

The twofold role of cognitive neuroscience in the study of bilingualism

Peter Indefrey

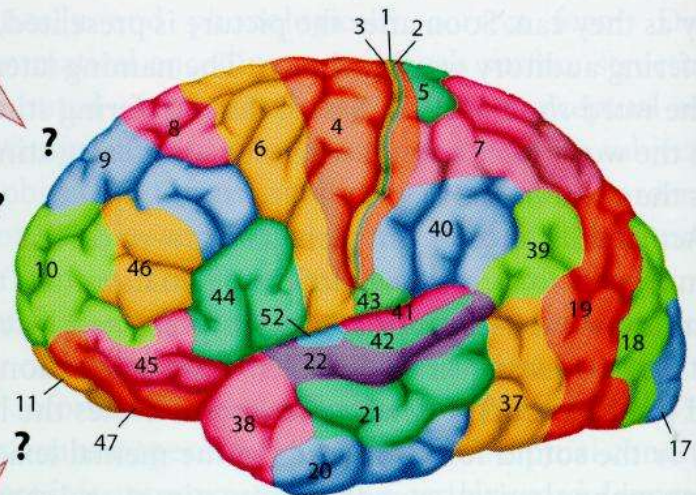
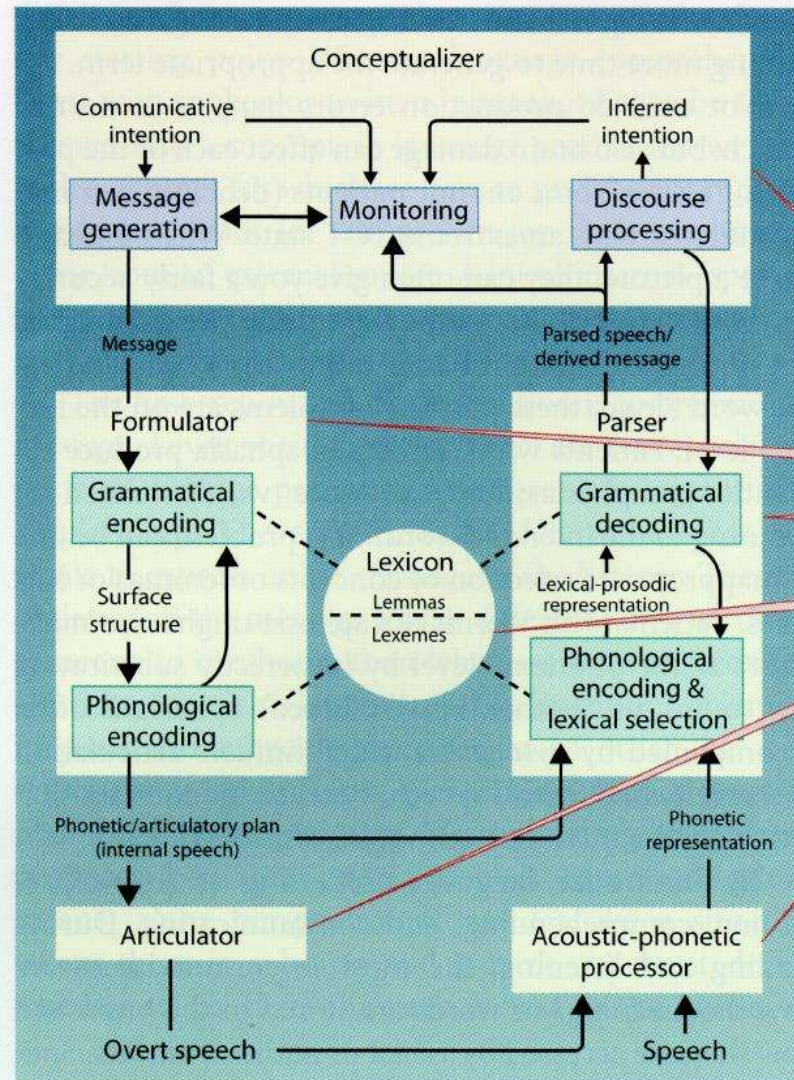


What can cognitive neuroscience tell us about bilingualism?

A – The mapping approach

B – The hypothesis testing approach

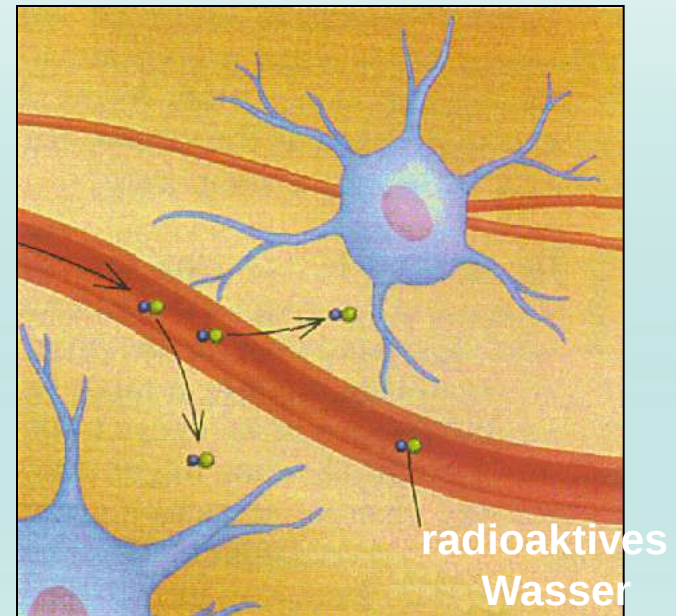
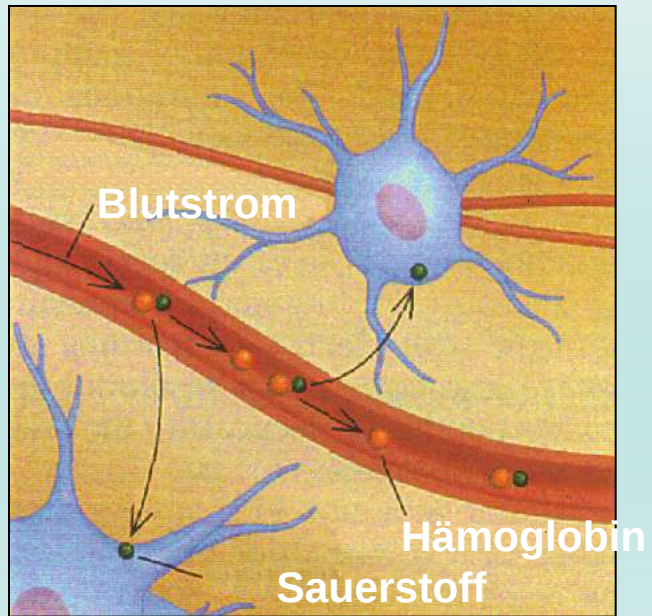
The mapping approach: Localisation of known functions



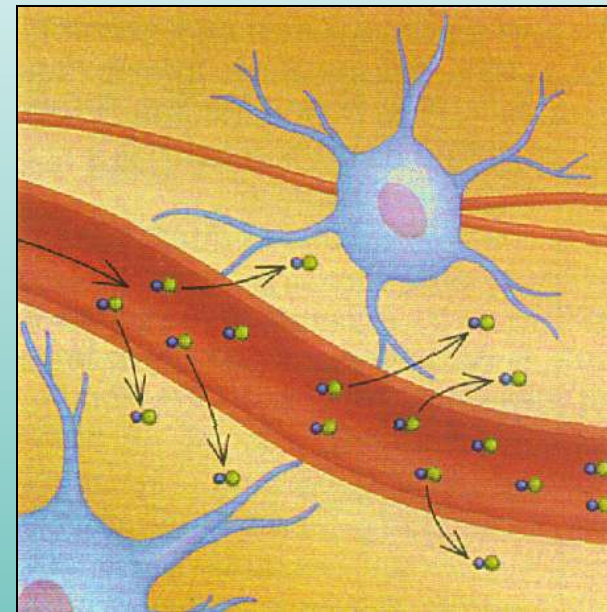
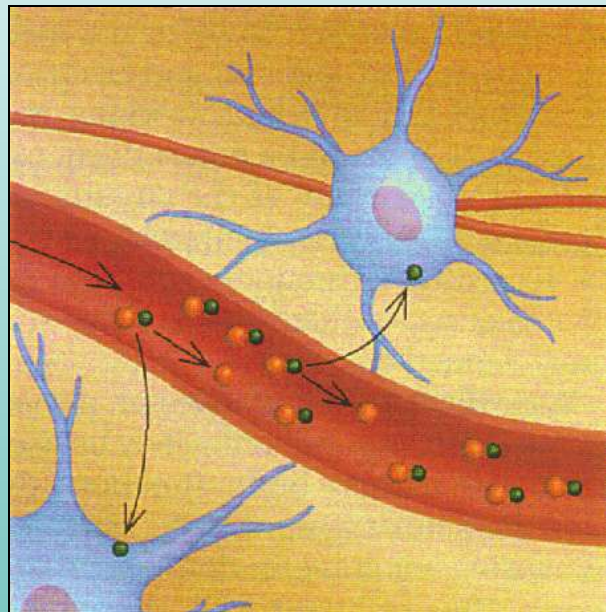
Functional MRI

PET

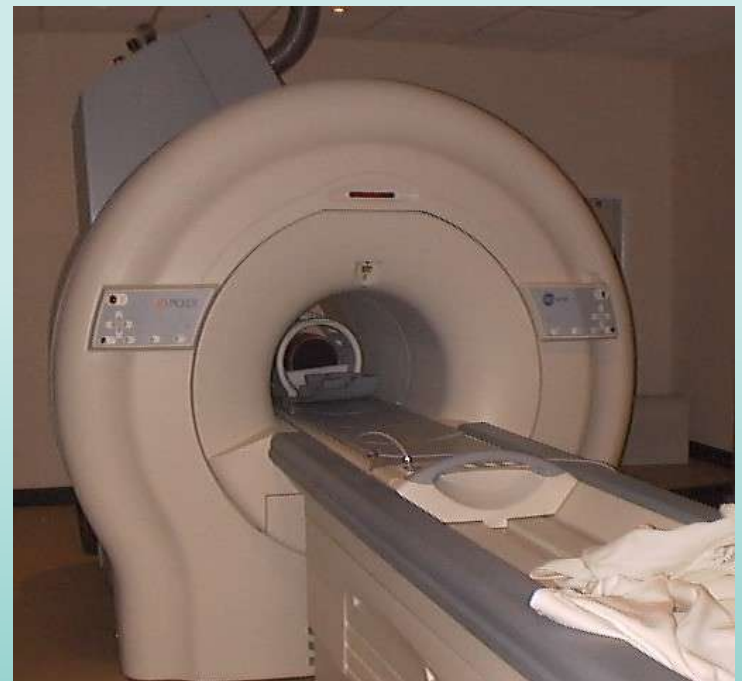
Rest state



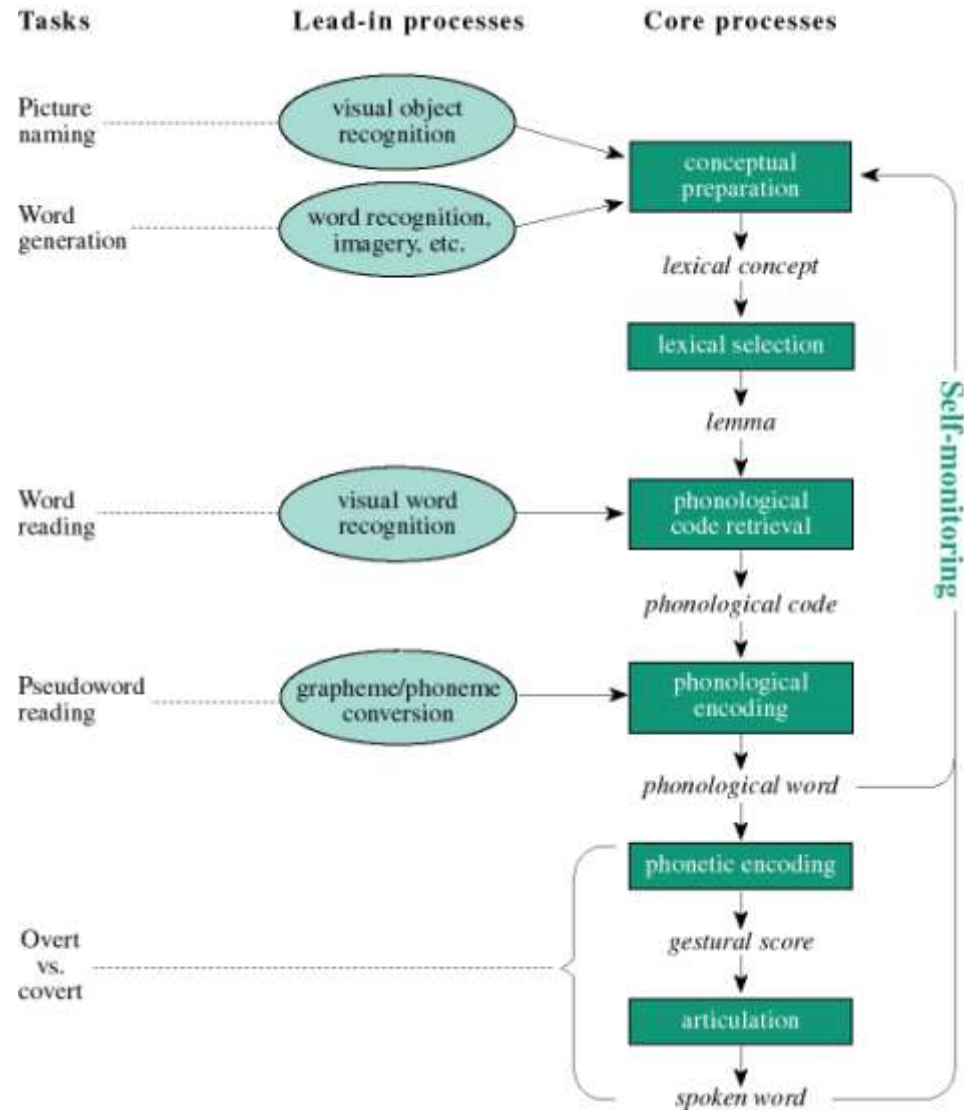
Active state



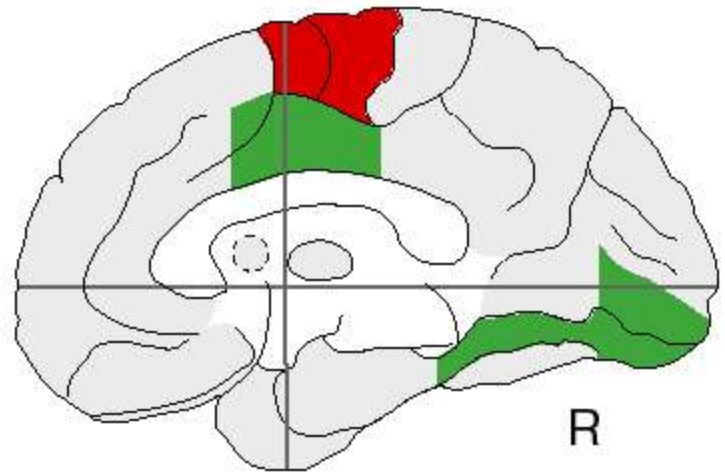
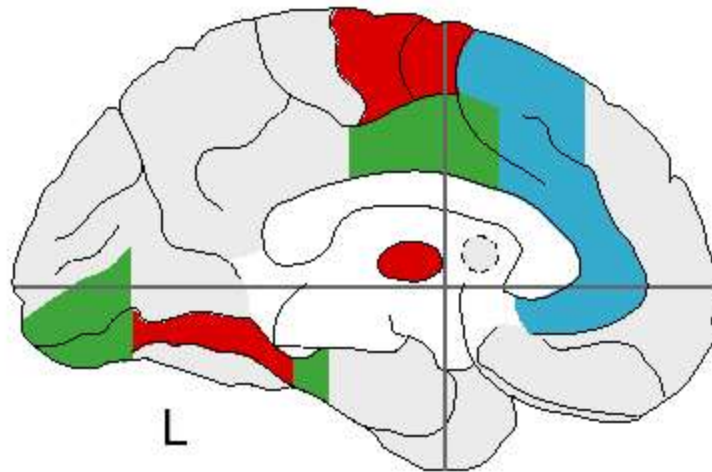
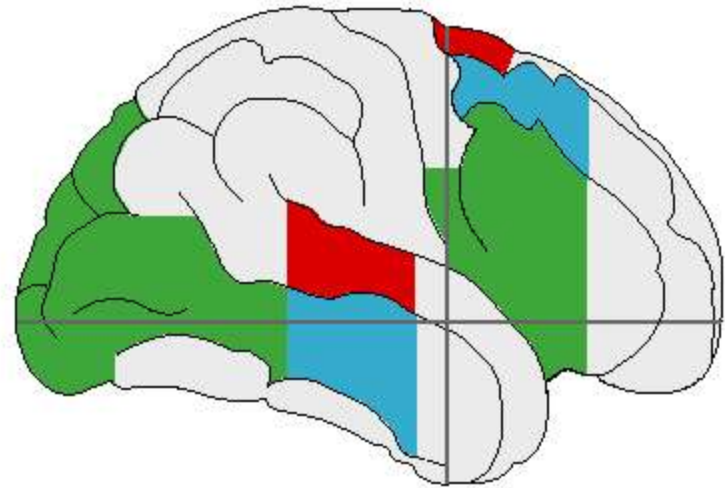
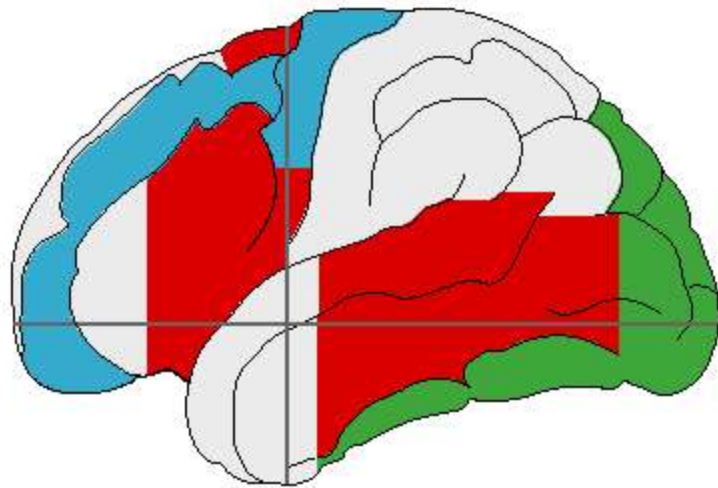
MRI-Scanner



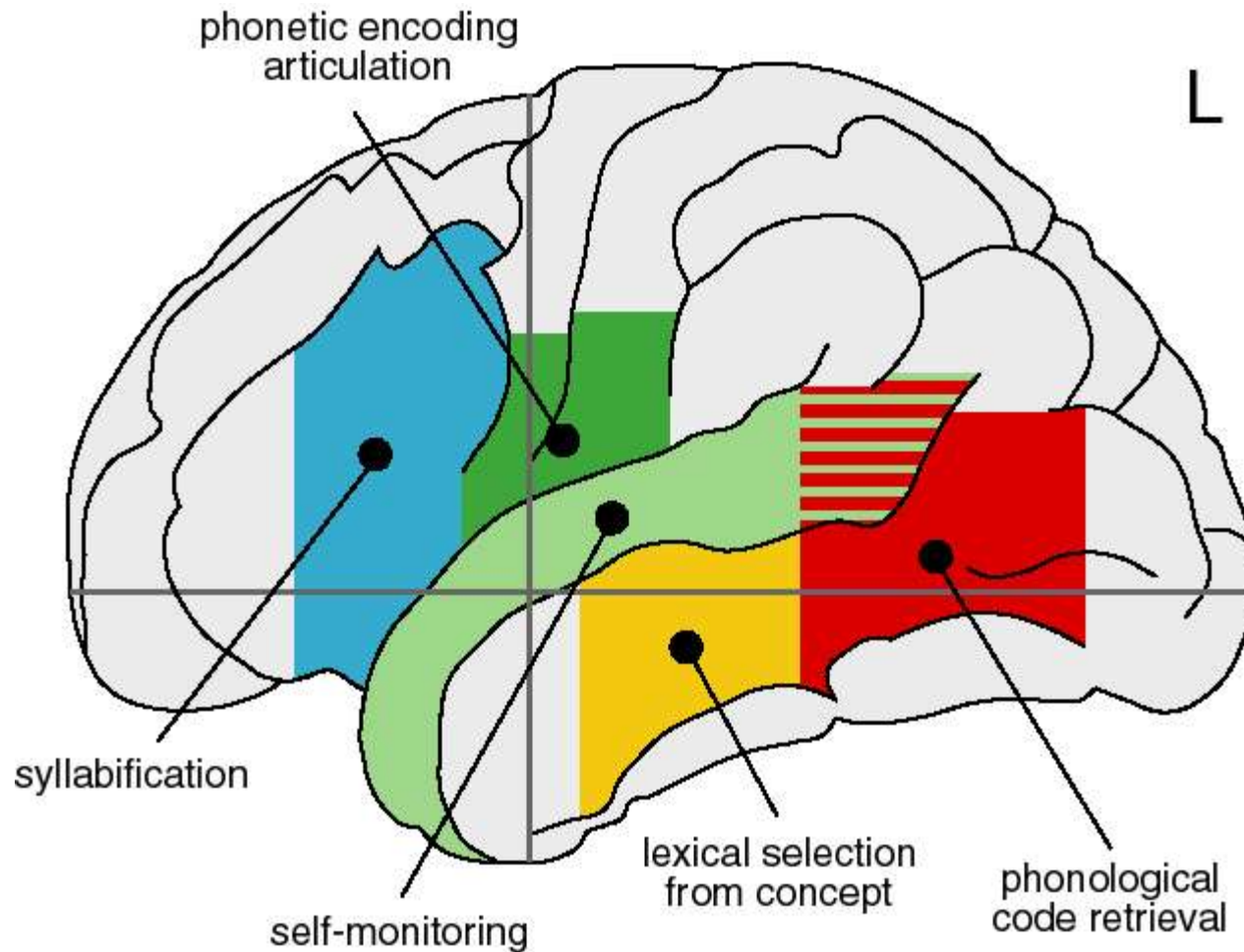
Meta-analysis of 82 word production studies



Picture naming (green), Word generation (blue),
Common regions (red)



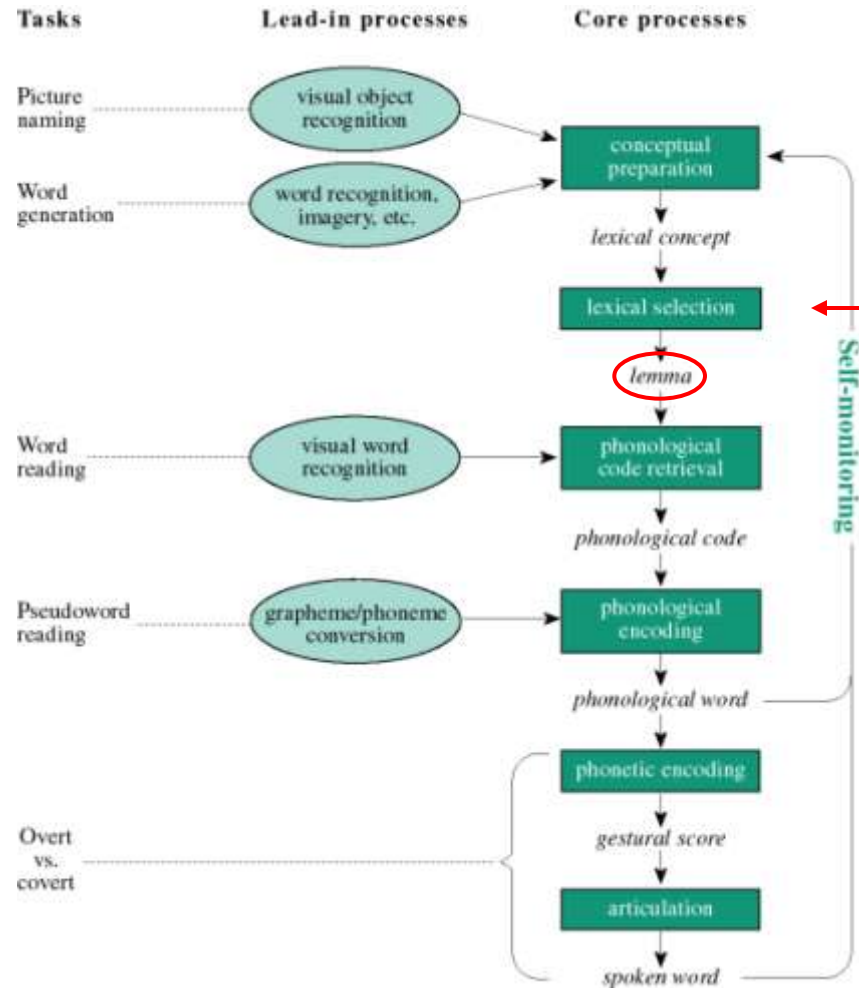
Schematic representation of meta-analysis results for word production (82 studies)



The hypothesis testing approach:

- This approach
 - presupposes that a hemodynamic or electrophysiological activation is a correlate of a certain cognitive process
 - tests a cognitive theory by investigating whether this activation is modulated according to a prediction derived from that theory
 - is to date infrequent in hemodynamic studies but the most common approach in ERP studies

Hypothesis testing: Serial versus cascaded processing



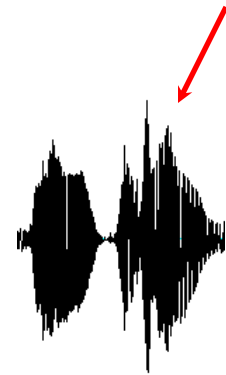
Semantic
interference



dog
cat



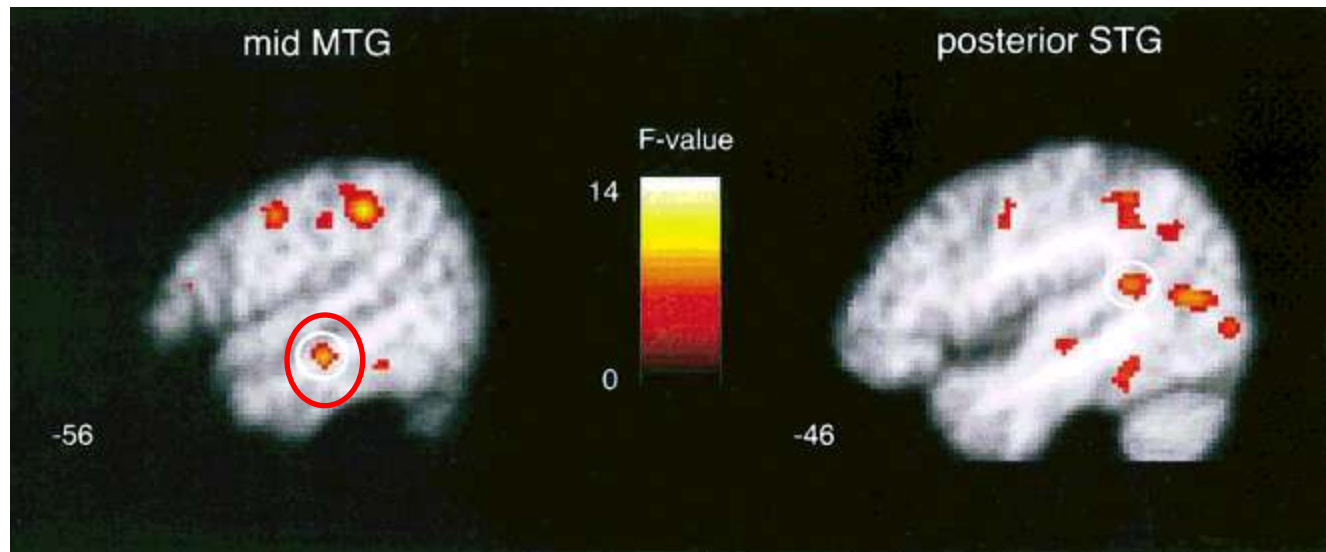
distractor
word



"cat"

semantic interference in picture
naming

Stronger hemodynamic activation in picture naming with semantic interference

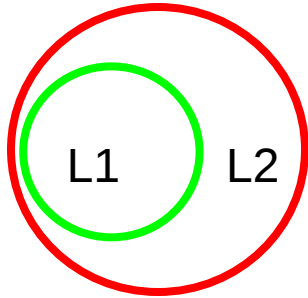


What can cognitive neuroscience tell us about bilingualism?

A – The mapping approach

“Where in the brain is the second language?”

Some proposed L1 and L2 activation patterns

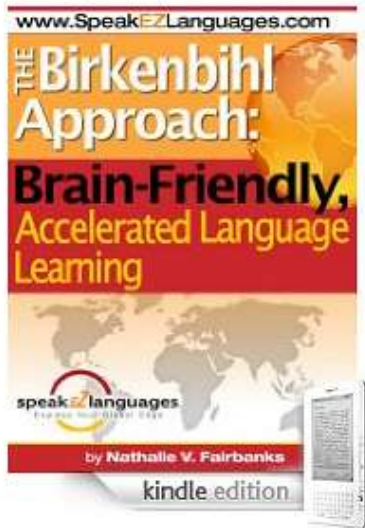


Genesee et al. (1978, 1982)

Evans et al. (2002)

L2 activation of right hemisphere

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by [Nathalie V. Fairbanks](#) (Author), [Vera F. Birkenbihl](#) (Foreword)

★☆☆☆☆ (1 customer review)

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Formats

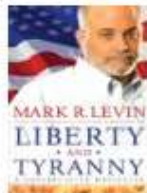
	Amazon Price	New from	Used from
Kindle Edition, January 16, 2006	\$21.85	--	--
Paperback, March 13, 2006	--	\$29.00	\$114.79

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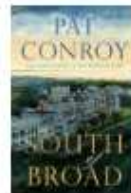
[Pursuit of Honor: A Novel](#) by Vince Flynn

★★★★☆ (204) \$11.50



[Liberty and Tyranny: A Conservative Manifesto](#) by Mark R. Levin

★★★★☆ (2,110)
\$13.69



[South of Broad](#) by Pat Conroy

★★★★☆ (642) \$13.79



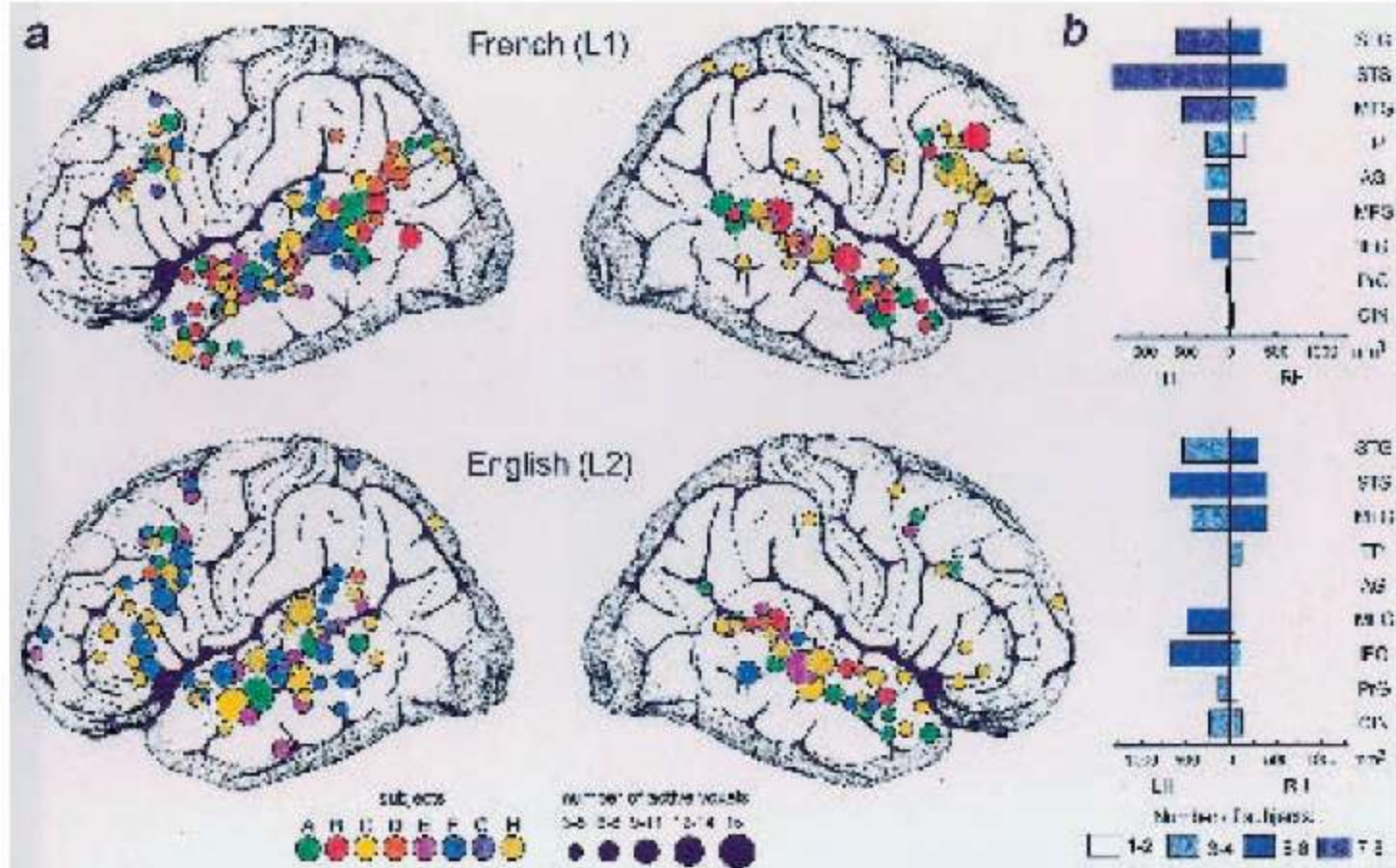
[Hostile Intent](#) by Michael Walsh

★★★★☆ (56) \$7.44



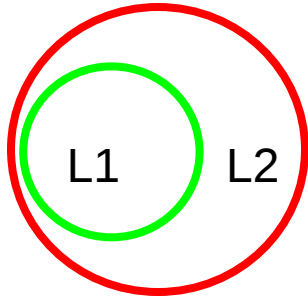
[The Complete User's Guide To the Amazon Kindle](#) by Stephen Windwalker

★★★★☆ (126) \$3.44



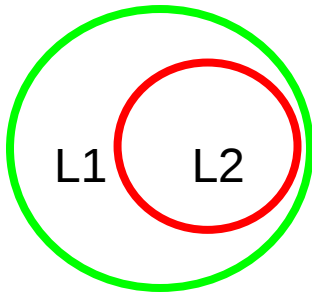
Dehaene et al. (1997) NeuroReport

Some proposed L1 and L2 activation patterns



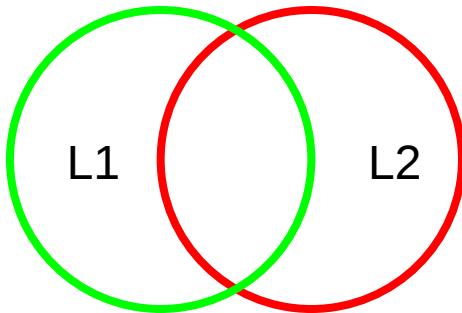
Genesee et al. (1978, 1982)
Evans et al. (2002)

Extra L2 activation of right hemisphere



Perani et al. (1998): Story listening

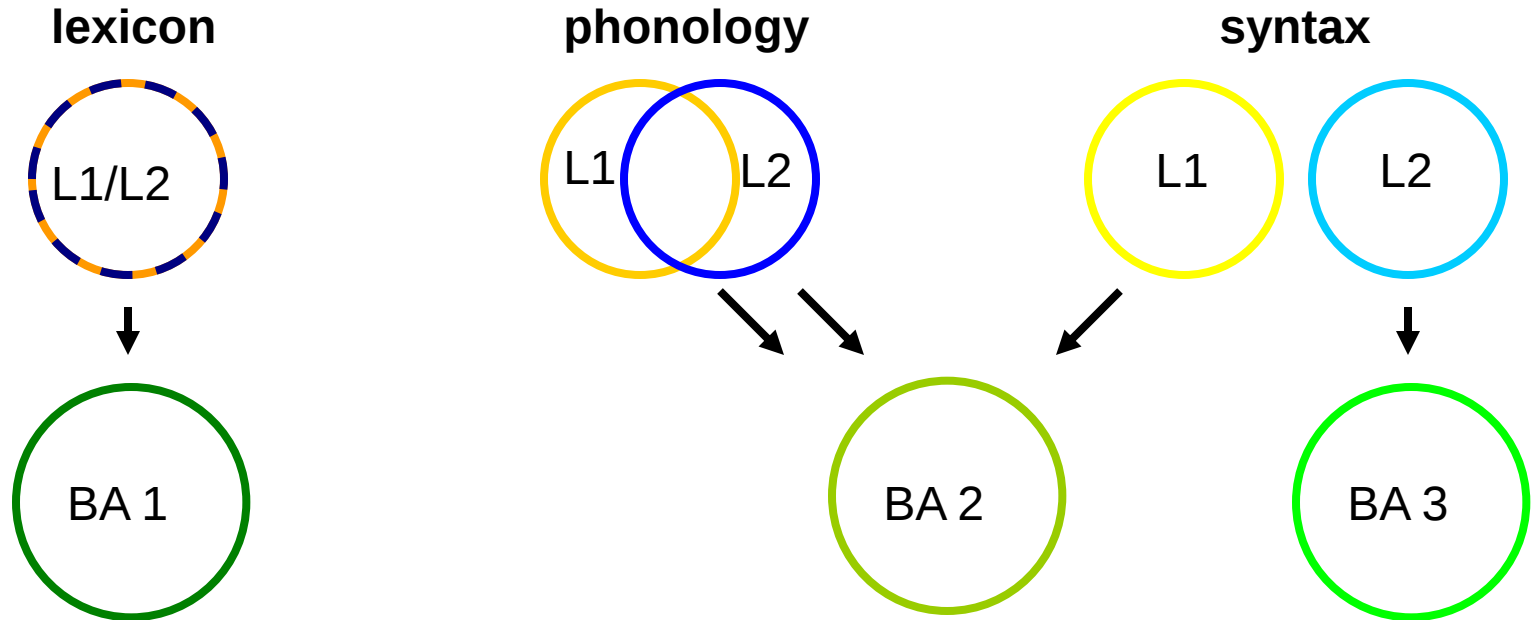
Extra L1 activation of left temporal pole



Dehaene et al. (1997): Story listening

Extra L2 activation of wide-spread areas
Extra L1 activation of left temporal pole

Hypothetical processes and brain areas in L1 and L2

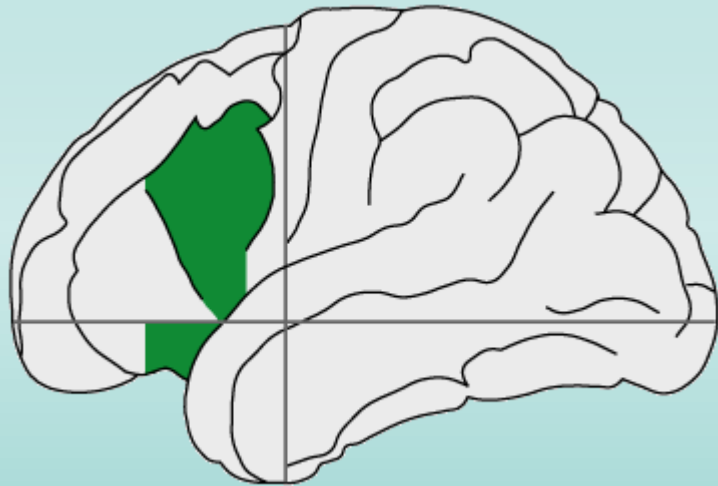


Hund

dog



Stronger activation in L2 as compared to L1 picture naming



found in

De Bleser 2003

Vingerhoets 2003

not found in

Rodrigues-Fornells 2005

Hernandez 2001

Hernandez 2000

L2
onset

L2
proficiency

L2
exposure

10

good – very good

?

10-14

mixed

low/high

3

balanced

dominant

<5

high

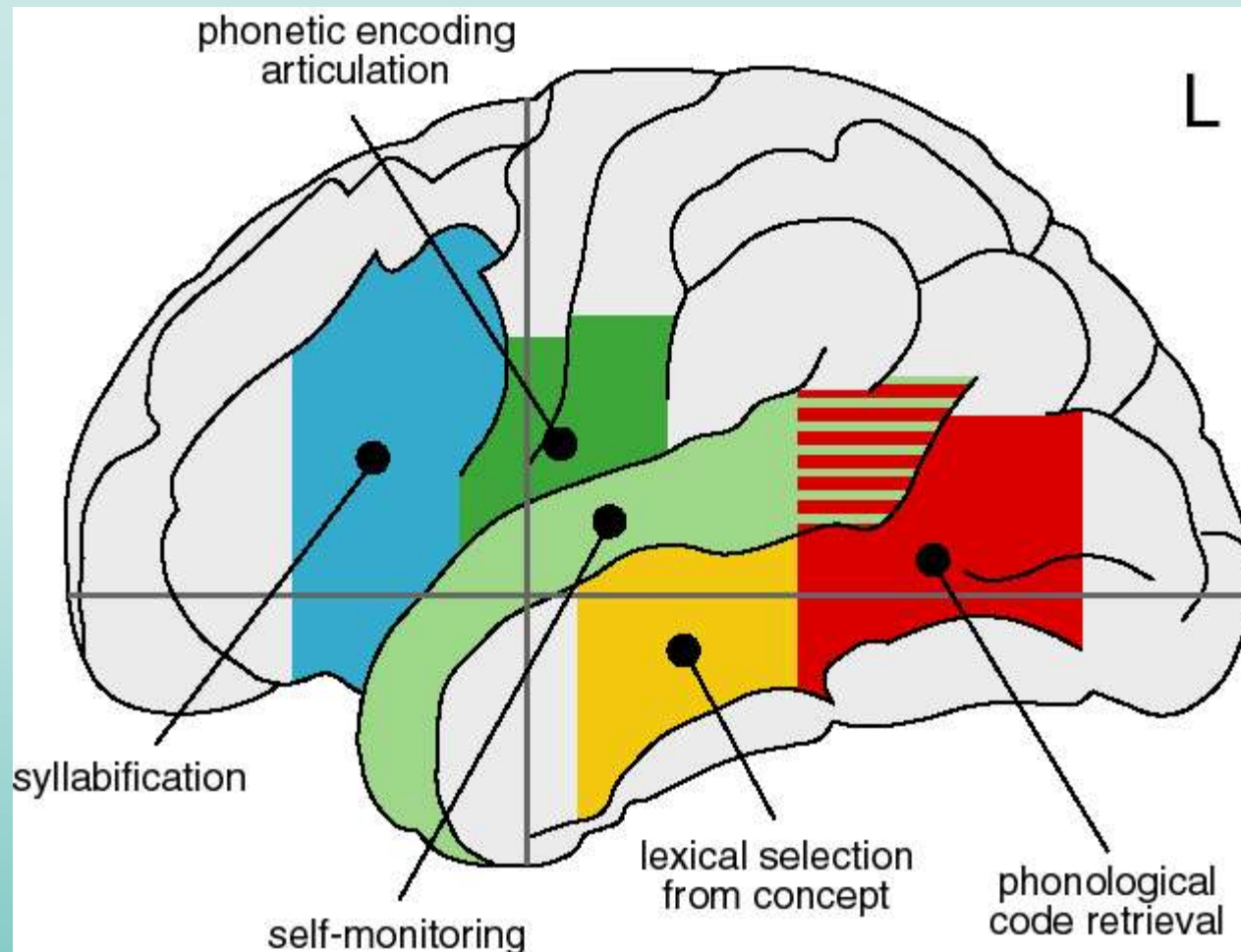
dominant

<5

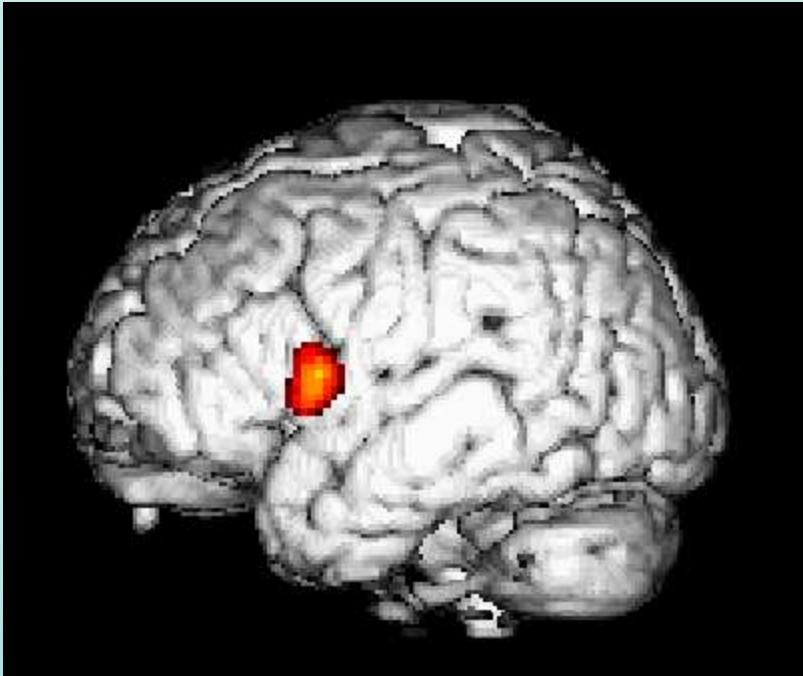
high

dominant

Schematic representation of meta-analysis results for word production (82 studies)

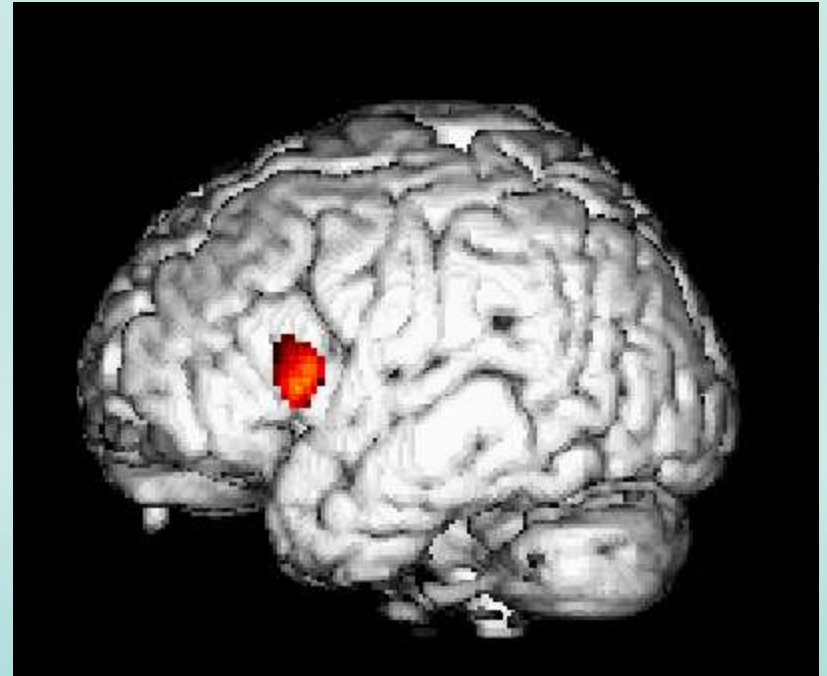


Sentence production vs. Single word production



Activation maximum at -54,6,10

Indefrey et al. (2001) PNAS



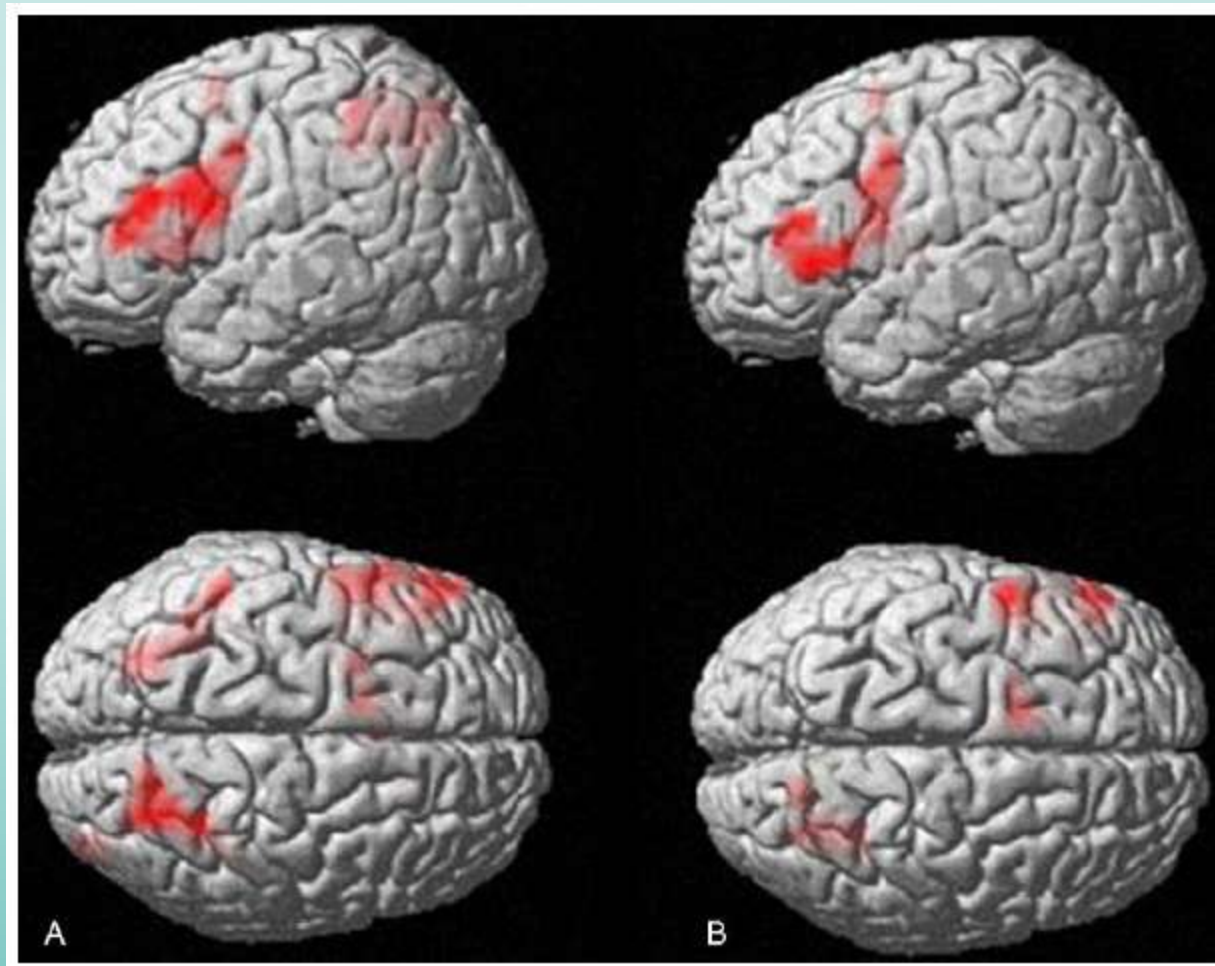
Activation maximum at -60,14,12

Indefrey et al. (2004) Brain & Language

Sentence production

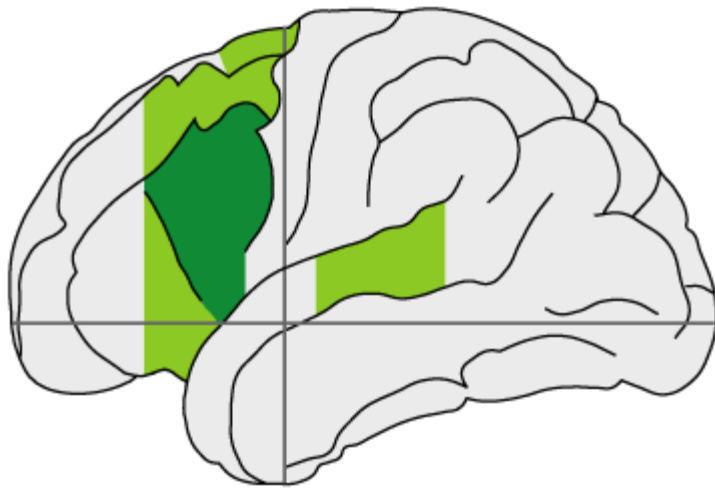
English (L2)

French (L1)



Sentence listening / reading

Stronger activation in L2 as compared to L1



found in

Nakai 1999

Rüschemeyer 2005

Luke 2002

**L2
onset**

**L2
proficiency**

**L2
exposure**

?

?

?

>12

high

high

>10

high

?

not found in

Perani 1998

Perani 1998

Perani 1996

Vingerhoets 2003

Nakada 2001

Hasegawa 2002

Chee 1999

Frenck-Mestre 2005

10

high

high

2

high

high

7

moderate

low

10-14

mixed

low/high

>10

high

?

12

high

high

<6

high

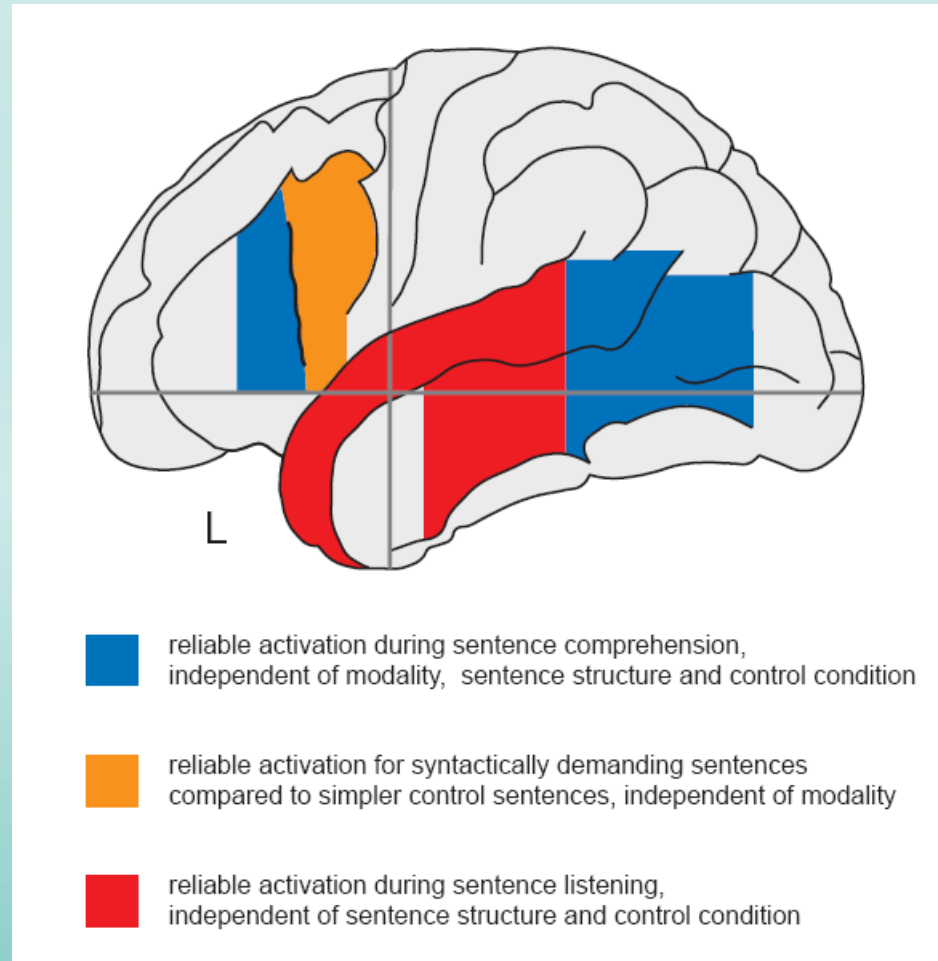
high

>12

high

high

Meta-analysis of 70 studies on native language sentence comprehension



Summary (1)

L1 and L2 word production, sentence production, and sentence comprehension recruit the same set of areas

The left posterior inferior frontal gyrus (Broca's area) may be recruited more strongly in L2 speakers with late L2 onset and/or low proficiency.

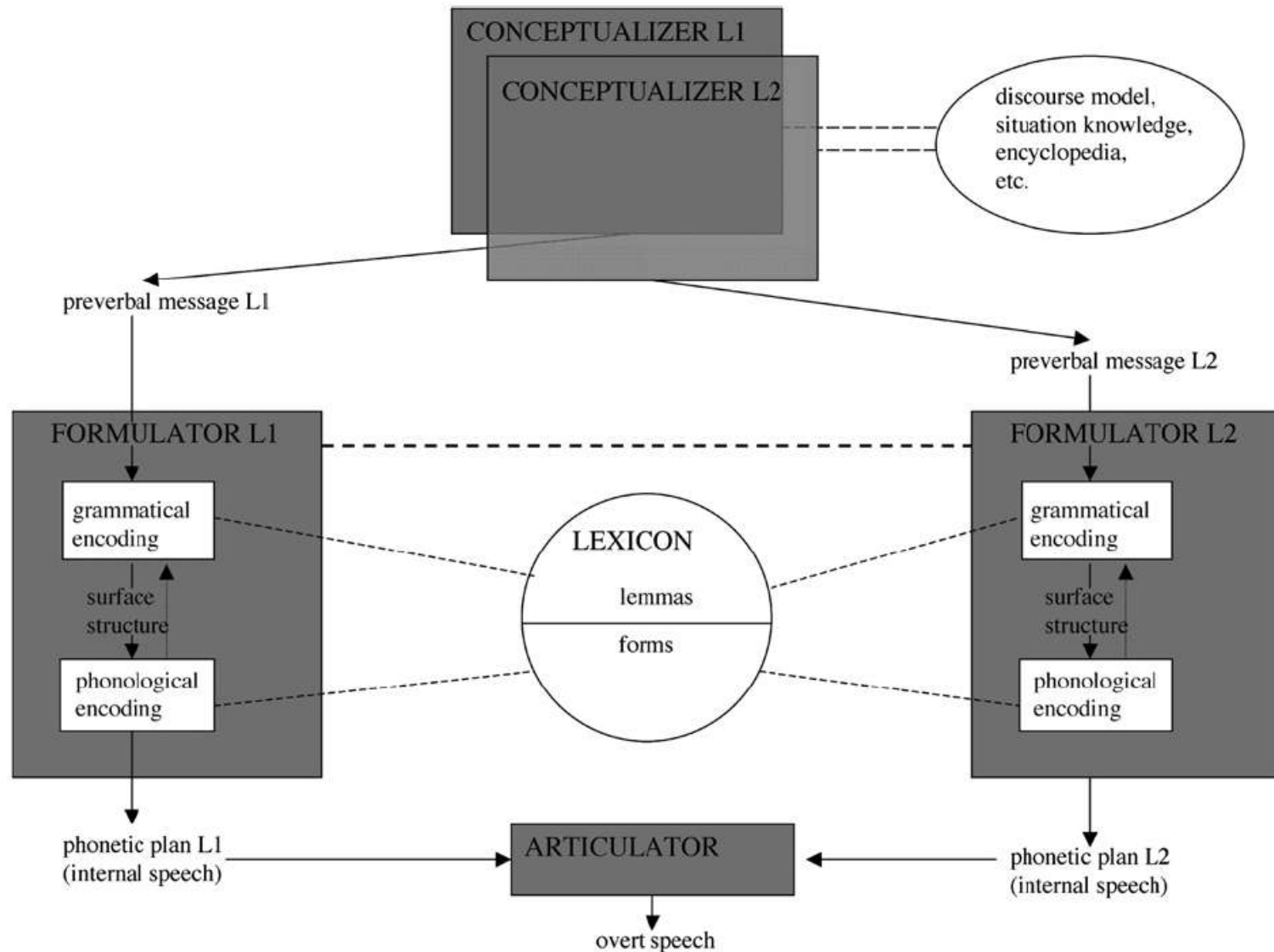
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Are these data informative with respect to
psycholinguistic theories of bilingual
processing?

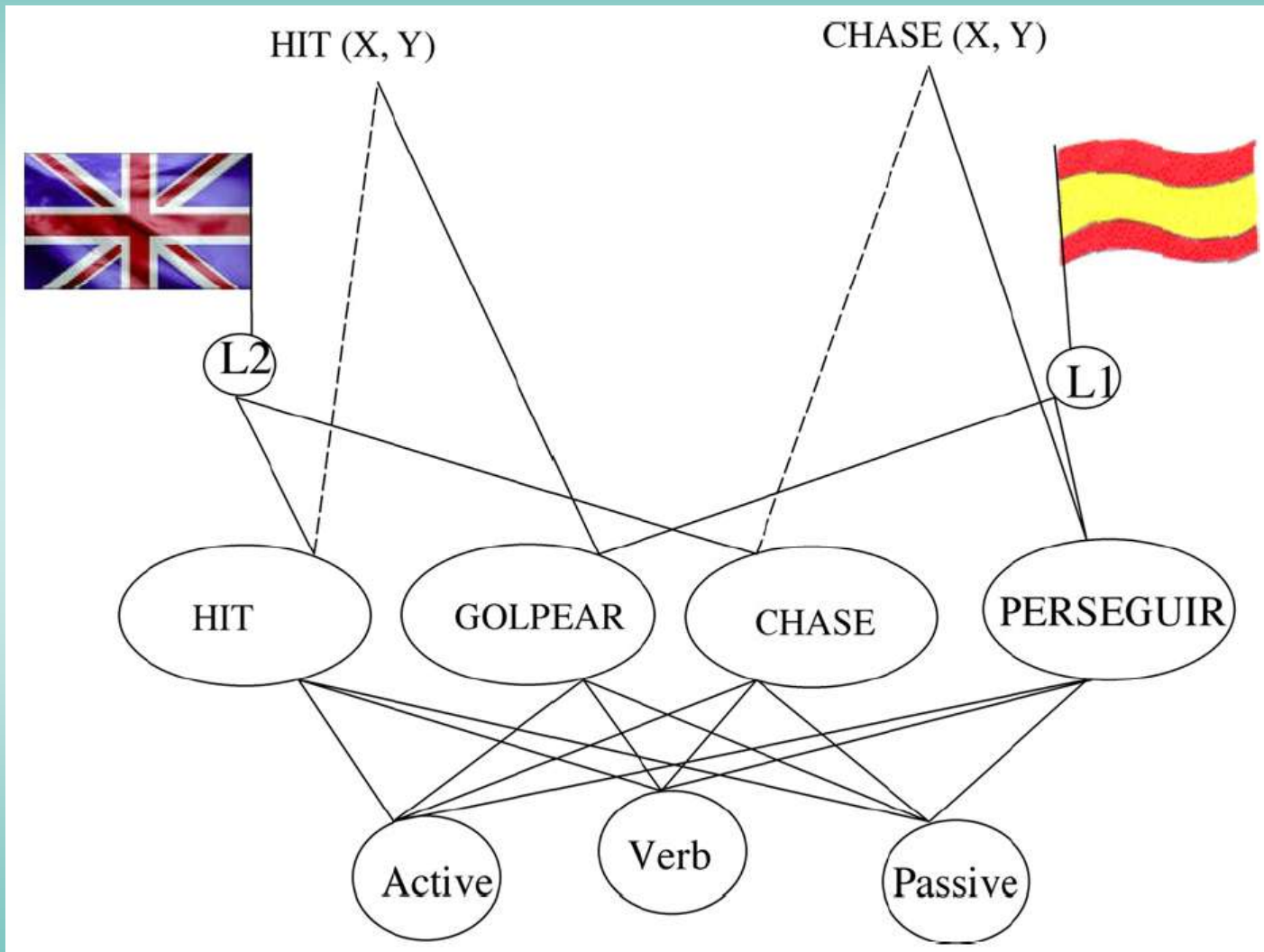
No

(Coltheart, 2006; Page, 2006)

Bilingual speaker (based on de Bot 1992)



Bilingual speaker (based on Hartsuiker et al. 2004)



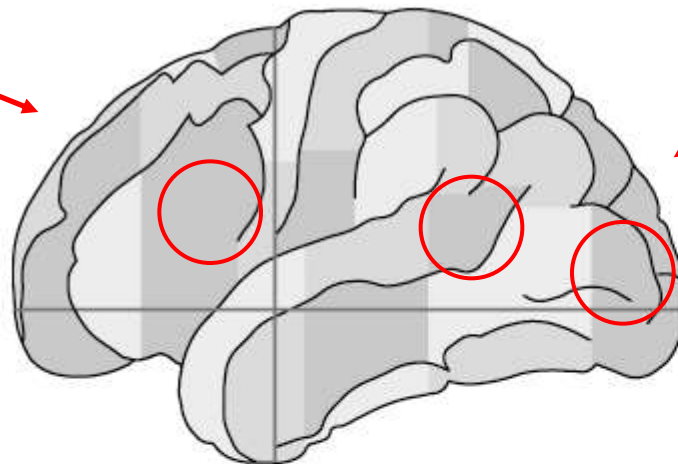
(1) Different sets of processes in two conditions can have the same brain activation pattern

> Identical activation patterns do not allow the conclusion of identical processes

“...no imaging data are capable, in principle, of contradicting a theory that predicts the engagement of two different functions in conditions C1 and C2.” (Page, 2006)

L1: P1, P2

Activations may be solely due to common process P1



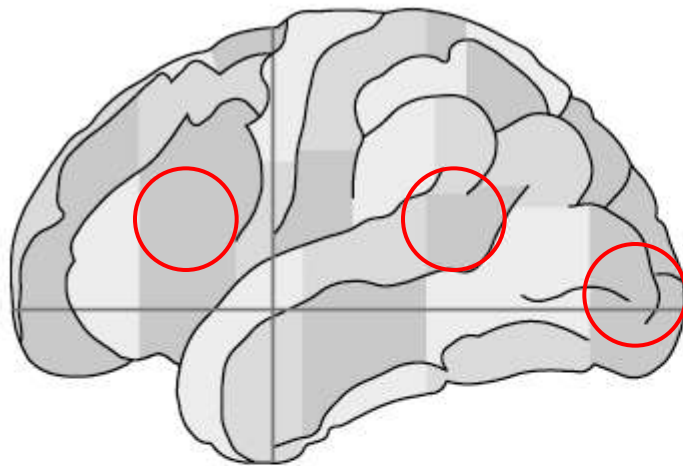
L2: P1, P3

Activations may be due to P2/P3 but resolution too coarse

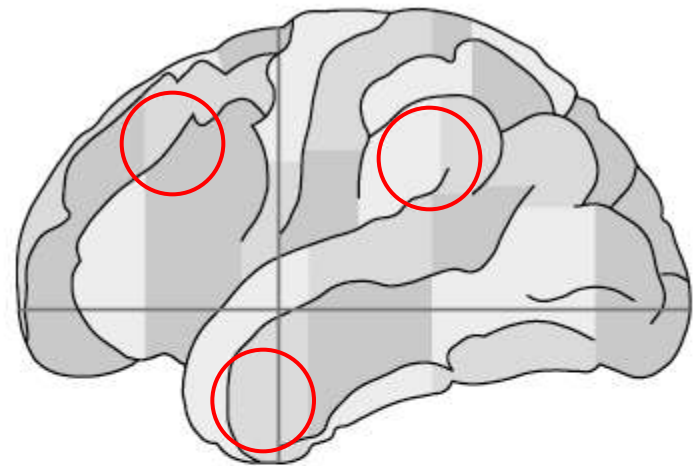
(2) Different brain activation patterns in two conditions allow the conclusion of different processes

... but that is trivial

“...it is a logical necessity that any two stimuli that give rise to different percepts or behaviors, that is, any two stimuli that are in any way discriminable, must give rise to different patterns of brain activity.” (Page, 2006)



P1, P2



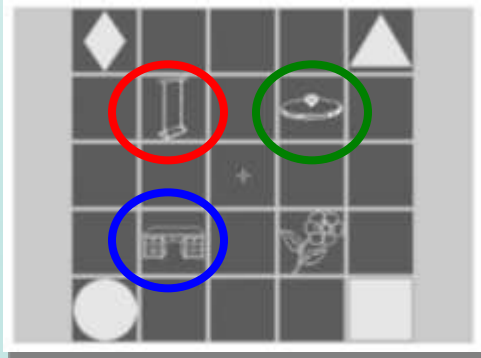
P1, P3

The reasoning of Coltheart and Page is in principle correct.

However if a more complete set of data is taken into account, the necessary argument to reject the activation overlap between L1 and L2 as evidence for common function becomes awkward.

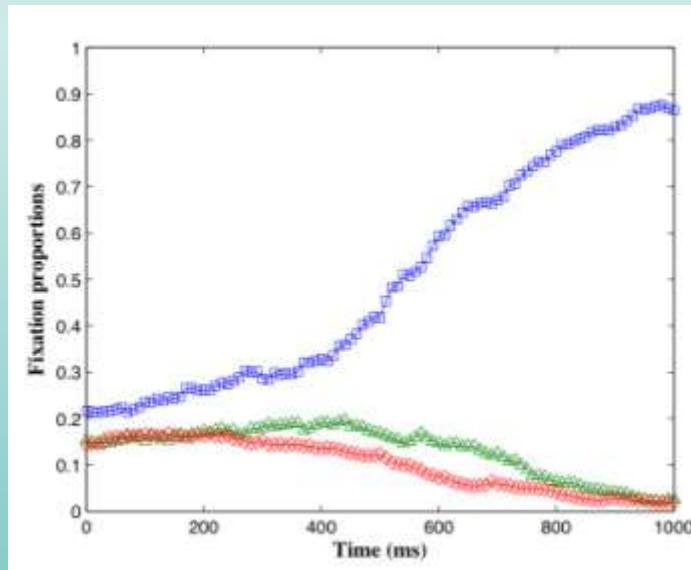
Thus, for example, L1 and L2 sharing Broca's area activation during sentence processing AND Broca's area being more strongly activated in L1 studies on syntactic processing makes it less plausible (though not impossible) that L1 and L2 share Broca's area due to a third, non-syntactic process.

Cross-linguistic activation



“Click on the ...”

Desk Lid (L1 Dutch: deksel) Swing



L2 sentence context reduces activation of L1 words



- **Fully Congruent (FC):**

*The goods from Ikea arrived in a large cardboard **box**.*

- **Fully Incongruent (FI):**

*He unpacked the computer, but the printer is still in the **towel**.*

- **Initially Congruent L2 (ICL2):**

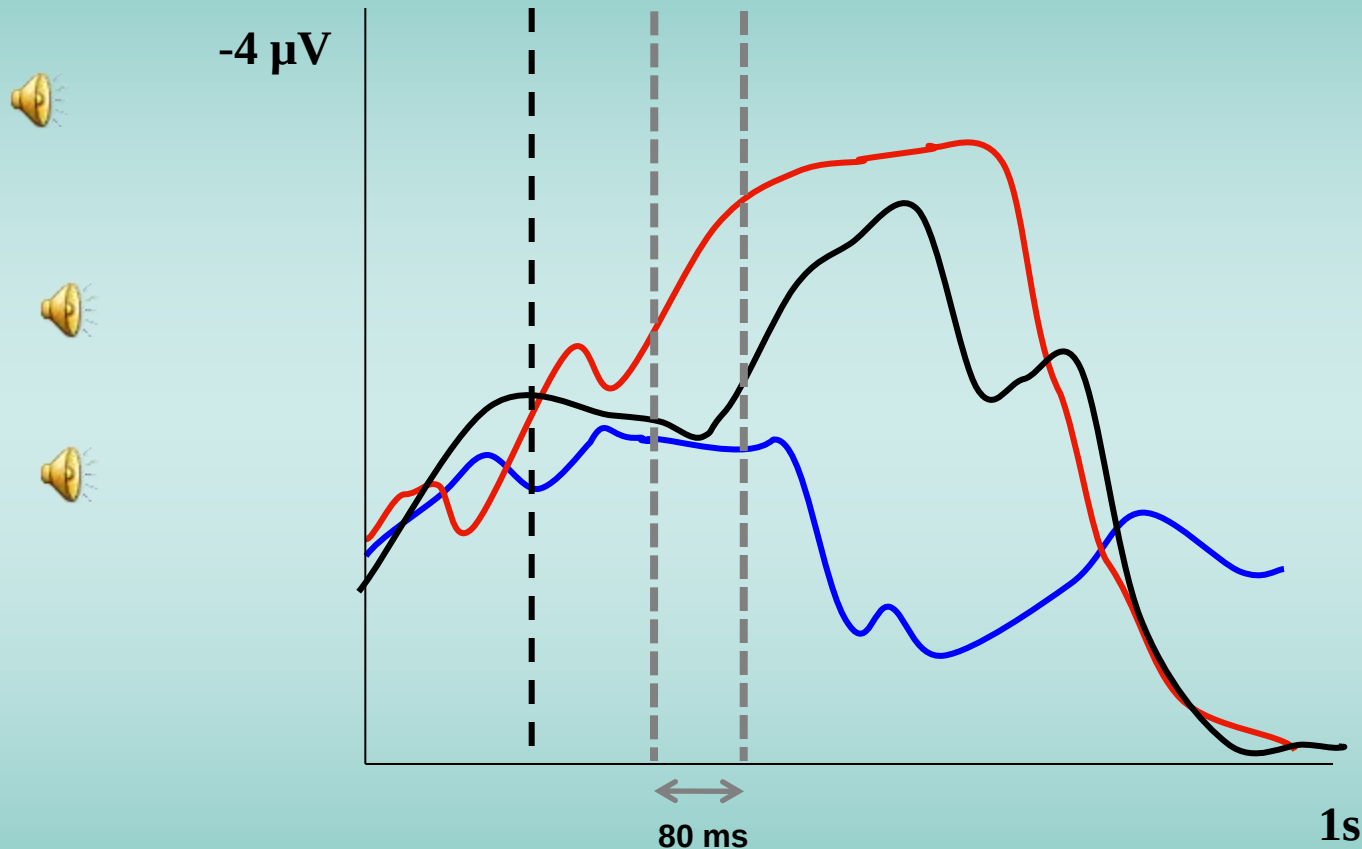
When we moved house I had to put all my books in a bottle.

- **Initially Congruent L1 (ICL1):**

My Christmas present came in a bright-orange doughnut.

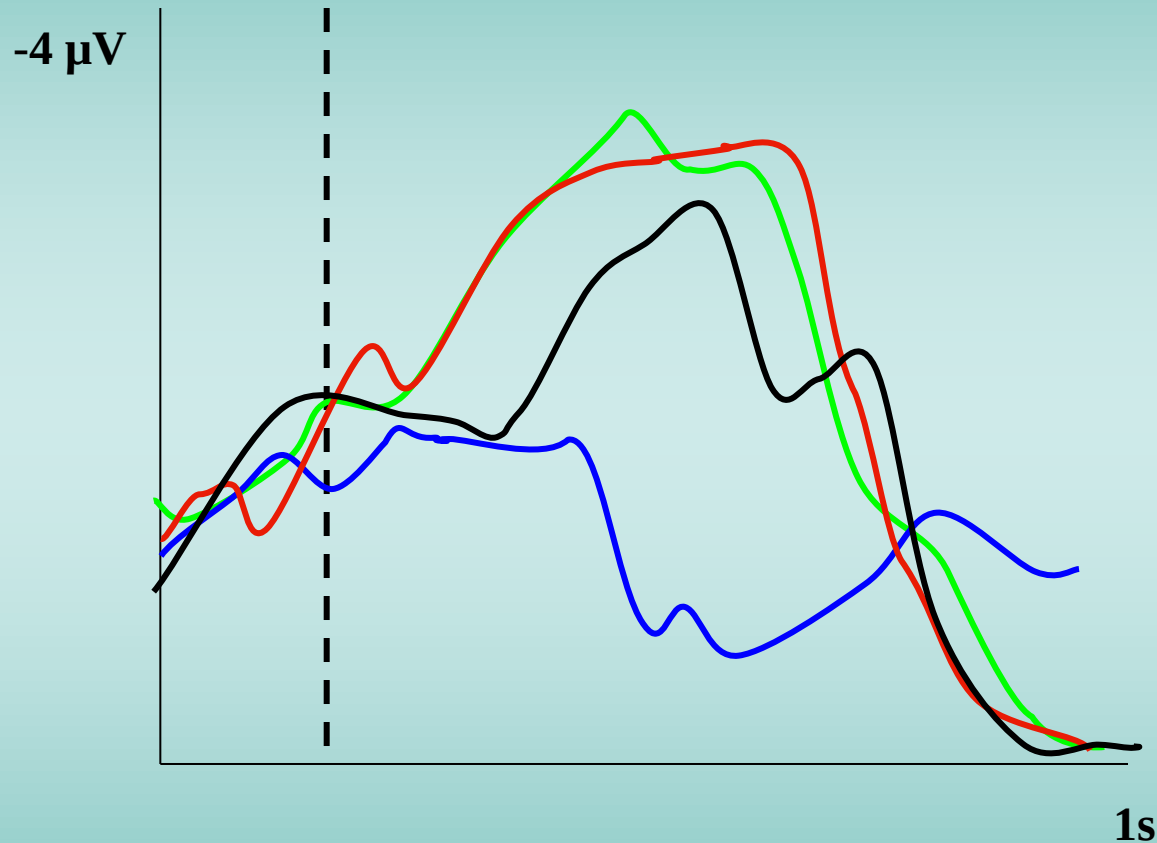
(Dutch: 'doos' = 'box')

Time course of L2 lexical access



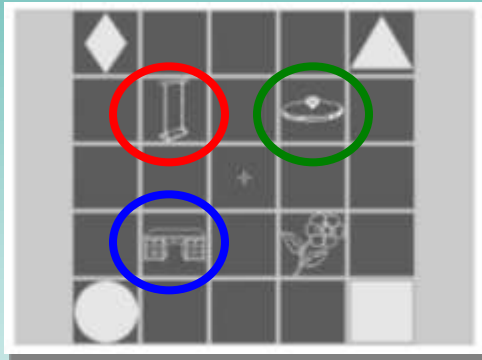
When we moved house, had to put all my books in a bottle. I?

Multilingual Cohort?



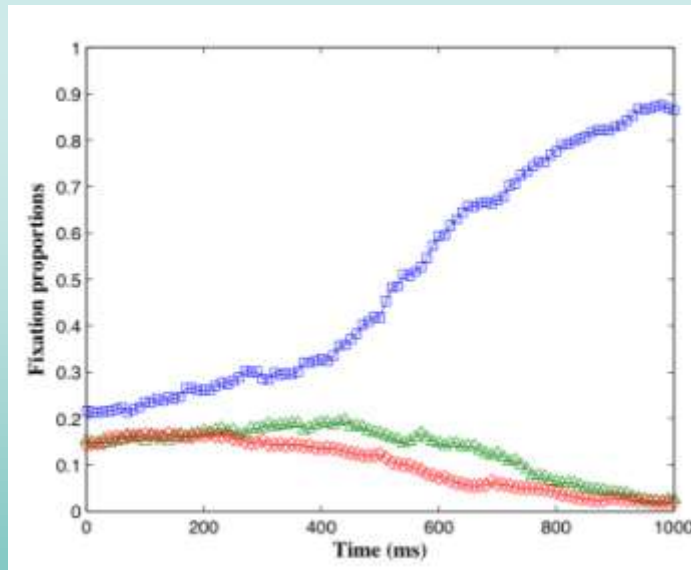
My Christmas present came in a bright-orange **doughnut**.

Cross-linguistic activation



“Click on the ...”

Desk Lid (deksel) Swing



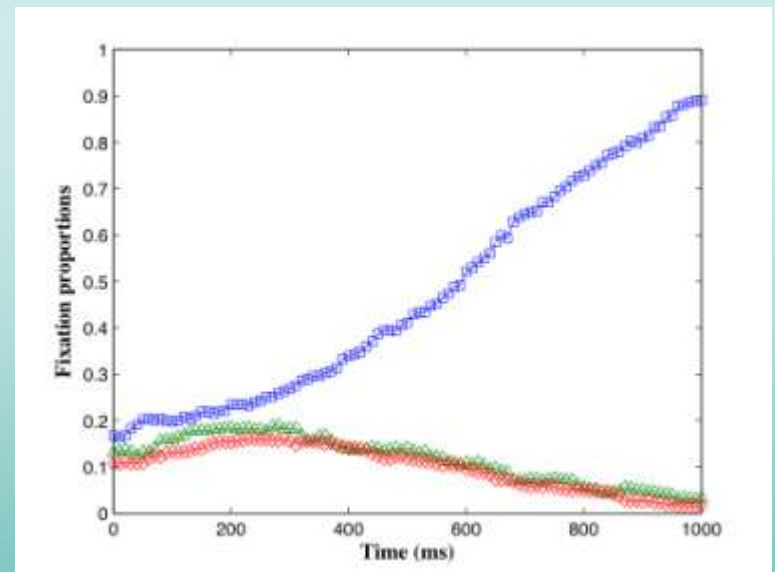
**

NO cross-linguistic activation in rich sentence context



“My grandma has an ugly ...”

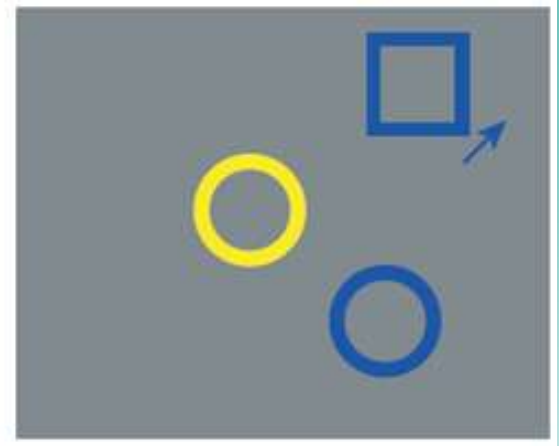
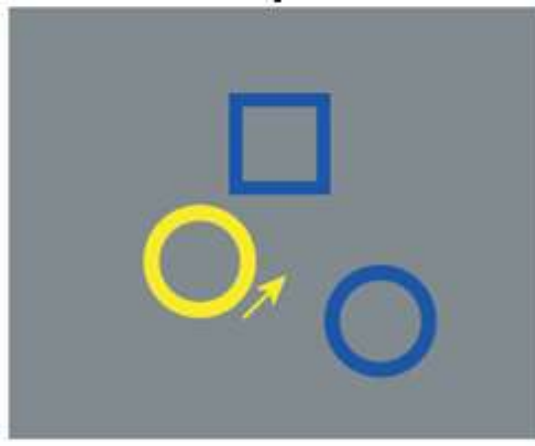
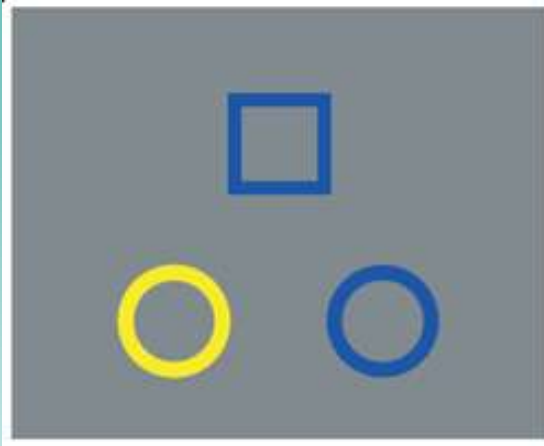
Desk Lid (deksel) Swing



n.s.

Hypothesis testing approach in hemodynamic studies on bilingualism

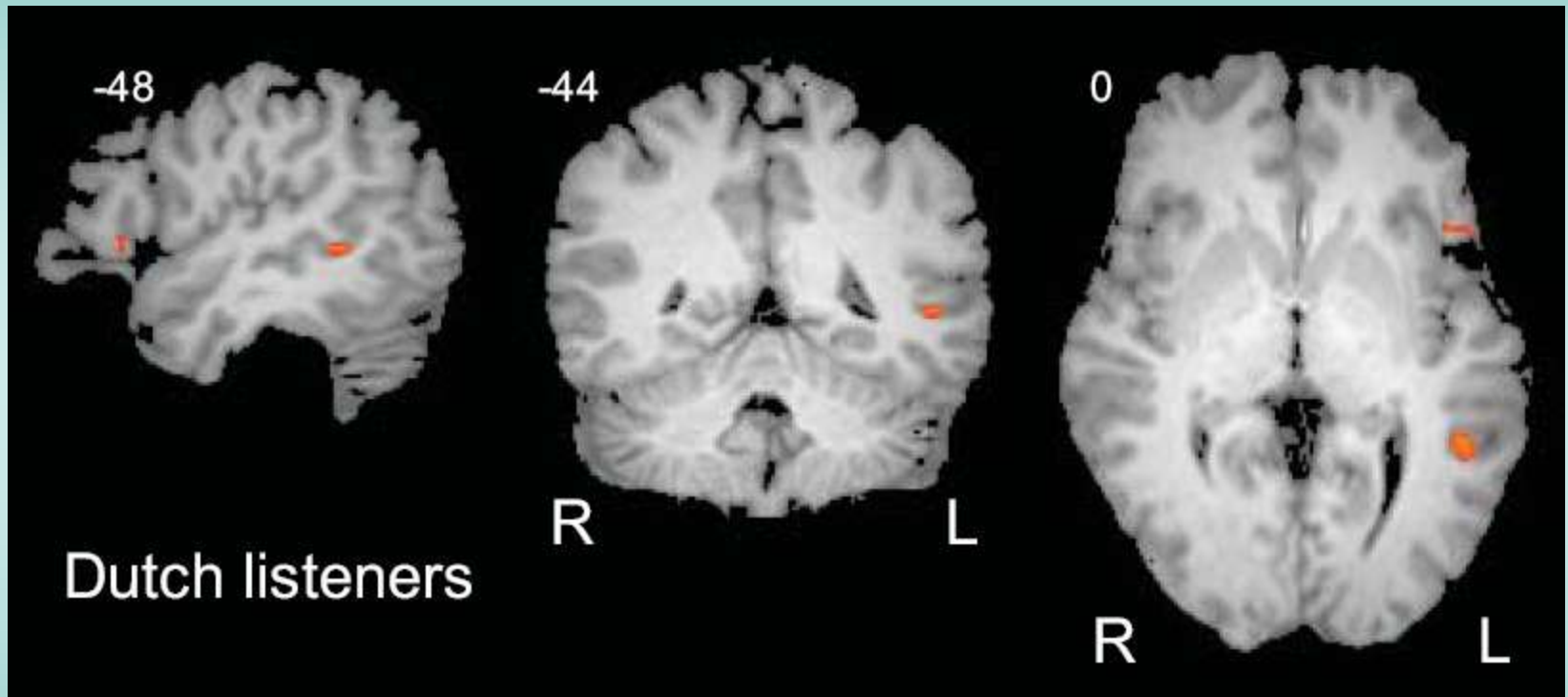
- Declarative/procedural model (Ullman 2001)
 - L2 speakers use a different system for syntactic processing (at least until they are very advanced)



- S:** Het blauwe vierkant wordt door de gele cirkel weggestoten. (correct)
 Lan2 fang1kuai4 bei4 huang2 yuan2quan1 tui1zou3.
The blue square is pushed away by the yellow circle.
- De gele cirkel wordt door het blauwe vierkant weggestoten. (incorrect)
 Huang2 yuan2quan1 bei4 lan2 fang1kuai4 tui1zou3
The yellow circle is pushed away by the blue square away
- W:** vierkant blauw cirkel geel wegstoten (incorrect)
 fang1kuai4 lan2se4 yuan2quan1 huang2se4 tui1zou3
square blue circle yellow push away
- cirkel geel cirkel blauw wegstoten (correct)
 yuan2quan1 huang2se4 yuan2quan1 lan2se4 tui1zou3
circle yellow circle blue push away

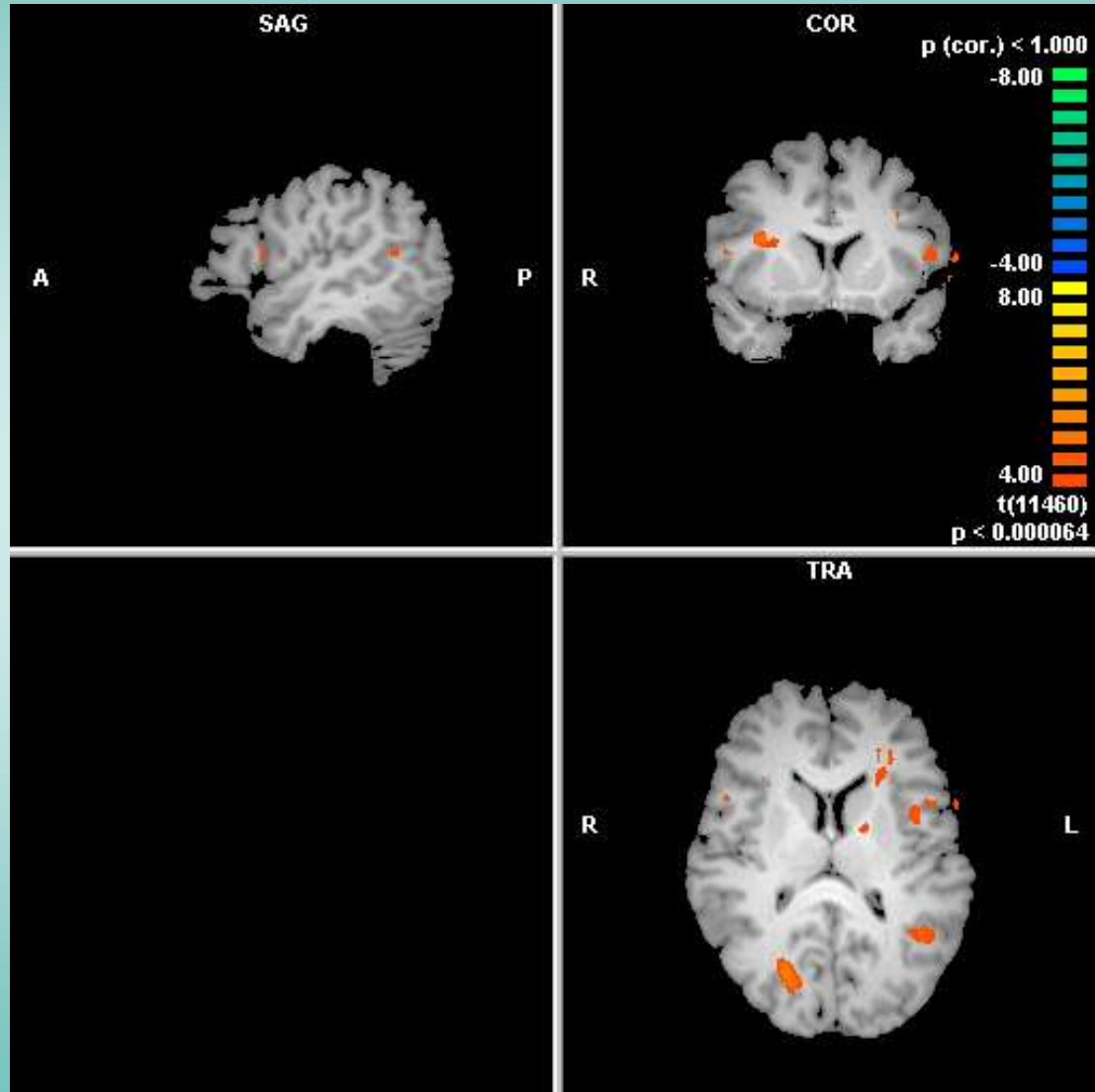


Dutch sentences versus words native Dutch listeners (n=12)

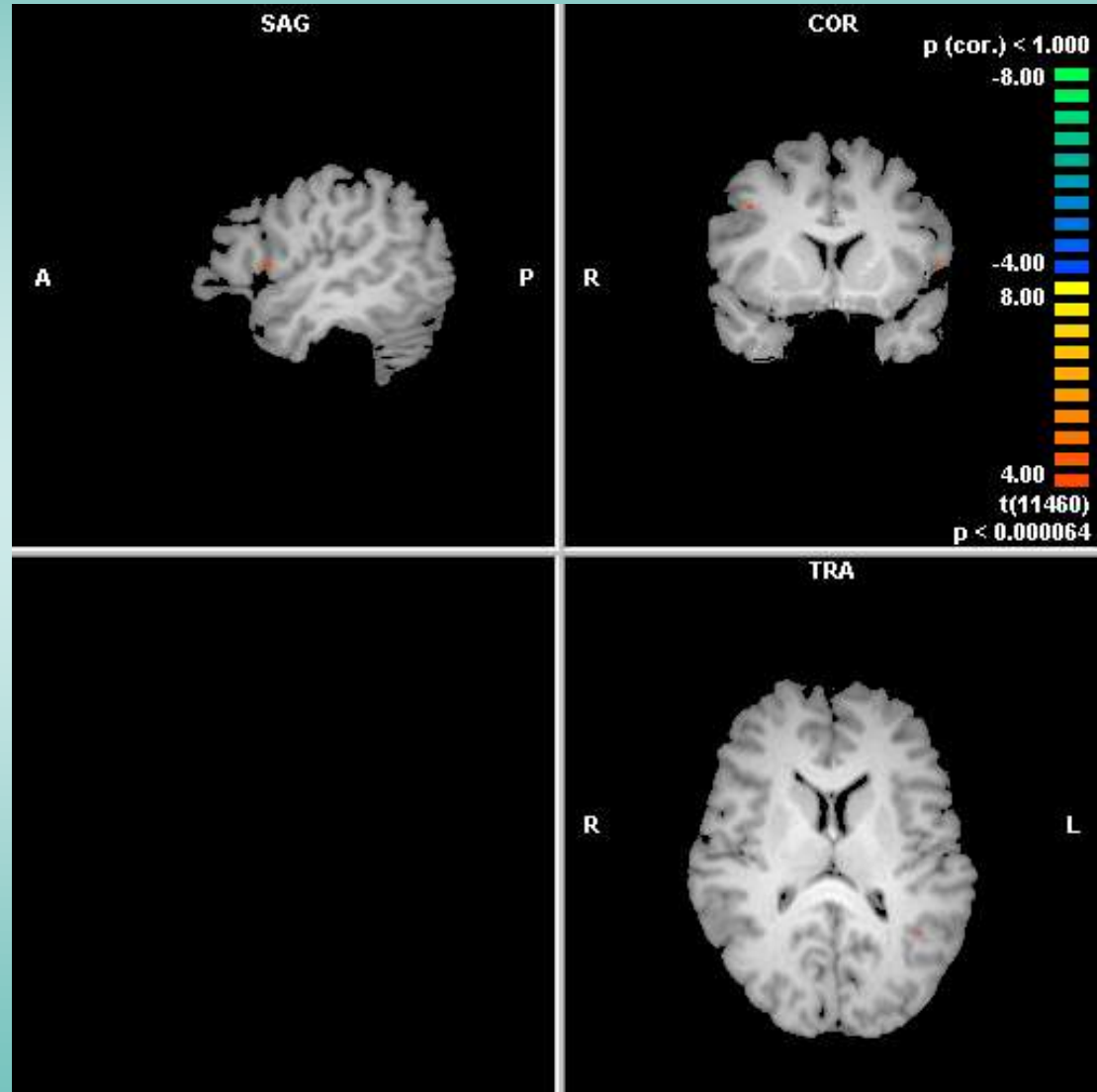


Chinese sentences versus words

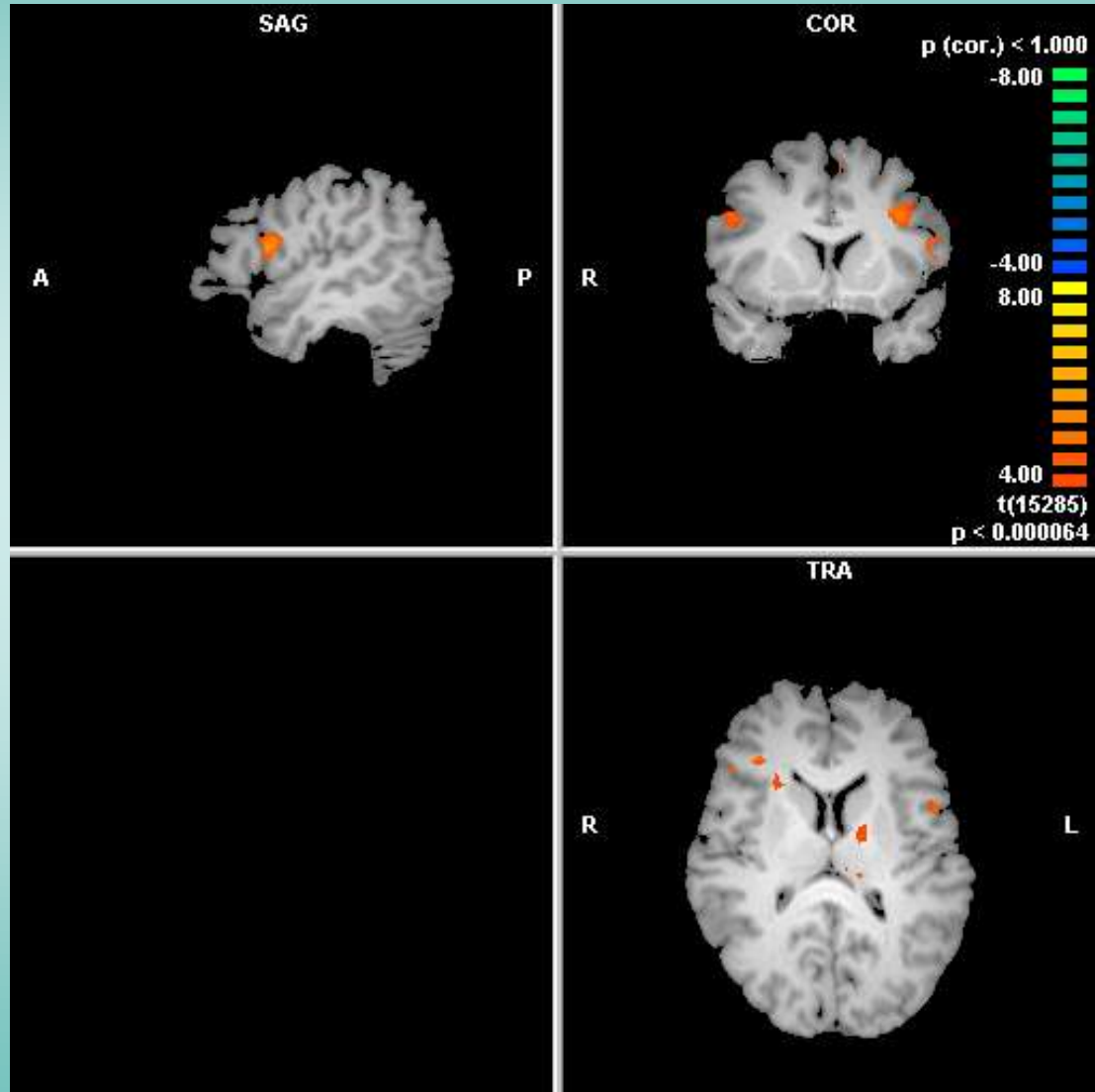
Chinese listeners, 3 months



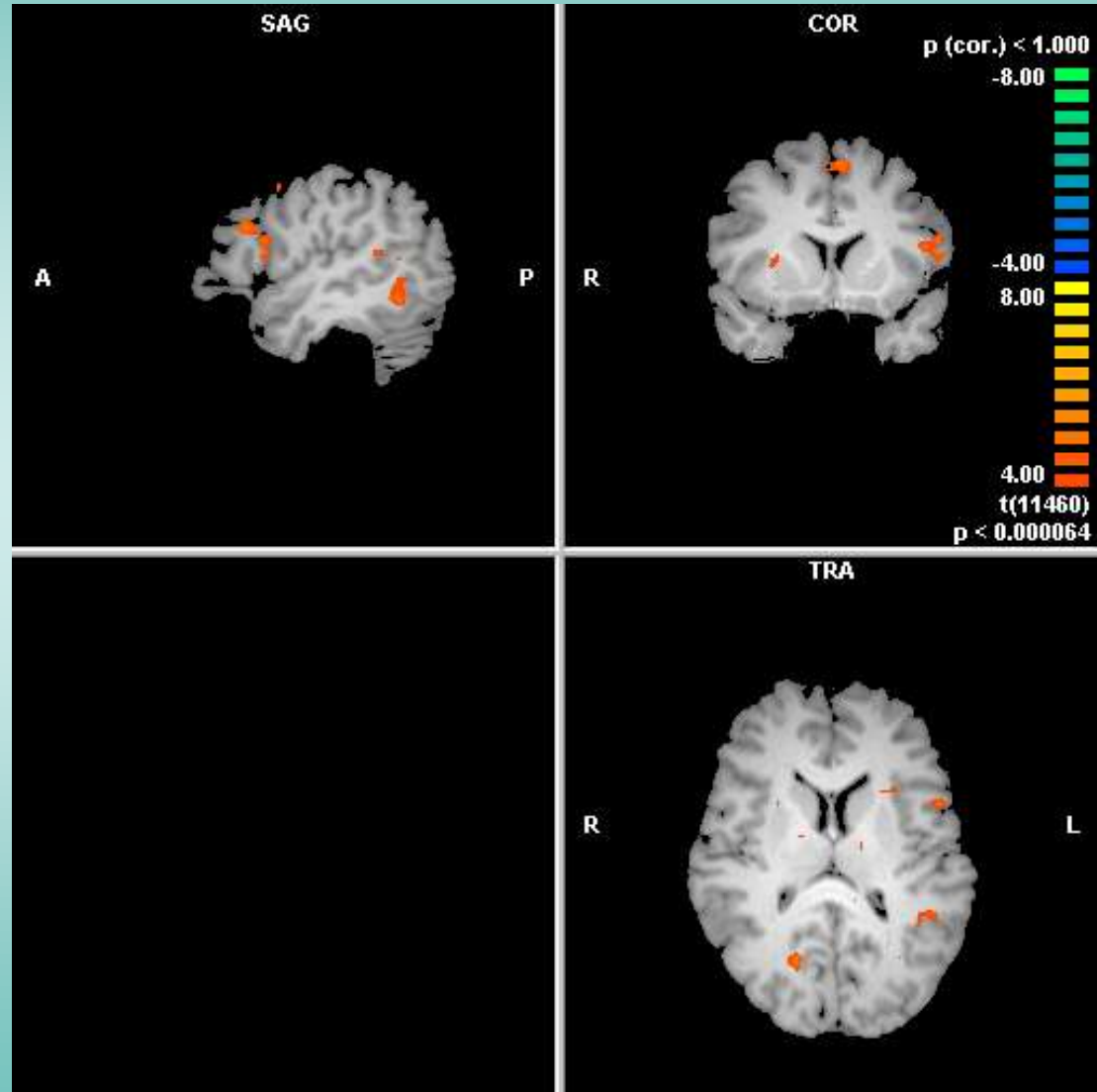
Dutch sentences versus words (Chinese listeners, 3 months)



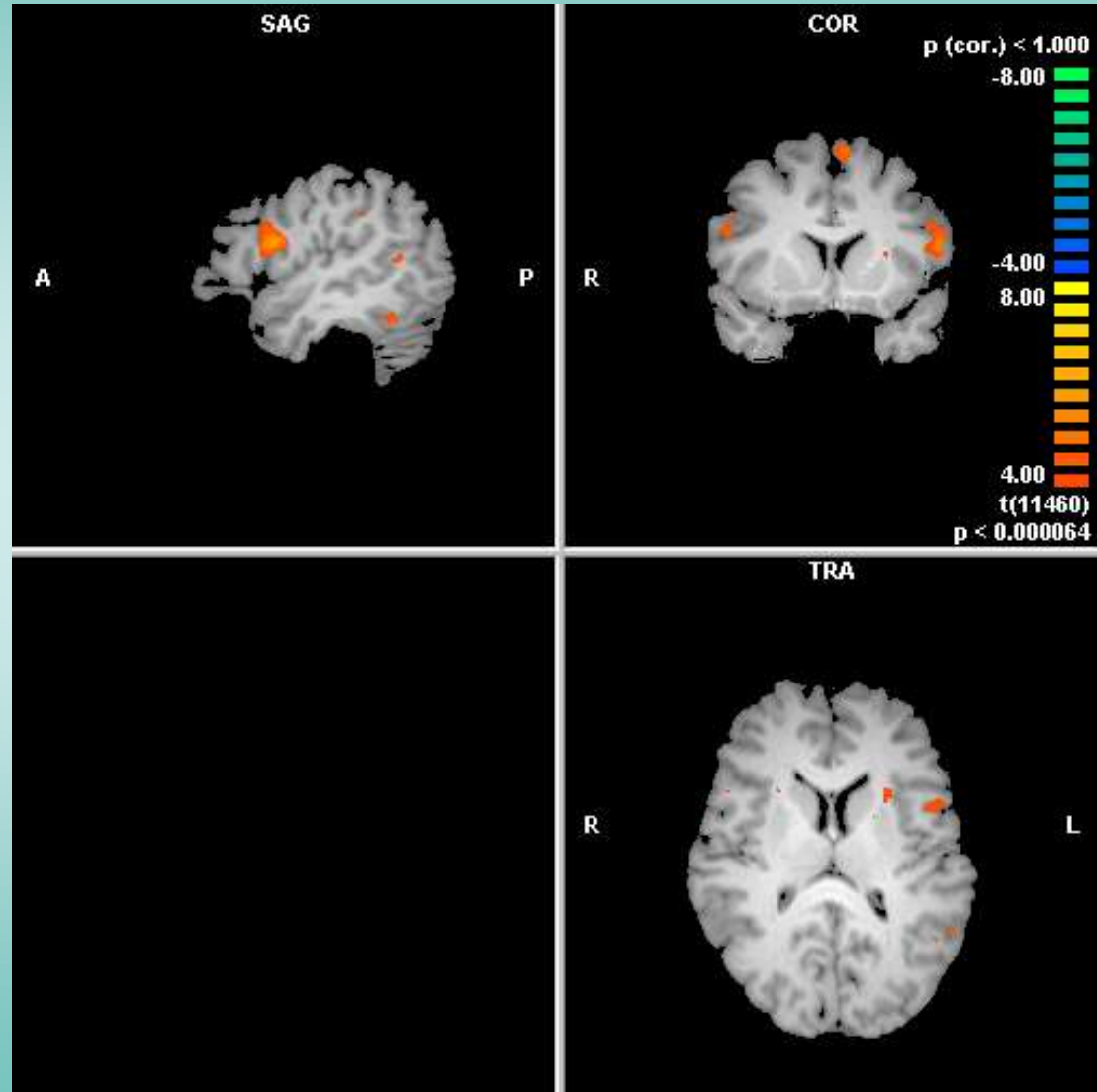
Dutch sentences versus words (Chinese listeners, 6 months)



Ducth sentences versus words (Chinese listeners, 9 months)

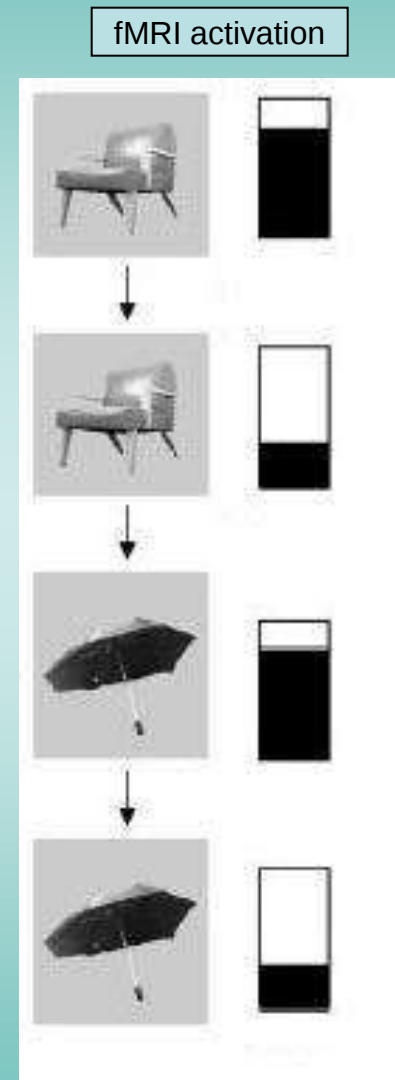


Dutch sentences versus words (Chinese listeners, 15 months)



Repetition Suppression

- Repetition suppression identifies neuronal populations that are sensitive to certain stimulus properties
- fMRI experiments: activation goes down after repetition



adapted from Henson (2003)

- Syntactic priming
 - Preactivating a syntactic structure leads to behavioural facilitation
 - Preactivating a syntactic structure leads to reduced activation of neurons that are sensitive to it (repetition suppression)

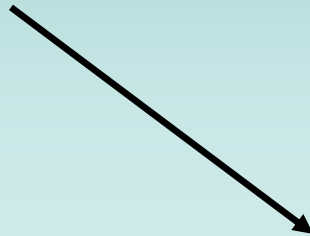
Syntactic priming

Prime

The moon was painted by the girl

No prime

The girl painted the moon.



The tree was painted by the artist.

Target



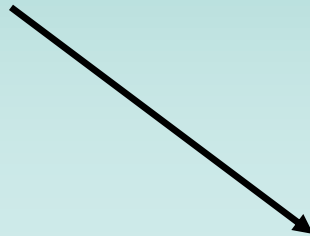
Syntactic priming

Prime

No prime

Der Mond wurde von dem Mädchen gemalt.

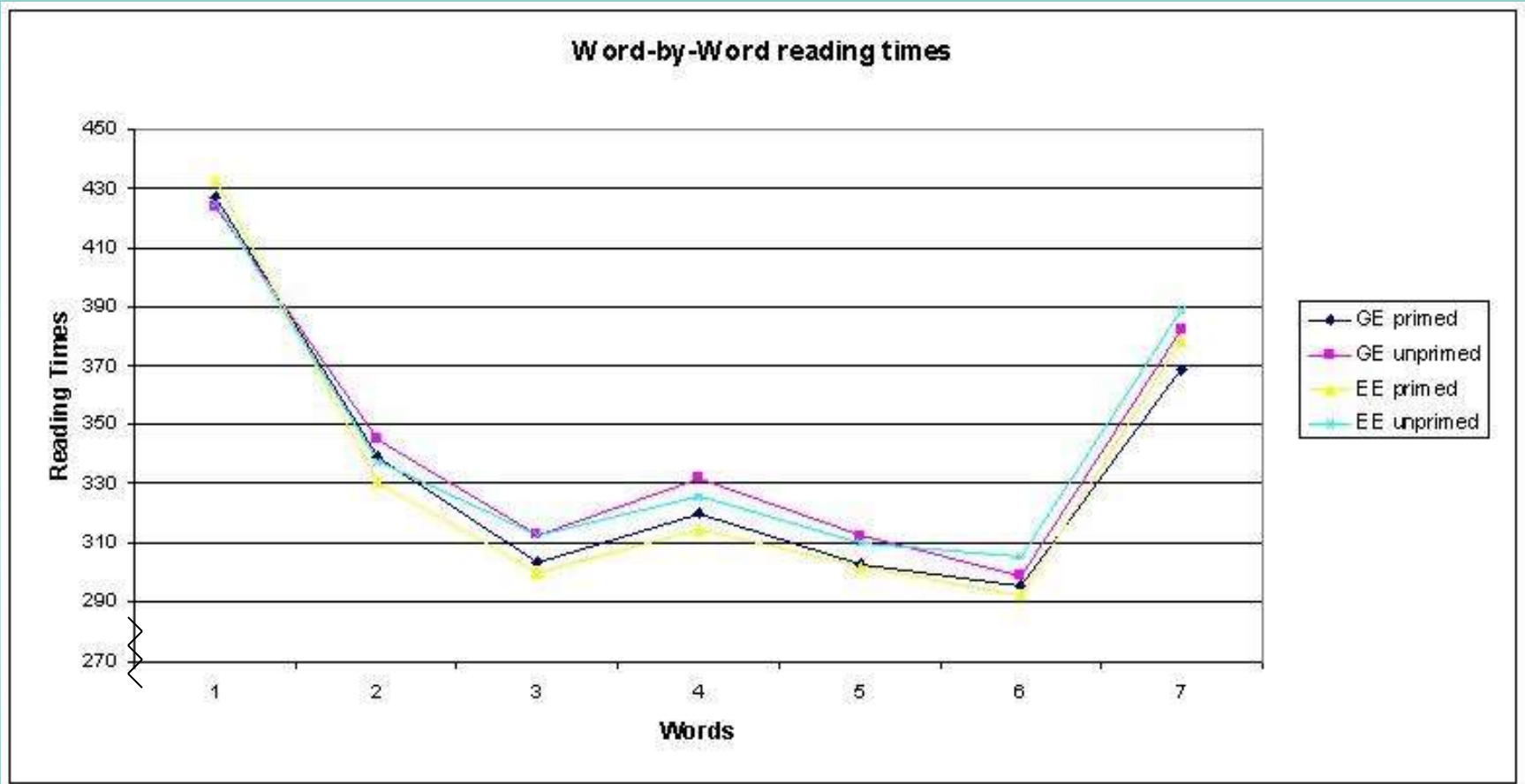
Das Mädchen malte den Mond.



The tree was painted by the artist.

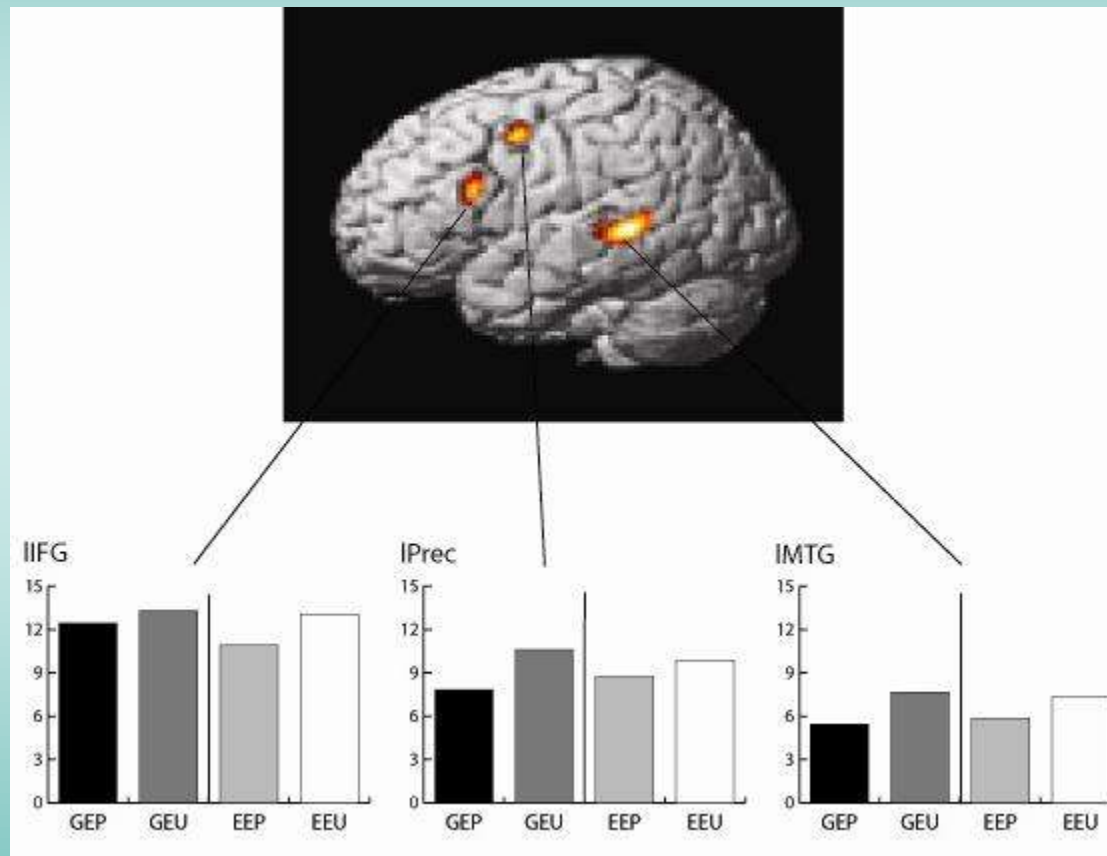
Target

Behavioural Results



- Main priming effect:
- $F(1,15)=13.86, p=0.002$

Areas showing syntactic repetition suppression from English ((L2) to English (L2) and from German (L1) to English (L2)



Summary (2)

- Even if one accepts the arguments against interpretability of cerebral localisation data with respect to cognitive theories (and ignores plausibility considerations) they do not hold for the psychological approach of cognitive neuroscience.
- The evidence for shared L1/L2 processing systems obtained with this approach confirms the localisation data.

Collaborating colleagues

Max Planck Institute for
Psycholinguistics

& Donders Centre,
Nijmegen

Forschungszentrum Jülich

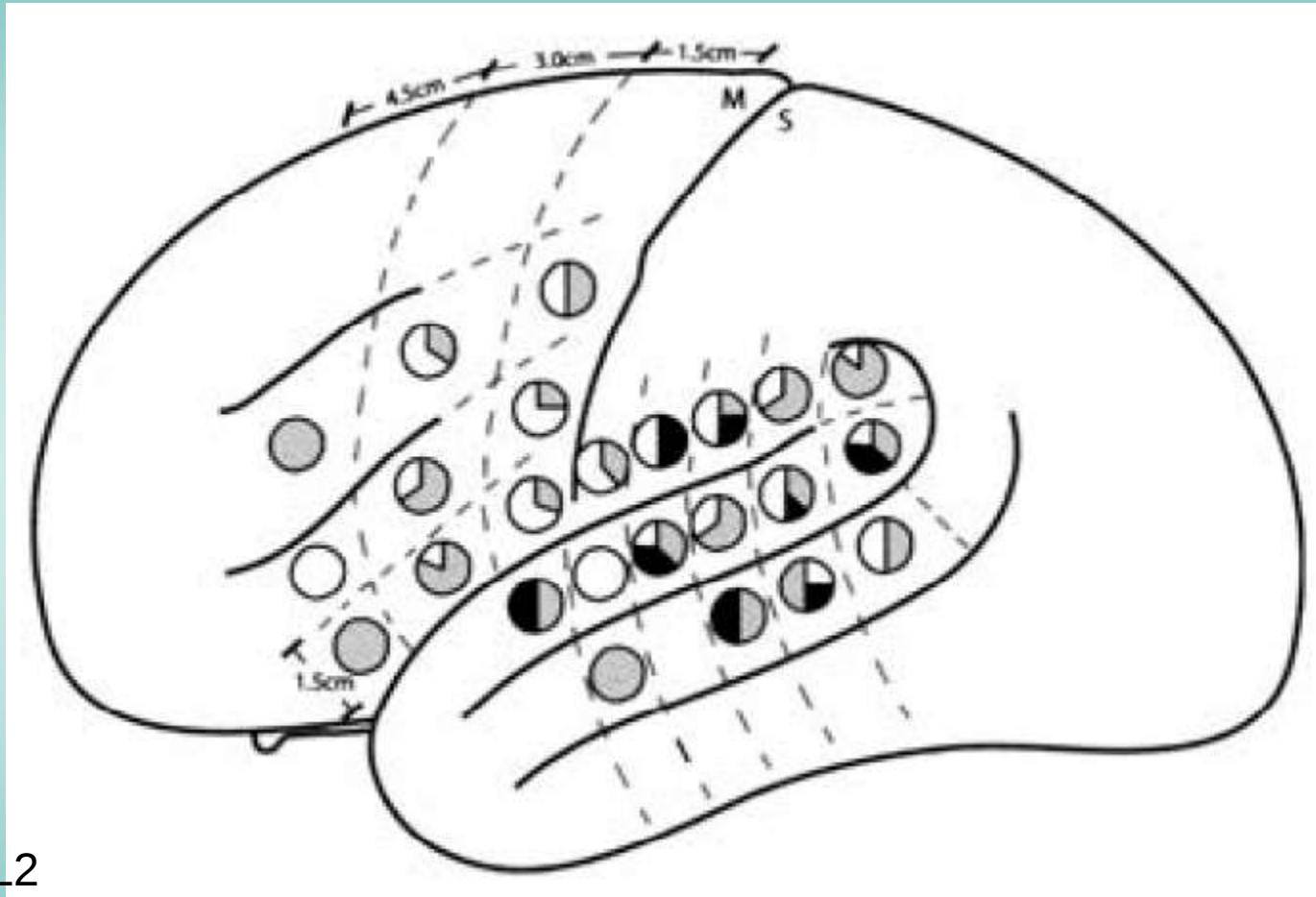
Heinrich-Heine-Universität
Düsseldorf

Doug Davidson
Marianne Gullberg
Peter Hagoort
Anne Cutler
Ian FitzPatrick
Jana Hanulová
Frauke Hellwig
Pim Levelt
Kirsten Weber

Katrin Amunts
Hans Herzog

Rüdiger Seitz

Electrocortical stimulation during picture naming



- L2
- L1
- shared