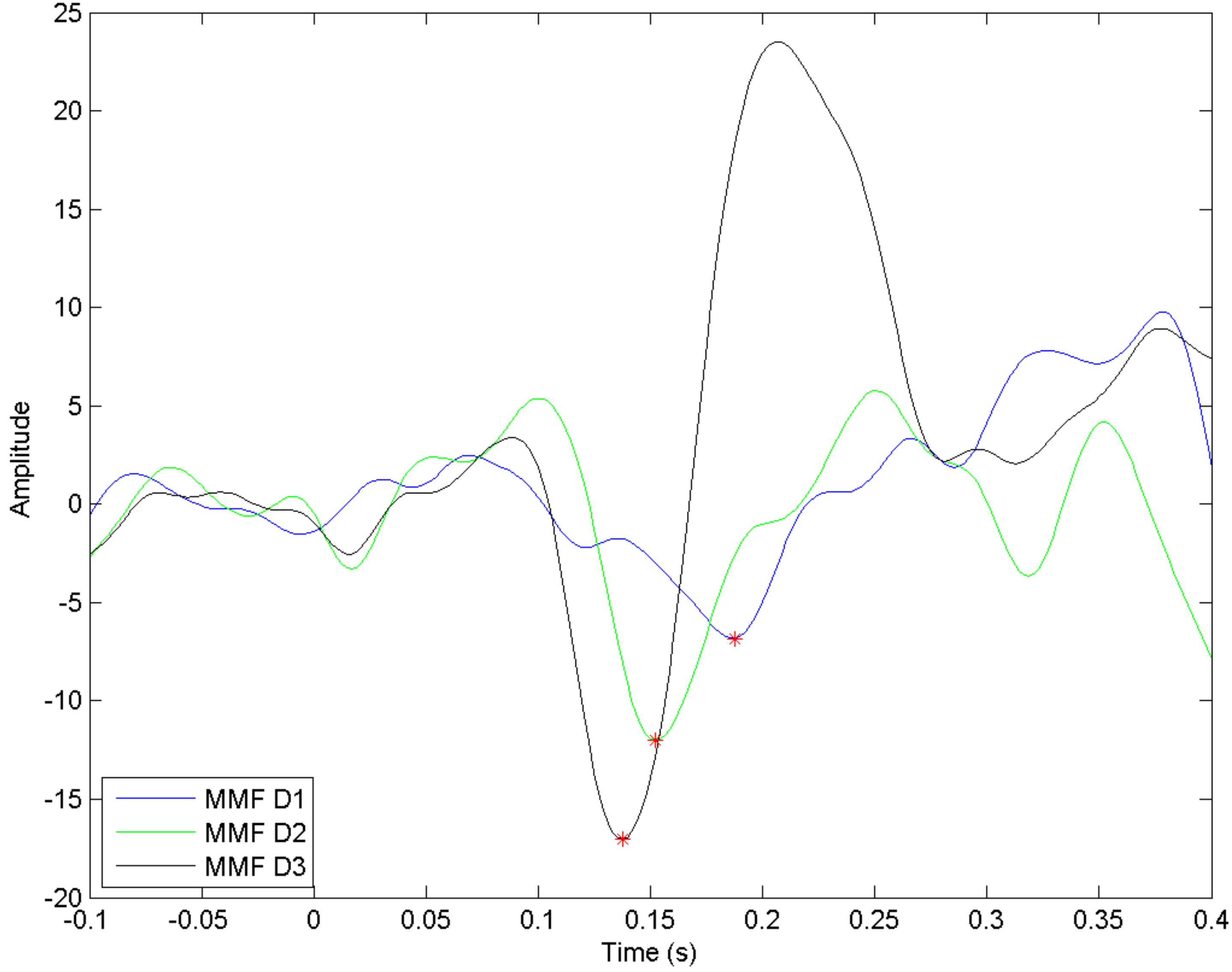
- It uses nonlinear optimization to test the strength of different dipole models based on pre-specified constraints on the position and moments of the dipoles.

- Evaluates the log evidence in favour of each model based on an optimization between goodness of fit and model complexity.

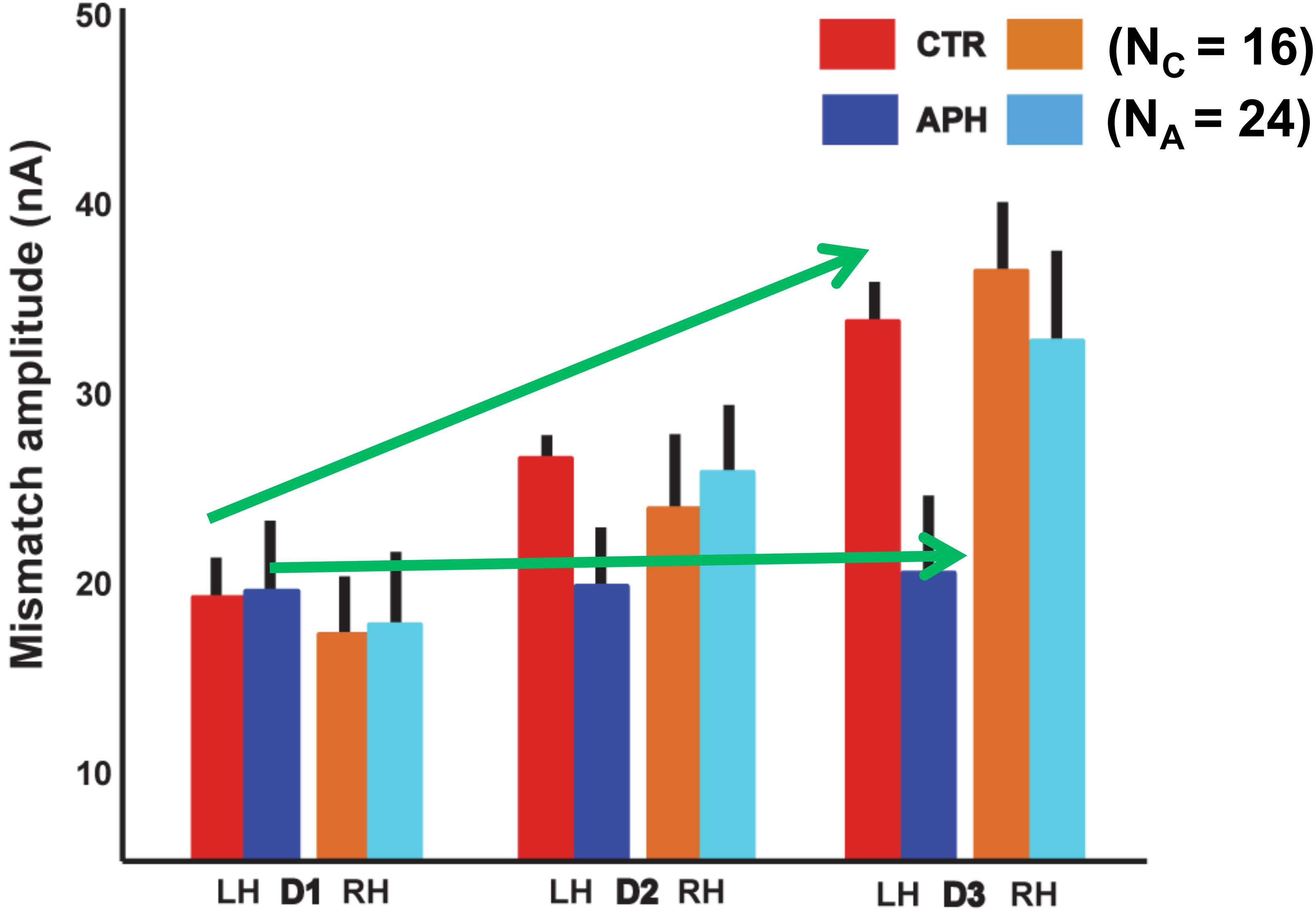
- Run for 100 iterations (models) for each model configuration (e.g. 2 vs. 4 dipole configurations) and the model with the maximum model evidence is chosen as the winning model.

- For aphasics, care taken that dipoles lie outside their lesions.

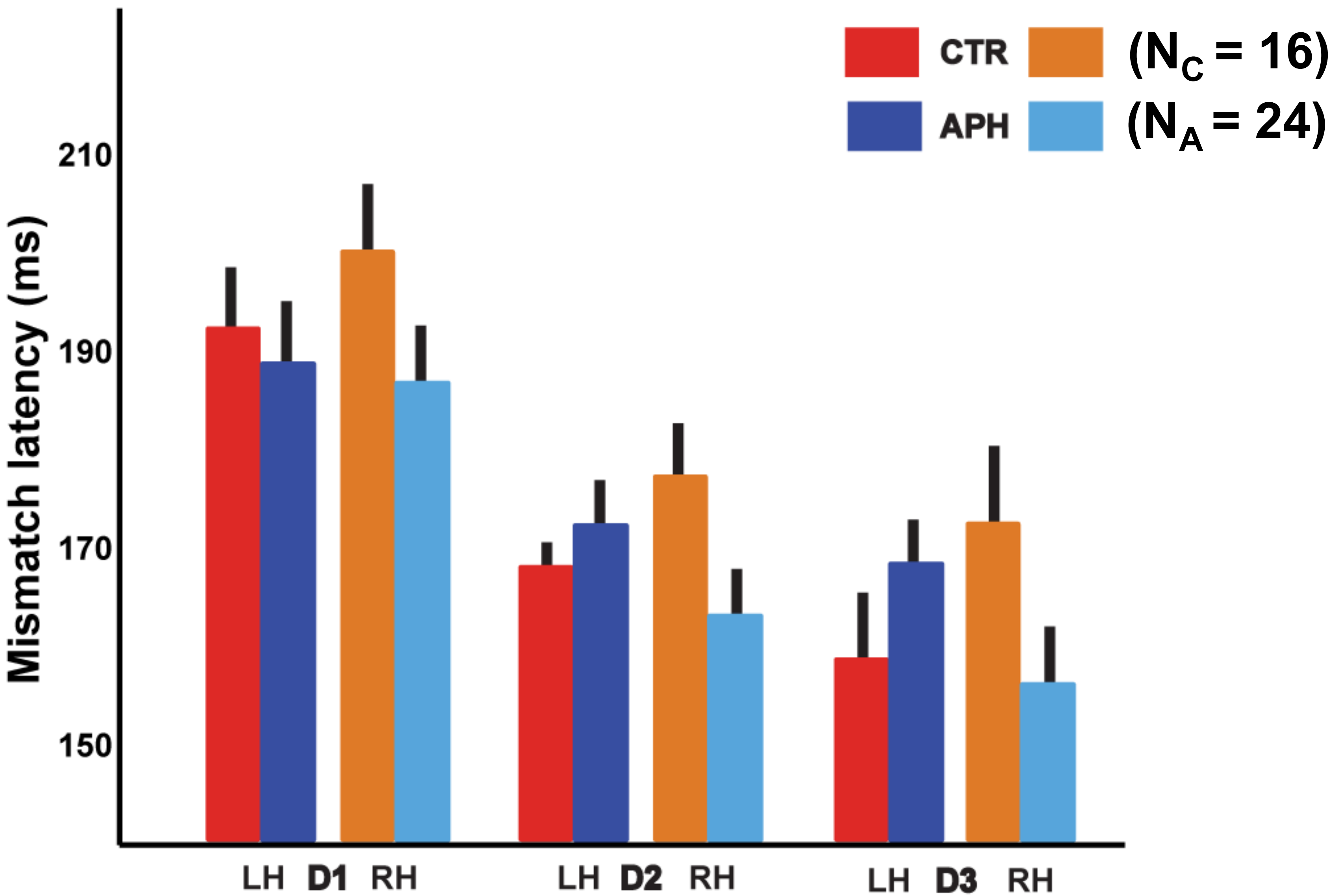
Source-space MMN responses



MMN amplitude



MMN latency



CTR
APH
(N_C = 16)
(N_A = 24)
210
190
170
150
Mismatch latency (ms)
LH D1 RH
LH D2 RH
LH D3 RH

MEG summary

- Aphasics ***do*** show robust MMN responses to speech stimuli.

- However, no significant difference between D1/D2/D3 amplitudes in left hemisphere.
- Right hemisphere MMN responses for speech are as robust as controls' left hemisphere MMN responses.

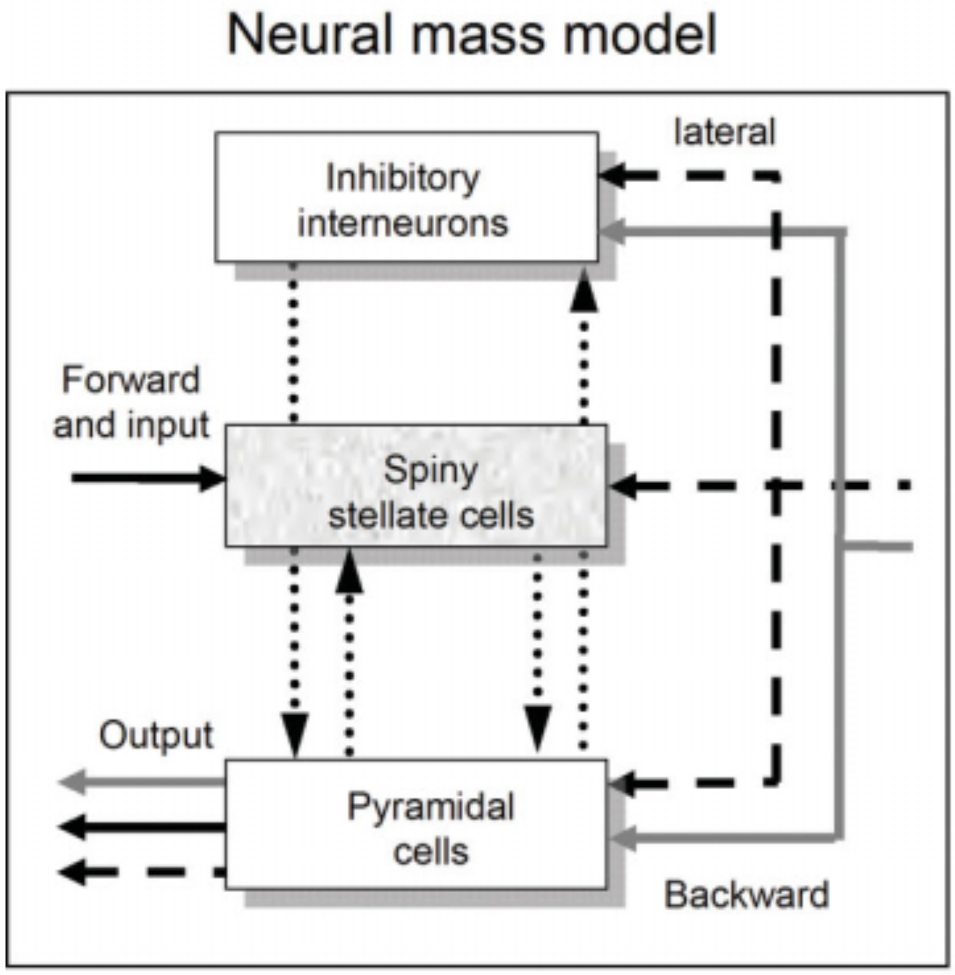
-> **Adaptation of phonemic processing from LH to RH**

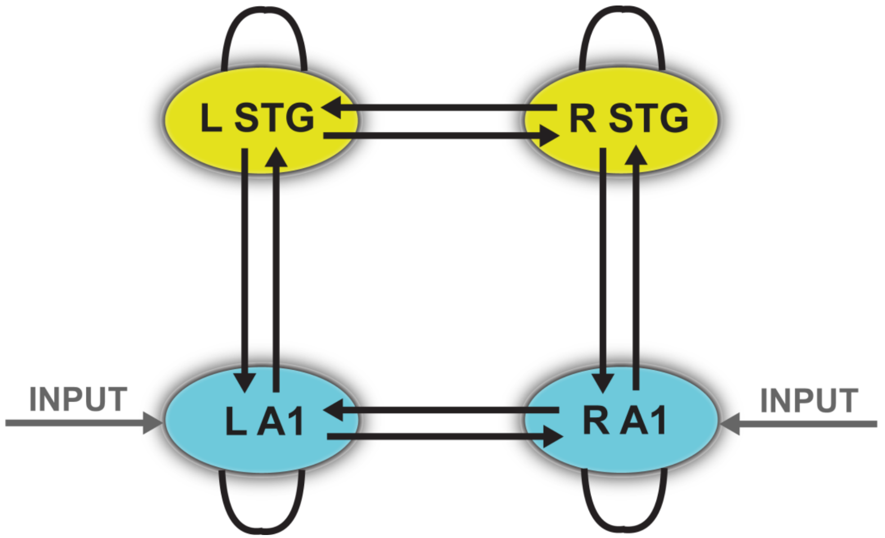
- **Limitations of previous work:**

- based on ERPs
- sensor-level data; few electrodes and poor spatial resolution
- stimuli not sophisticated enough to look at graded deviant responses across phonemic boundaries

IV. DCM

DCM for evoked MEG





Jansen and Rit, 1995
Felleman & Van Essen, 1991

DCM for MEG

- MEG data specified in terms of its ECDs (0-300 ms at source)

- Specify different models that can explain the data

- **Bayesian inversion** of multiple models for each dataset, which provides a posterior distribution.

- **Bayesian model selection**: Select best model based on highest model evidence.

- **Bayesian model averaging**: Infer parameters of the best model(s), using their posterior distributions.

Kiebel et al., 2009

DCM analysis

- **Predictive coding:** **(Kiebel & Friston, 2009)**

  Prediction error = Predictions - Sensory input

- **Self-connections:**

  sensitivity or precision of neural response to sensory input

- **Forward connections:**

  bottom-up propagation of prediction error from lower to higher level of the hierarchical system

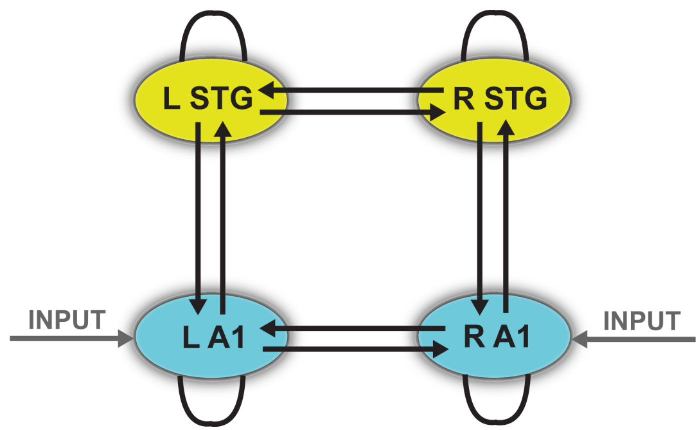
- **Backward connections:**

  top-down predictions from higher to lower levels.

DCM analysis

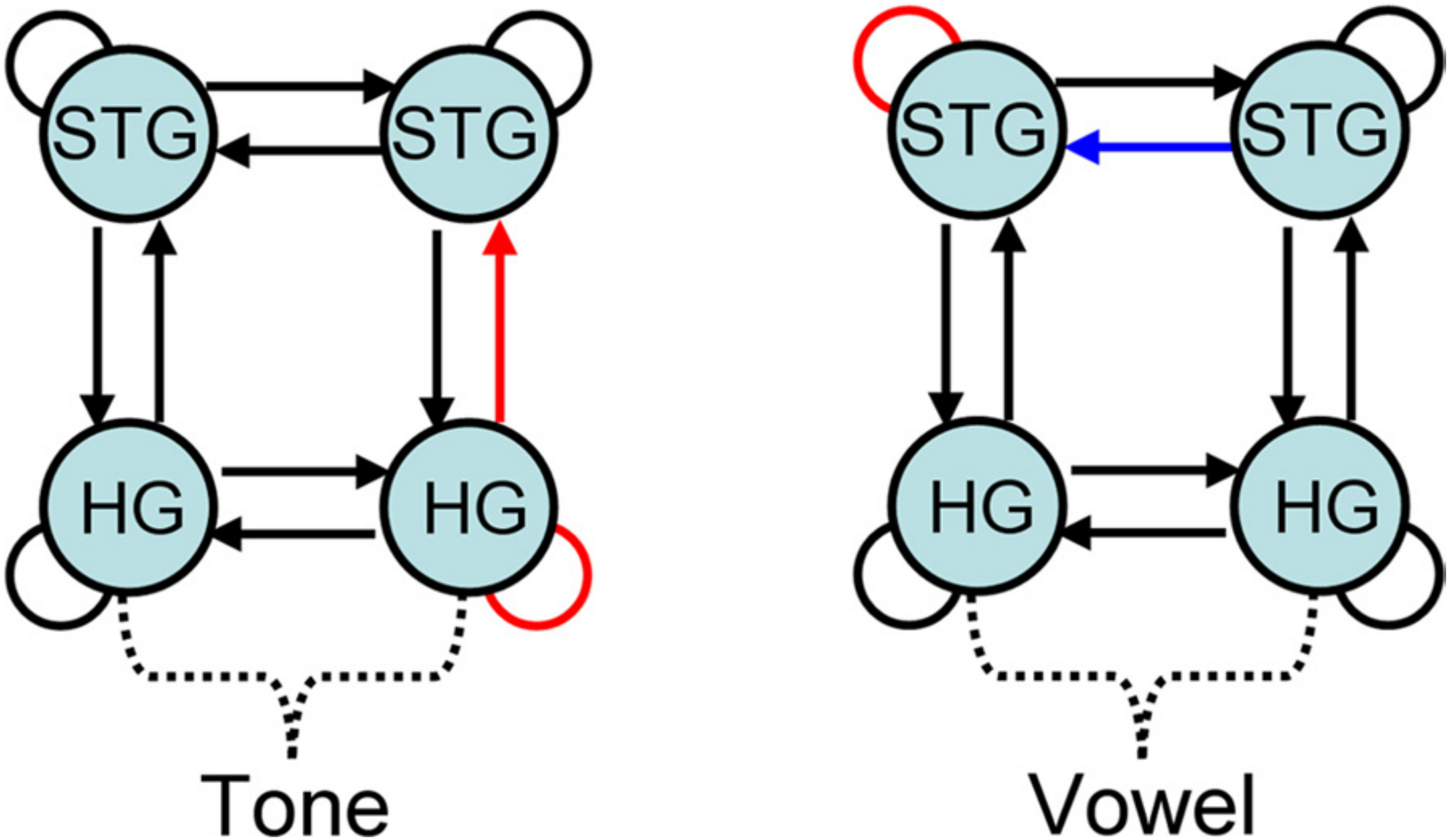
Aim: To investigate modulation of the connections as a function of phonemic deviancy: (D3 & D2) vs. D1

Models: 12 connections between A1 and STG were modelled, yielding 255 models for each participant.

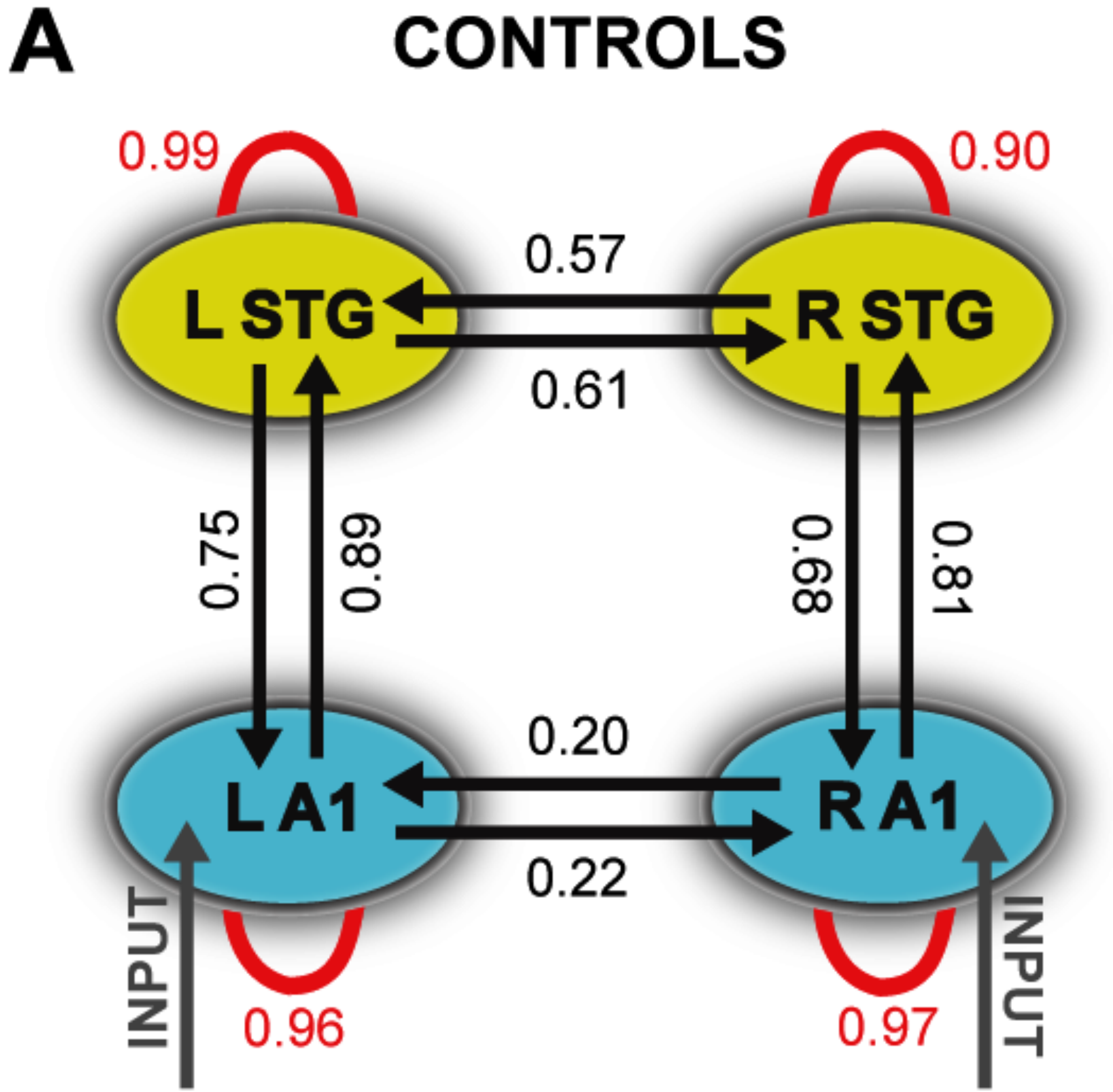


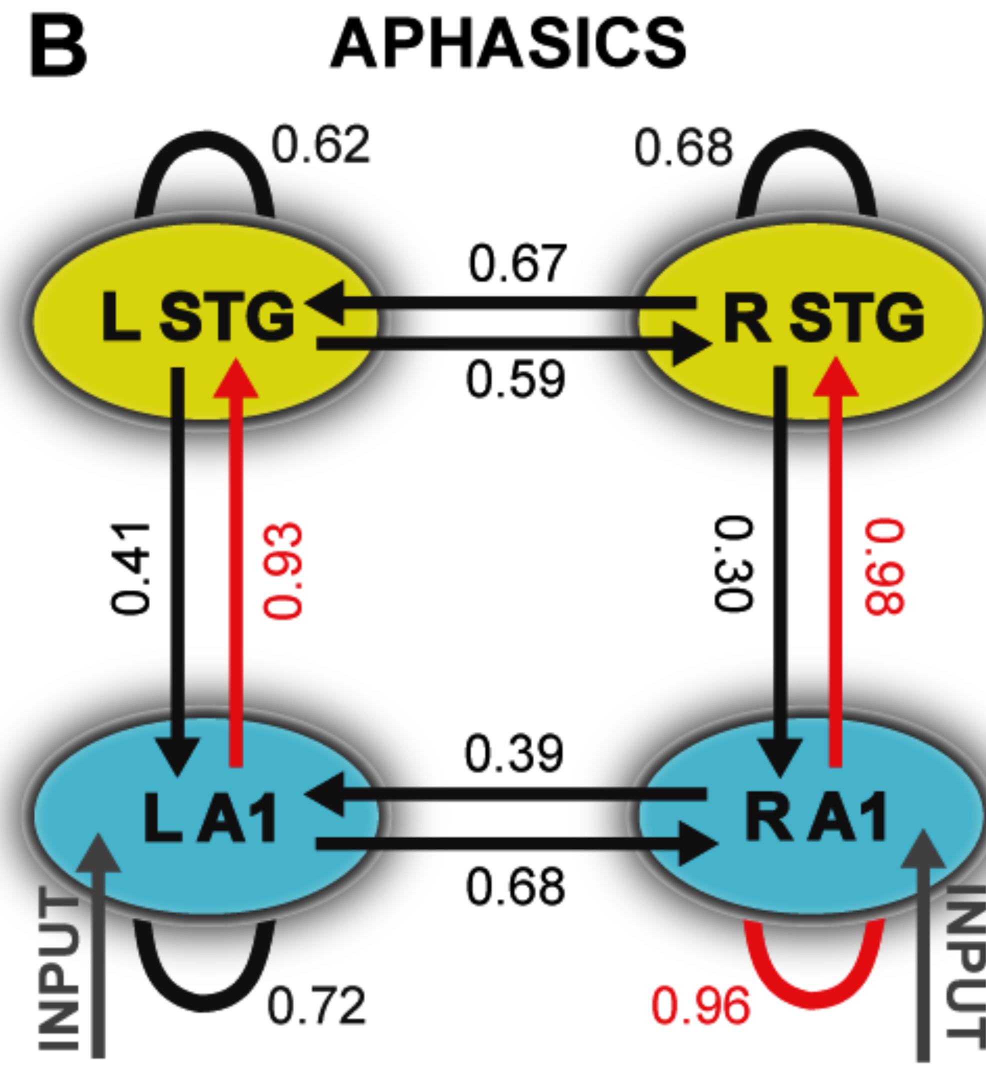
Hypotheses: aphasics may show deficits at the higher level of the network (STG) and impaired left hemisphere function.

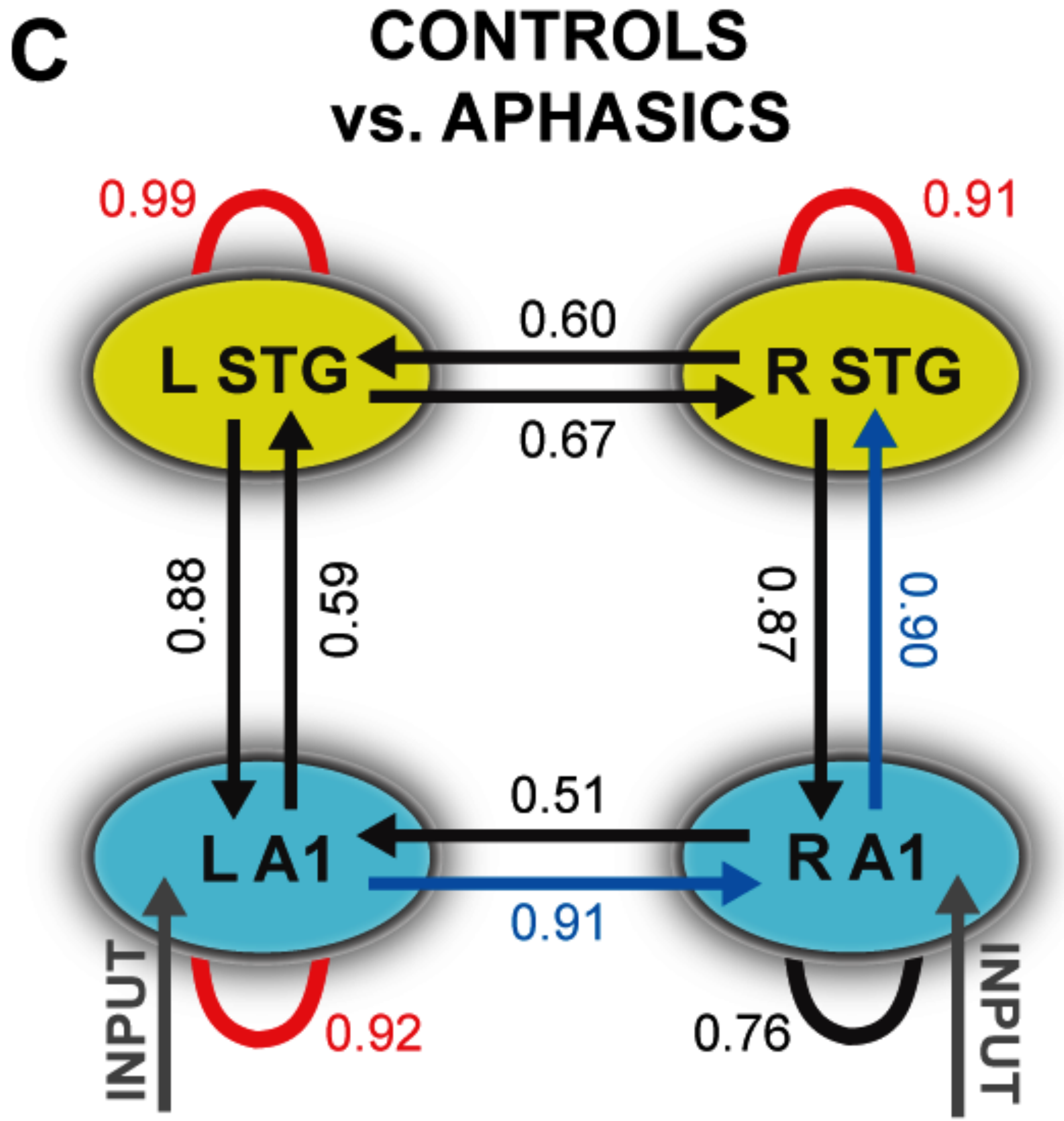
Previously (in controls)...



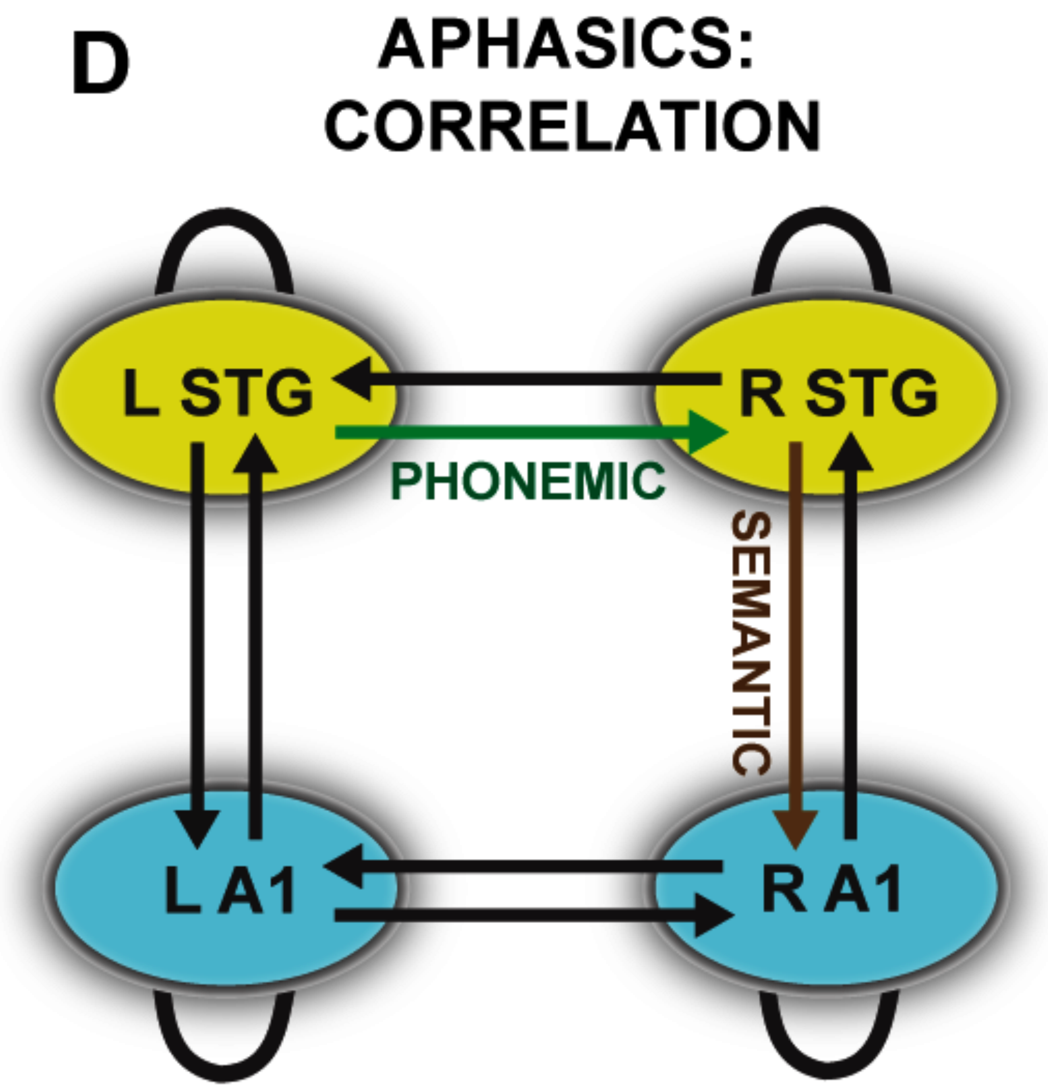
Schofield et al., 2009. *PNAS*


A
CONTROLS
0.99
0.90
0.57
L STG
R STG
0.61
0.75
0.89
0.68
0.81
0.20
L A1
R A1
0.22
INPUT
INPUT
0.96
0.97


B
APHASICS
L STG
R STG
L A1
R A1
0.62
0.68
0.67
0.59
0.41
0.93
0.30
0.98
0.39
0.68
0.72
0.96
INPUT
INPUT


C
CONTROLS
vs. APHASICS
0.99
0.91
0.60
L STG
R STG
0.67
0.88
0.59
0.87
0.90
0.51
L A1
R A1
0.91
INPUT
0.92
0.76
INPUT

D



DCM summary

- Aphasics lack modulated self-connections in L A1, L STG, & R STG
  -> decreased sensitivity to phonemic input at these nodes
  -> impaired phonemic processing at higher level (STG)

- Aphasics show increased modulation of forward connections from R A1 to R STG, i.e., from lower to higher level of the hierarchy.
  -> greater phonemic prediction error in the system
  -> consistent with a predictive coding account

- Aphasics show increased modulation of lateral connection from L A1 to R A1 and modulated self-connection at R A1.
  -> adaptation of phonemic analysis from left to right hemisphere

Overall summary

- Aphasics *do* show robust speech mismatch responses.
- MEG source-space responses indicative of reorganization from left to right hemisphere in aphasics.
- DCM analysis of MEG data suggests distinct speech networks for aphasics vs. controls.
- Speech comprehension deficits in aphasics can be explained by a predictive coding theory of brain function (cf. Friston).
- Phonemic prediction errors and prediction signals may have different oscillatory signatures (cf. Poeppel/Giraud)
- **Next:** longitudinal analysis following drug/phonological therapy

Questions/Comments?