Signed, Spoken Languages and Human Actions: Implications for a Neural Model of Human Language

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CUHK. 2015

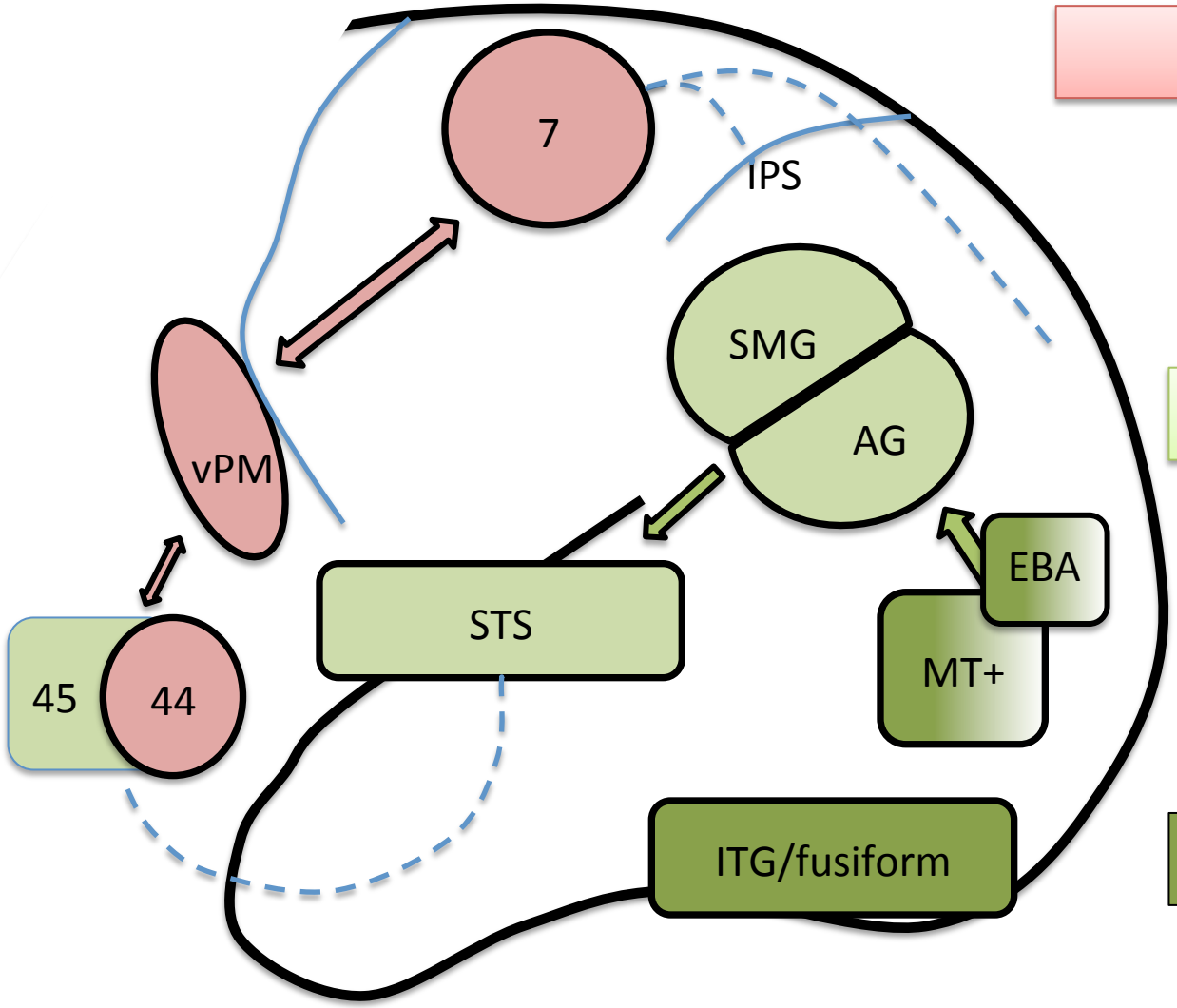
- Sign language processing lies at the intersection of many research domains:
- Language
- Vision
- Motor Control
- Human Action Processing

We should expect a neural model that incorporates and integrates these systems.

Outline

- Studies of sign languages and human actions can help guide us to a model of human language.
- I propose a three-pathway model to help us understand sign language processing
- Action, Meaning and Form
- I'll provide examples from my research to support the validity of this model
- Work in progress.

My Proposal

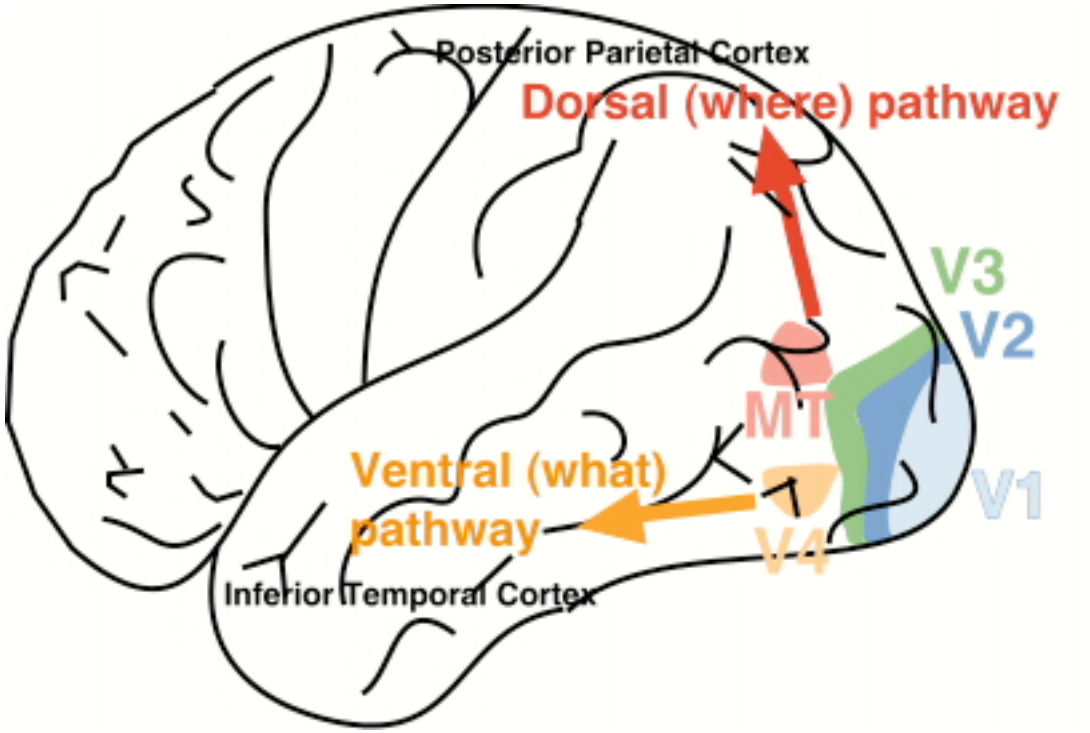


Action

Meaning

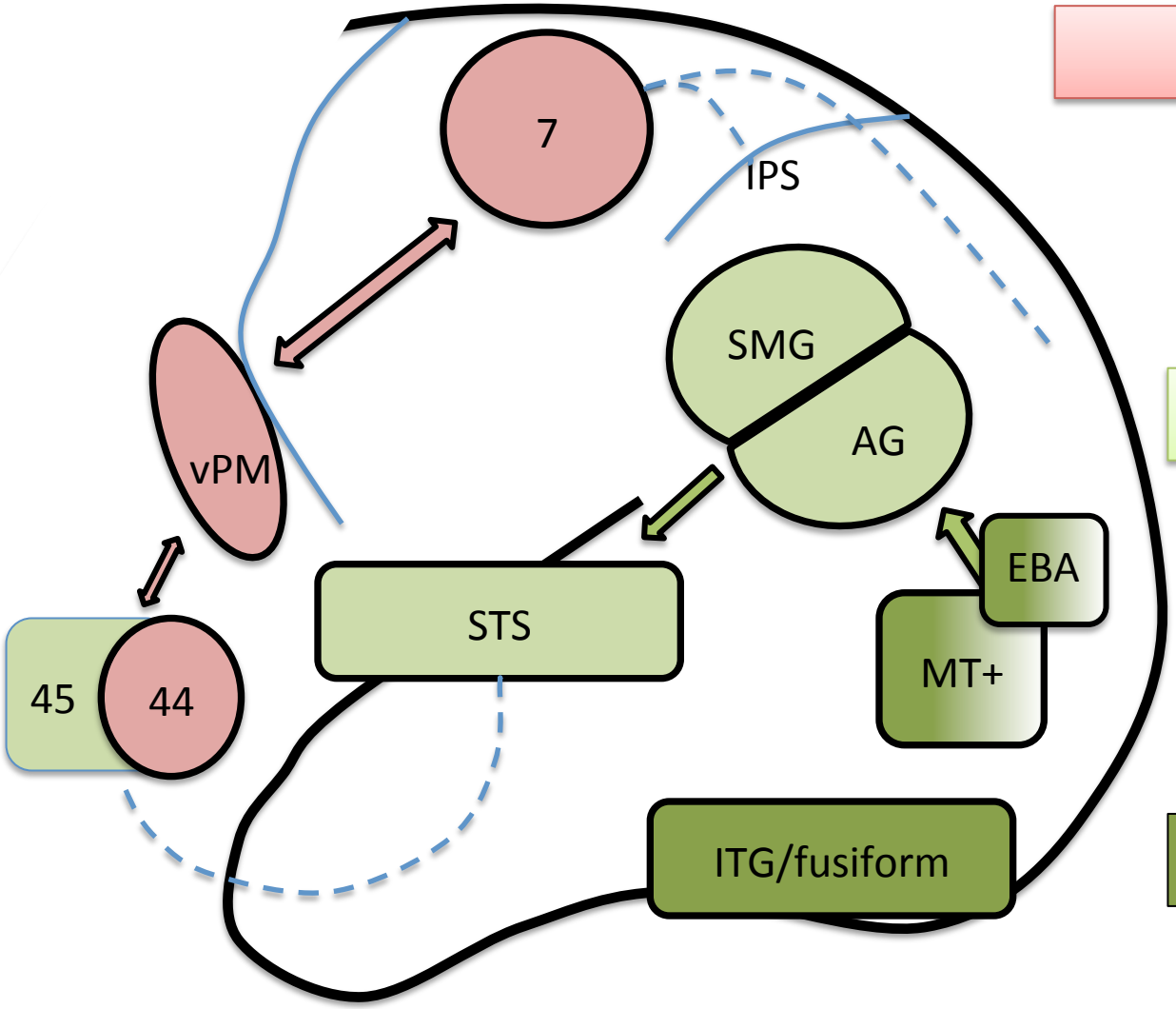
Form

Ventral and Dorsal Visual Streams



Recognition of forms: ventral visual pathway

My Proposal



Action

Meaning

Form

Recognition of body form

- Should expect specialized temporal-ventral systems sensitive to body forms.

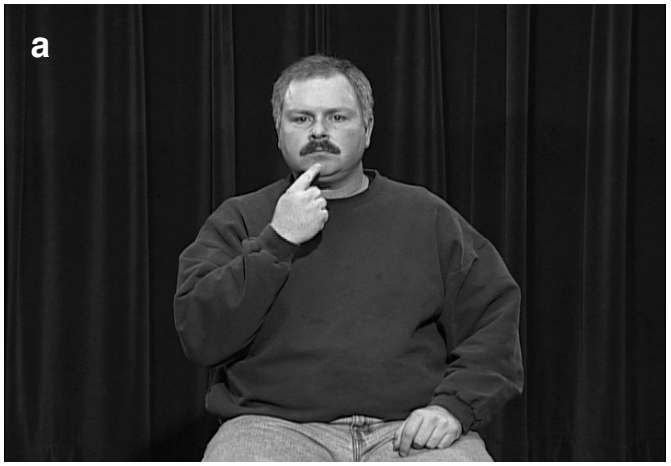
- MEG study
  - body form violations
- fMRI study
  - Body form and handshape recognition

MEG: Body Form Violations

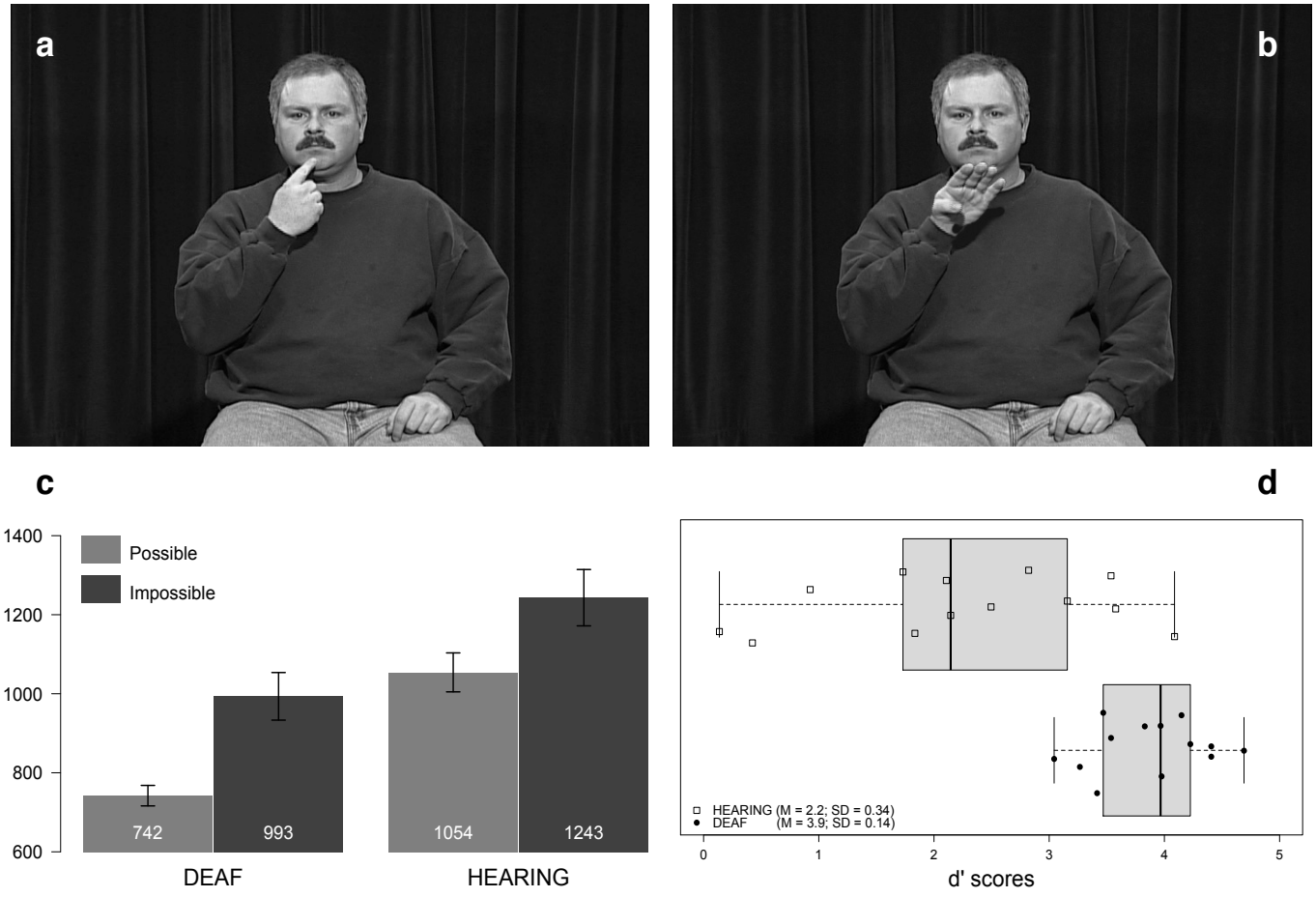
Method: MEG

- Task: Possible/Impossible Judgments

- Subject's 13 hearing, 13 deaf native signers



Deaf signers are very sensitive to human forms



Deaf show faster responses and better discrimination

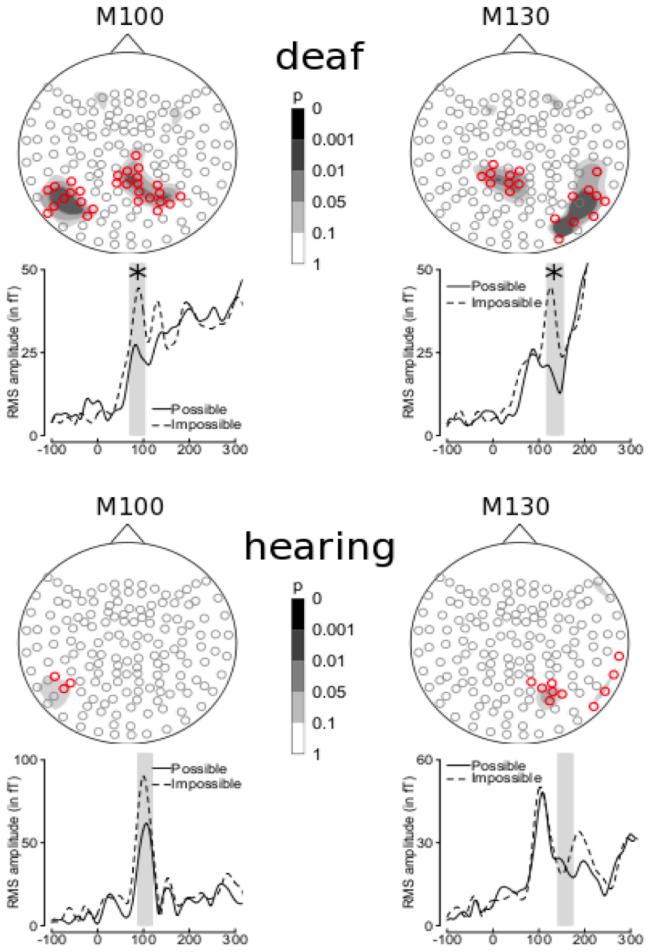
MEG topographic maps

MEG Results

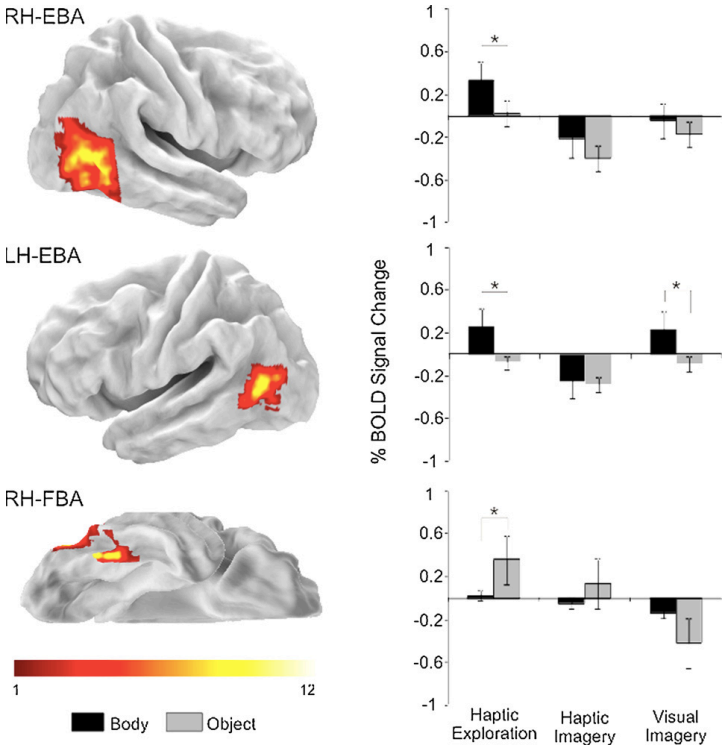
Components:

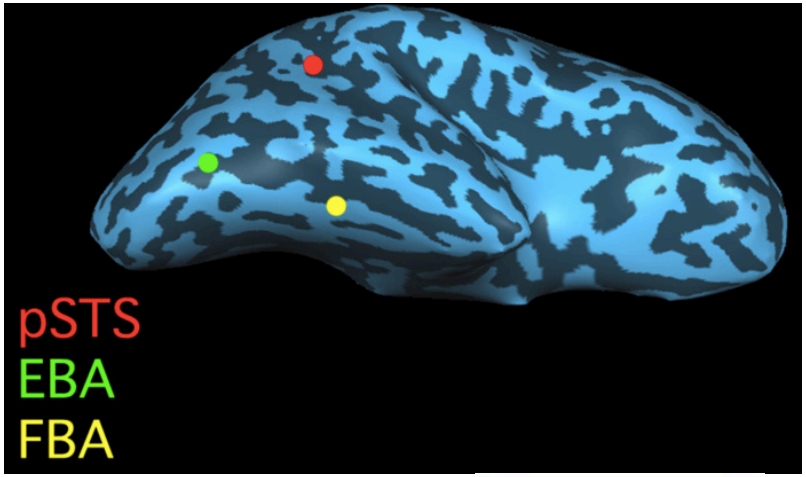
- M-100
- M-130

- Occipital-temporal focus in signers



fMRI: Body *Form* (EBA)





EBA (left: -45, -74, -3; Right 48, -68, 0)

Downing et al (2001)

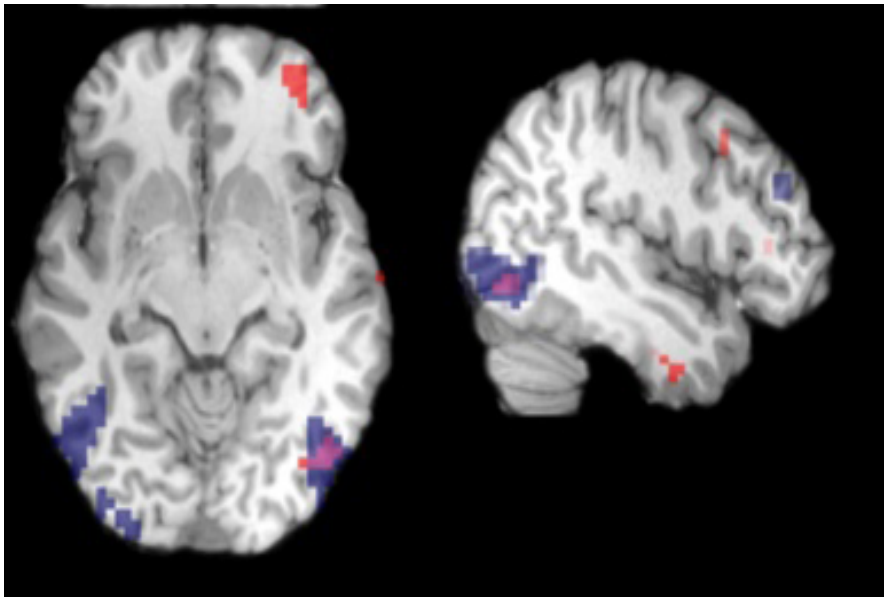
Extra-striate Body Area Localizer

Downing et al (2001)

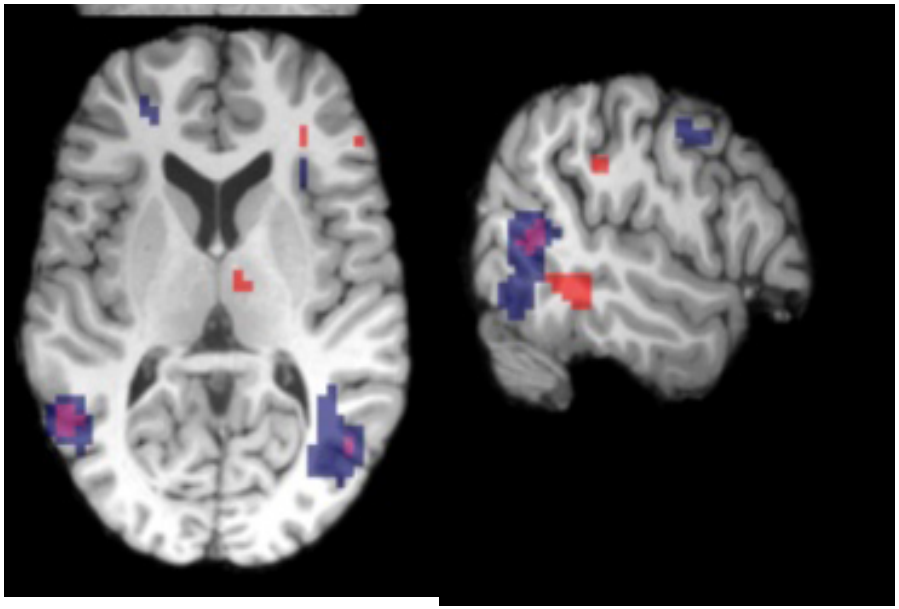
Sign Recognition Test (implicit)

Task: Is sign produced with one or two hands ?

EBA (red) and Sign (blue)



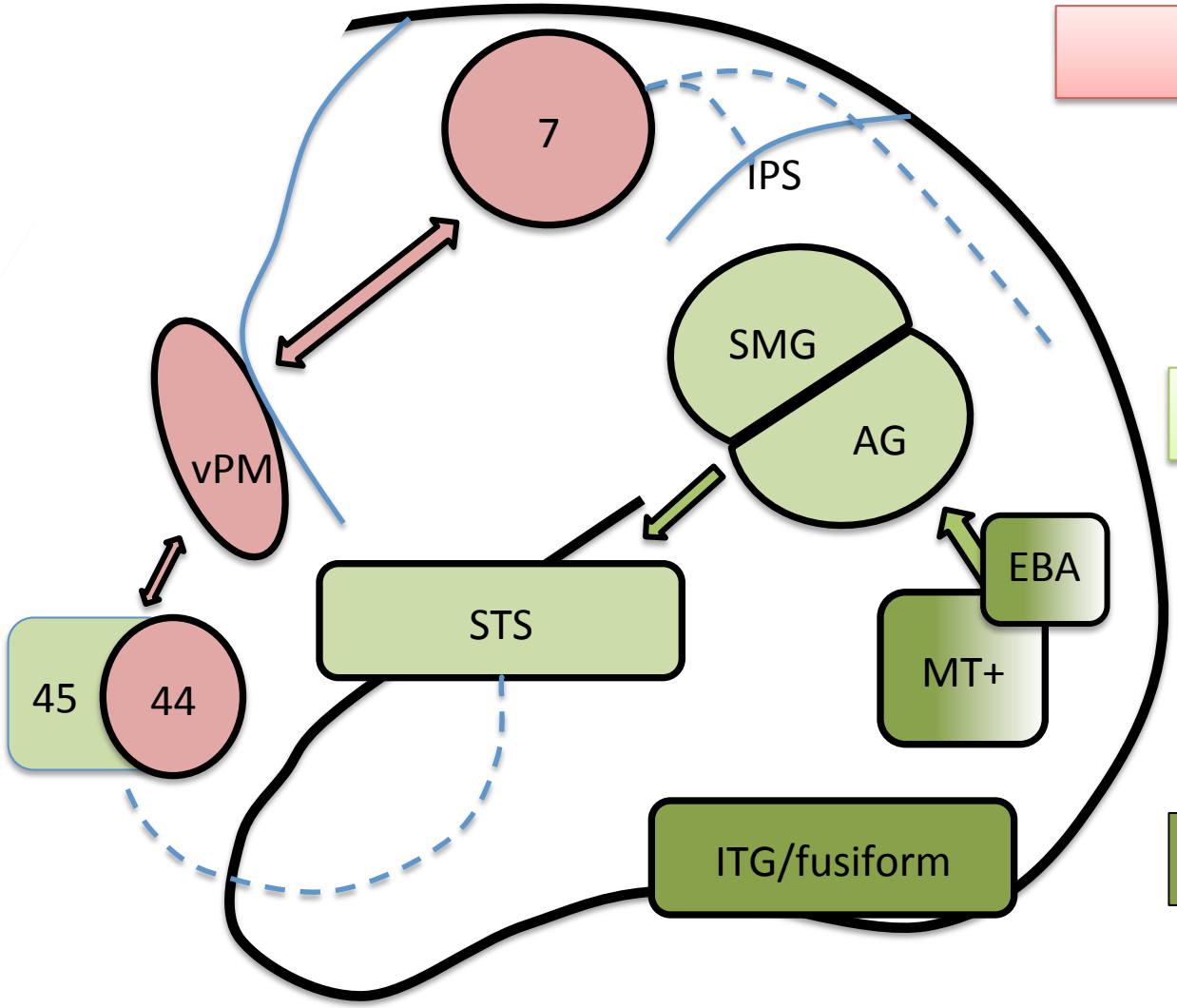
Subject 1



Subject 2

Overlapping activations
Signs (blue) and EBA localizer (red)

Ventral Stream cont.



Action

Meaning

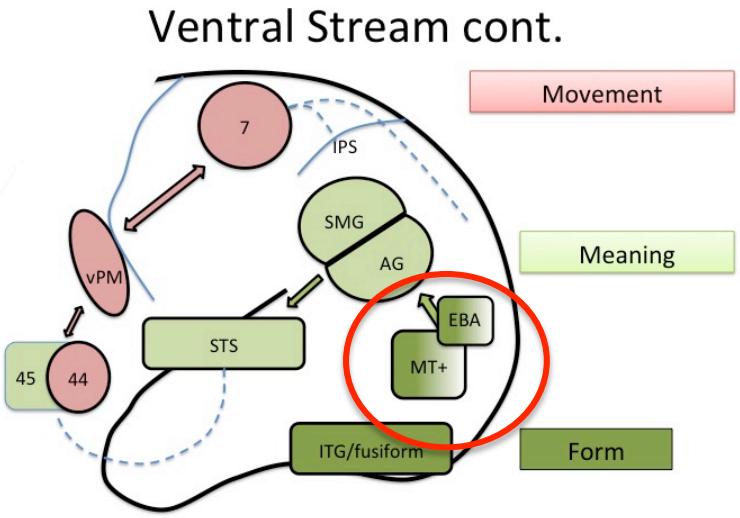
Form

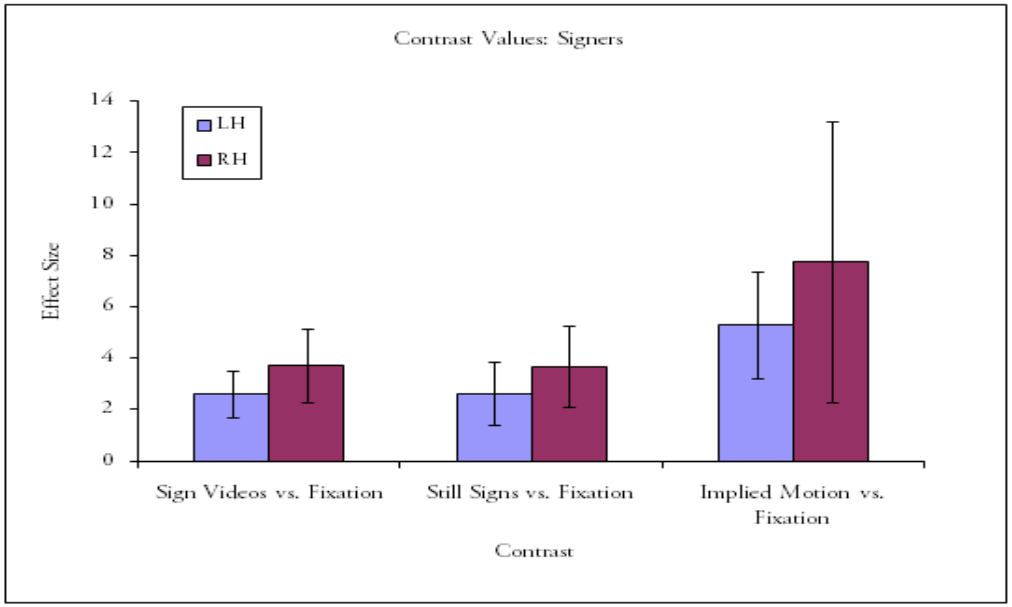
Ventral Area MT+

- fMRI study of Implied motion, moving signs, and ASL stills



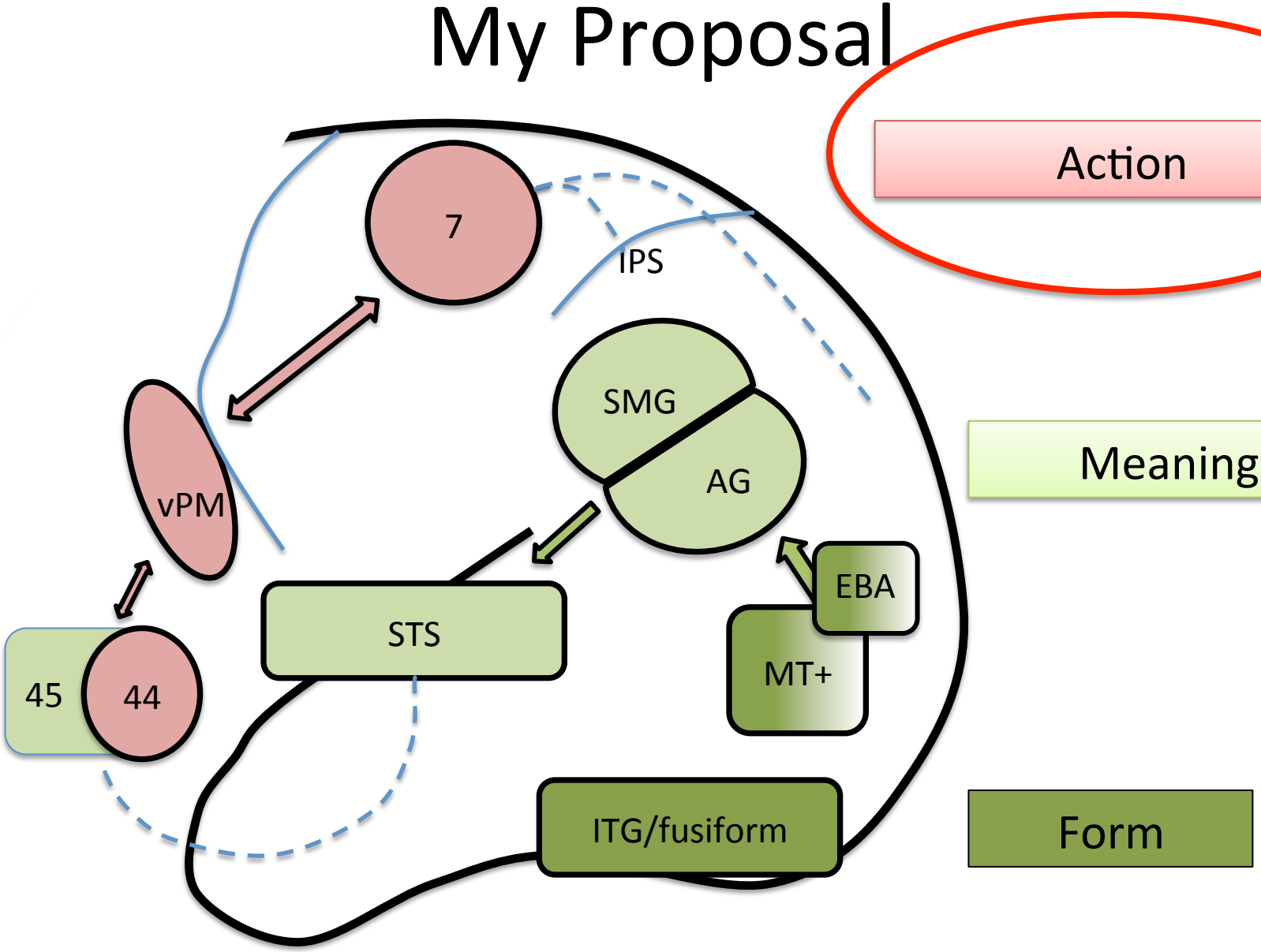

Sign Movement: Area MT+



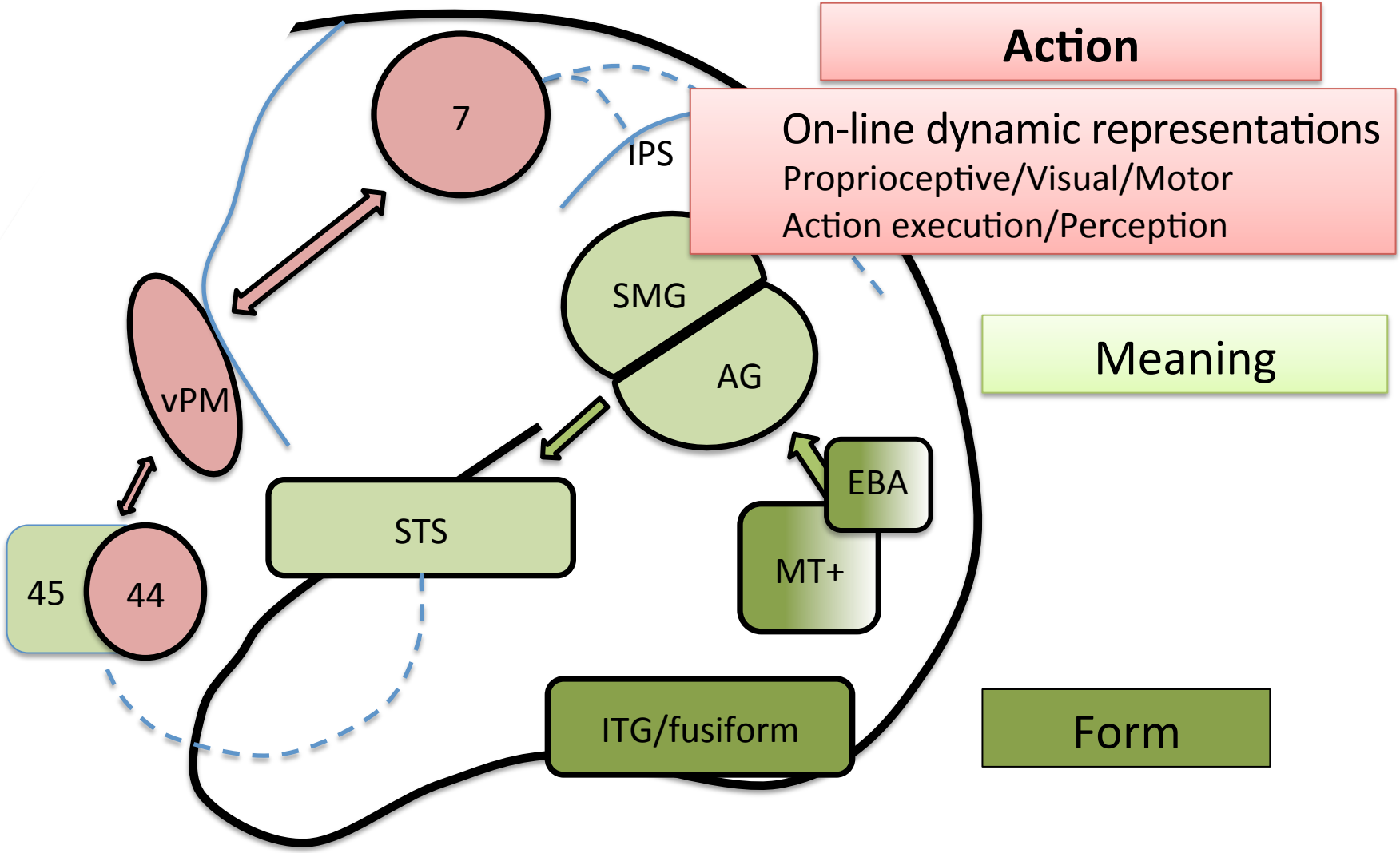


Contrast values from Deaf signers activation (n=6) from MT+ ROI ([+/-48, -70, 6],10mm radius sphere) for three conditions; Moving Signs vs. Fix., Static Sign vs. Fix., Implied Actions vs. Fix.

My Proposal


7
IPS
SMG
AG
vPM
EBA
STS
MT+
45
44
ITG/fusiform
Action
Meaning
Form

Dorsal Stream



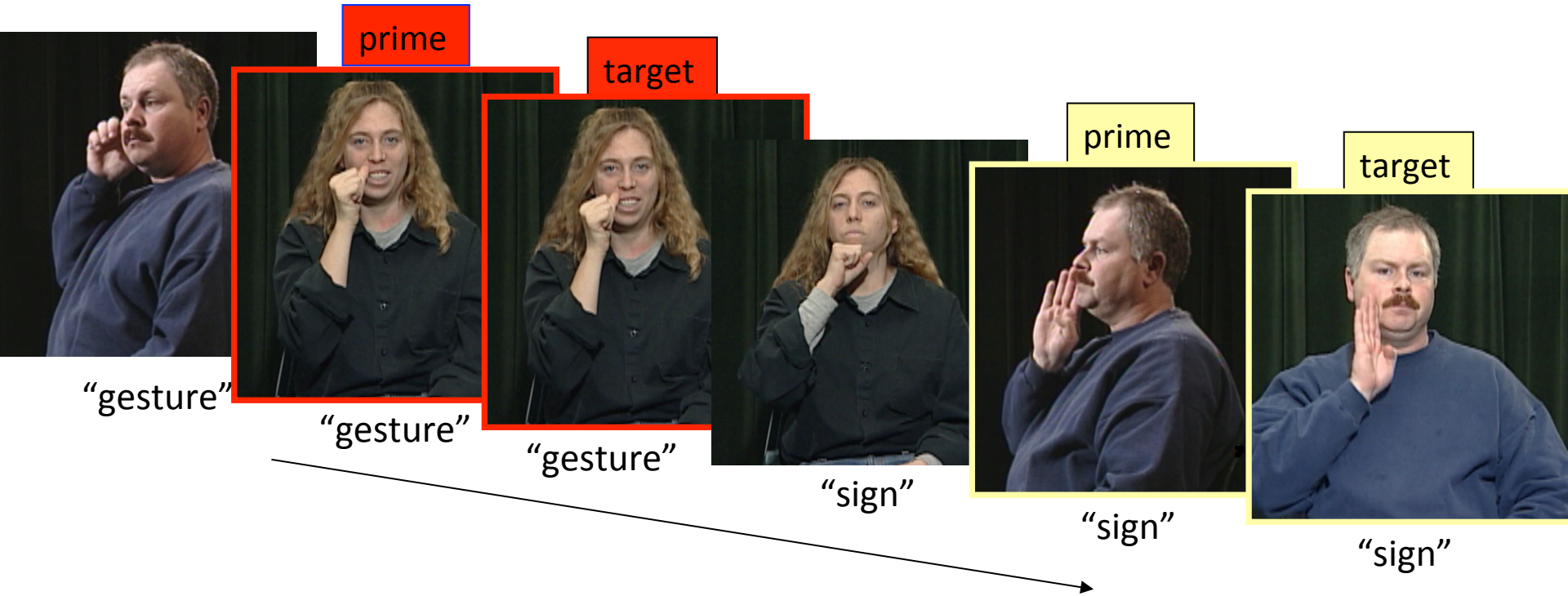
Perceptual Invariance



"Through-plane spatial transformation"

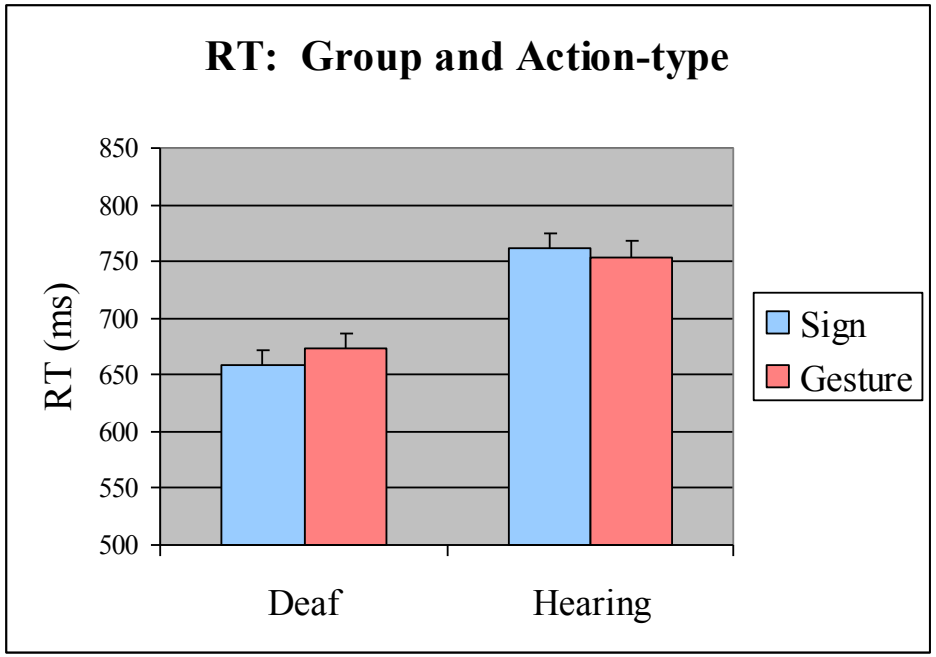
A form of perceptual invariance, NOT sign specific

Sign versus Gesture Categorization



Signs and gestures filmed from different viewpoints

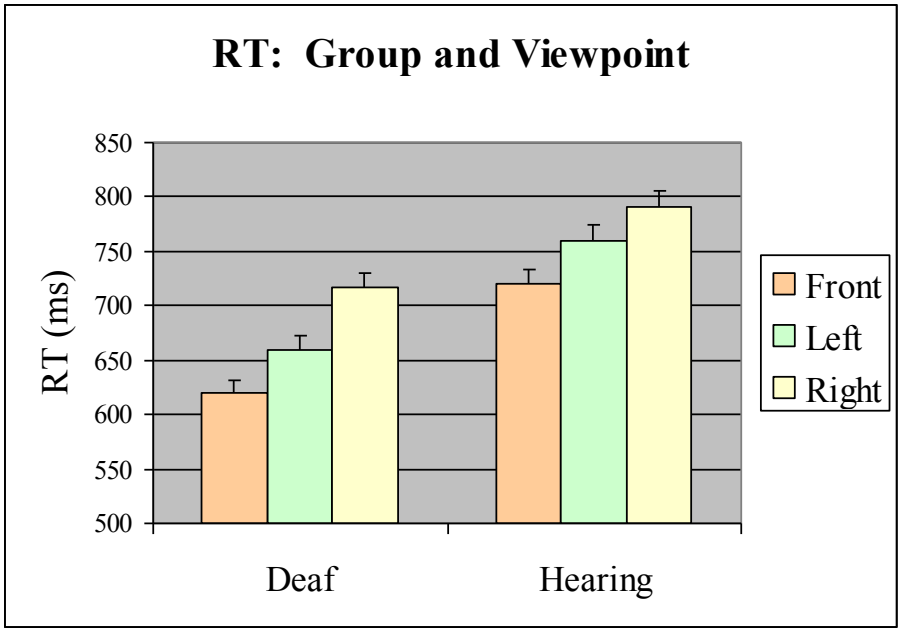
Results



Overall RT

Deaf are faster than hearing subjects.

Deaf and hearing respond to sign and gestures equivalently.

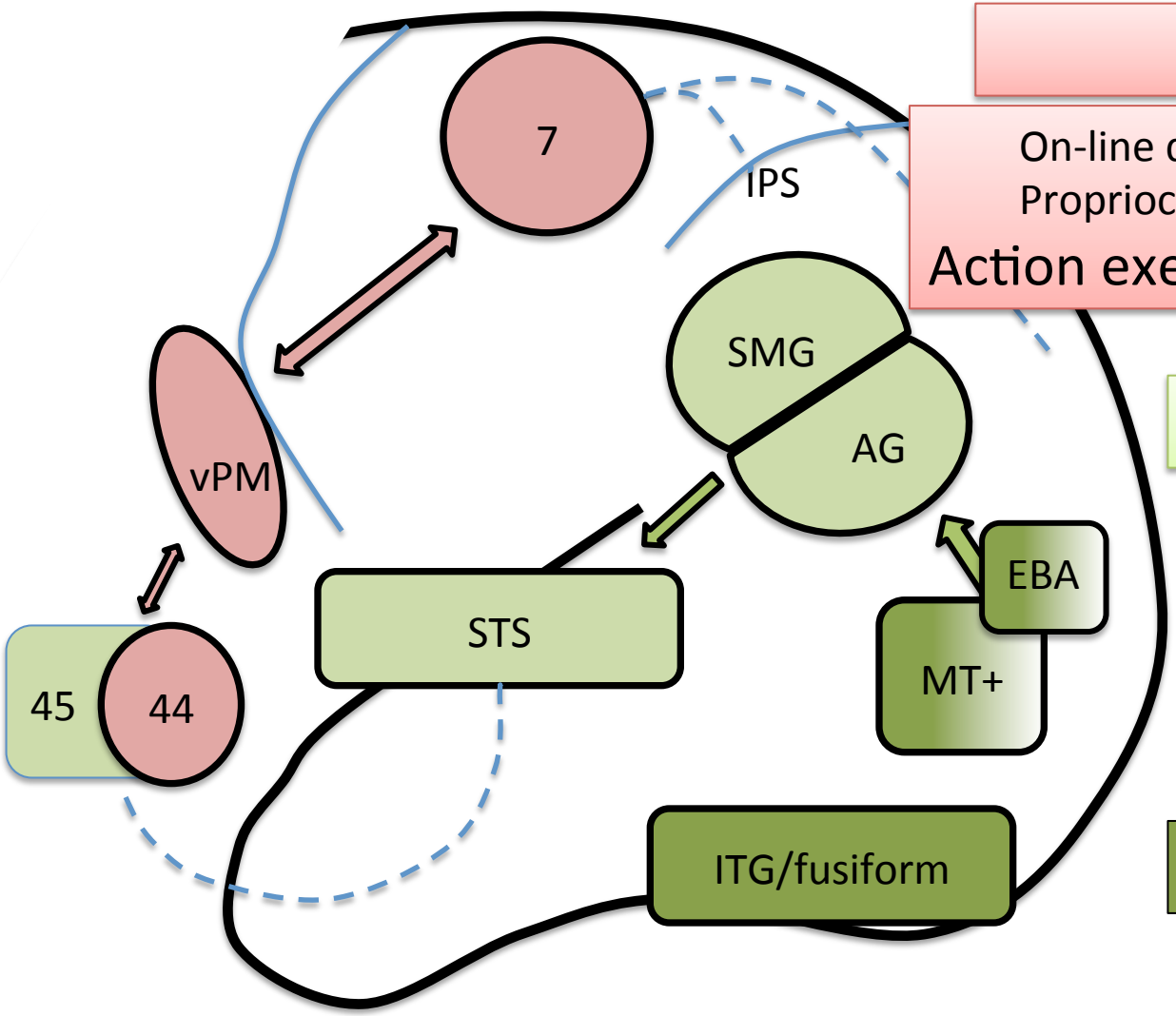


RT as a function of prime

PRIME	**TARGET**
Front-view	Front-view
Left-view	Front-view
Right view	Front-view

Deaf and hearing show same pattern of results

Dorsal Stream



Action

On-line dynamic representations
Proprioceptive/Visual/Motor

Action execution/Perception

Meaning

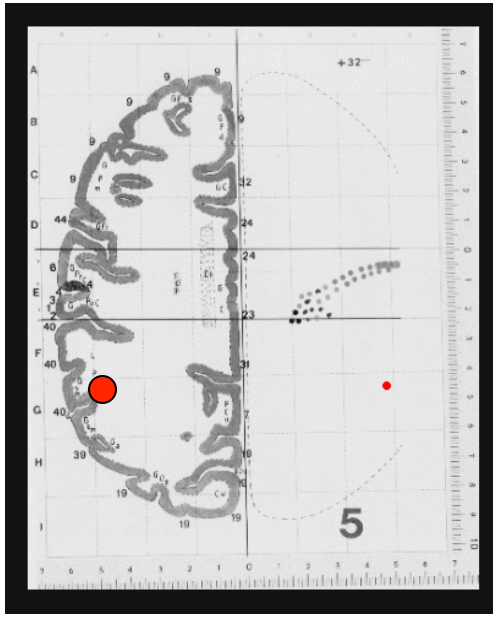
Form

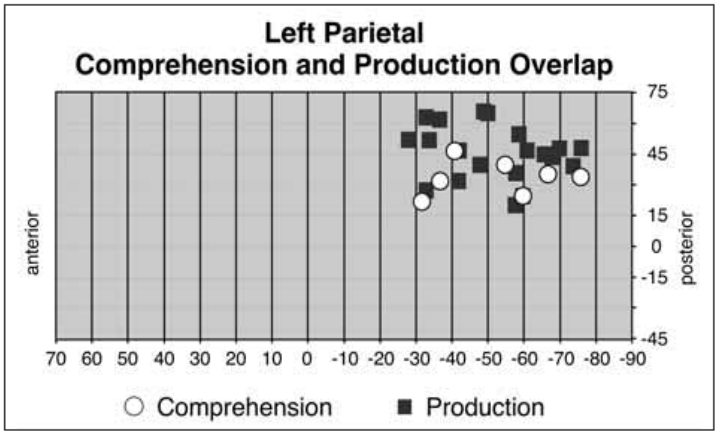
Action Execution/Perception

- The hypothesis that we make use of representation involved in production in comprehension.
  - Motor theory of speech perception
  - Mirror neuron theories
  - Embodiment

Predicts we should may see overlapping brain areas for sign production and comprehension

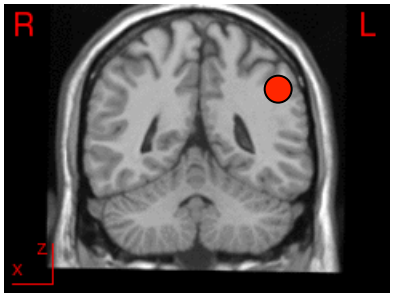
Meta-Analysis Common Parietal Activations

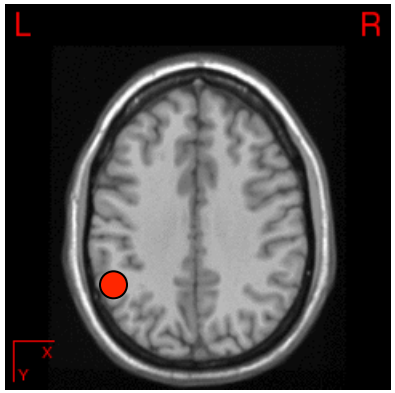


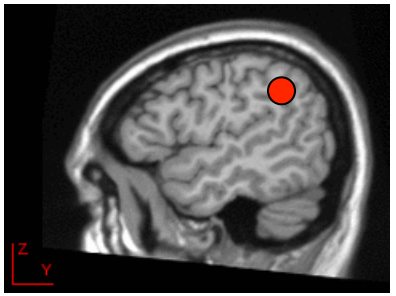


Z plane

Y plane





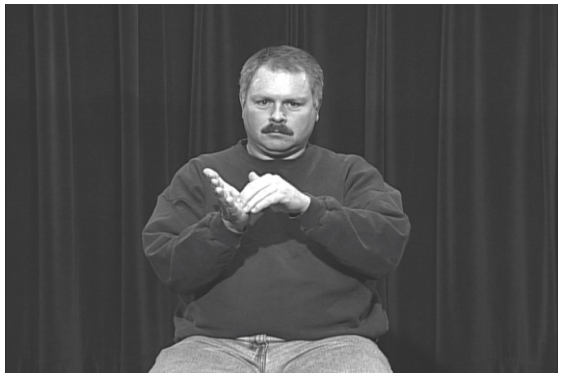


-48 -46 33 IPL/SMG

Common processing during sign production and sign comprehension

Embodiment

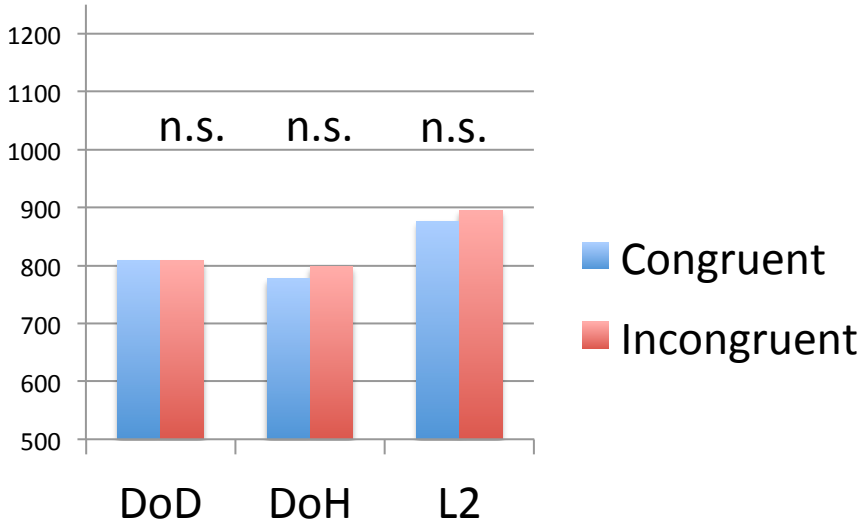




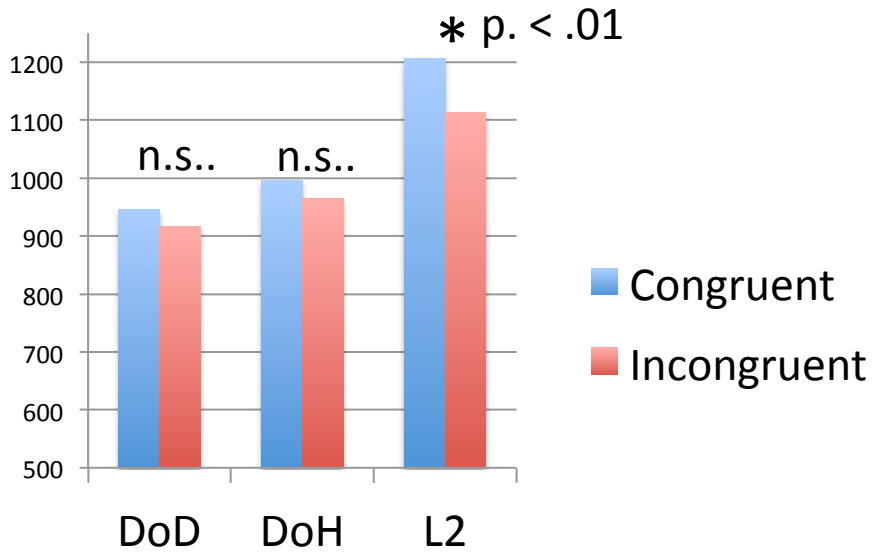

Decide whether the form is an ASL sign or a pseudo sign
Does it matter if the signer shown is right or left handed ?

16 Native, 20 Non-Native 21 hearing interpreters (L2)

Lexical Decision and Handedness Congruency



ASL Signs



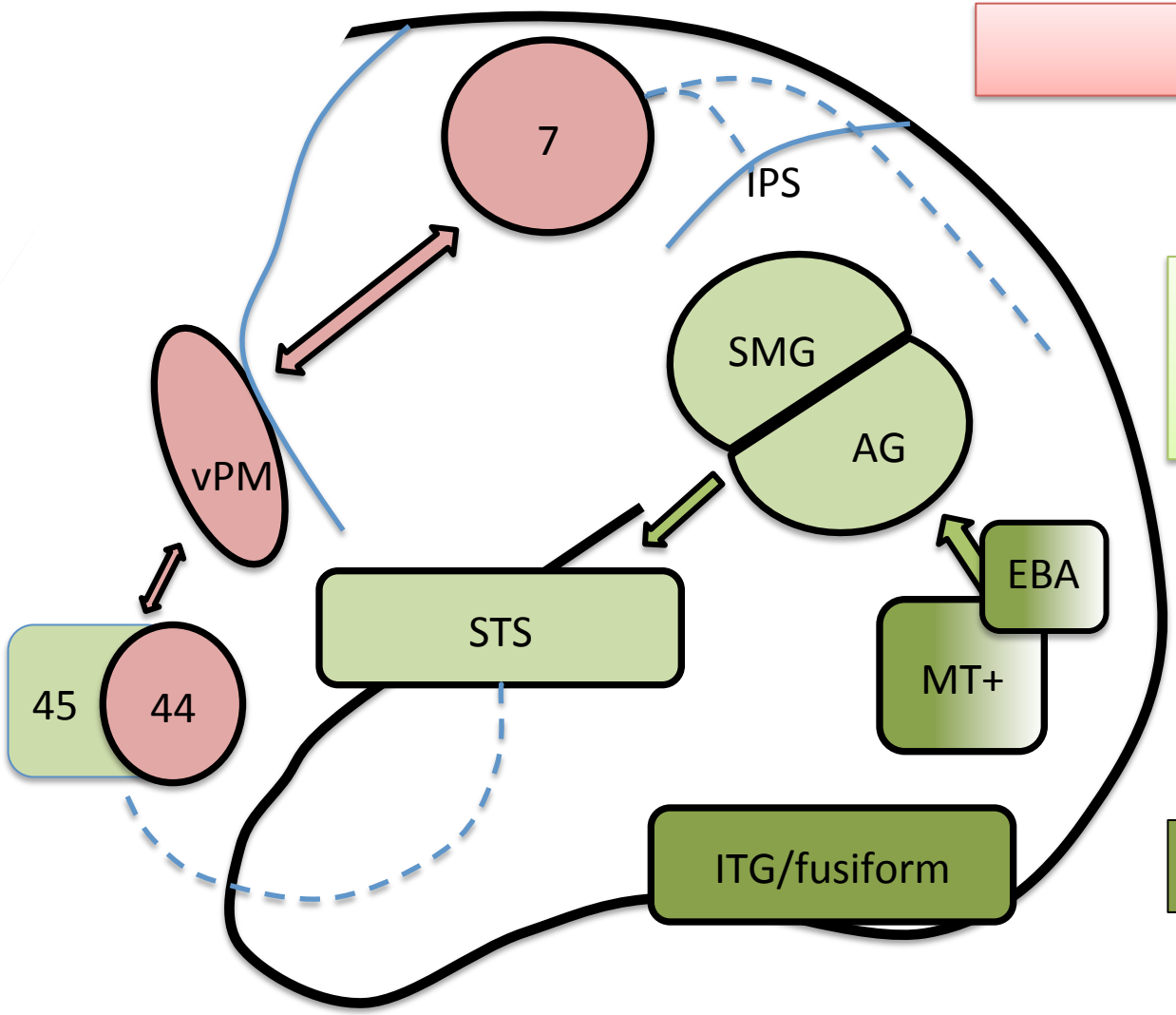
ASL Pseudo Signs

Only hearing interpreters (L2) showed an effect .
Limited to pseudo-signs.

Motor simulation as basis of sign language understanding ?

- Likely multiple levels
- Somatic level
  - Action execution/motor planning forward models
- Lexical semantic level
  - Deaf signer are “encapsulated” may be inefficient to utilize such processes
  - Novice learners ?

The Third Stream



Action

Meaning
Learned Movement
Symbolic Movement

Form

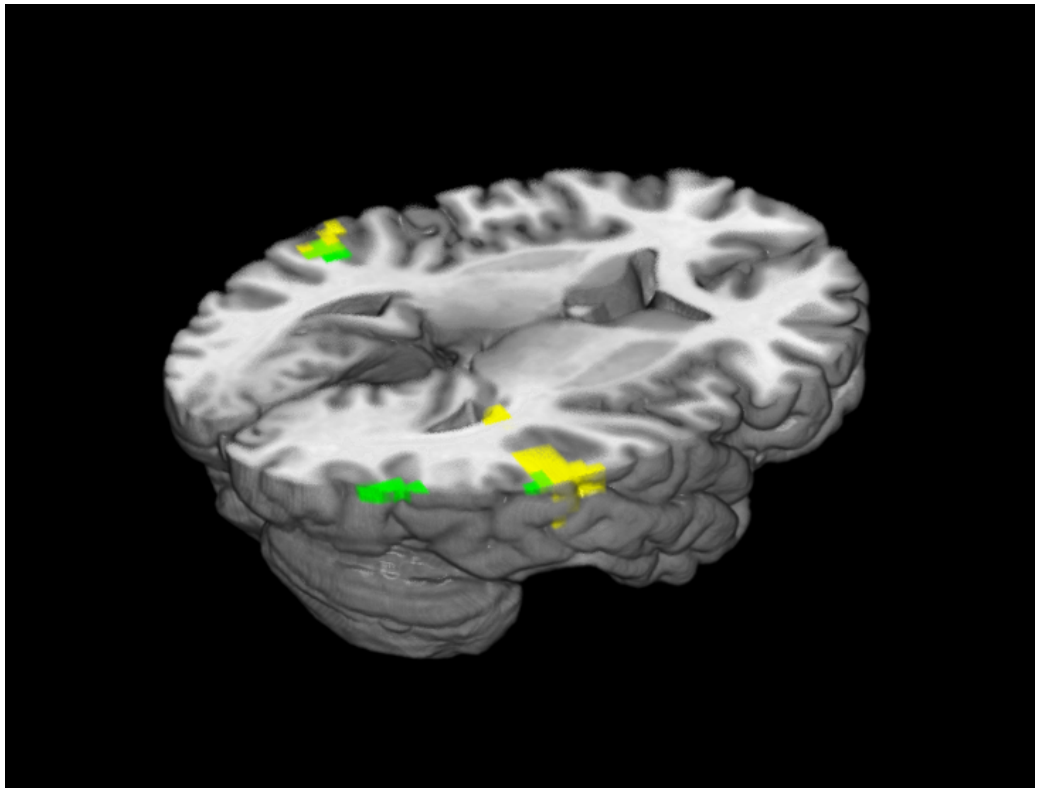
Where in the brain does differentiation occur ?
fMRI Study : ASL vs. Gesture

ASL

Gesture

Task: Is action performed with one or two hands ?

ASL vs. Gesture in Deaf Signers



[ASL vs. Fixation]
[GESTURE vs. Fixation]

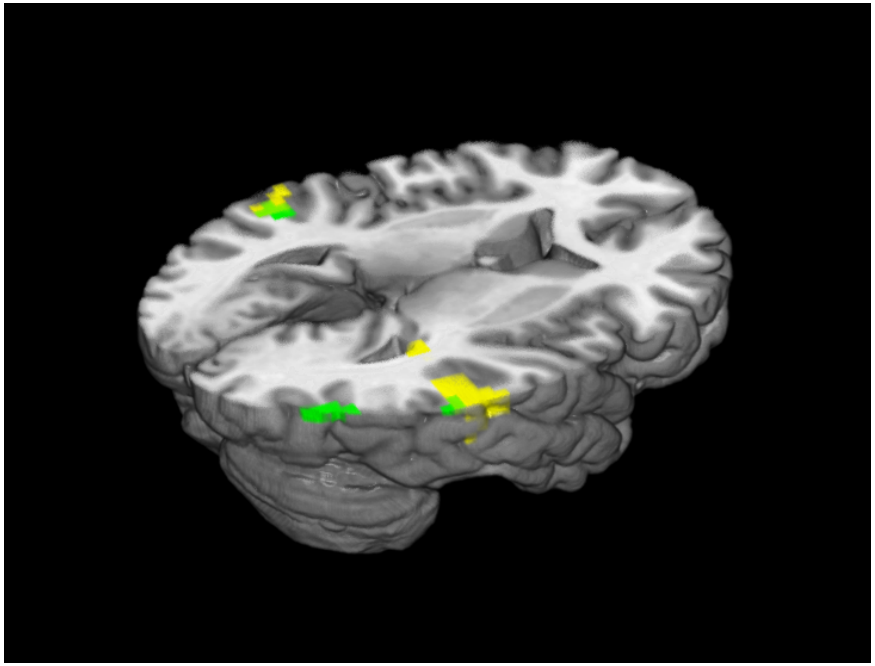
Sign
Gesture

Posterior-Superior Temporal Sulcus
p < .001 uncorr. 10 voxel cluster

Corina, Lawyer, Hafer et al in progress

Language selectivity in posterior STS

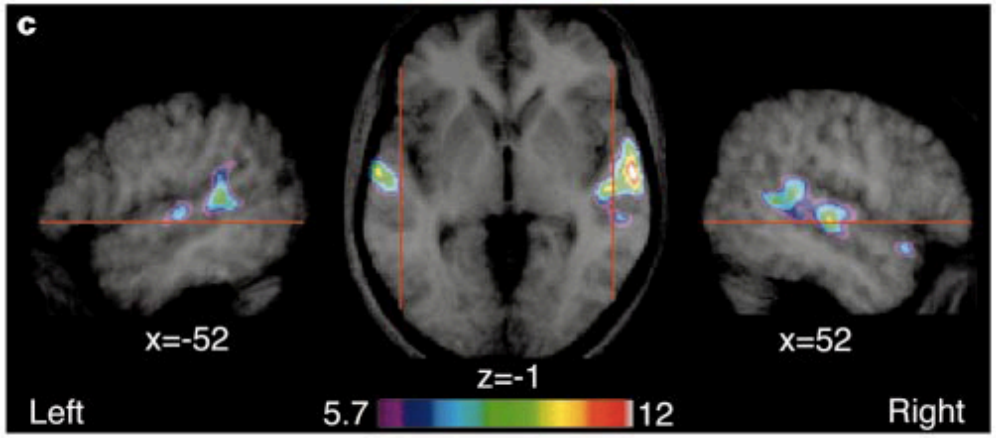
Sign versus Gesture



Sign

Gesture

Voice versus Non-Language



Belin et al. Voice-selective areas in human auditory cortex. Nature 403, (2000)

Words versus laughs, sighs, grunts, onomatopoeia, and other non-vocal sounds

Into the Linguistic Realm

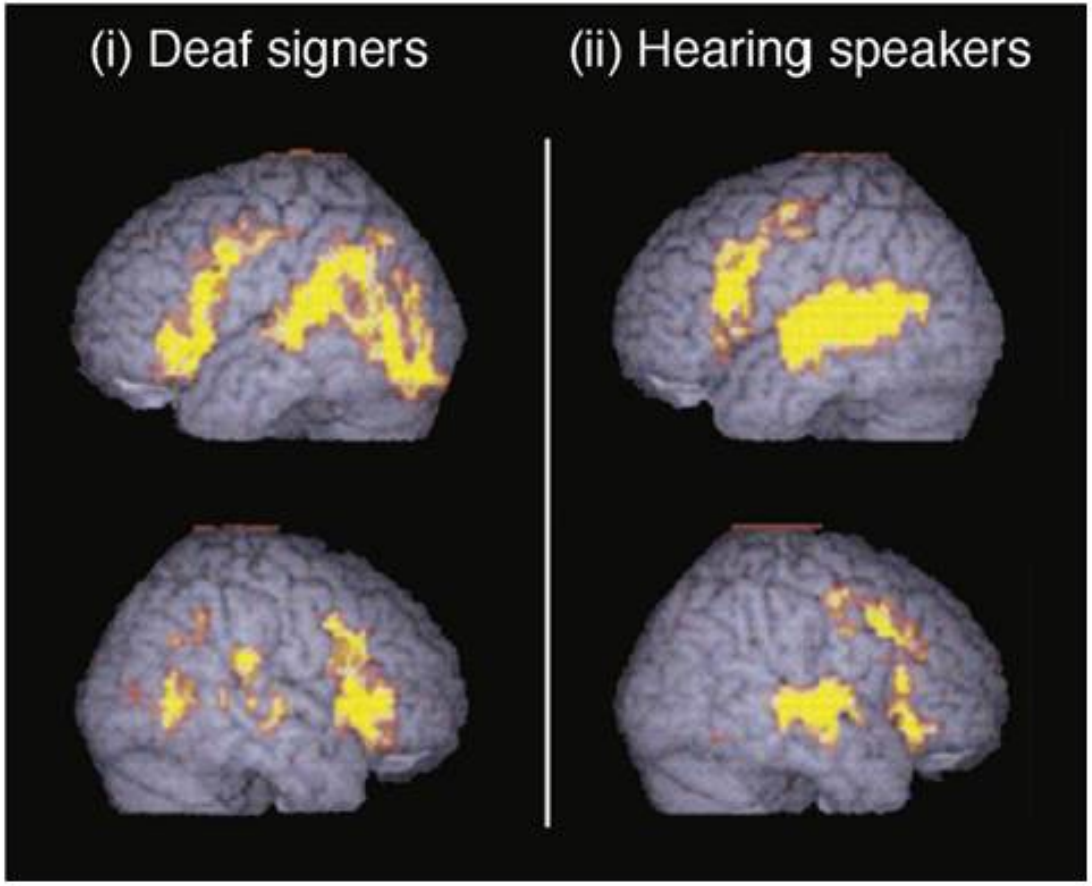
Superior and middle/inferior temporal lobe structures (form-meaning interfaces).

These regions are shared by spoken and sign languages

Common “linguistic combinetrics”

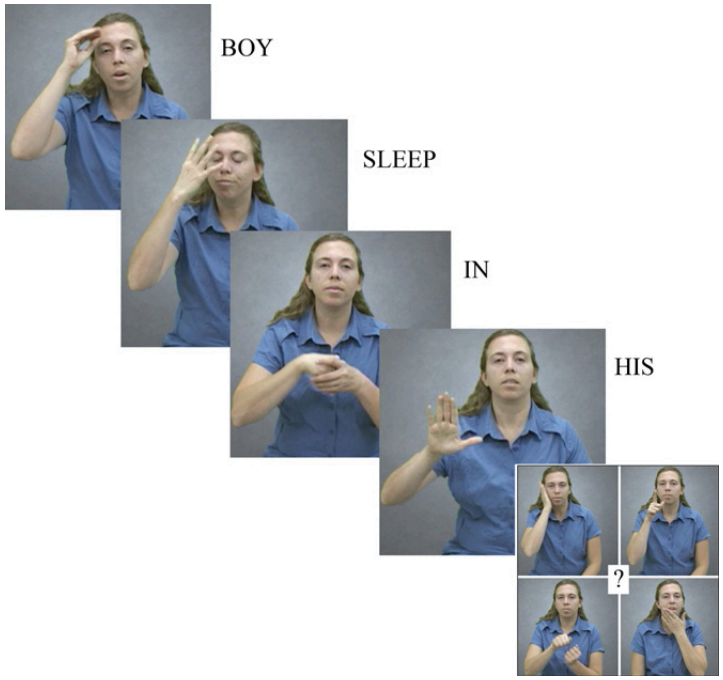
Lexical access, syntax etc.

Sentence processing in Sign (BSL) and Speech (English) activates highly similar areas in left and right hemisphere

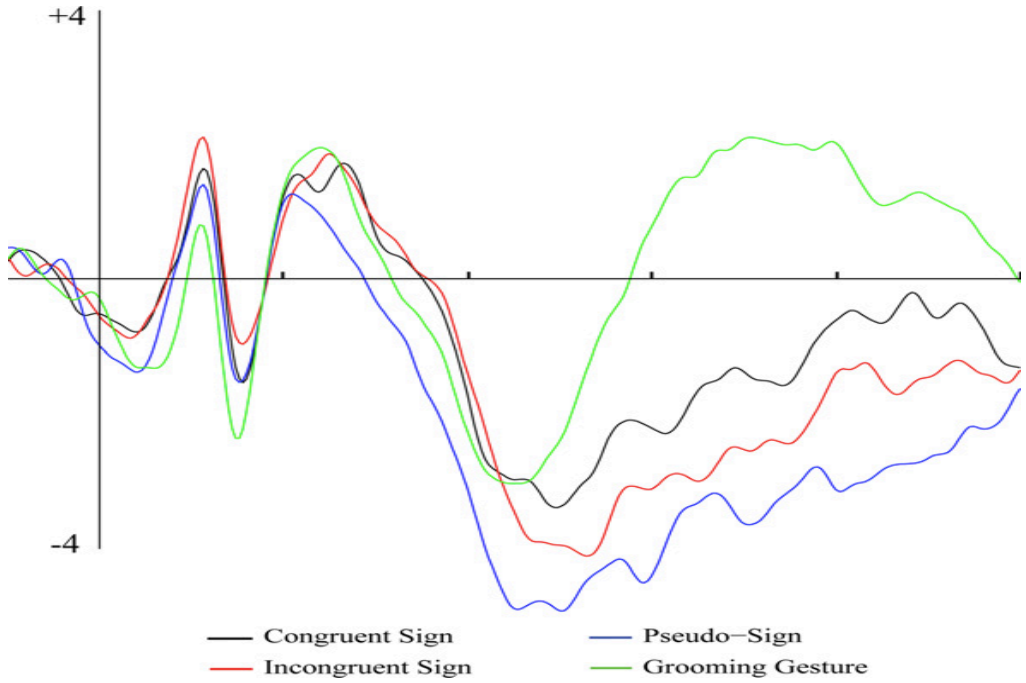


(MacSweeney et al 2010)

ASL sentence processing: ERP effects of encountering non-linguistic actions.



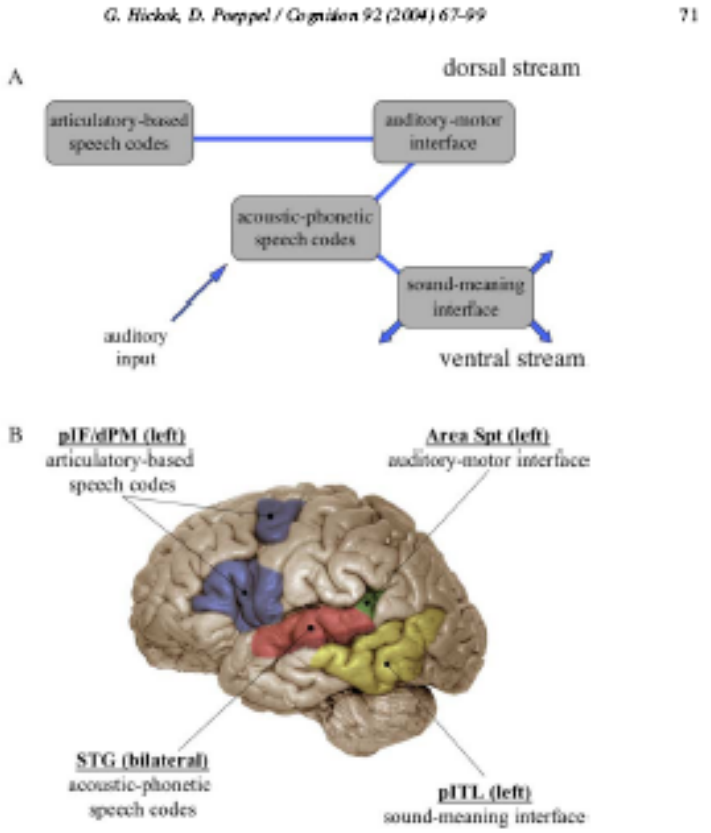
The boys sleeps in his ... BED
LEMON
"blick"
scratches face



Grand-average waveforms at the OZ site
(Negative down, Positive up…*sorry Steve*)

Grosvald, Gutierrez, Hafer, & Corina (2012) Brain and Lang.

Relation to Speech Processing



Signed Languages

Strobe photograph of ASL signs "join" and "inform." (Reprinted by permis-

Spoken Languages

Human Actions

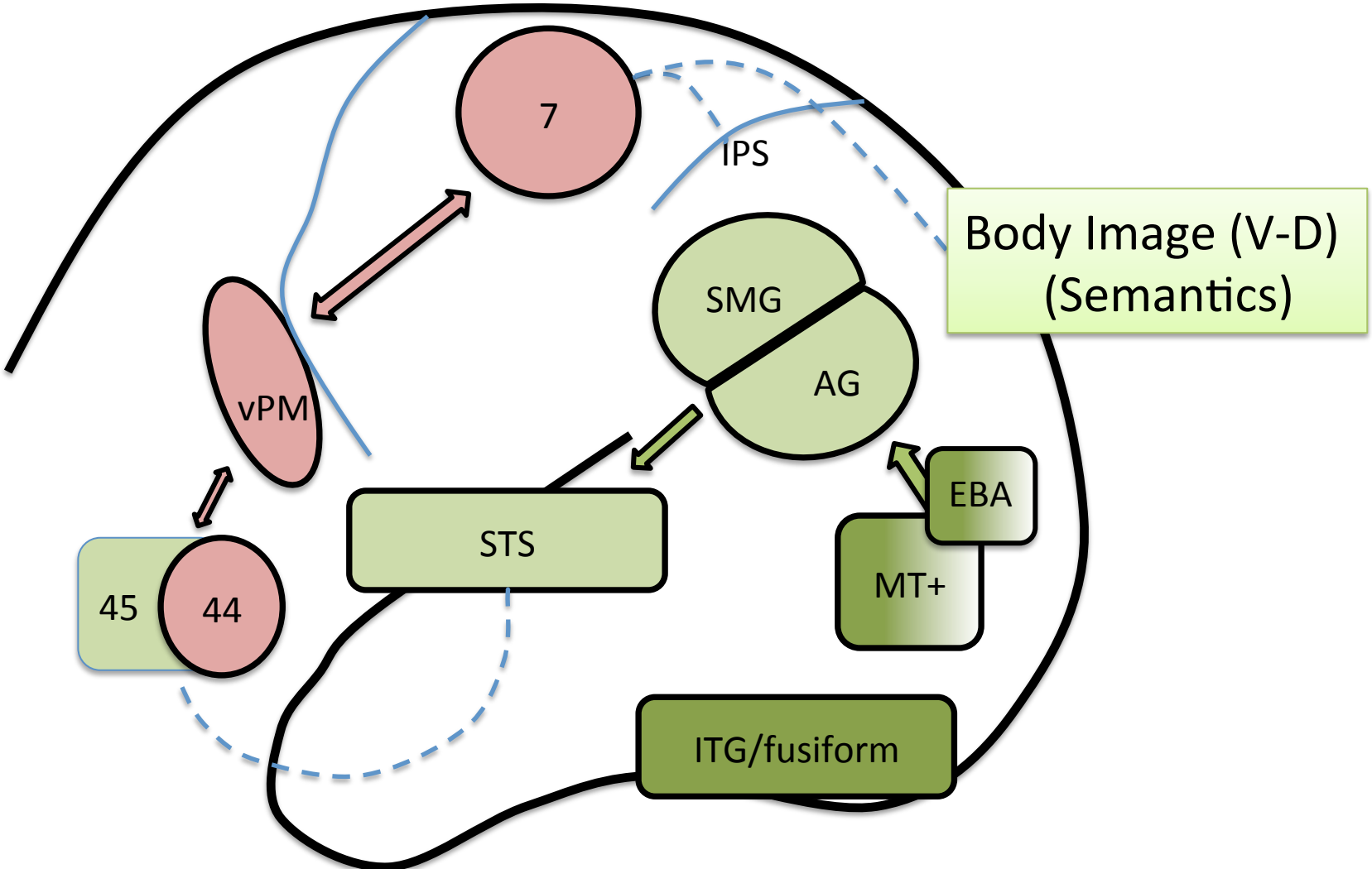
Conclusions

Brain representation for language represents the intersection of multiple domains.

Studies of signed languages, human actions and speech can guide through this complex system.

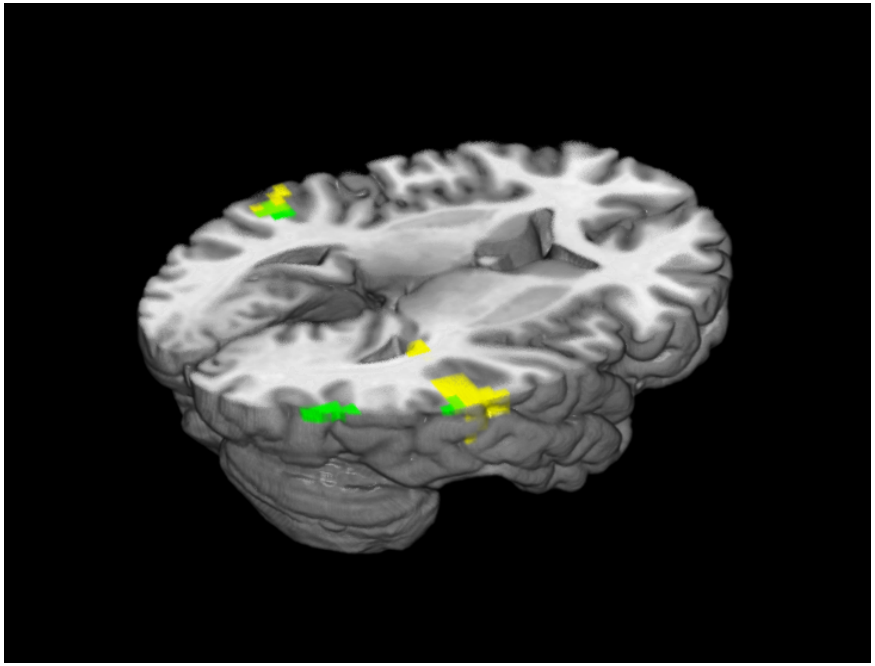
Inferior (VD) Parietal Lobe Summary

- Interpretation of human actions
- Specialization for sign form and semantics



Language selectivity in posterior STS

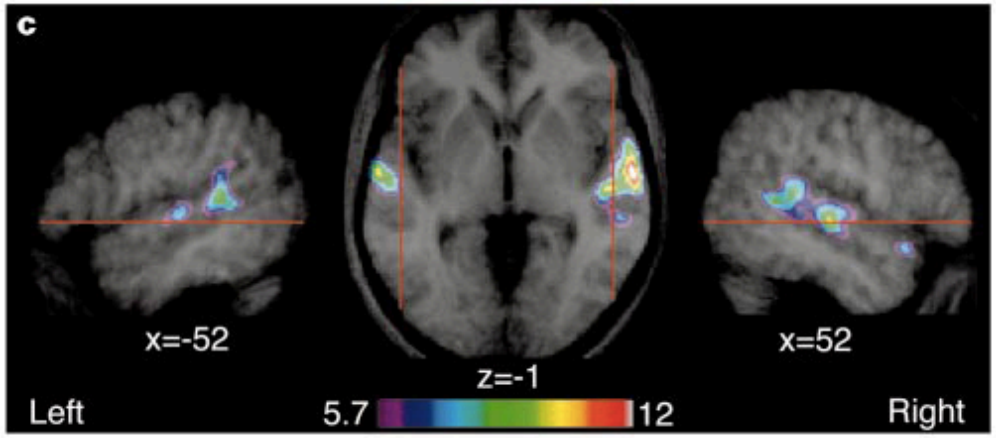
Sign versus Gesture



Sign

Gesture

Voice versus Non-Language



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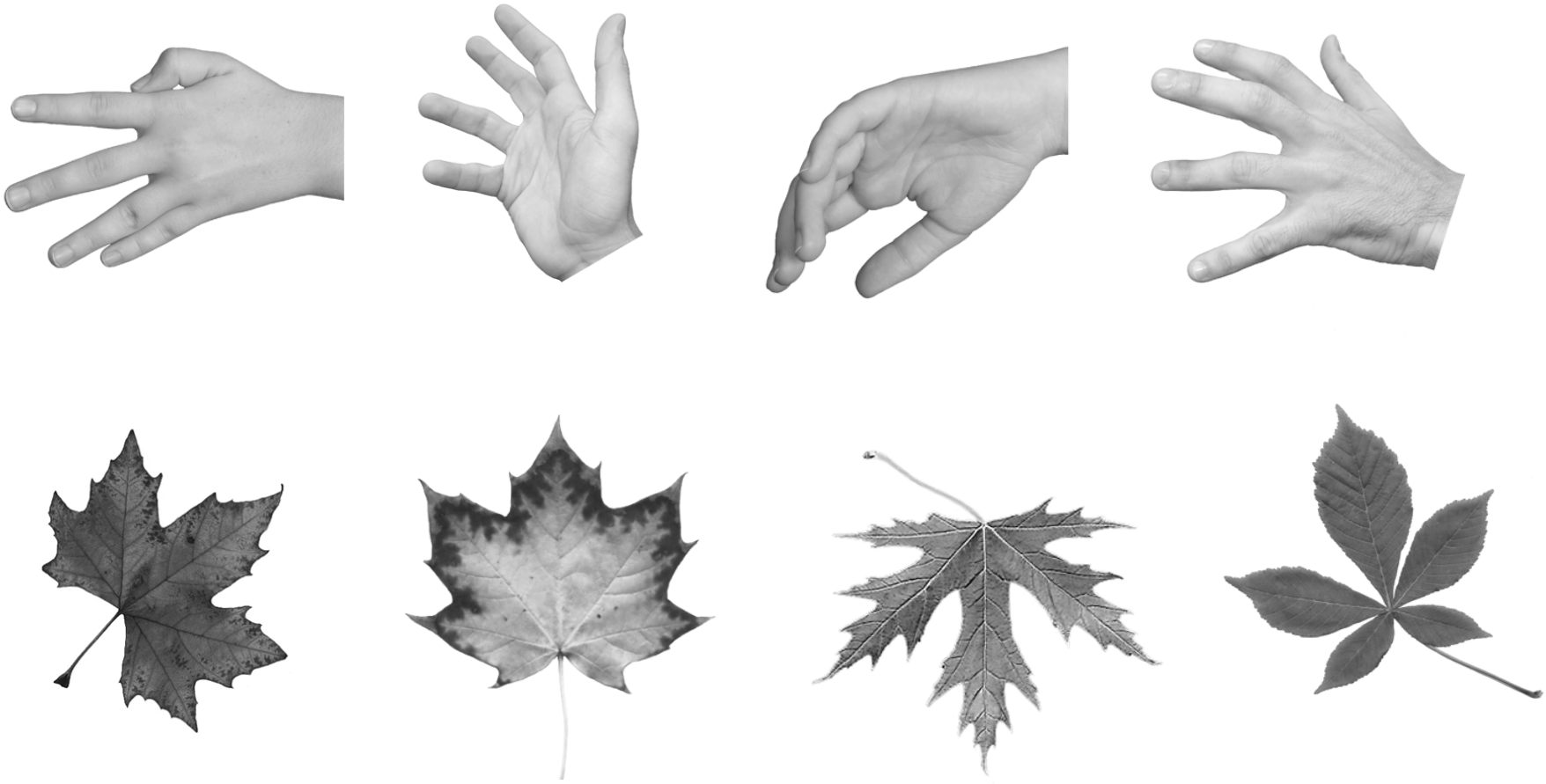
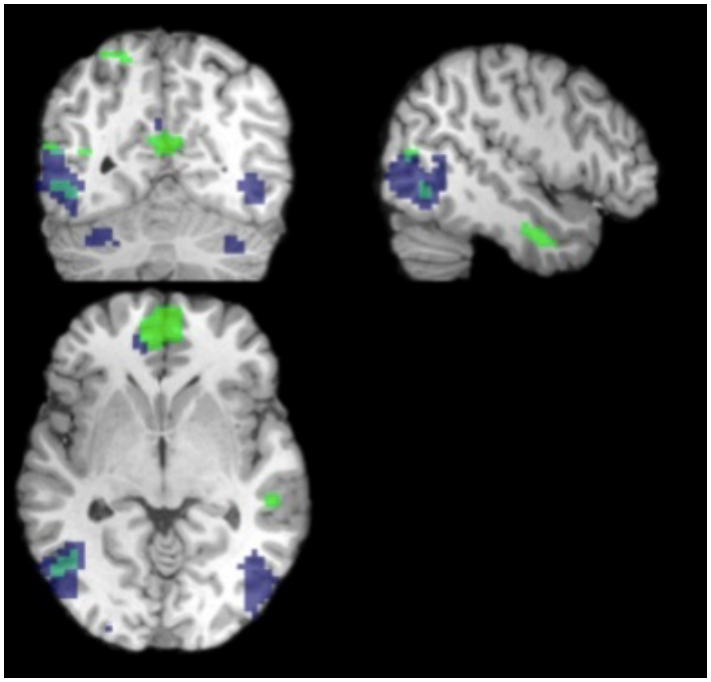
Hand Localizer

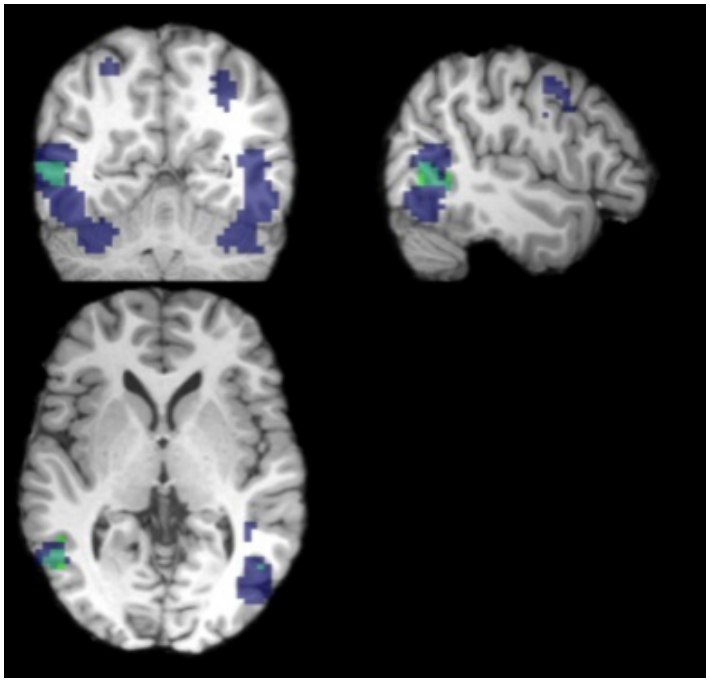


Corina et al (in prep.)

Sign (blue) and Hands (green)



Subject 1



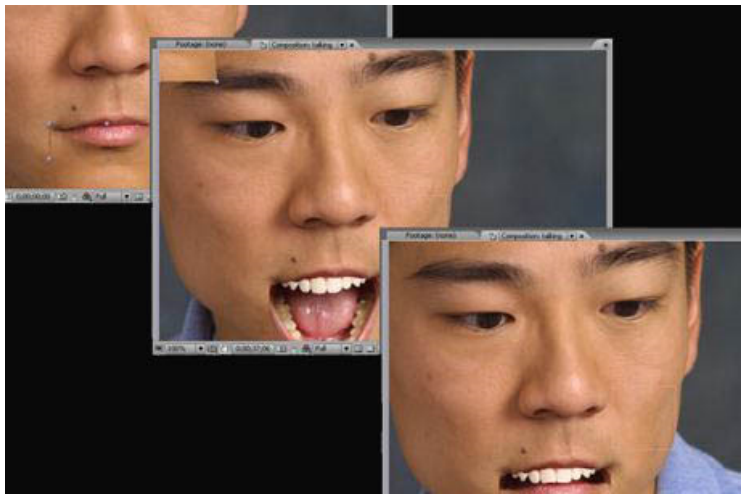
Subject 2

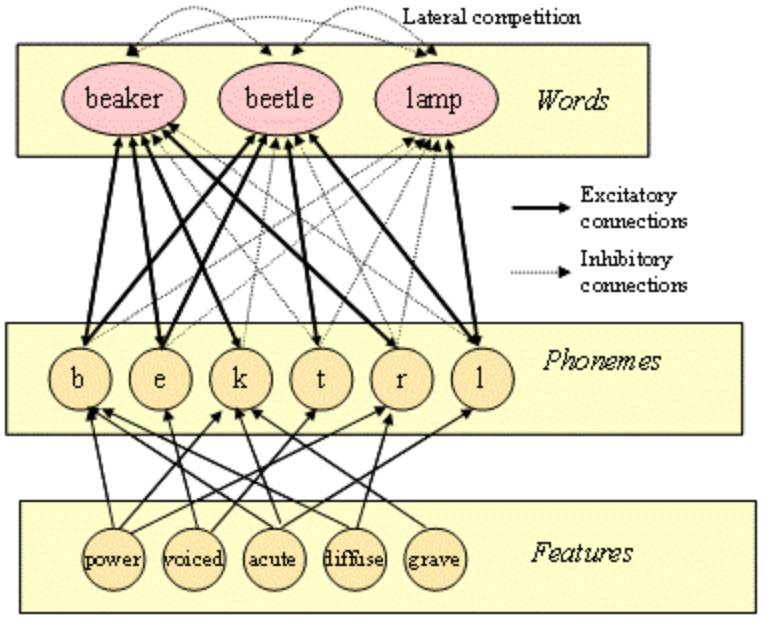
Overlapping activations of signs (blue) and Hand localizer (green)

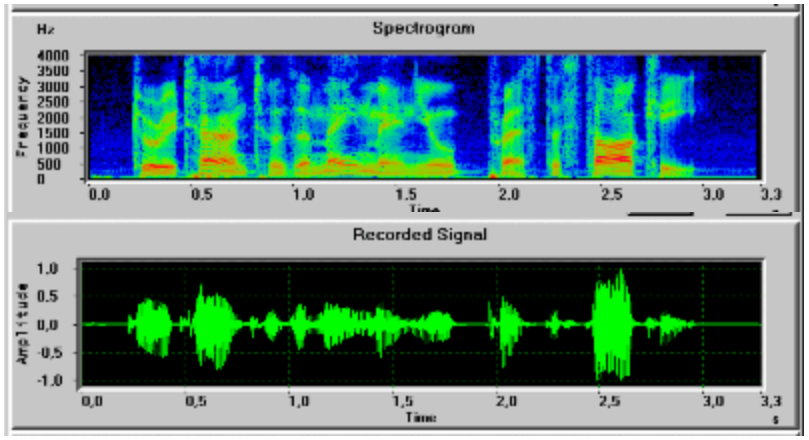
Speech: Decomposition and reconstruction

Speech recognition:

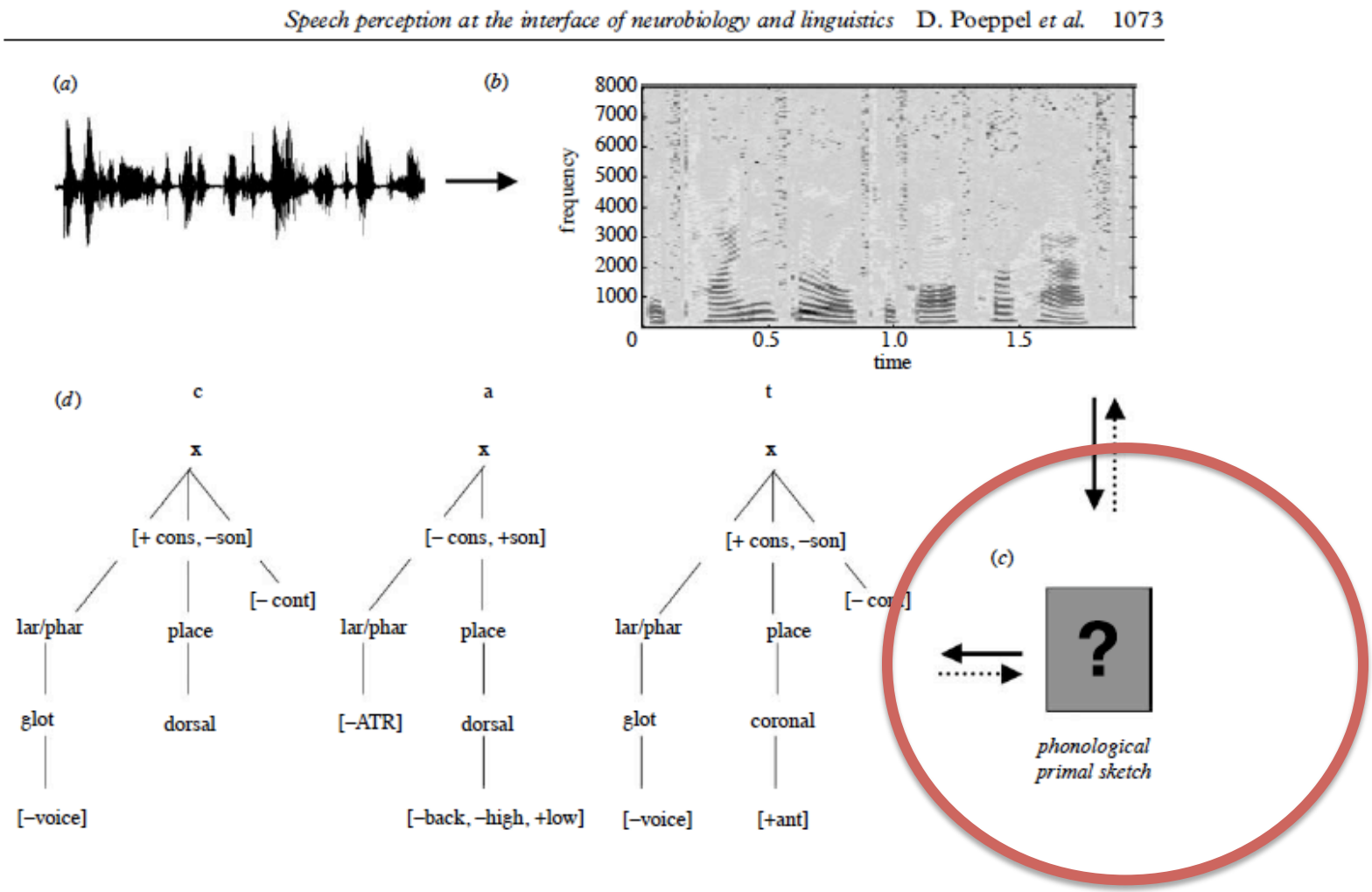
- hierarchical series of steps
- recoding of the acoustic wave form
- extraction of feature components
- Matching into sub-lexical representation of word and eventually word forms themselves.
- Activation of conceptual-semantic forms.







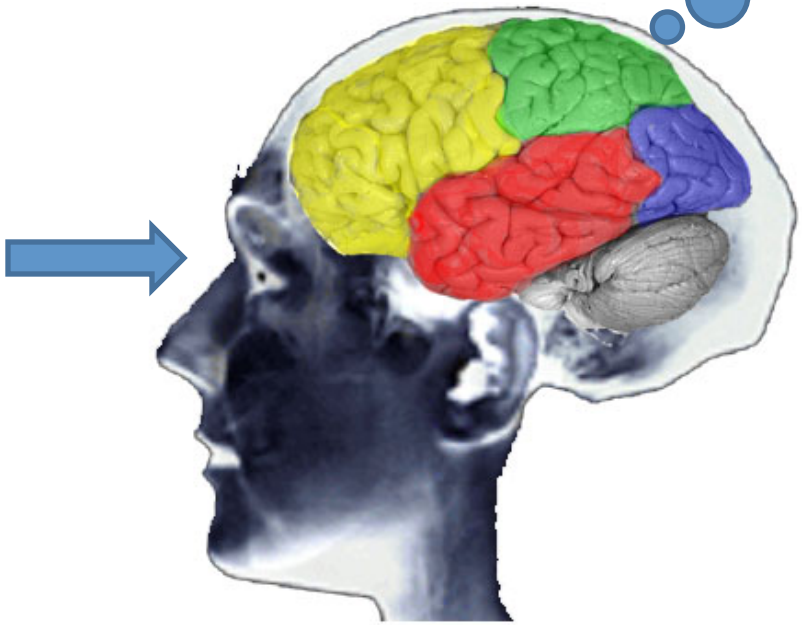
Recent Model (Poeppel et al 2008)

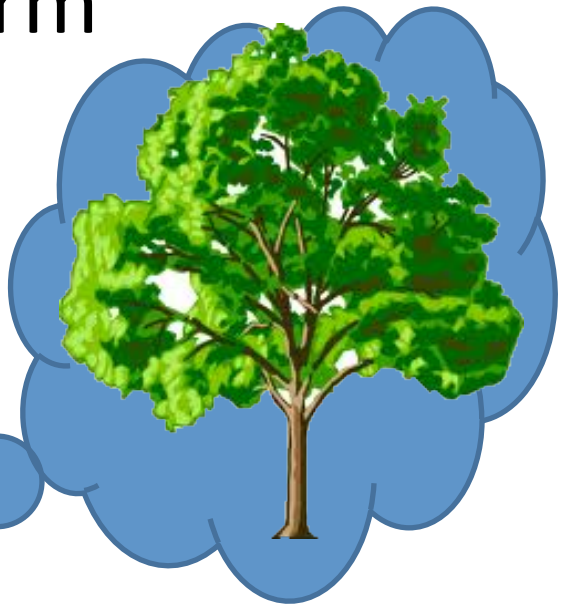


Phil. Trans. R. Soc. B (2008) 363, 1071–1086

How do we map the physical form of a sign's action onto a meaning representation ?

ASL: TREE





Semantic-conceptual representation

But we are faced with a myriad of human actions

How do we recognize and make sense of these multiple forms ? Is sign special ?

I don’t think so

A tacit assumption; sign recognition will entail similar processing stages as words.

Extraction of feature components which feed into sub-lexical representation of sign and eventually word forms themselves.