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March 2025

Brain and Second Language Learning

Jubin Abutalebi, MD, Phd

Center for Neurolinguistics and Psycholinguistics (CNPL) University San Raffaele Milan

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Overview

1. Basics in Neuroanatomy
2. Psycholinguistic background
3. Language control
4. Brain plasticity
5. A follow-up study in school children
6. The foreign language effect
7. Bilingualism and Aging
8. Floor discussion about best learning methods for school settings

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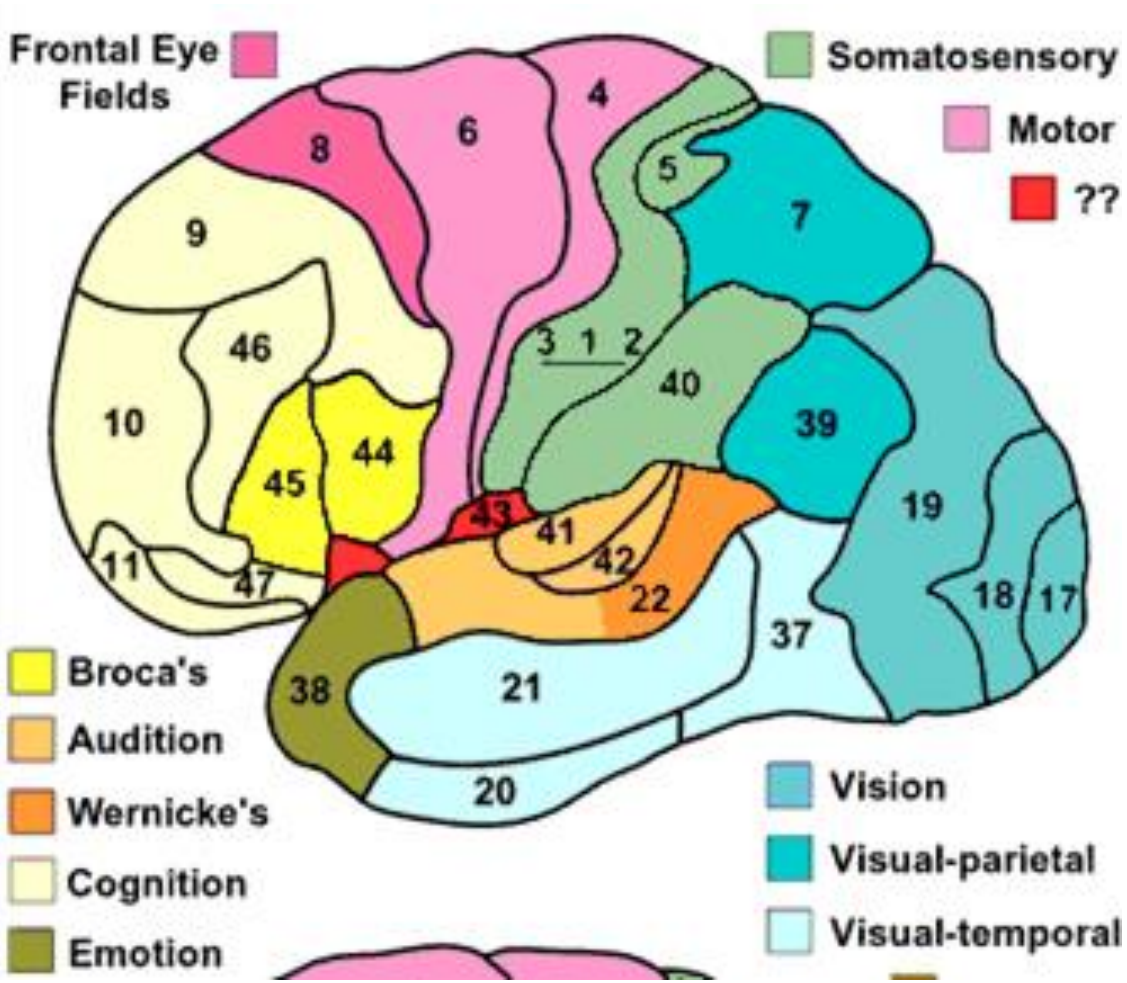
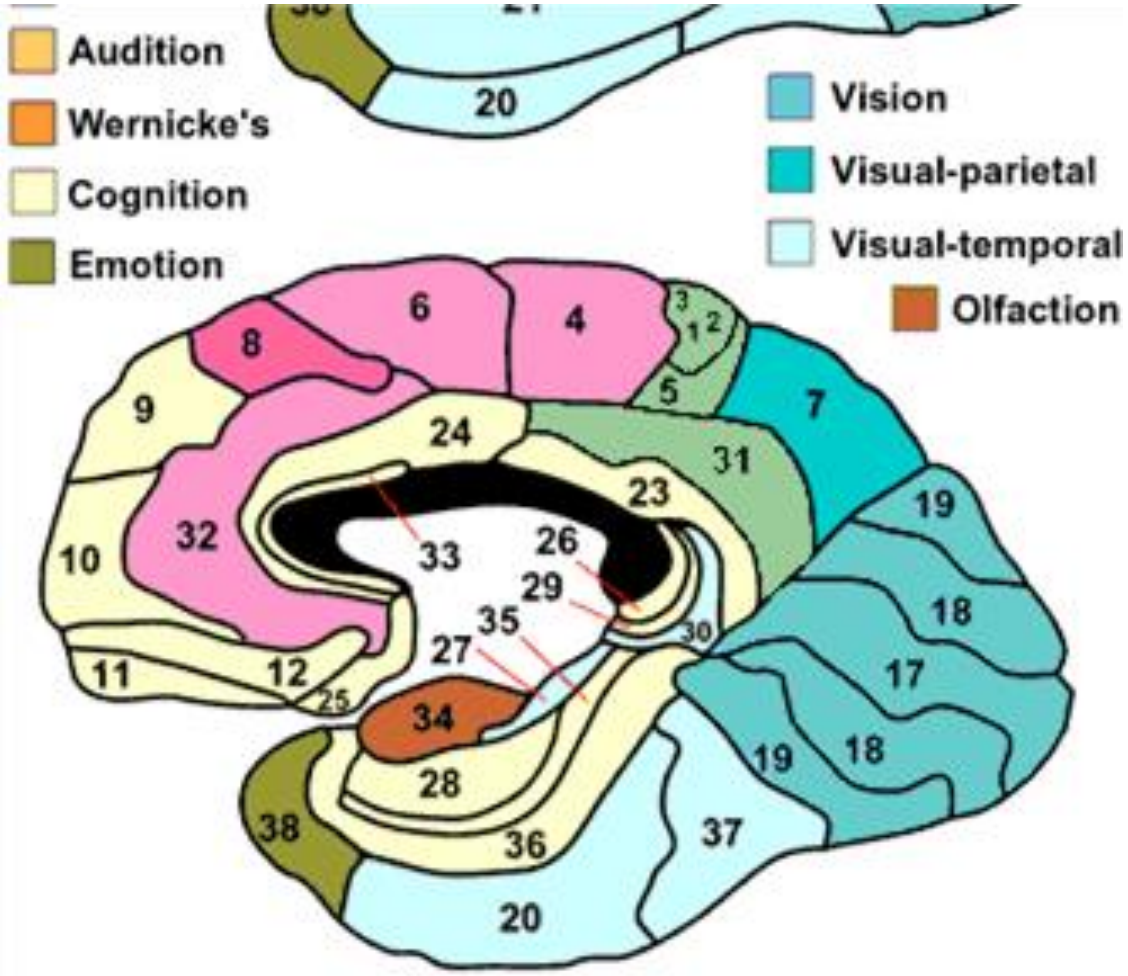
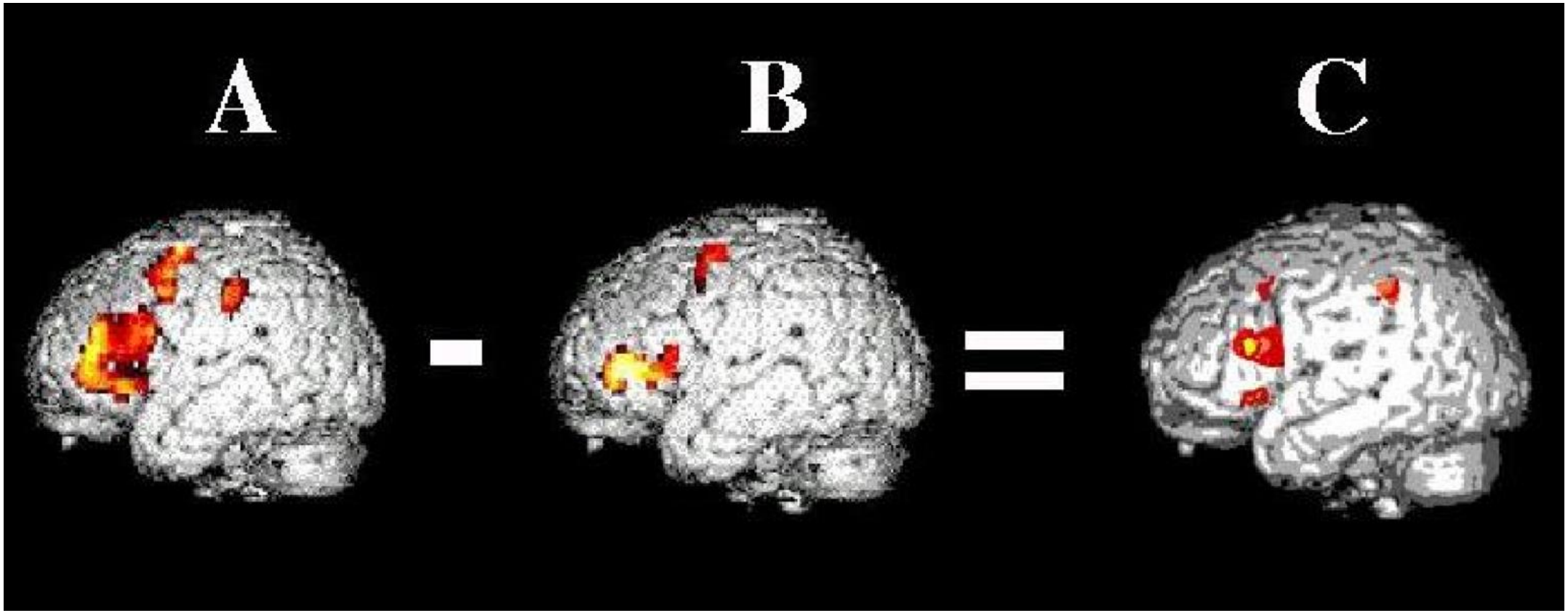
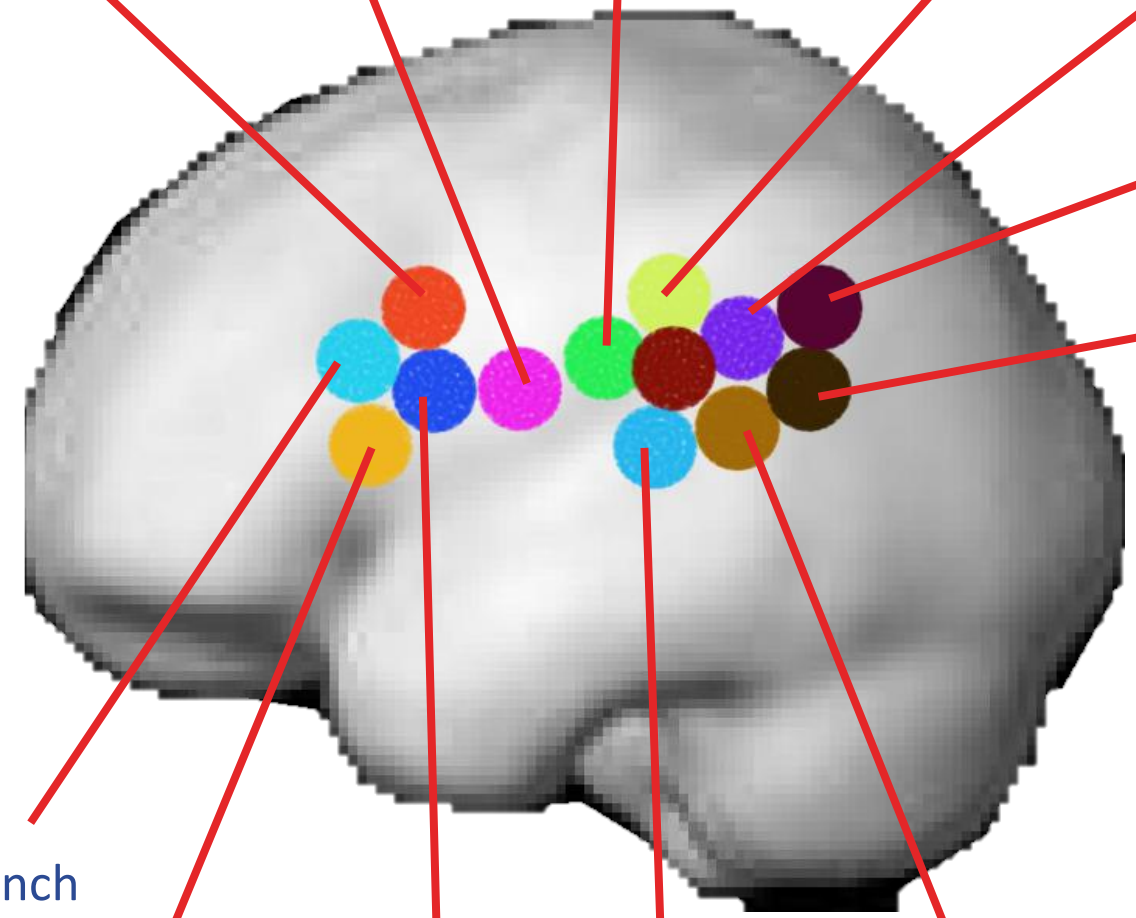

Frontal Eye Fields
Somatosensory
Motor
??
Broca's
Audition
Wernicke's
Cognition
Emotion
Vision
Visual-parietal
Visual-temporal


Audition
Wernicke's
Cognition
Emotion
Vision
Visual-parietal
Visual-temporal
Olfaction

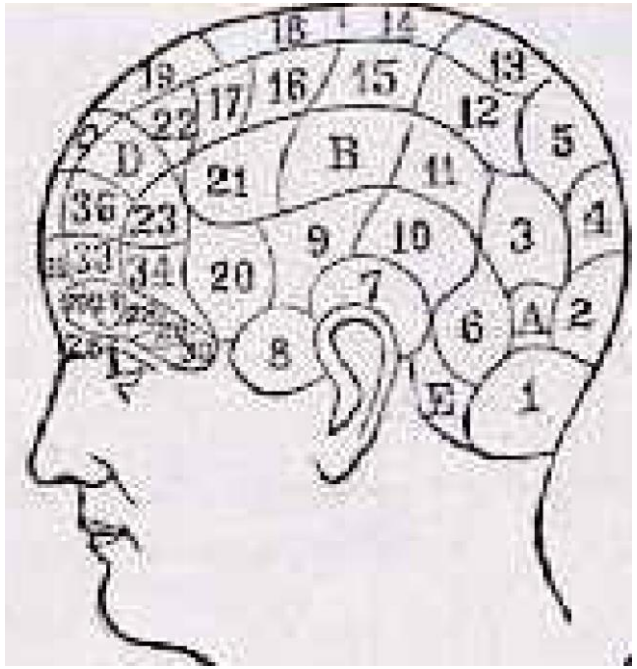
Subtraction method (fMRI)



German
Spanish
Hebrew
Farsi
Russian
Hindi
etc, etc…



French
English
Japanese
Tagalog
Mandarin



A

B

Many functional neuroimaging studies report that a second language entails more brain activity as compared to the first language, i.e., especially for a low proficient L2 and/or less exposed L2

FIRST MESSAGGE: bilingual variables can make a difference, i.e. Language proficiency, language exposure, Age of L2 acquisition, immersion, etc.....

Monolingual language production

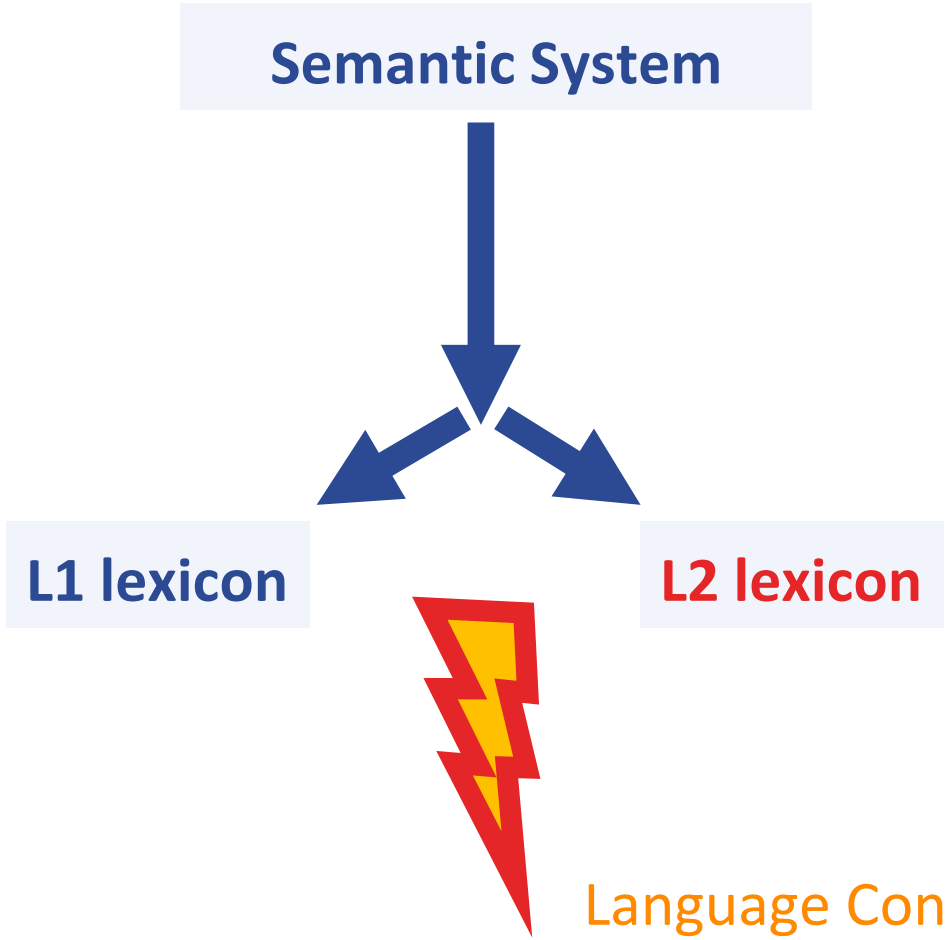
hat **CAT** dog

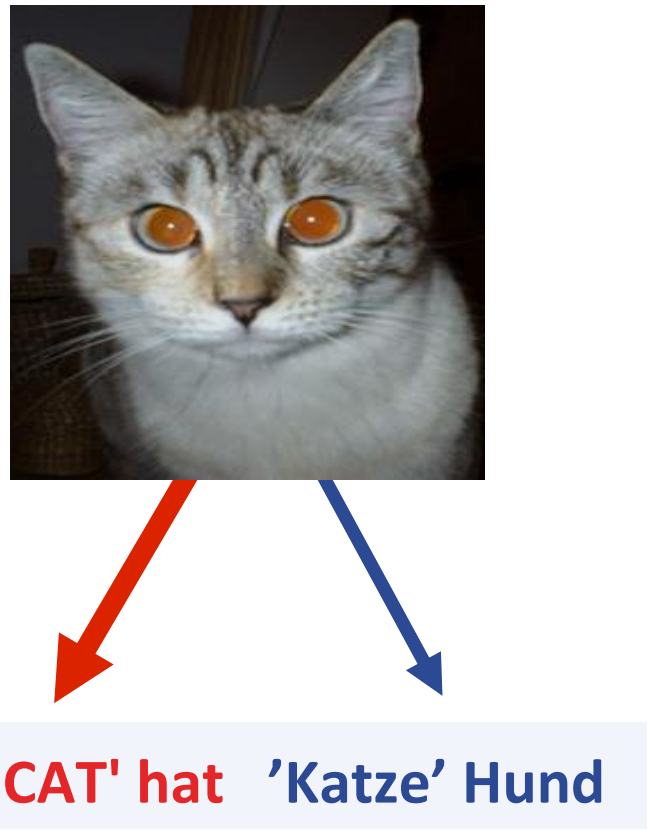
Semantic System

↓

lexicon

Bilingual Language Production





Dog 'CAT' hat ’Katze’ Hund

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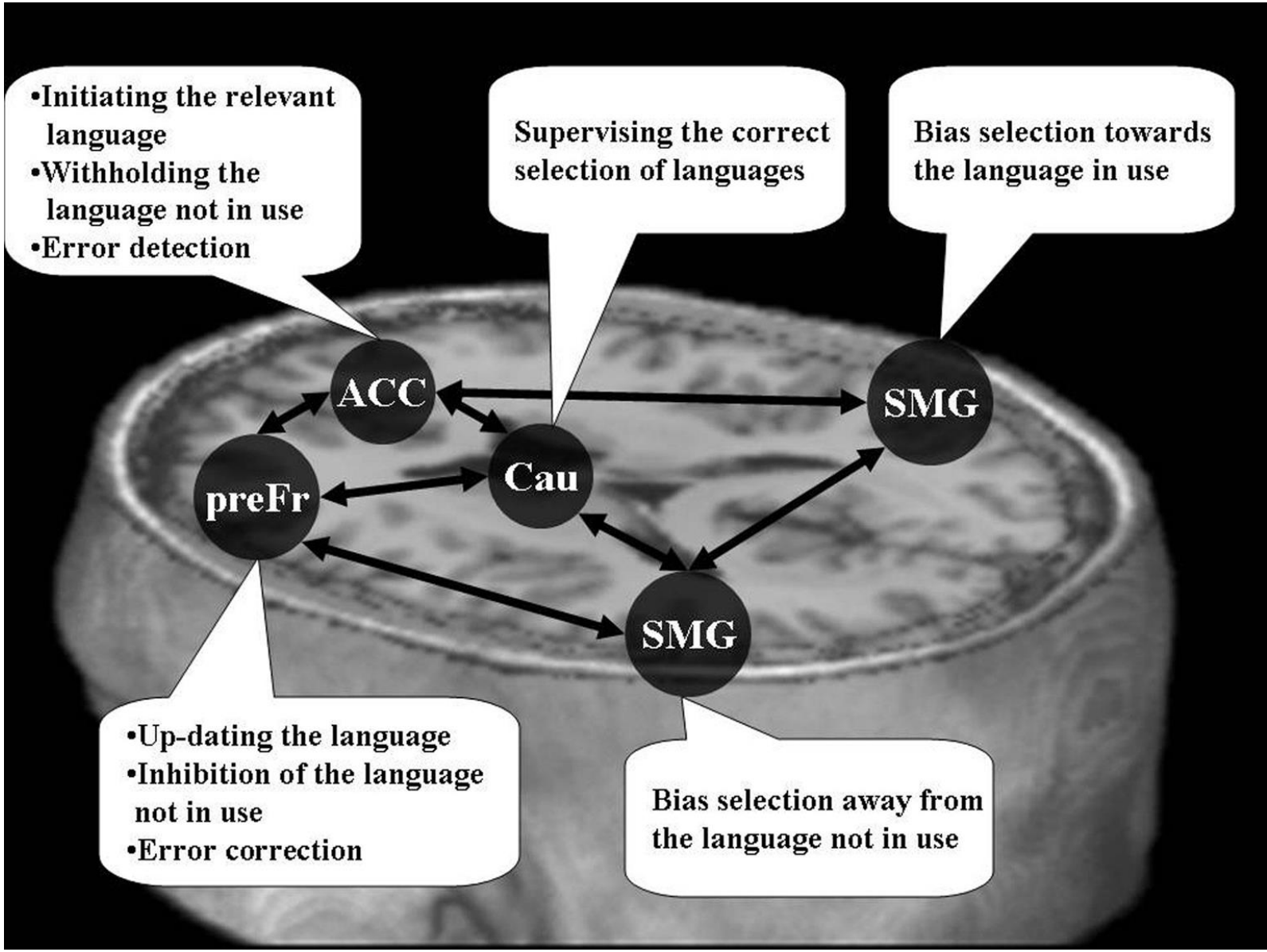
How do bilinguals avoid language conflicts?



From: Abutalebi & Green, *Language and Cognitive Processes*, 2008

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Clinical evidence from language control failures:

AH, 74-year-old a right-handed woman

L1 = Armenian, L2 = English, L3 = Italian

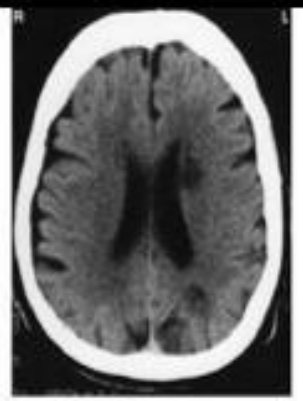
I can not comunicare con you;

Oggi I can not say il mio nome to you;

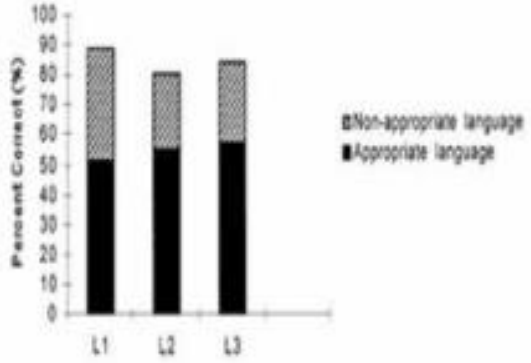
I am a disastro today.

I bambini steal the bsicuits from the armadio;

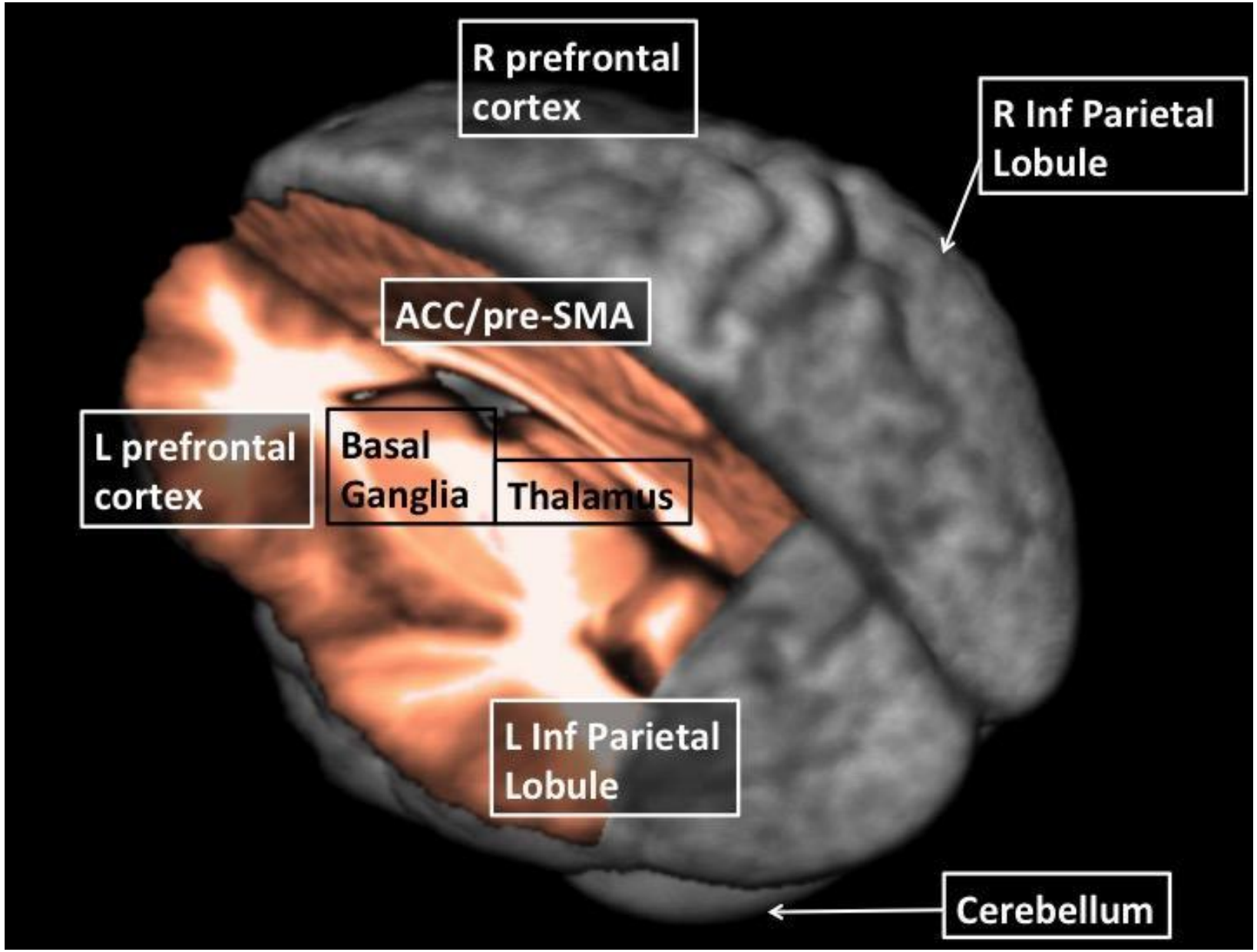
The water sta cadendo per terra.



Infarction in the periventricular white matter surrounding the left caudate nucleus



(Abutalebi et al., 2000)


R prefrontal cortex
R Inf Parietal Lobule
ACC/pre-SMA
L prefrontal cortex
Basal Ganglia
Thalamus
L Inf Parietal Lobule
Cerebellum

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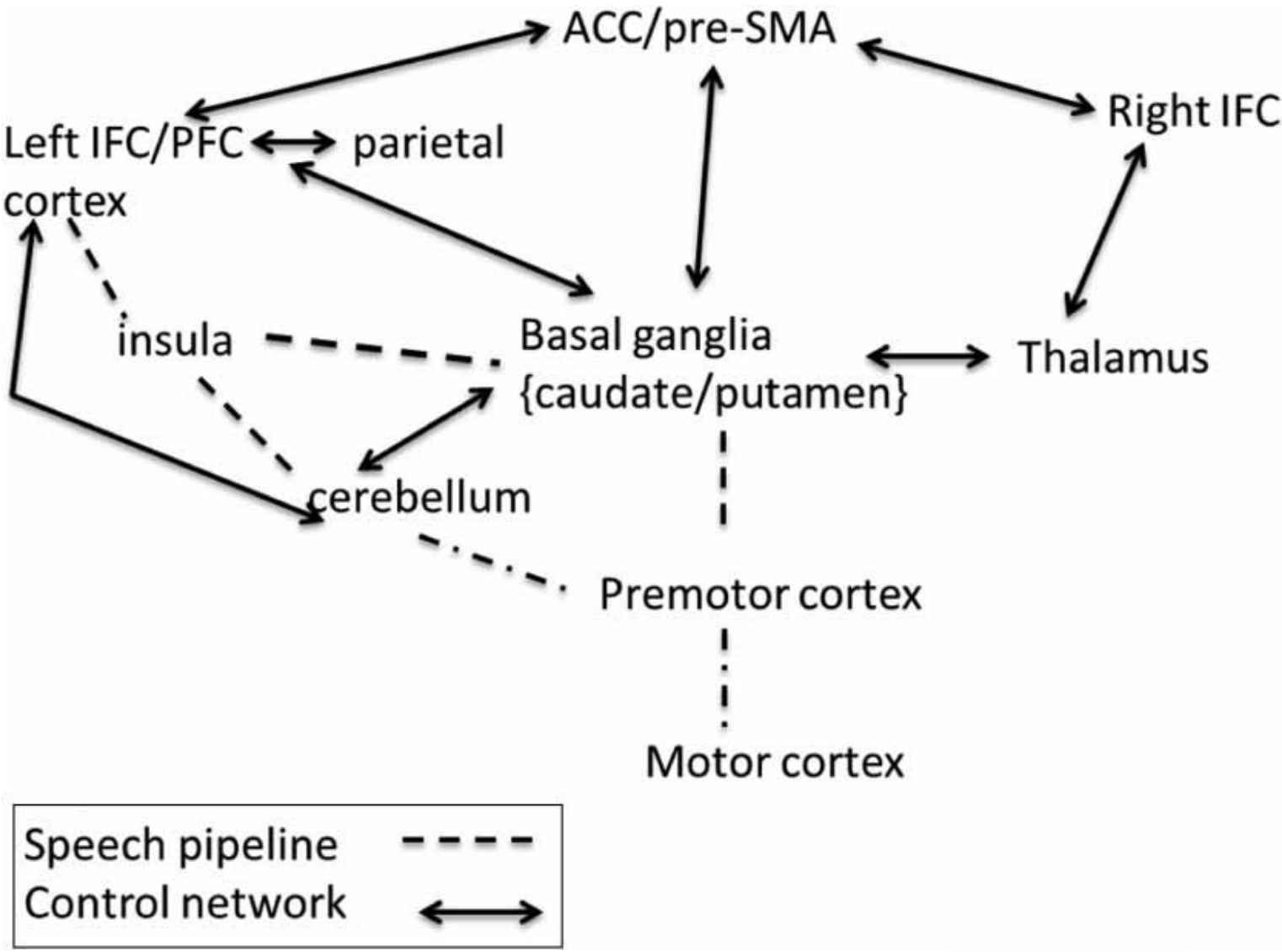
Language control in bilinguals: The adaptive control hypothesis 2013

David W. Green & Jubin Abutalebi



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Predictions of the ACH:

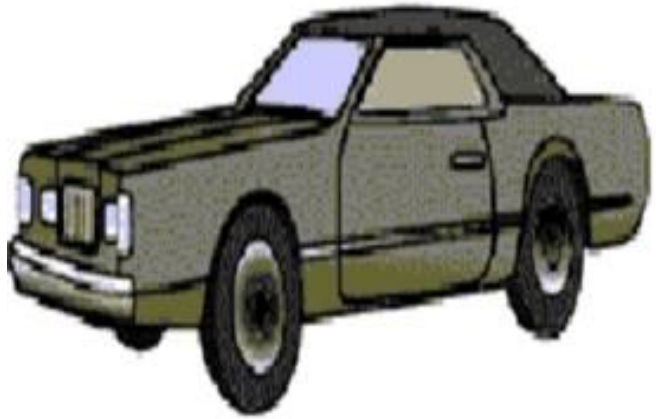
1. Different situational contexts engage differentially the network

2. The network adapts to given situational contexts

with important repercussions also for school settings as we will see !!

Language control in bilinguals

Subjects:
12 students from the translation school of the University of Geneva
First language: German
Second language: French

Stimulus	Selection	Response	
	Nome	Auto / Fahrzeug	Selection only in L1
	Verbo	fahren	
	Deutsch	Auto / Fahrzeug	Selection between L1 e L2
	Français	voiture	

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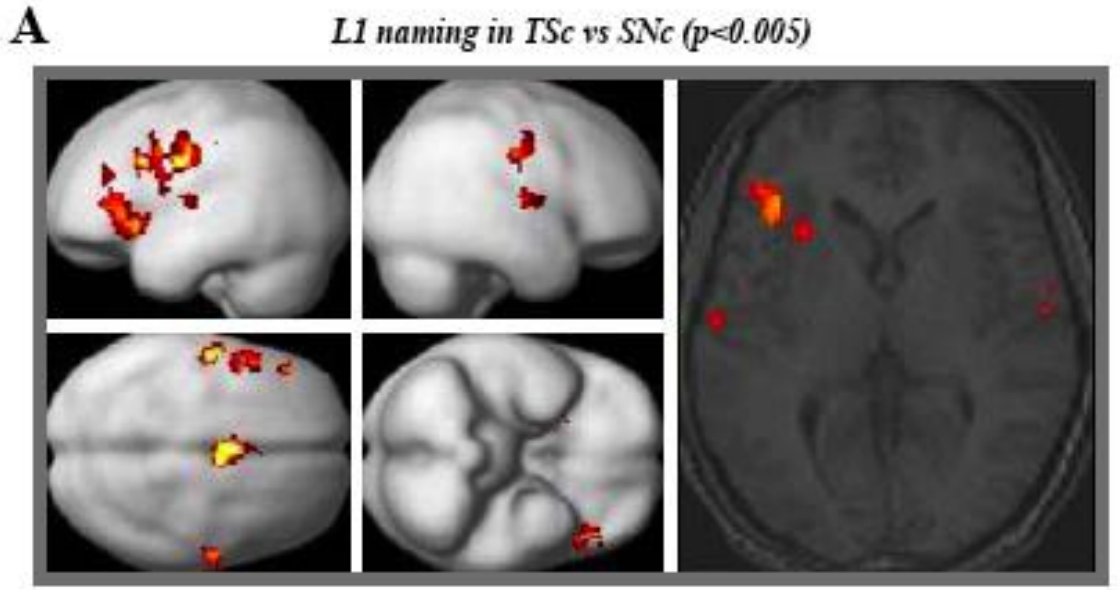
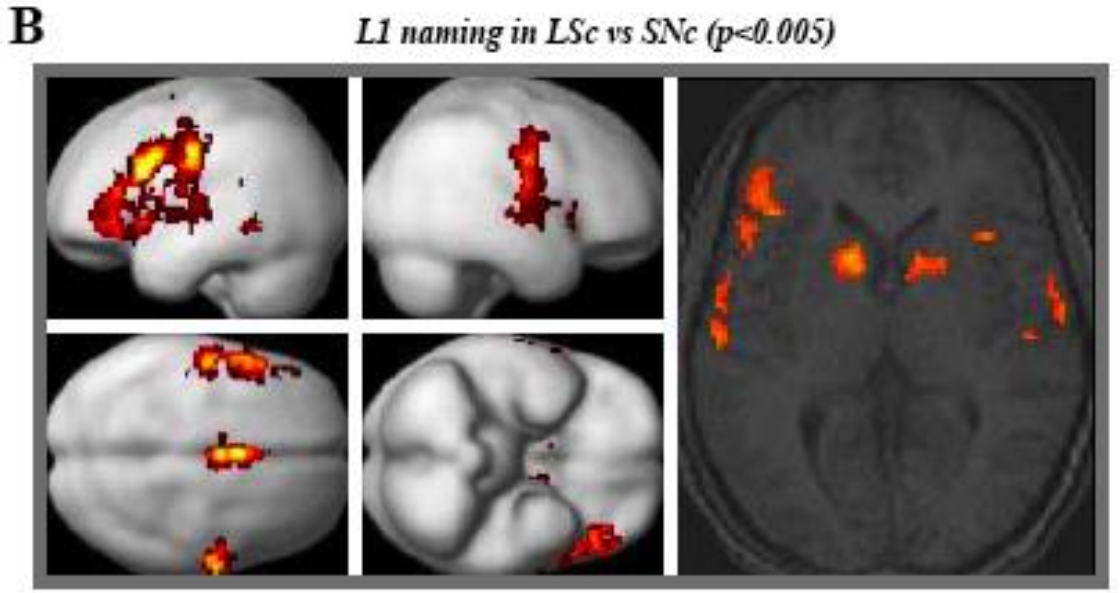
Selection of L1 Nouns in a Monolingual context



Selection of L1 nouns in a Bilingual Context



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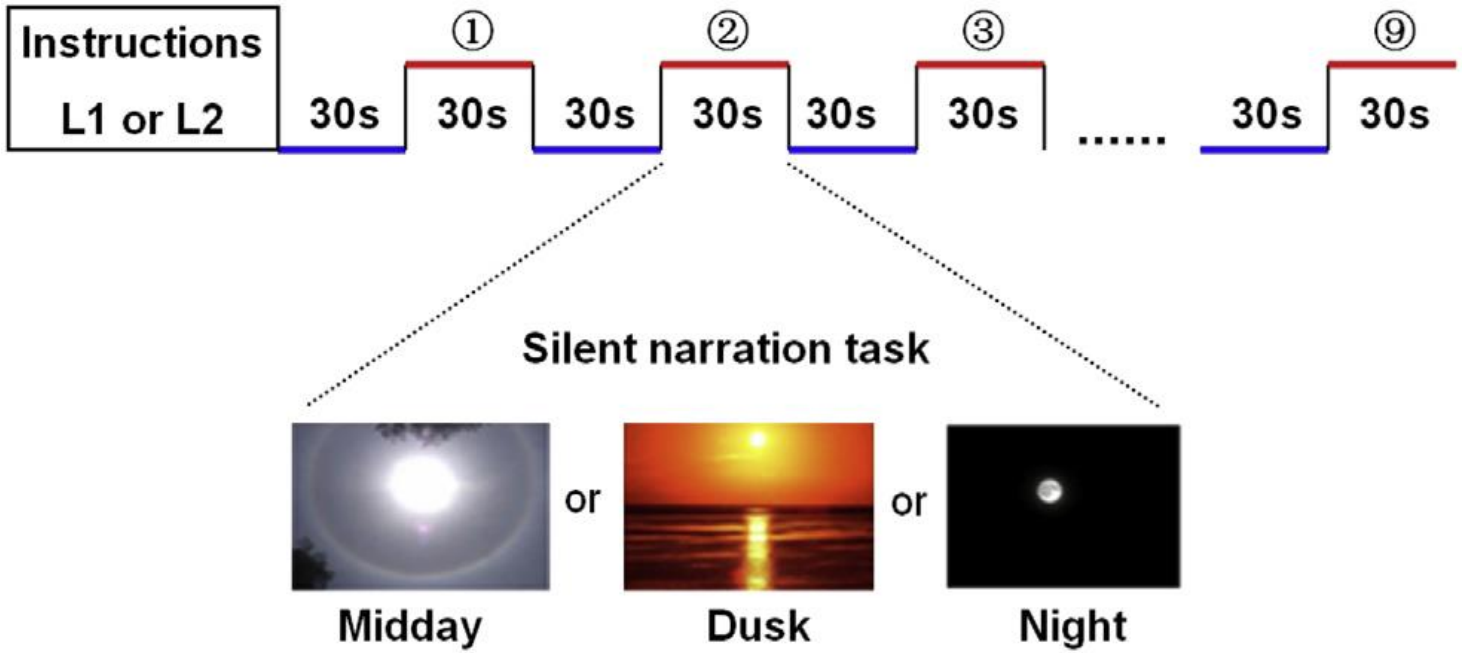
ADAPTATION (2015)

Language exposure induced neuroplasticity in the bilingual brain: A follow-up fMRI study

Liu Tu [a,1], Junjing Wang [b,1], Jubin Abutalebi [c], Bo Jiang [d], Ximin Pan [d], Meng Li [a], Wei Gao [a], Yuchen Yang [e], Bishan Liang [b], Zhi Lu [f,*] and Ruiwang Huang [b,**]

(2015)



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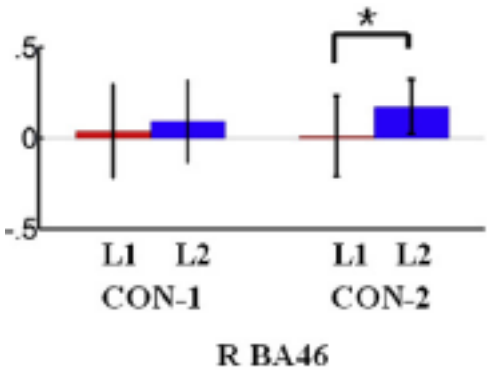
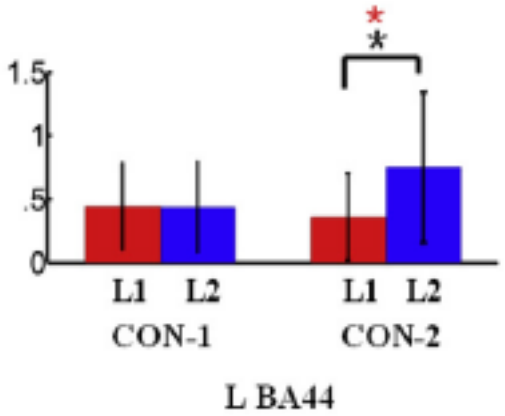
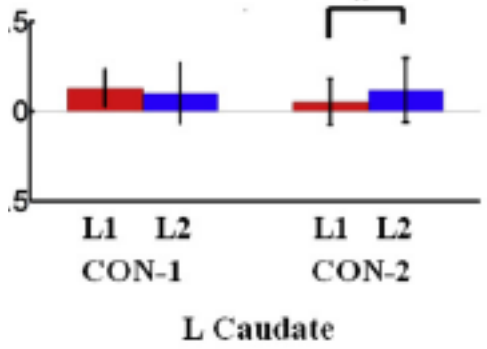
..even short periods of differential exposure to a given language may induce significant neuroplastic changes in areas responsible for language control

CON 1: scanning prior to differential language exposure
CON 2: scanning after differential exposure







Response Inhibition

Language Production

Allocating control

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Language control in bilinguals: The adaptive control hypothesis 2013

David W. Green [a] & Jubin Abutalebi [b c]

A cascade of control processes

Control processes	Interactional contexts		
			
	Single language	Multi-language	Dense code-switching
Goal maintenance	+	+	=
Interference control conflict monitoring interference suppression	+	+	=
Salient cue detection	=	+	=
Selective response inhibition	=	+	=
Task disengagement	=	+	=
Task engagement	=	+	=
Opportunistic planning	=	=	

School settings !!!!

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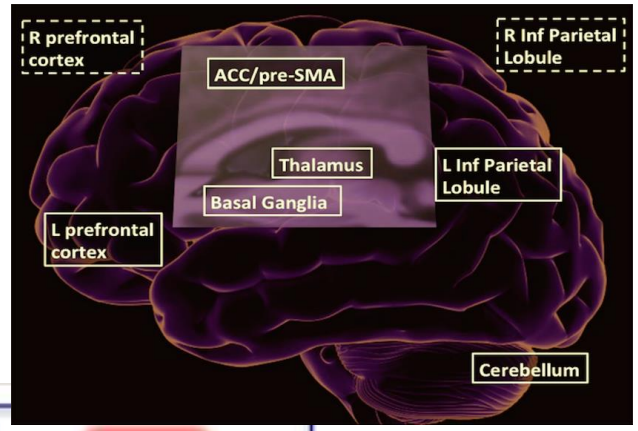
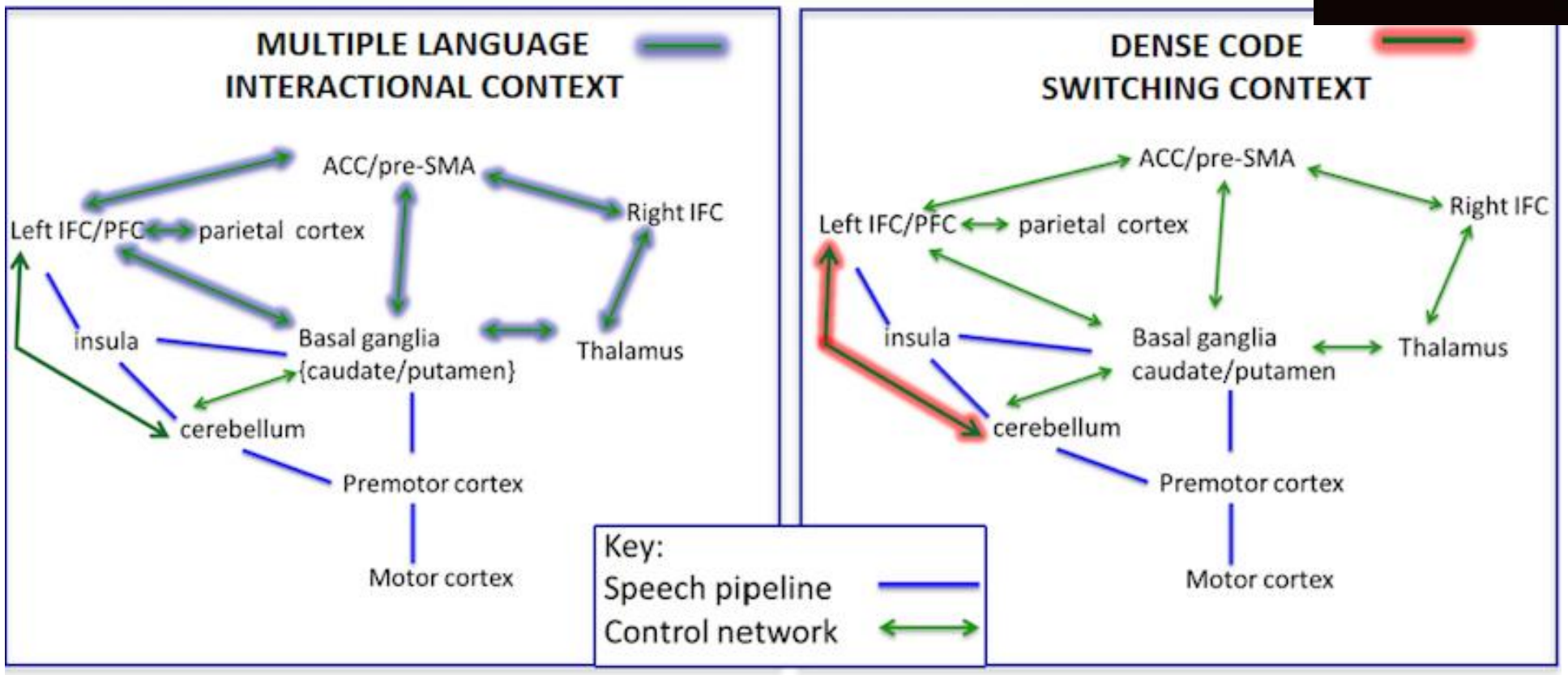
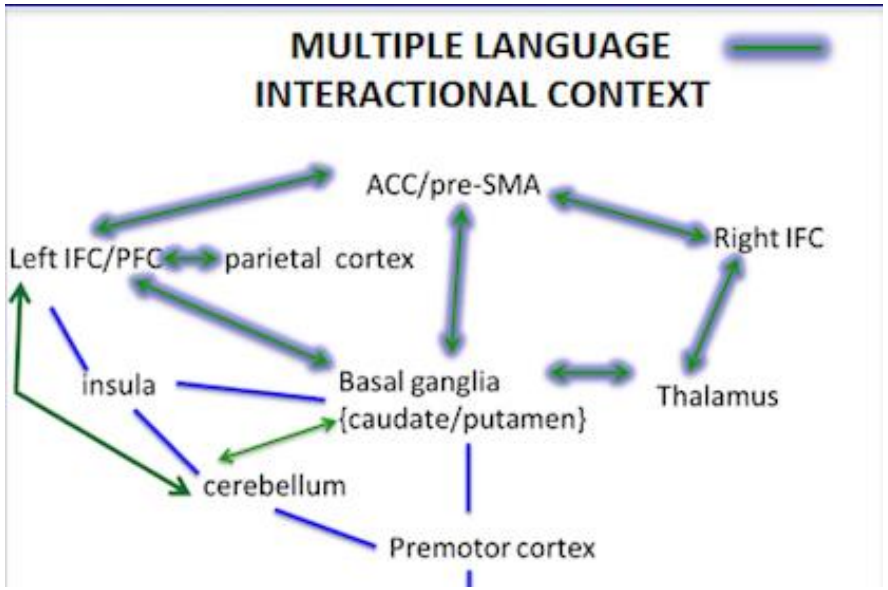
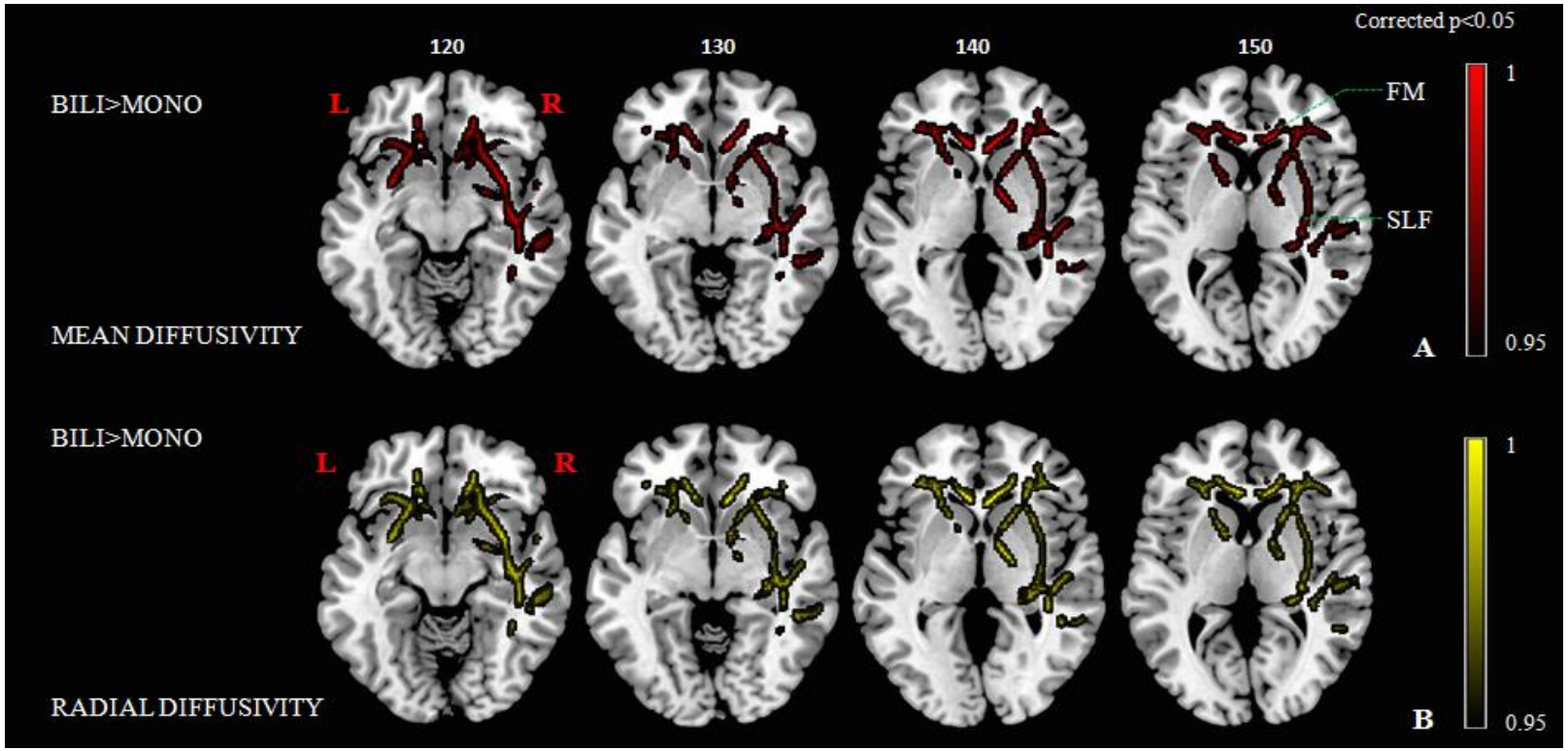




(Abutalebi & Green, 2016)


MULTIPLE LANGUAGE
INTERACTIONAL CONTEXT
ACC/pre-SMA
Left IFC/PFC
parietal cortex
Right IFC
insula
Basal ganglia
{caudate/putamen}
Thalamus
cerebellum
Premotor cortex


Corrected p<0.05
120
130
140
150
BILI>MONO
L
R
FM
SLF
1
0.95
MEAN DIFFUSIVITY
A
BILI>MONO
L
R
1
0.95
RADIAL DIFFUSIVITY
B

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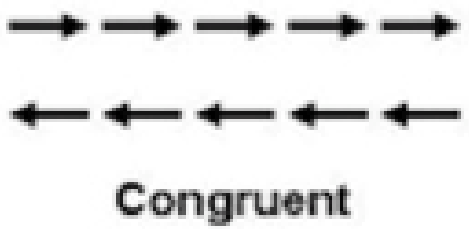
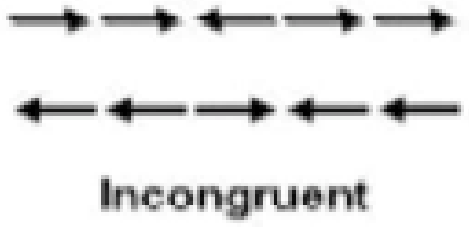
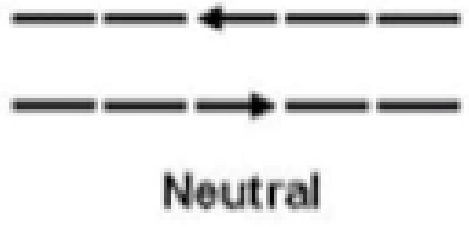
A. STIMULI



Congruent

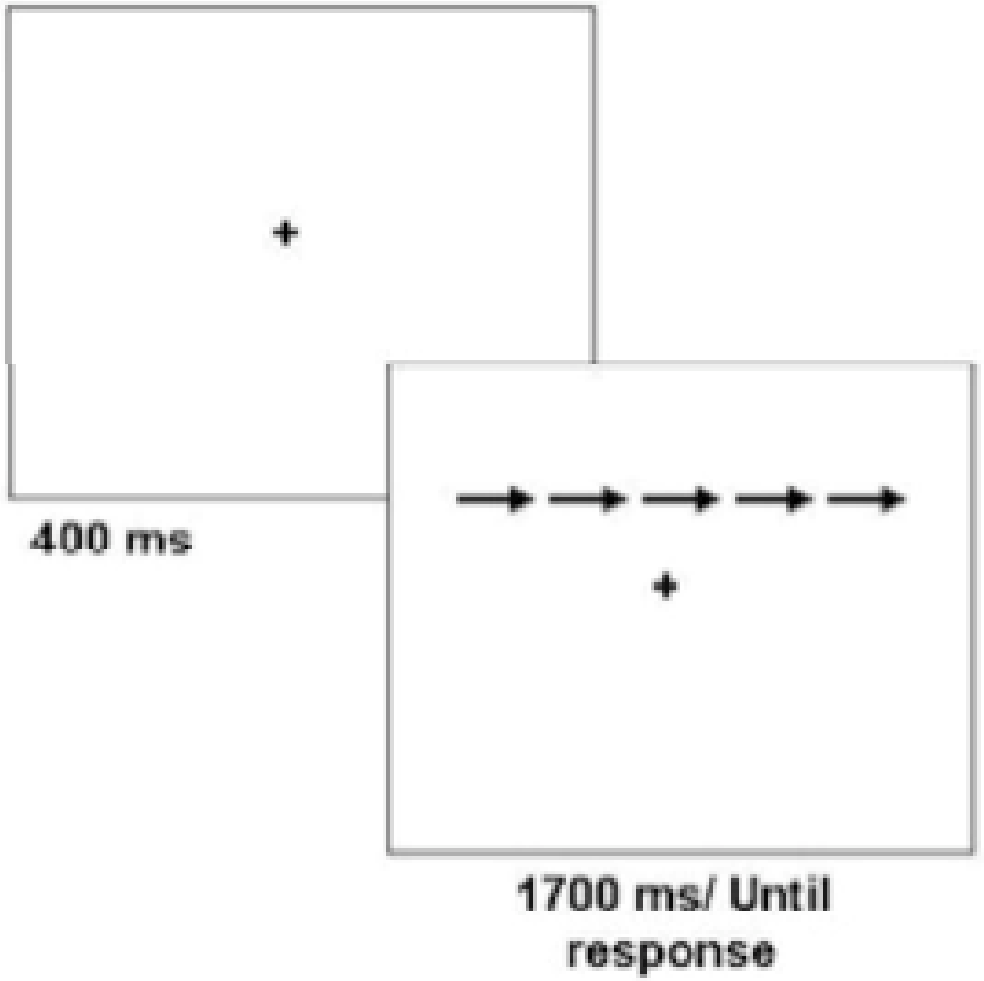


Incongruent



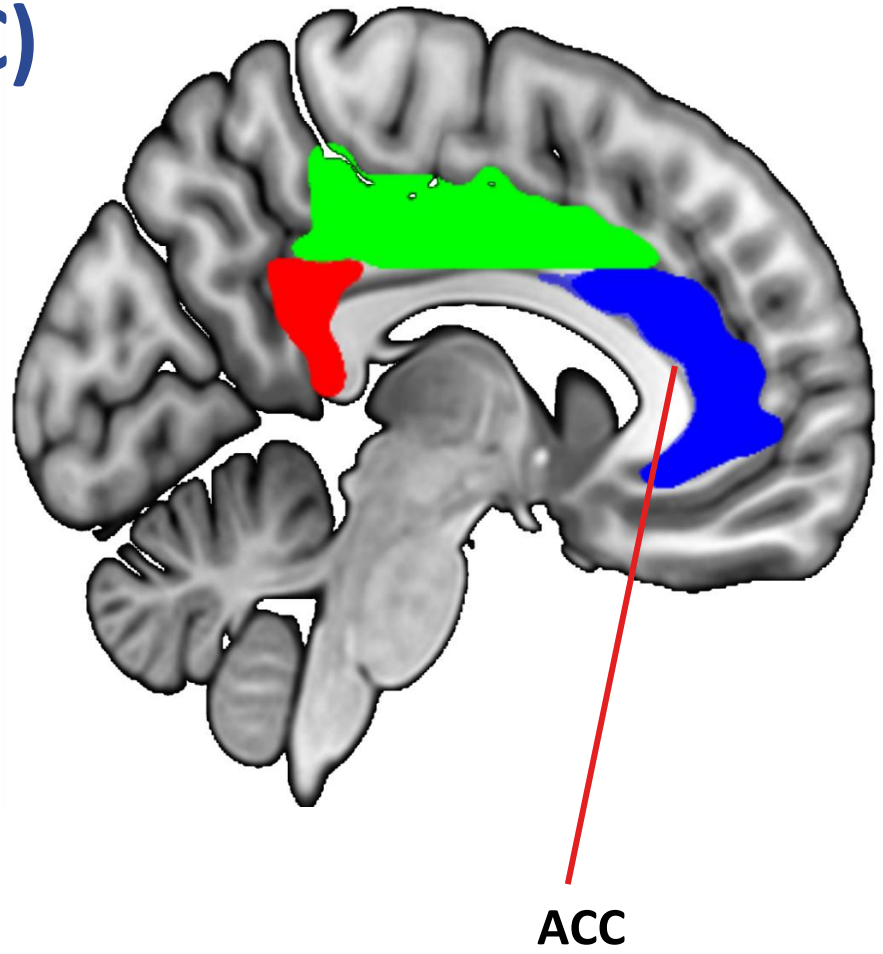
Neutral

B. PROCEDURE



Anterior Cingulate Cortex (ACC)

The (d)ACC is a key structure underpinning conflict monitoring



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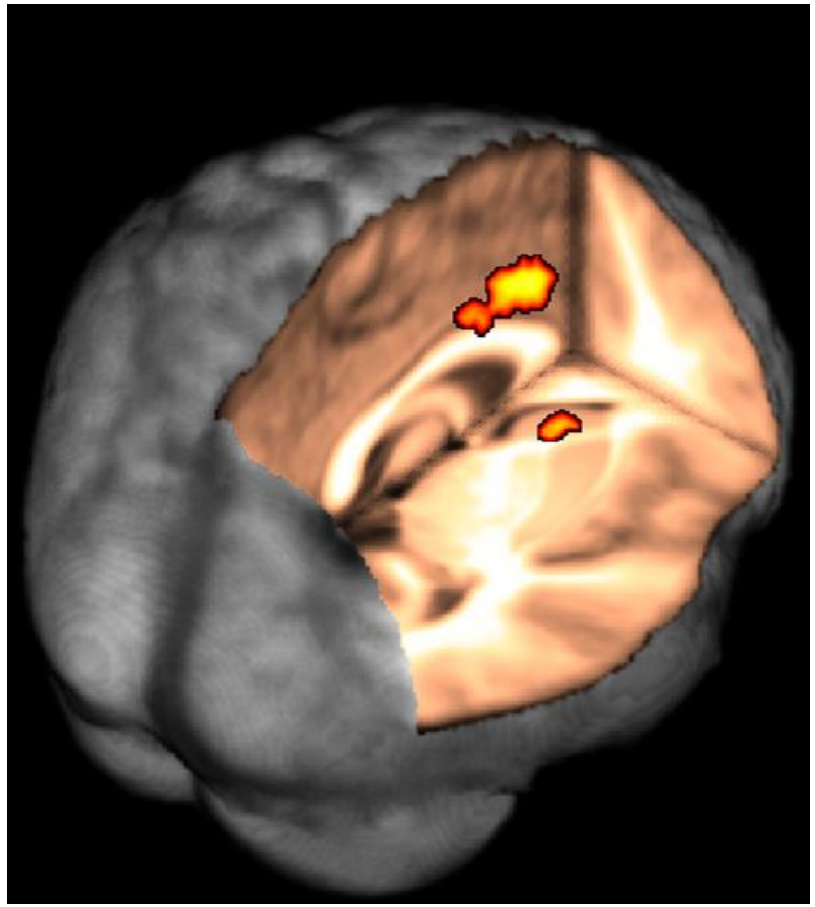
Functional data (Flanker task)

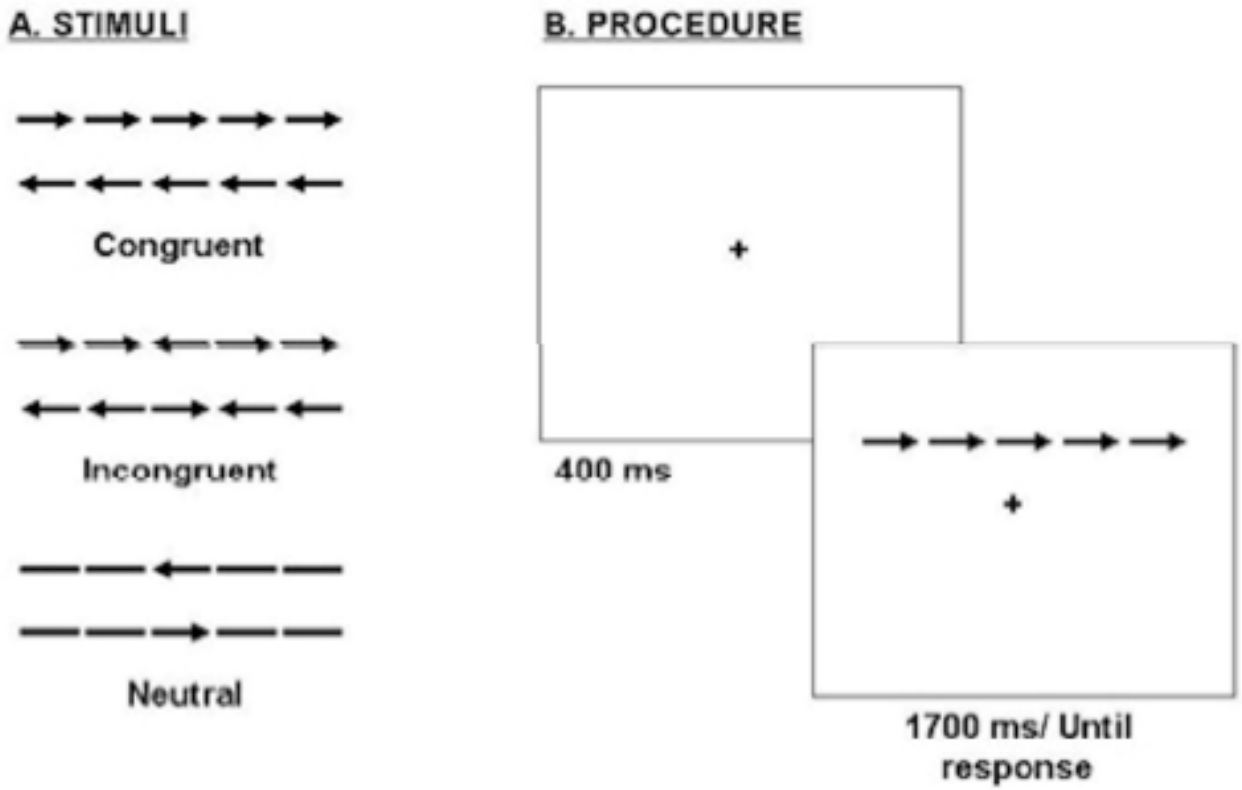


Monolinguals vs Bilinguals

Cerebral Cortex September 2012;22:2076-2086
doi:10.1093/cercor/bhr287
Advance Access publication October 29, 2011

Bilingualism Tunes the Anterior Cingulate Cortex for Conflict Monitoring

Jubin Abutalebi[1,2], Pasquale Anthony Della Rosa[1], David W. Green[3], Mireia Hernandez[4,5], Paola Scifo[1], Roland Keim[1], Stefano F. Cappa[1] and Albert Costa[4,6]



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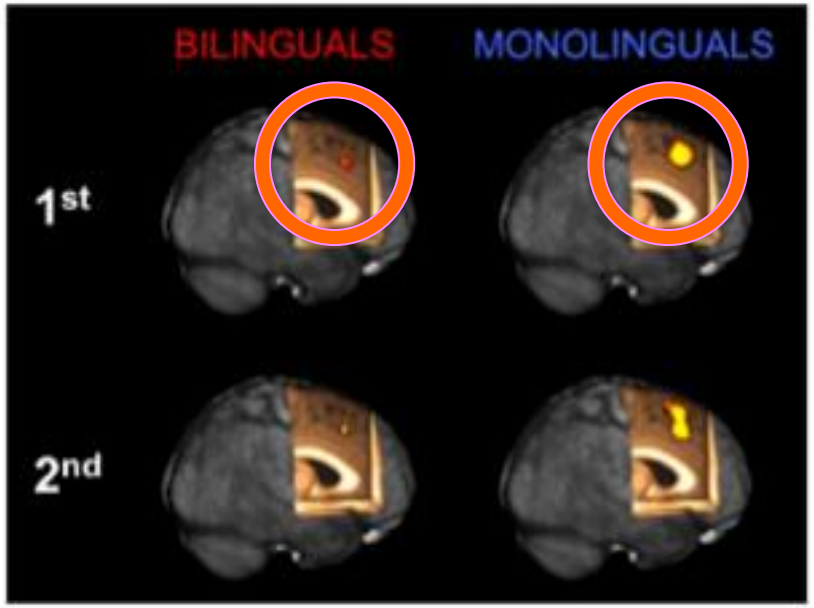
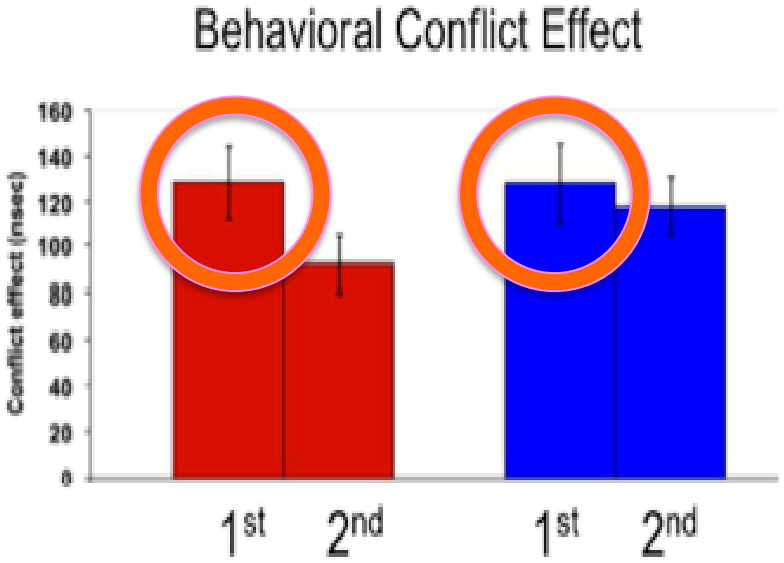
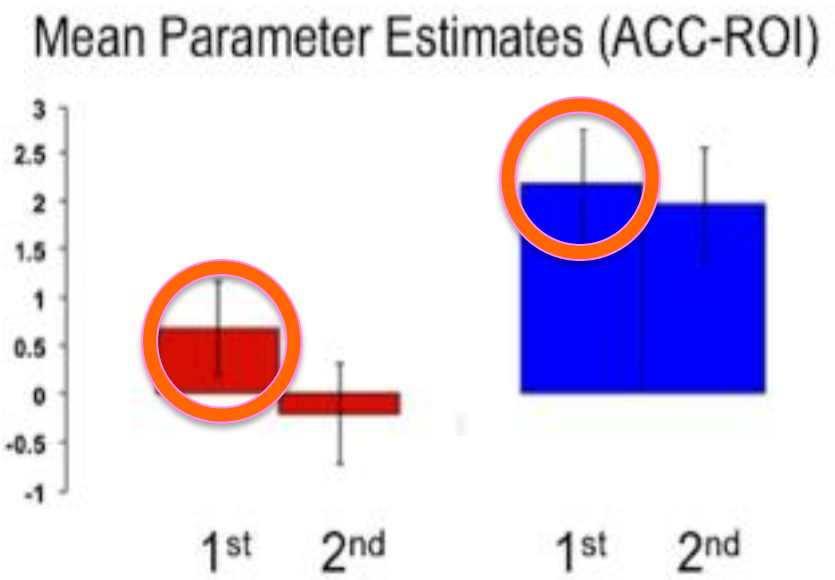
Behaviour vs Brain







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Structural Neuroimaging
A powerful tool to investigate neuroplasticity

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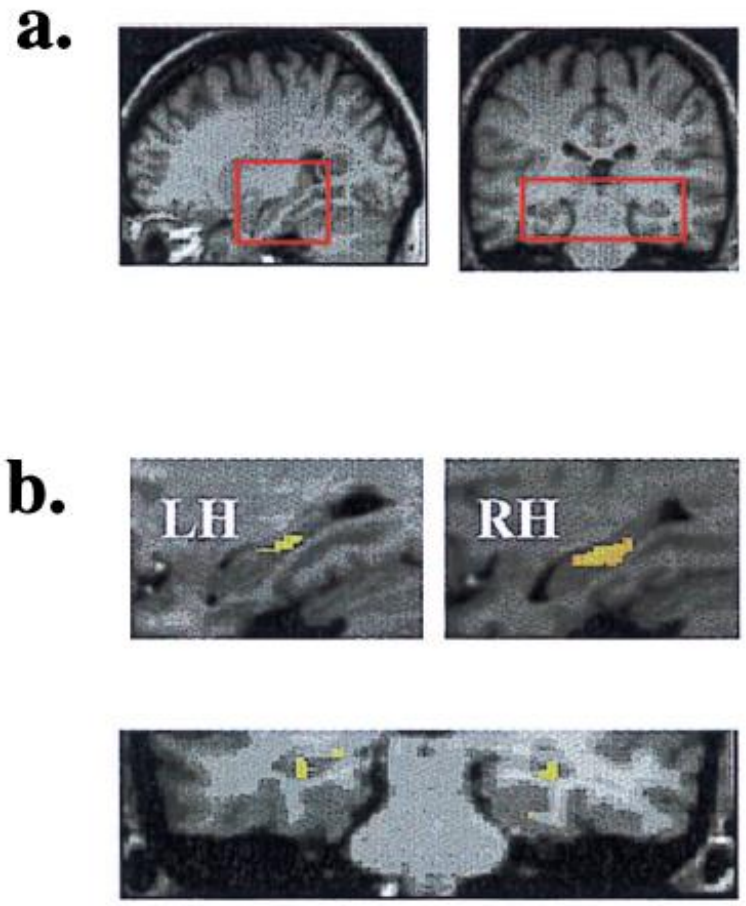
Voxel-based morphometry (VBM)

measuring lifelong experiences

Navigation-related structural change in the hippocampi of taxi drivers

Eleanor A. Maguire*†, David G. Gadian‡, Ingrid S. Johnsrude†, Catriona D. Good†, John Ashburner†, Richard S. J. Frackowiak†, and Christopher D. Frith†



4398–4403 | PNAS | April 11, 2000 | vol. 97 | no. 8

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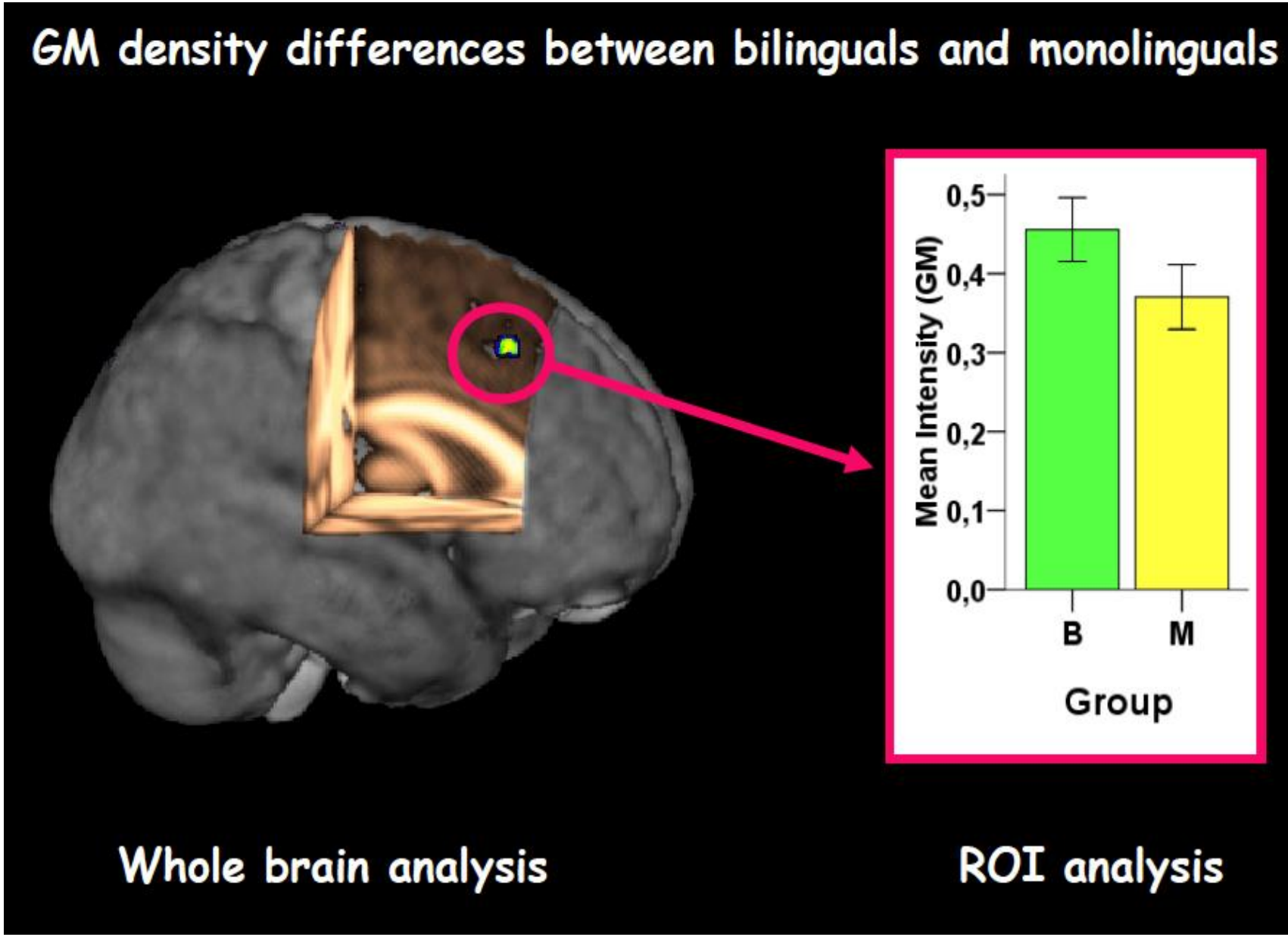
Investigating Neuroplasticity in Bilinguals



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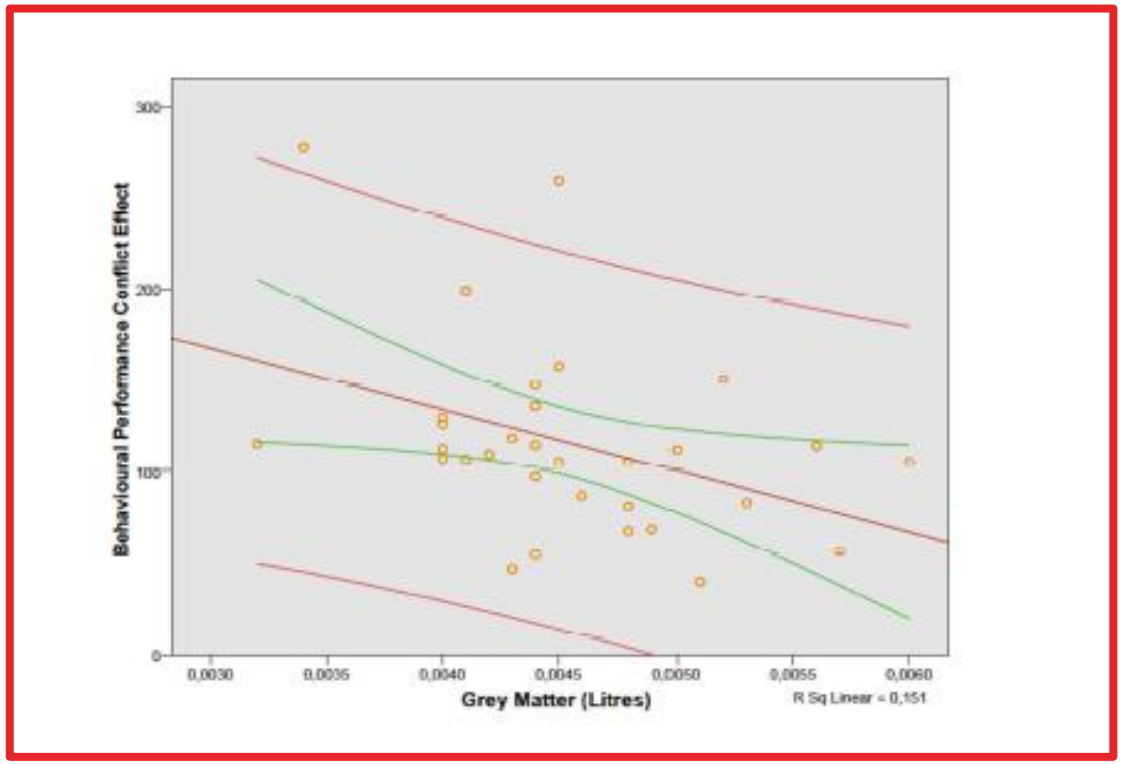
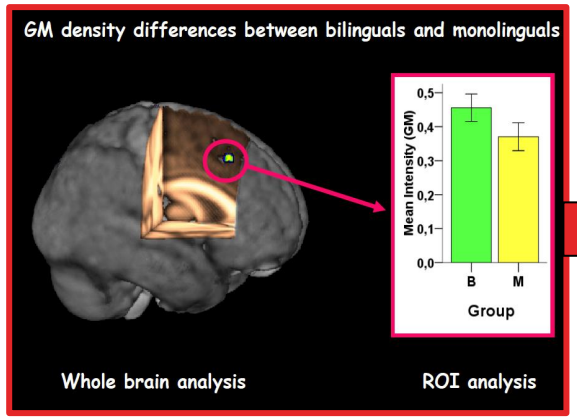
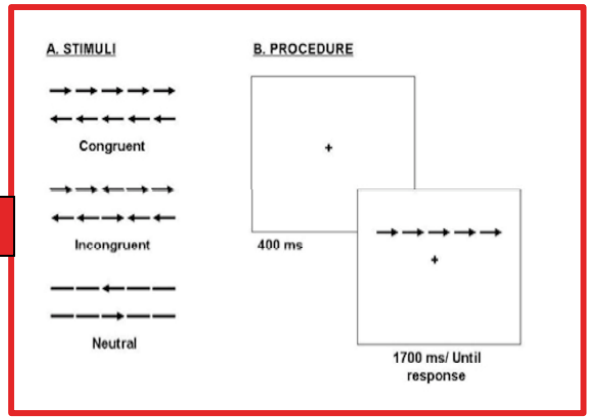
Behavioral (conflict effect) – grey matter correlation in the ACC







Abutalebi et al., 2012

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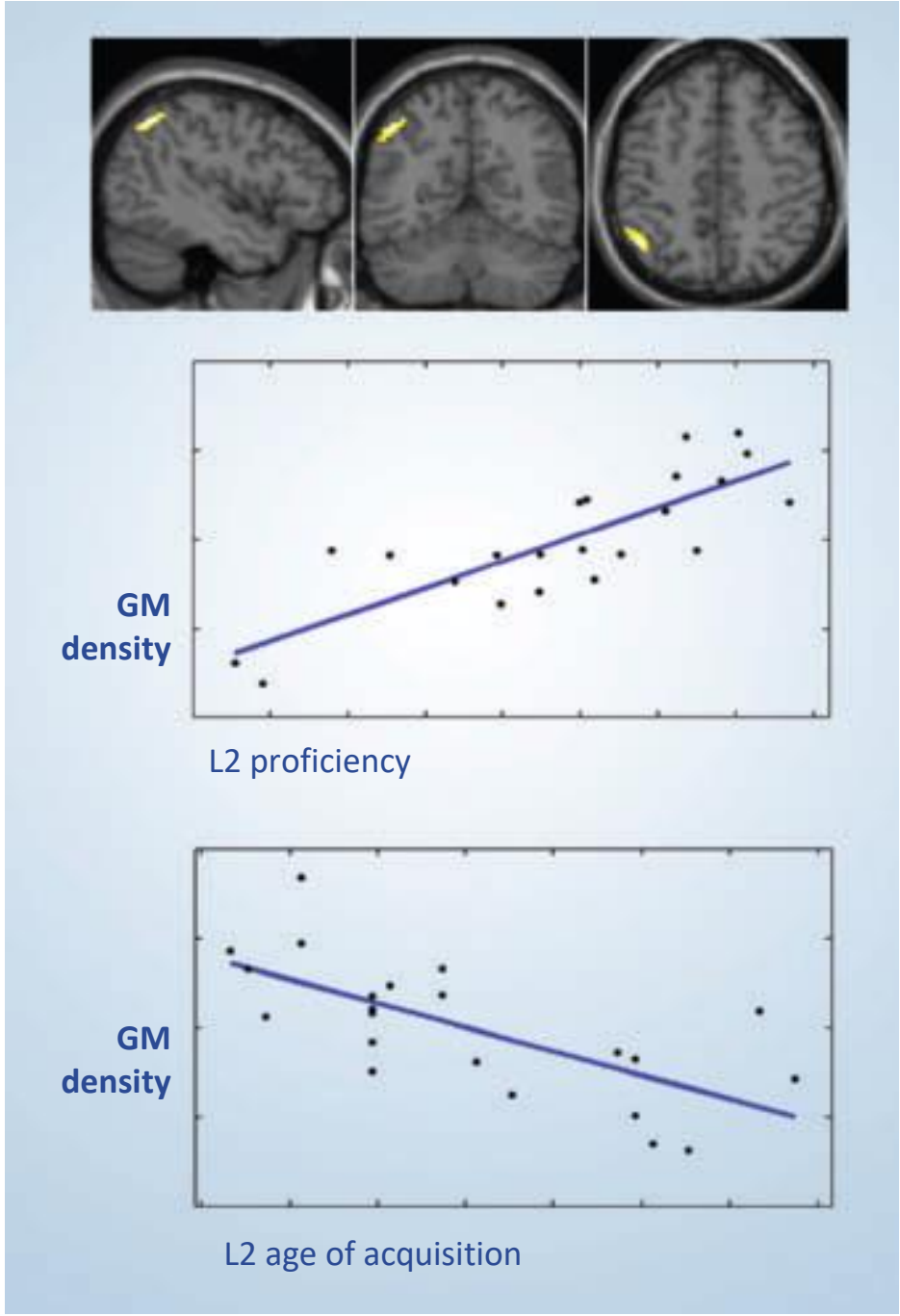
Structural changes in the LIPL



Mechelli, Crinion, Noppeney, O'Doherty, Ashburner, Frackowiak, & Price. (2004). Neurolinguistics: structural plasticity in the bilingual brain. *Nature*, *431*, 757

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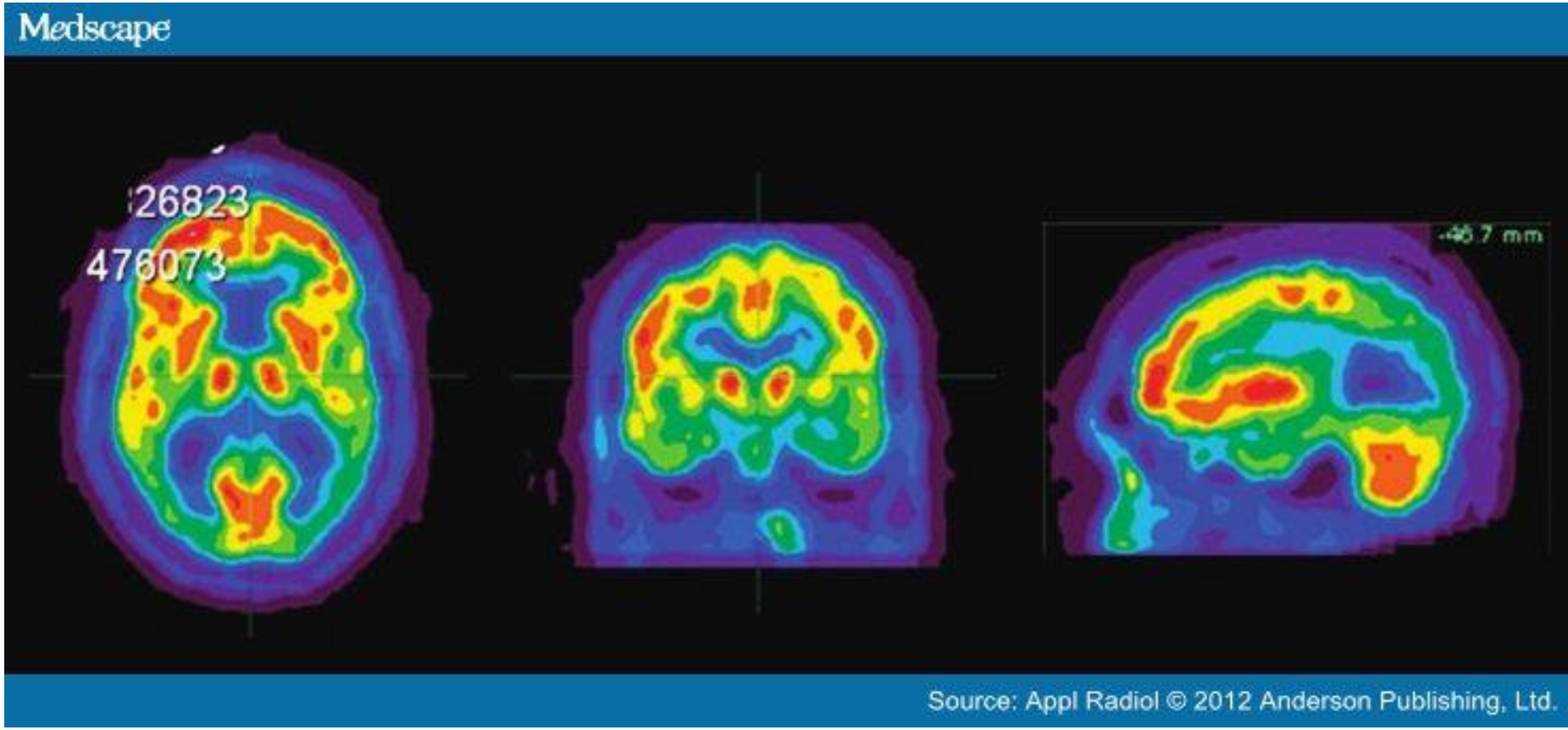
Parietal lobe atrophy in AD

Parietal dysfunction assessed by FDG PET as a metabolic reduction in the inferior
parietal lobule is the first marker of progression to Alzheimer's dementia in MCI

[Cerami, Della Rosa, ……& Perani, 2015]



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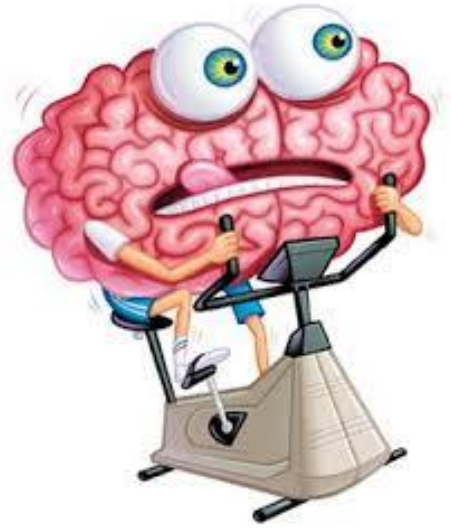
A follow-up study in school children



Does linguistic competence matters?

subjects: 16 kids, 11 male e 5 female,
(mean age = 8.74; st.dev = 1.45).

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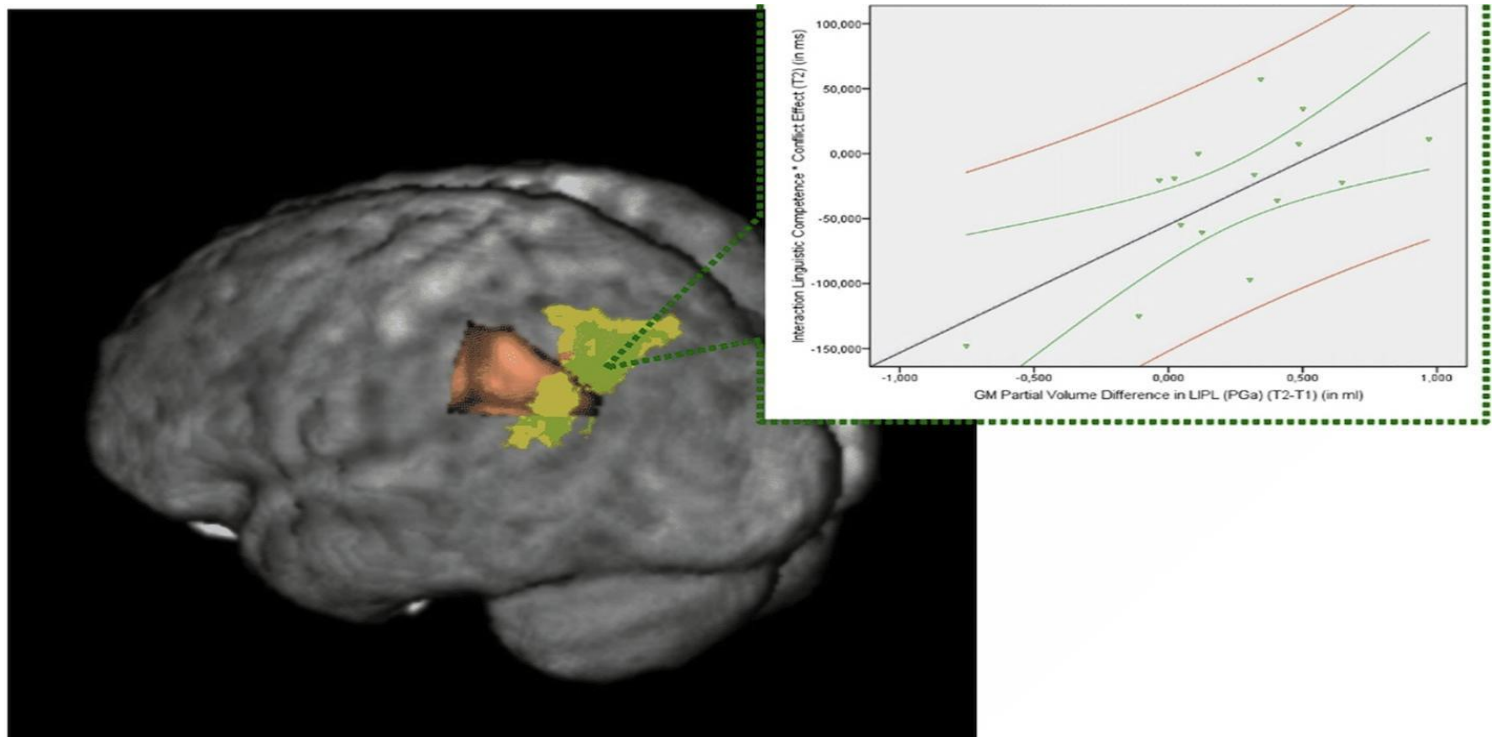
Follow-up study in children

Fifteen multilingual Ladin-German-Italian-English children (10 boys, 5 girls) (mean age = 9.86; SD= 1.44 years) from South Tyrol, Italy, participated in this longitudinal study (mean scan interval (T1-T2) = 0.97 years, SD = 0.1 years).

Interaction between conflict effect and increasing proficiency correlated to brain structure

Comparison between T2 and T1 (1 year difference)



Della Rosa, Videsott, Borsa, Canini, Franceschini & Abutalebi , CORTEX, 2013

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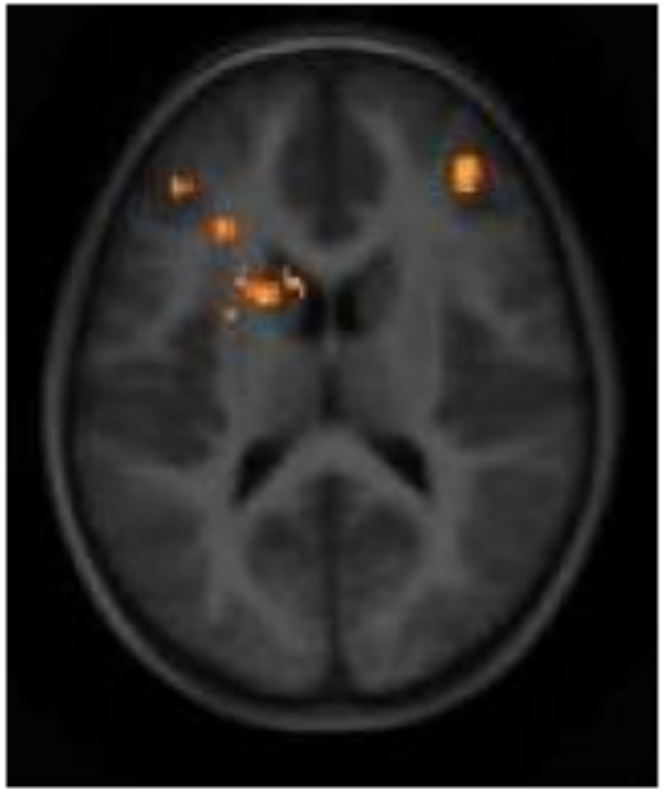
Functional Activity

+ Brain Activity



- Brain Activity

- MLC

+ MLC

0.05 FWE corrected

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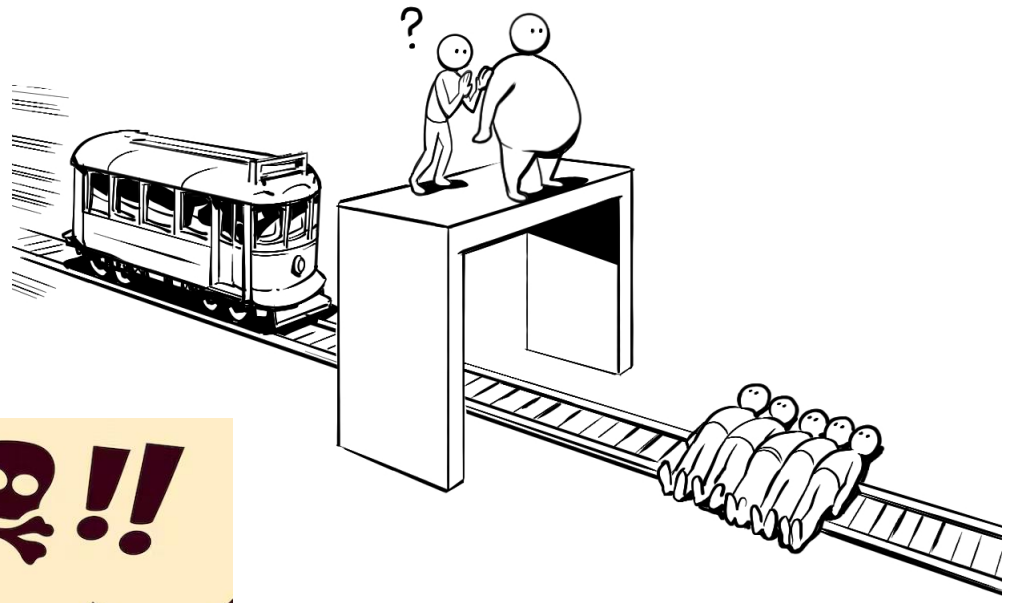
THE FOREIGN LANGUAGE EFFECT (FLE)

Rational Choice Theory

The theory states that people make decisions based on what will profit them the most out of self-interest during the decision-making process.



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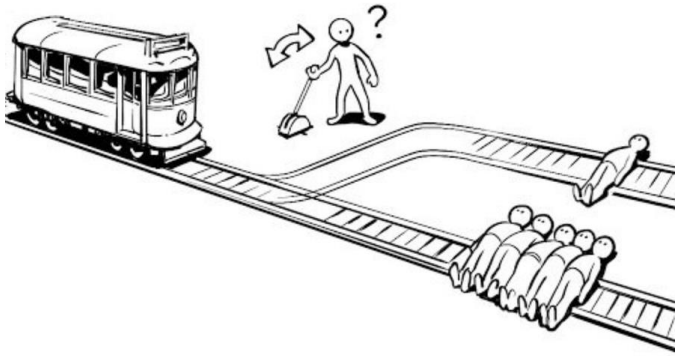
Emotion, bilingualism and (moral) decision-making

FOREIGN LANGUAGE EFFECT (FLE)

Decision-making in a L2 may result in choices that are systematically different from those that would be made in the L1 (Hadjichristidis et al., 2019): more analytical and less emotionally-driven decisions (e.g., Keysar et al., 2012)



Moral domain

Bilinguals are less likely to act deontologically, opting for the greater good (utilitarianly) (for meta-analyses, see Del Maschio et al., 2022; Stankovic et al., 2022)

Explaining the FLE

cognitive enhancement hypothesis
increased reliance on deliberative processes

reduced emotionality hypothesis
decreased reliance on gut-feeling emotional reactions

reduced access to norm hypothesis
less automatic access to normative knowledge

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Not all bilinguals are the same

heightened cognitive resources for language processing in a L2 for late vs. early AoA, lower vs. higher proficiency, and a less “dominant” language.

cognitive enhancement hypothesis

incresead reliance on deliberative processes

reduced emotionality hypothesis

decreased reliance on gut-feeling emotional reactions

shrunk emotional resonance for a late vs. early L2 AoA, lower vs. higher L2 proficiency, and lower vs. higher daily L2 usage.

reduced access to norm hypothesis

less automatic access to normative knowledge

less automatic access to normative knowledge for a late vs. early L2 AoA, lower vs. higher L2 proficiency, and lower vs. higher L2 daily use.

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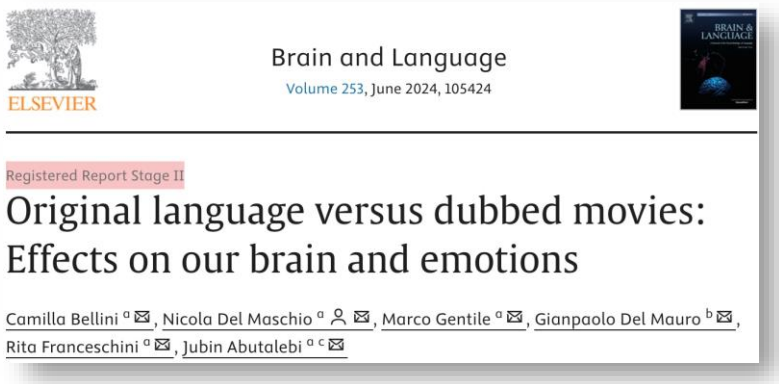
Research Hypotheses



1. Emotional movies in L1 vs. L2 → enhanced brain activations within the conceptualization network (Satpute & Lindquist, 2019; Lindquist & Barrett, 2012).
2. Emotional movies in L1 vs. L2 → greater involvement of the amygdala.
3. Emotional movies in L2 → increased activation of the amygdala as a function of bilingual profile (i.e., proficiency, immersion, exposure).

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Screening

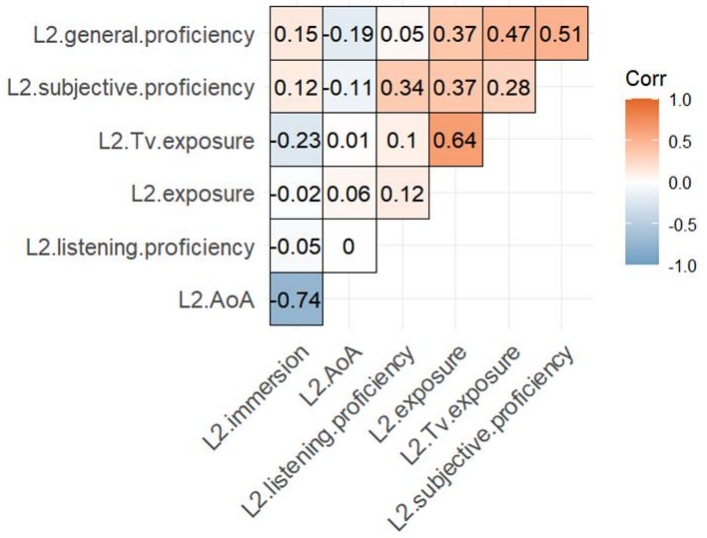
Cambridge Assessment English (First Certificate in English (FCE) Listening)
Edinburgh Handedness Inventory

Participants

52 Italian-English bilinguals (35F; Age: 23.21 ± 2.45 years)

Bilingual experience

Language History Questionnaire (version 3) (Li, Zhang, Yu, & Zhao, 2020)



L2 AoA	52	5.35 (1.34)	0-8
L2 objective general proficiency	52	21.21 (2.12)	17-25
L2 objective listening proficiency	52	4.62 (0.63)	3-5
L2 subjective proficiency	52	0.78 (0.09)	0.61-1
L2 immersion	52	0.75 (0.04)	0.62-0.88
L2 daily exposure	52	0.14 (0.08)	0.01-0.36
L2 daily exposure to TV	49	1.44 (0.71)	0.2-3

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Stimuli

Initial Stimuli Selection

60 ~1-min videoclips dubbed in each language (L1 and L2):

- 20 funny
- 20 neutral
- 20 sad

Stimuli Norming

33 Italian native-speakers appraised for valence each L1 videoclip on a 7-point Likert scale

Final Stimuli Selection

L1: 36 ~1-min videoclips

L2: 36 ~1-min videoclips

→ 12 videoclips per emotion category (funny, sad, neutral)

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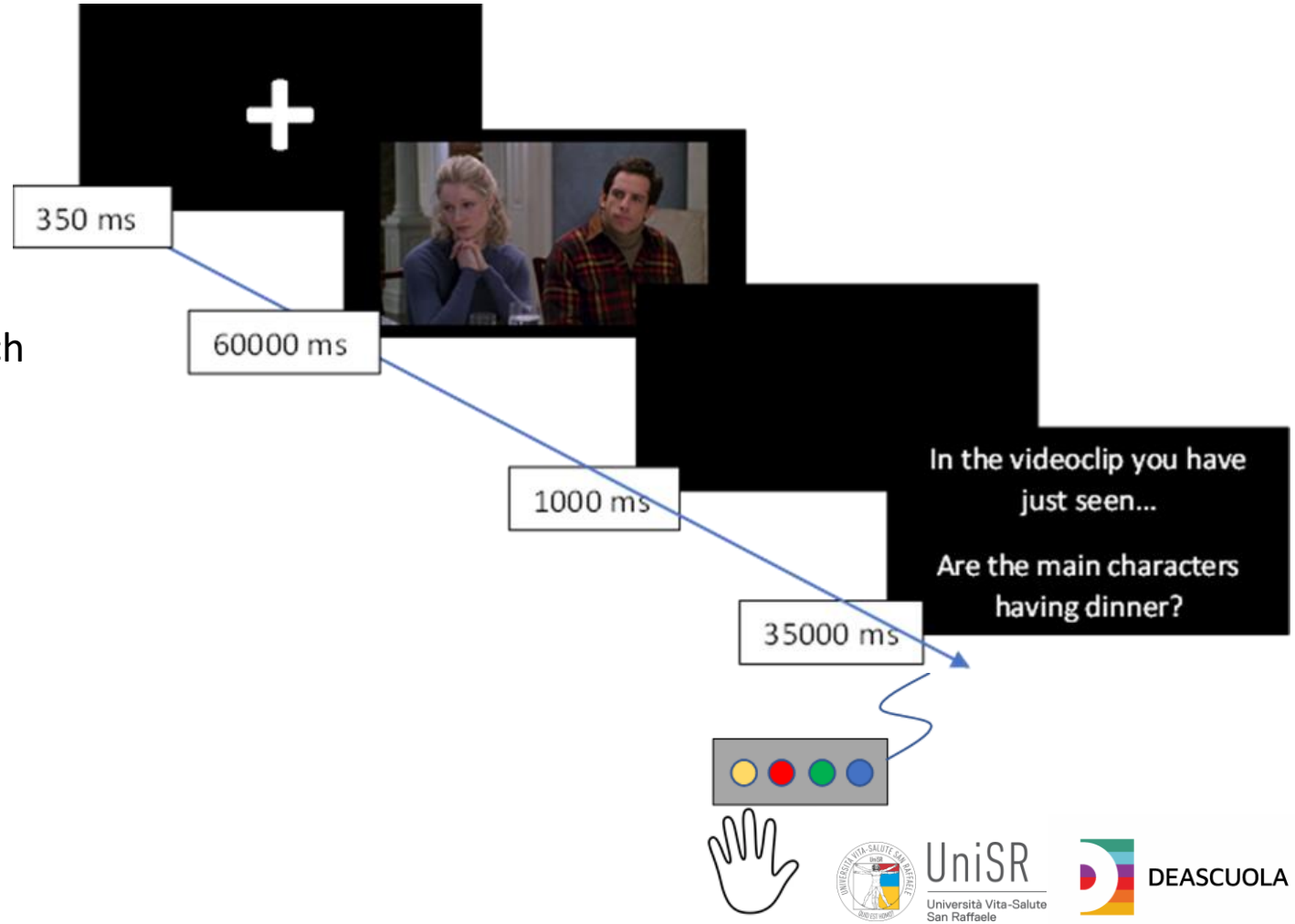
Experimental design and procedure

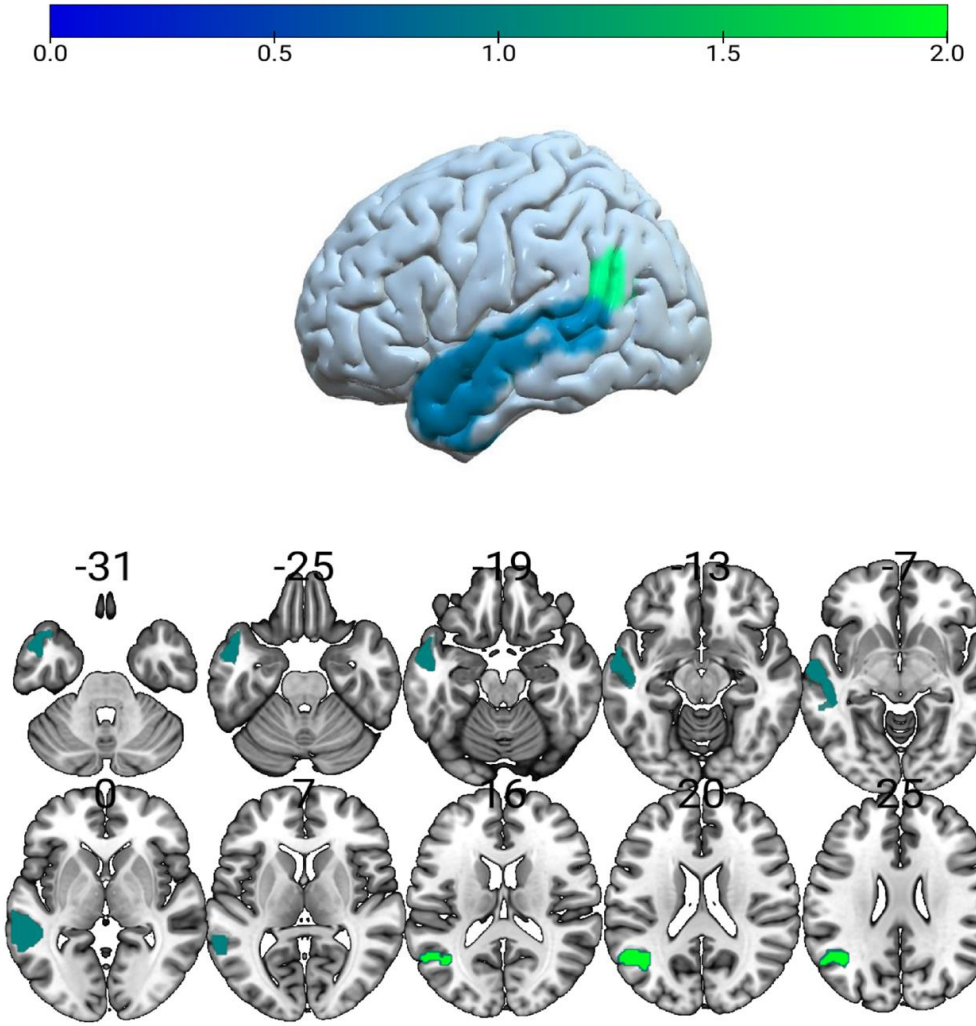


In the fMRI scanner, participants watched each videoclip and then responded to a closed-answer question presented after it.

2 runs, one per language, each comprising 2 sessions of 18 trials each (6 funny, 6 sad, 6 neutral)

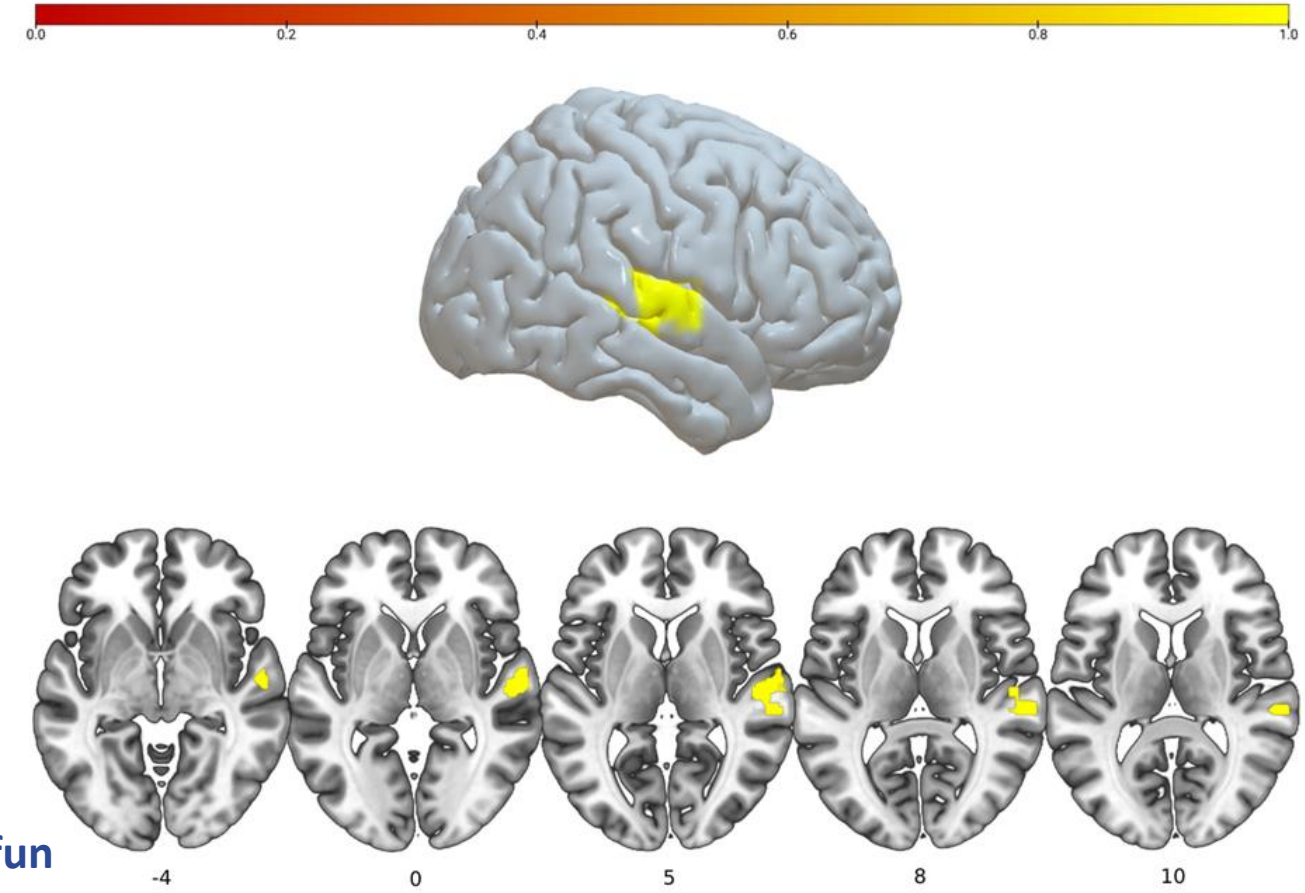
Total scanning time: ~ 1 hour

Results: Whole-brain analyses



L1 [emotional vs. neutral] vs L2 [emotional vs. neutral]

Results: Whole-brain analyses

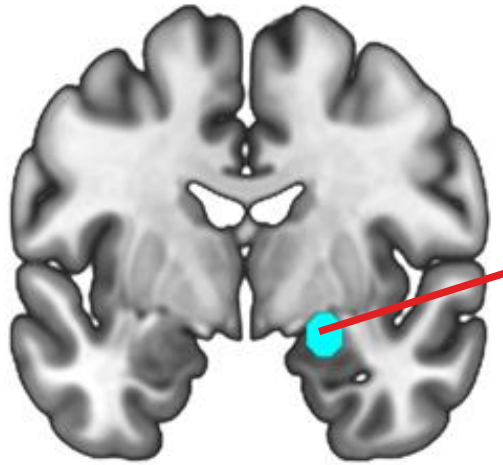


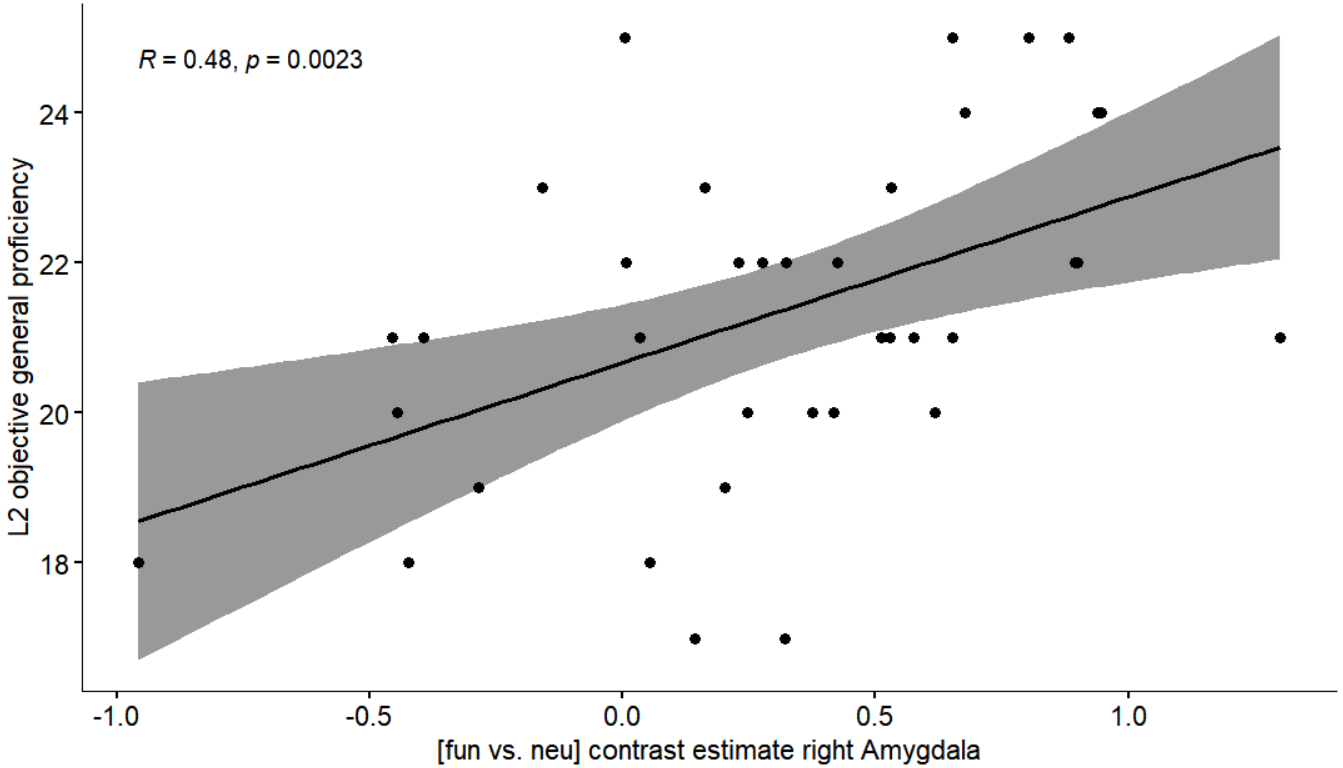
L1 [fun vs. neutral] vs L2 [fun vs. neutral]

Results: ROI analyses

L1 [emotional vs. neutral] vs L2 [emotional vs. neutral]
(*t* = 1.997, st. dev = 1.196, *p* = .053)

L1 [fun vs. neutral] vs L2 [fun vs. neutral]
(*t* = 3.181, st. dev = .753, *p* = .003)





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Conclusions

Emotional videoclips in L1 vs. L2 → enhanced brain activations within the conceptualization network (Satpute & Lindquist, 2019; Lindquist & Barrett, 2012).	Greater language-dependent access to conceptual knowledge to construct emotions in the native language
Emotional videoclips in L1 vs. L2 → greater involvement of the amygdala.	Easier and faster activation of affective properties for L1 vs. L2 concepts leading to a deepest emotional resonance.
Emotional videoclips in L2 → increased activation of the amygdala as a function of bilingual profile.	When the L2 is mastered at native-like levels, a corresponding native-like emotional response to positive stimuli arise.

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Healthy Aging

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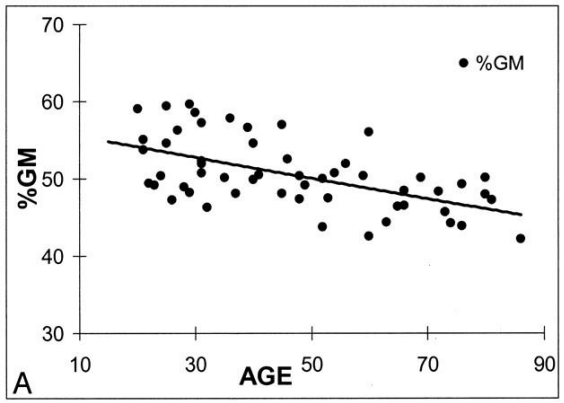
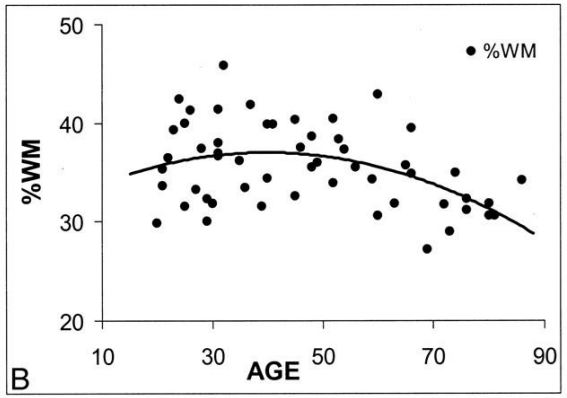
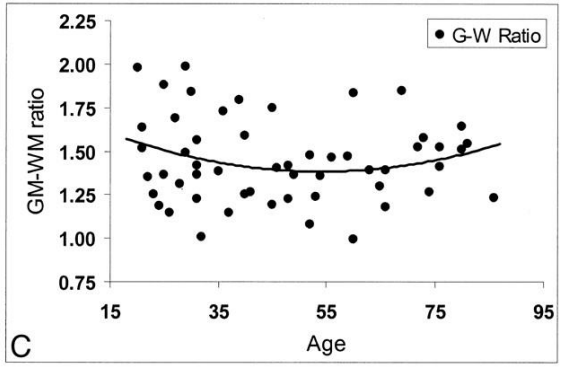
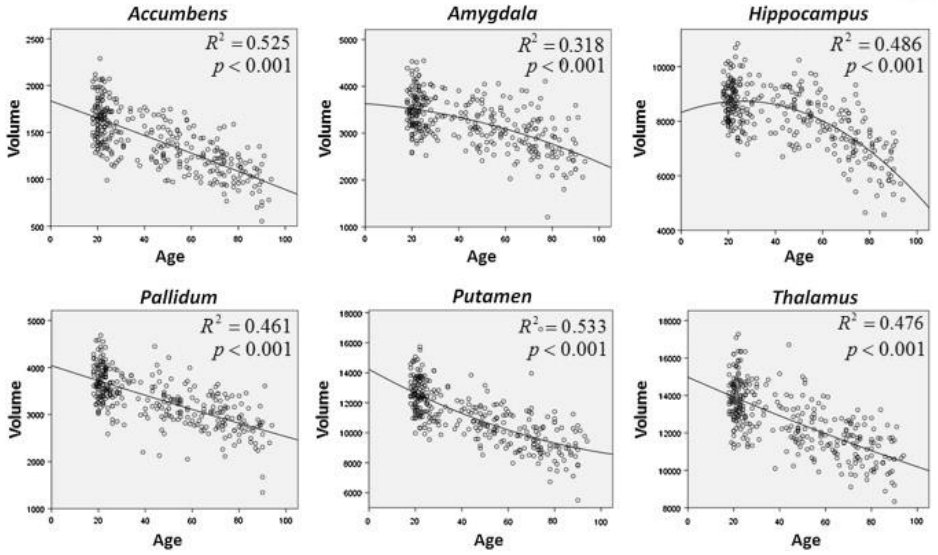
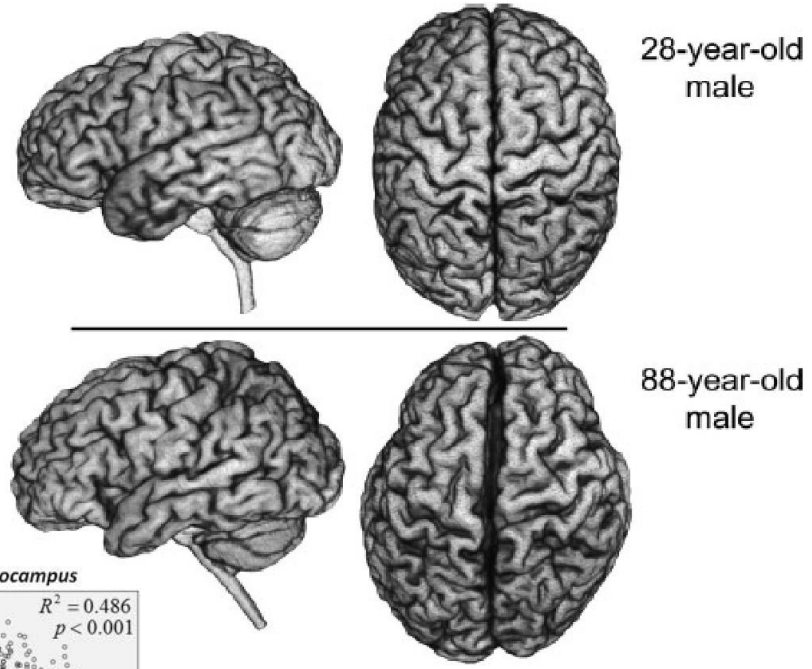
The aging brain











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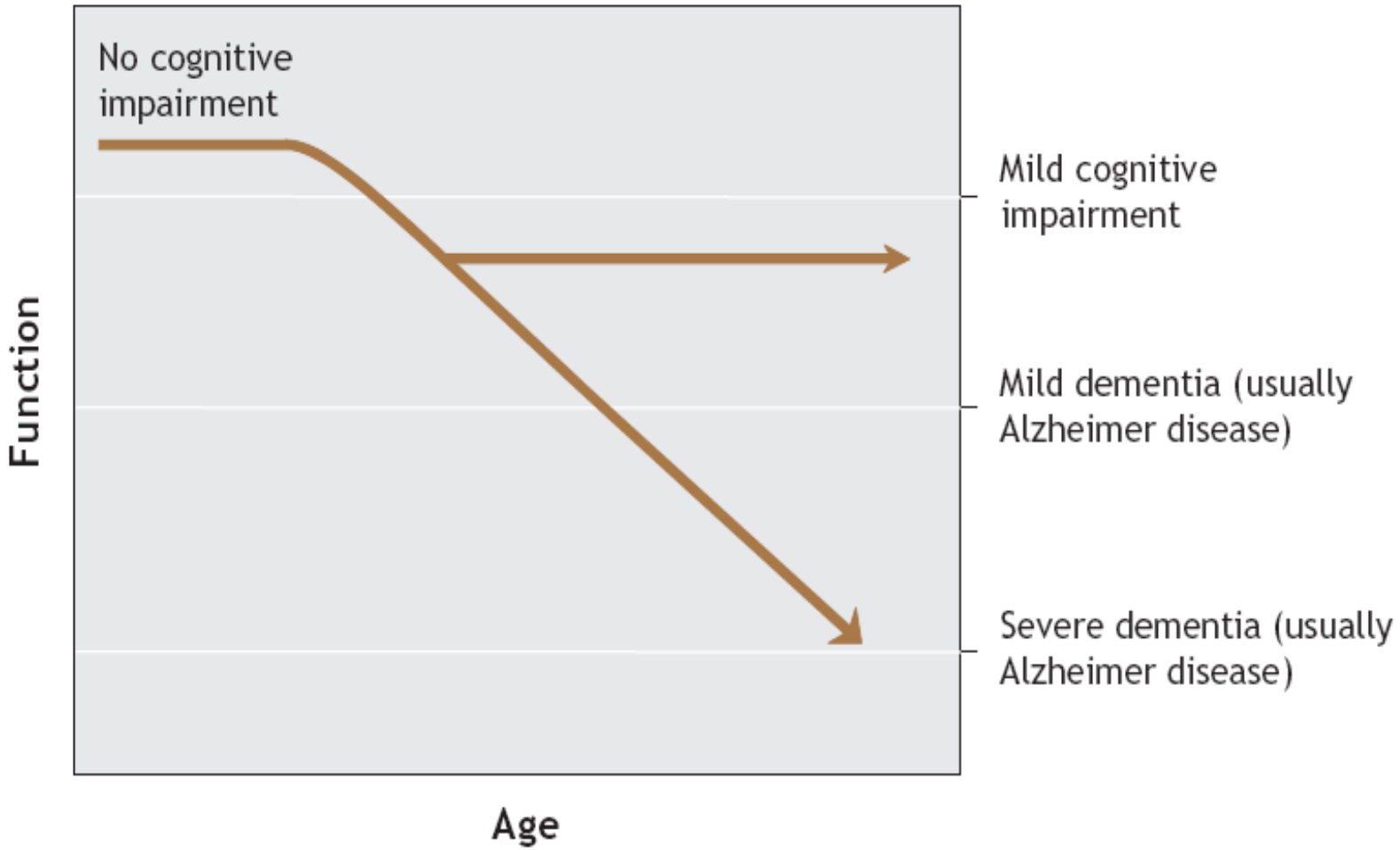
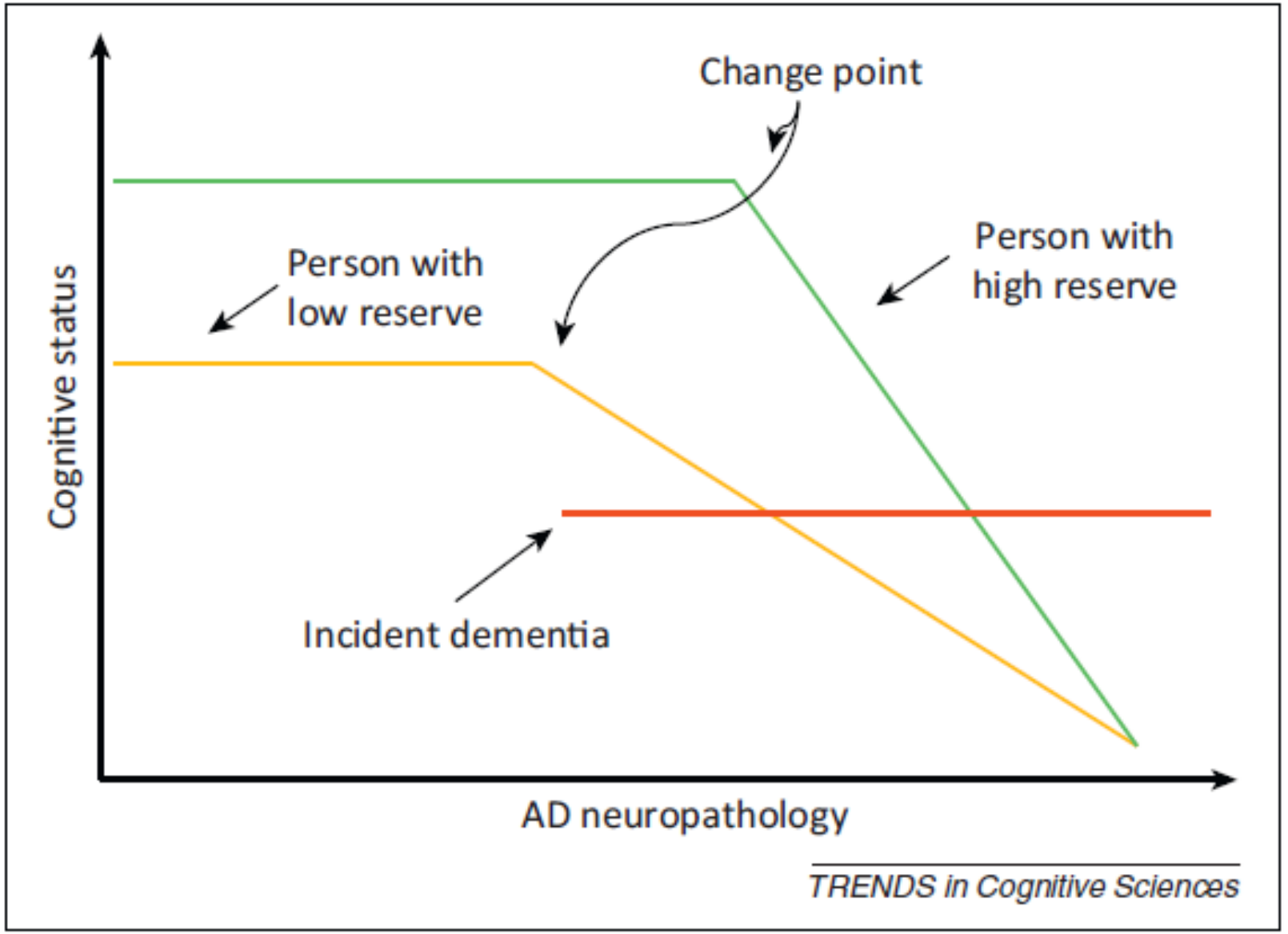
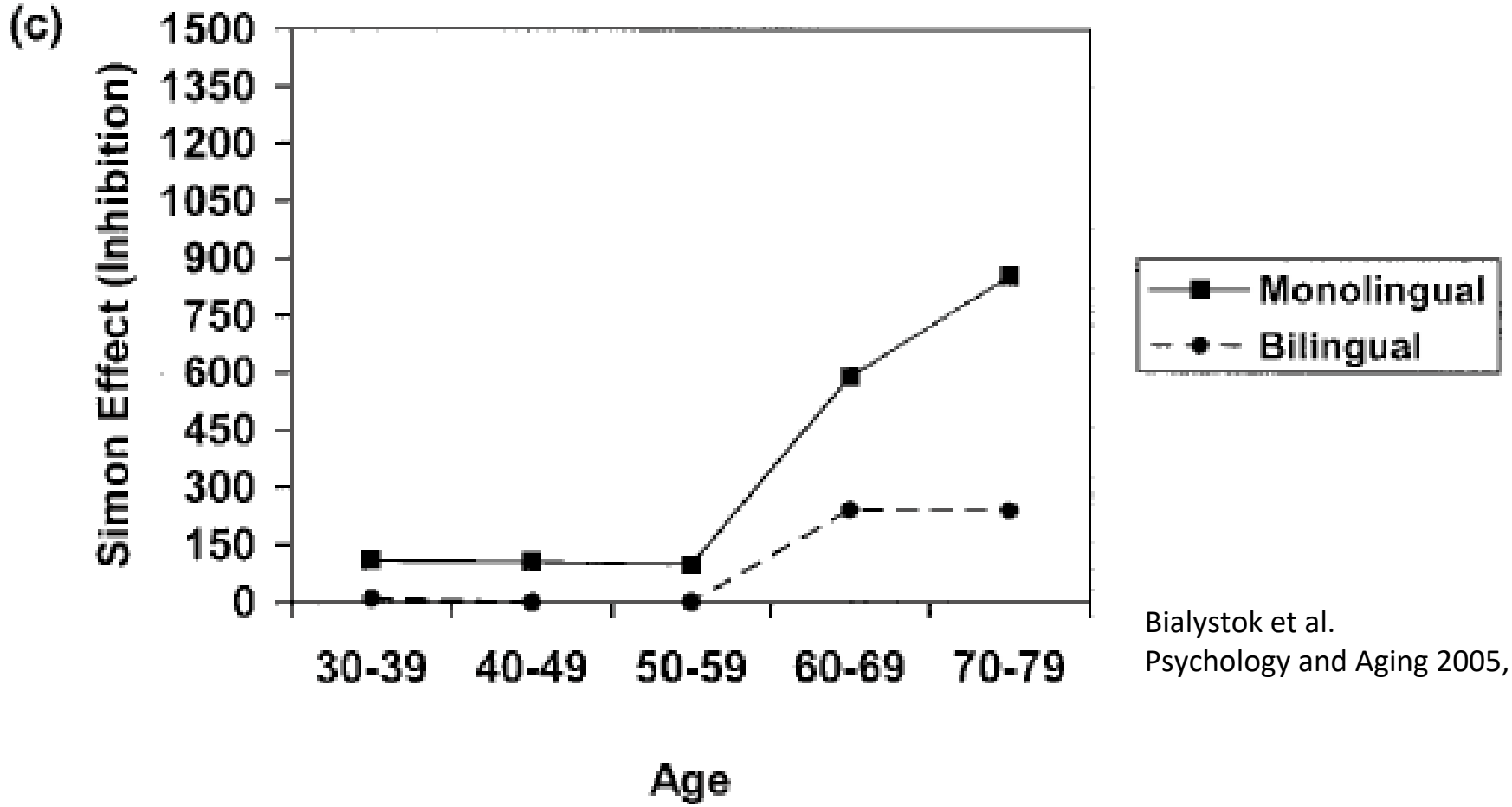
The aging brain





Barulli and Stern, 2013

What about bilingualism as a cognitive and/or neural reserve



Bialystok et al.
Psychology and Aging 2005, Vol. 19, No. 2, 290–303

Table 1
Mean, standard deviation, and range values for control and target variables used in the statistical models throughout the study; *p*-values for independent sample *t* test between groups of monolingual and bilingual participants are provided

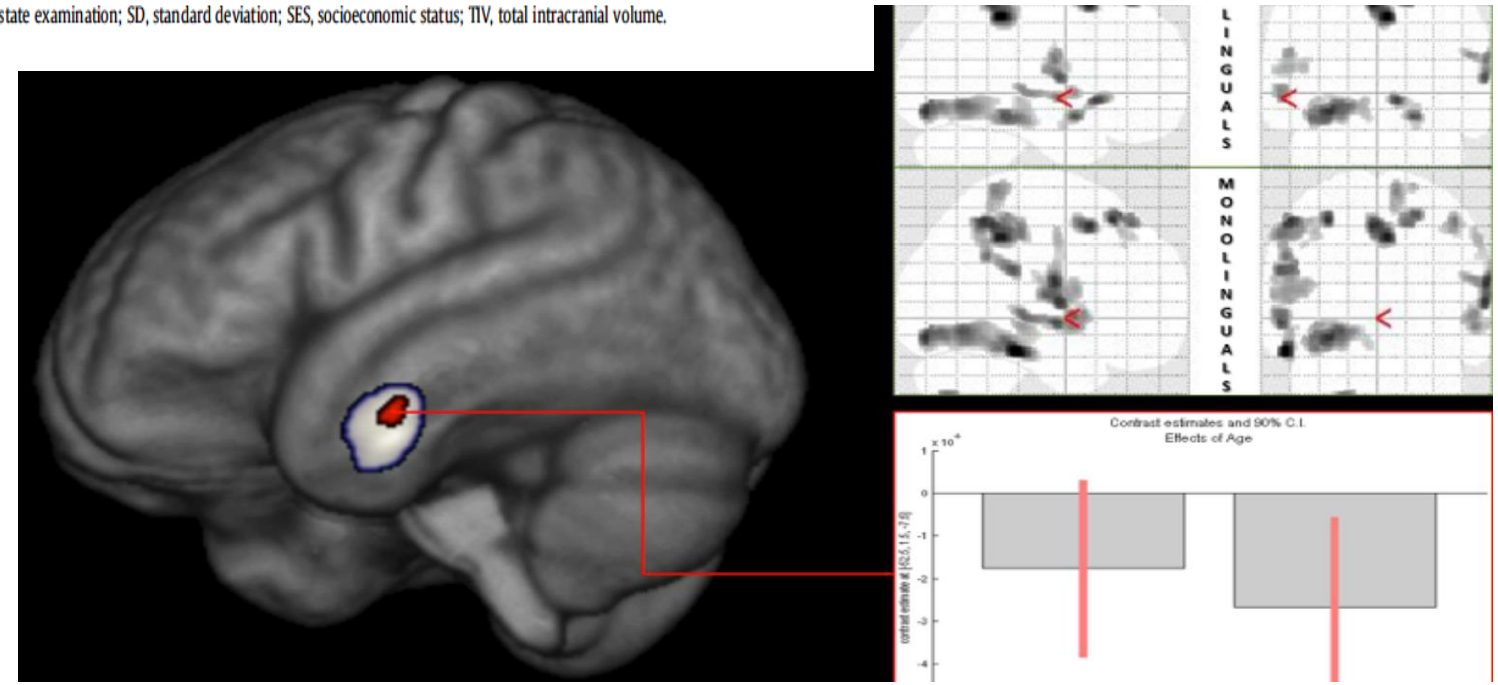
	Bilinguals N = 23 9 M/14 F			Monolinguals N = 23 10 M/13 F			*t* Test *p*-value
	Mean	SD	Range	Mean	SD	Range	
Age	62.17	5.36	55:73	61.92	6.80	49.29:74	0.888
Education	13.87	5.25	6:26	12	4.41	5:25	0.198
MMSE	28.91	0.67	28:30	28.74	0.92	27:30	0.466
TIV	1021.77	107.81	854:1250	1107	116	926.56:1370.5	0.013[a]
SES	21.1	8.4	14.5:37.5	22	7	12:36	0.544

Key: F, female; M, male; MMSE, mini mental state examination; SD, standard deviation; SES, socioeconomic status; TIV, total intracranial volume.
[a] *p* is significant at the 0.05 level.

Bilingualism protects anterior temporal lobe integrity in aging

Jubin Abutalebi [a,b,*], Matteo Canini [b,c], Pasquale A. Della Rosa [c], Lo Ping Sheung [a], David W. Green [d], Brendan S. Weekes [a]

AGING EFFECTS



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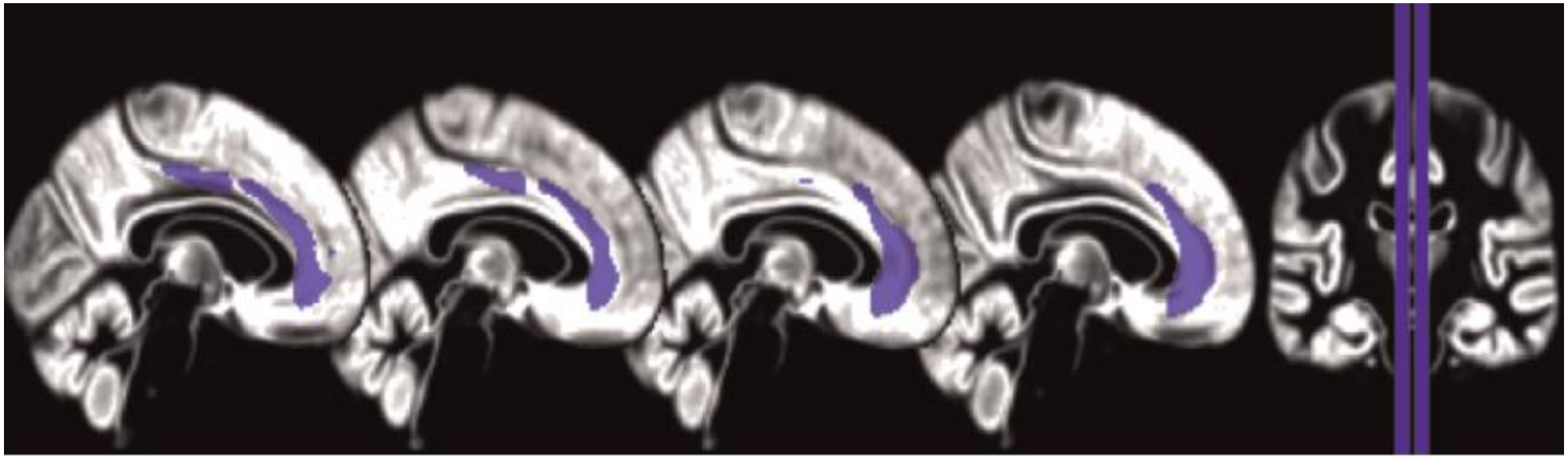
Bilingualism provides a neural reserve for aging populations

Jubin Abutalebi [a,b,*], Lucia Guidi [b,c], Virginia Borsa [b], Matteo Canini [b,d], Pasquale A. Della Rosa [d], Ben A. Parris [e], Brendan S. Weekes [a]

BILINGUALISM AS A NEURAL RESERVE



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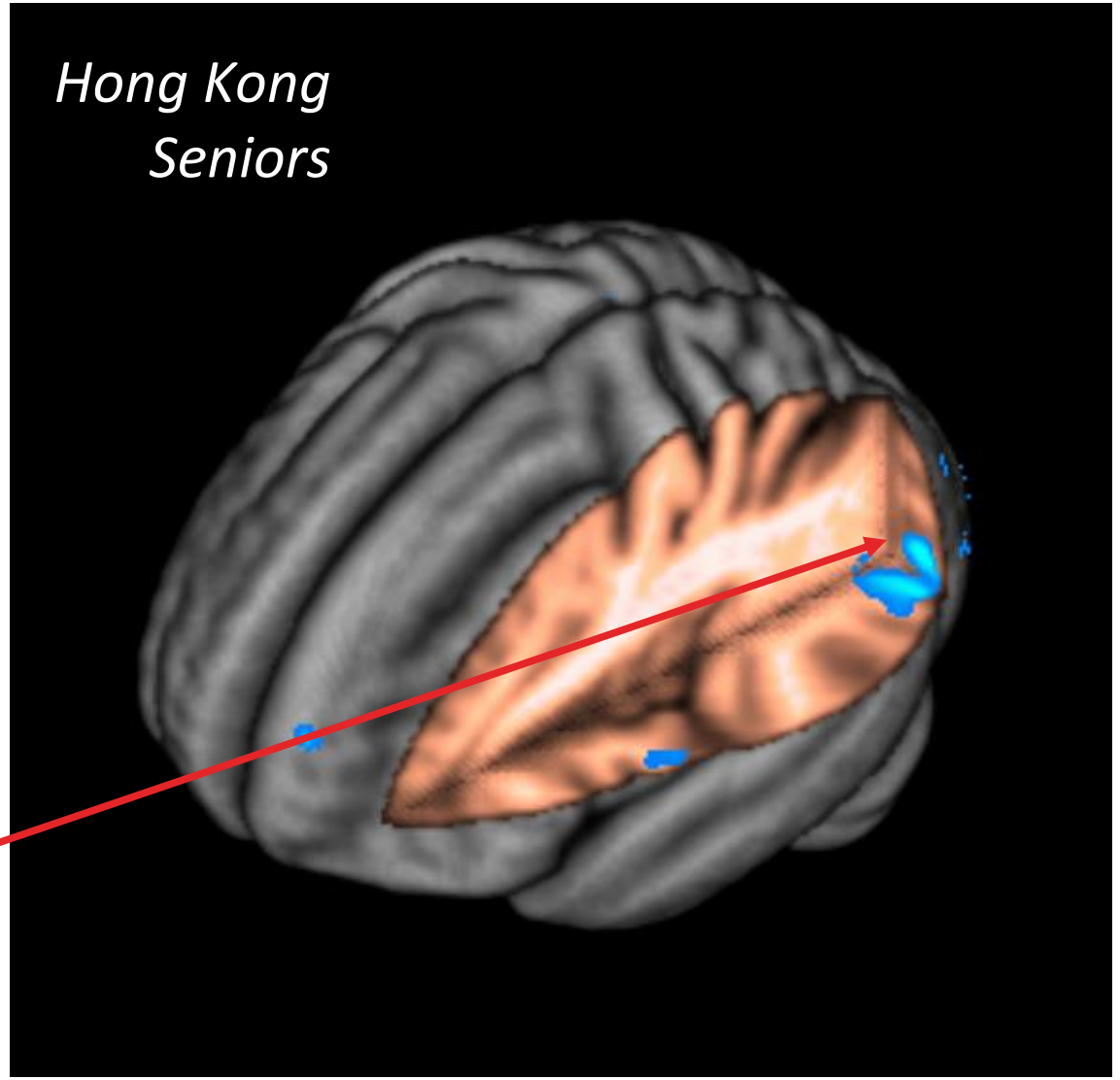
LANGUAGE PROFICIENCY POSITIVE CORRELATION WM

GROUP RESULTS;n=34; (p<0.001; 10 voxels)



Left Inferior parietal lobule

03/03/12

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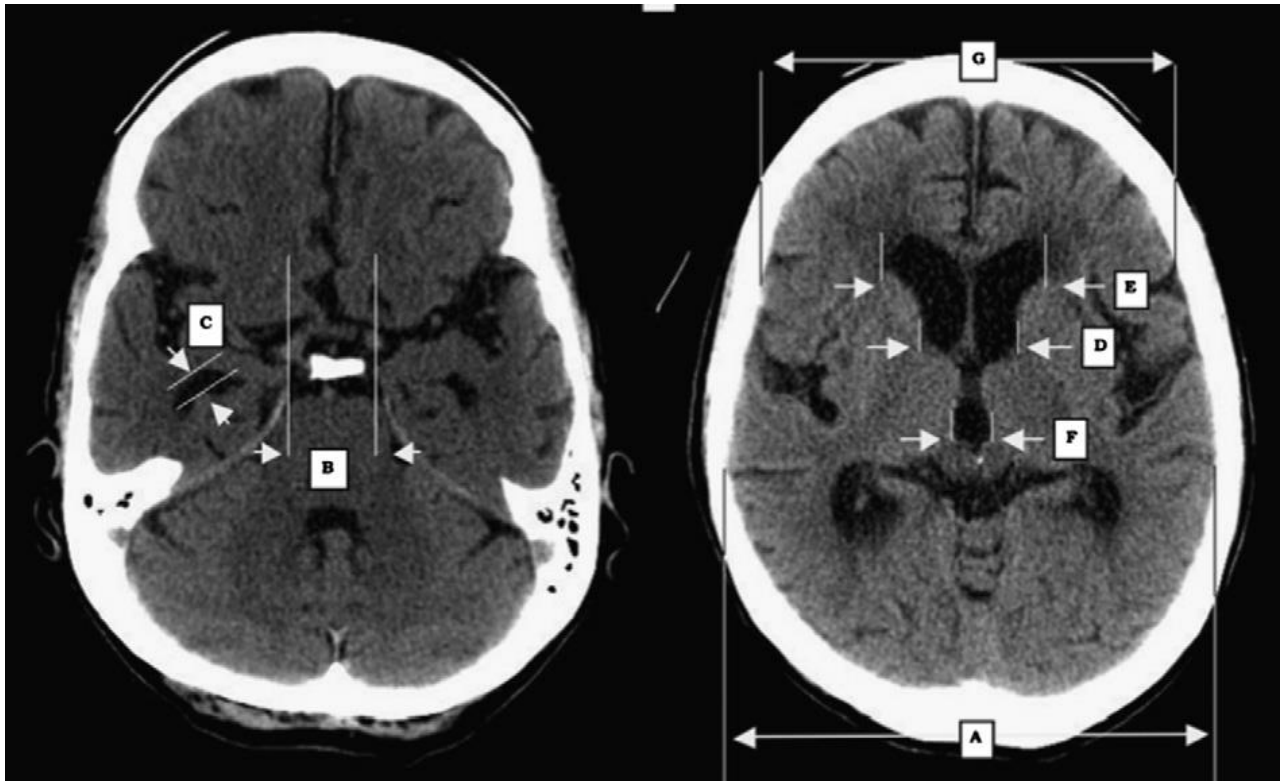
Bilingualism as a contributor to cognitive reserve: Evidence from brain atrophy in Alzheimer's disease

Tom A. Schweizer [a,b,c,*], *Jenna Ware* [b], *Corinne E. Fischer* [a,d], *Fergus I.M. Craik* [e,f] *and Ellen Bialystok* [e,g]



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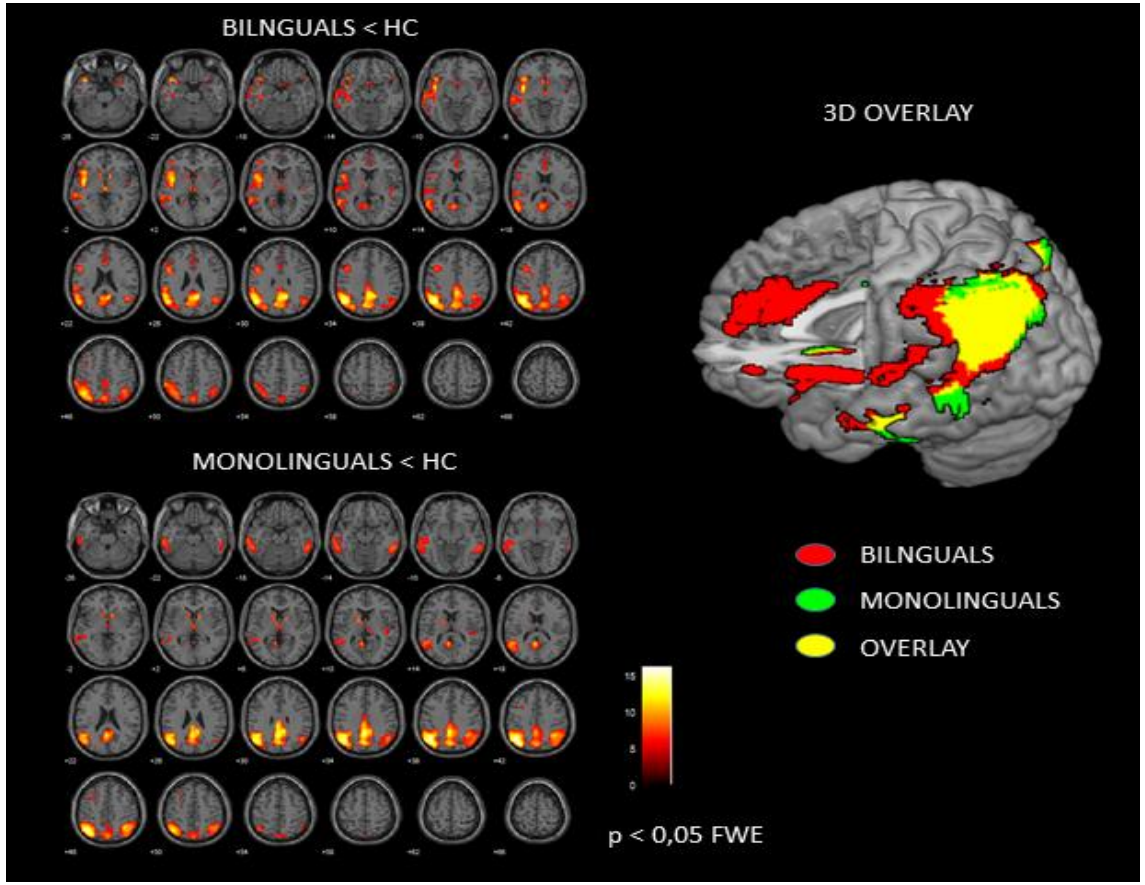
Neural reserve vs Neural Compensation

Bilingualism and brain reserve in Alzheimer's dementia: a brain metabolism and connectivity study

Daniela Perani[a,b,c,1], Mohsen Farsad[d], Tommaso Ballarini[b], Francesca Lubian[e], Maura Malpetti[a], Alessandro Fracchetti[f], Giuseppe Magnani[g], Albert March[e], and Jubin Abutalebi[a]

[a]Vita-Salute San Raffaele University, 20132 Milan, Italy; [b]Division of Neuroscience, San Raffaele Scientific Institute, 20132 Milan, Italy; [c]Nuclear Medicine Unit, San Raffaele Hospital, 20132 Milan, Italy; [d]Nuclear Medicine Unit, Azienda Sanitaria dell'Alto Adige, 39100 Bolzano, Italy; [e]Memory Clinic, Geriatric Department, Azienda Sanitaria dell'Alto Adige, 39100 Bolzano, Italy; [f]Department of Physics, Azienda Sanitaria dell'Alto Adige, 39100 Bolzano, Italy; and [g]Department of Neurology, San Raffaele Hospital, 20132 Milan, Italy



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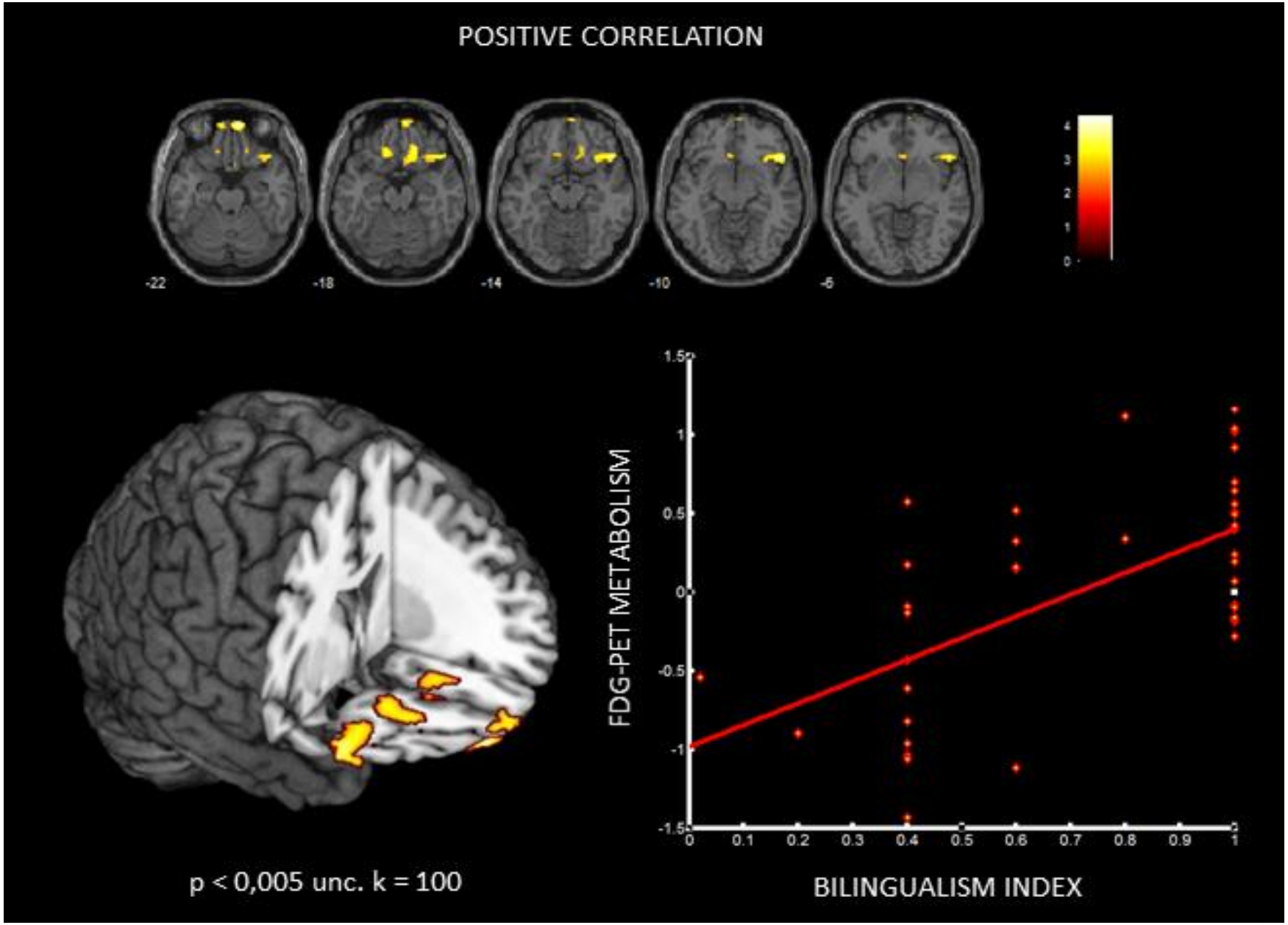

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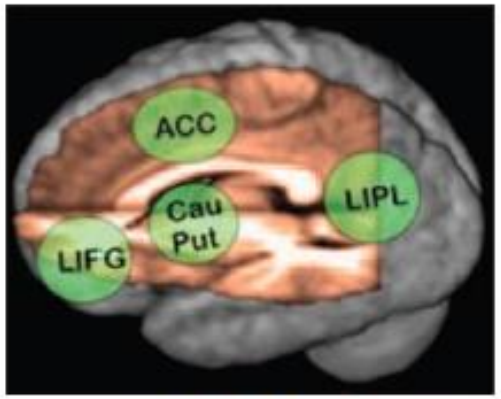
Lifelong usage of two or more languages

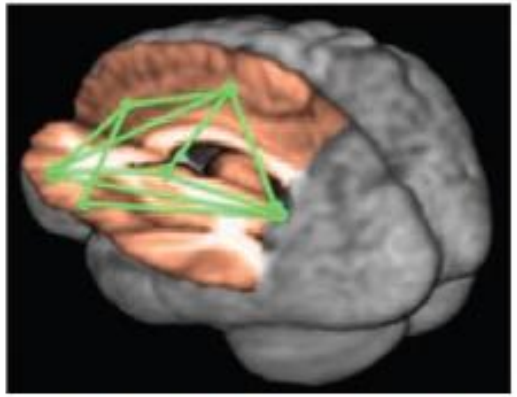
Enhancement of executive control

Neurostructural changes (grey/white matter)



NEURAL RESERVE

Neurofunctional changes (brain connectivity)



NEURAL COMPENSATION

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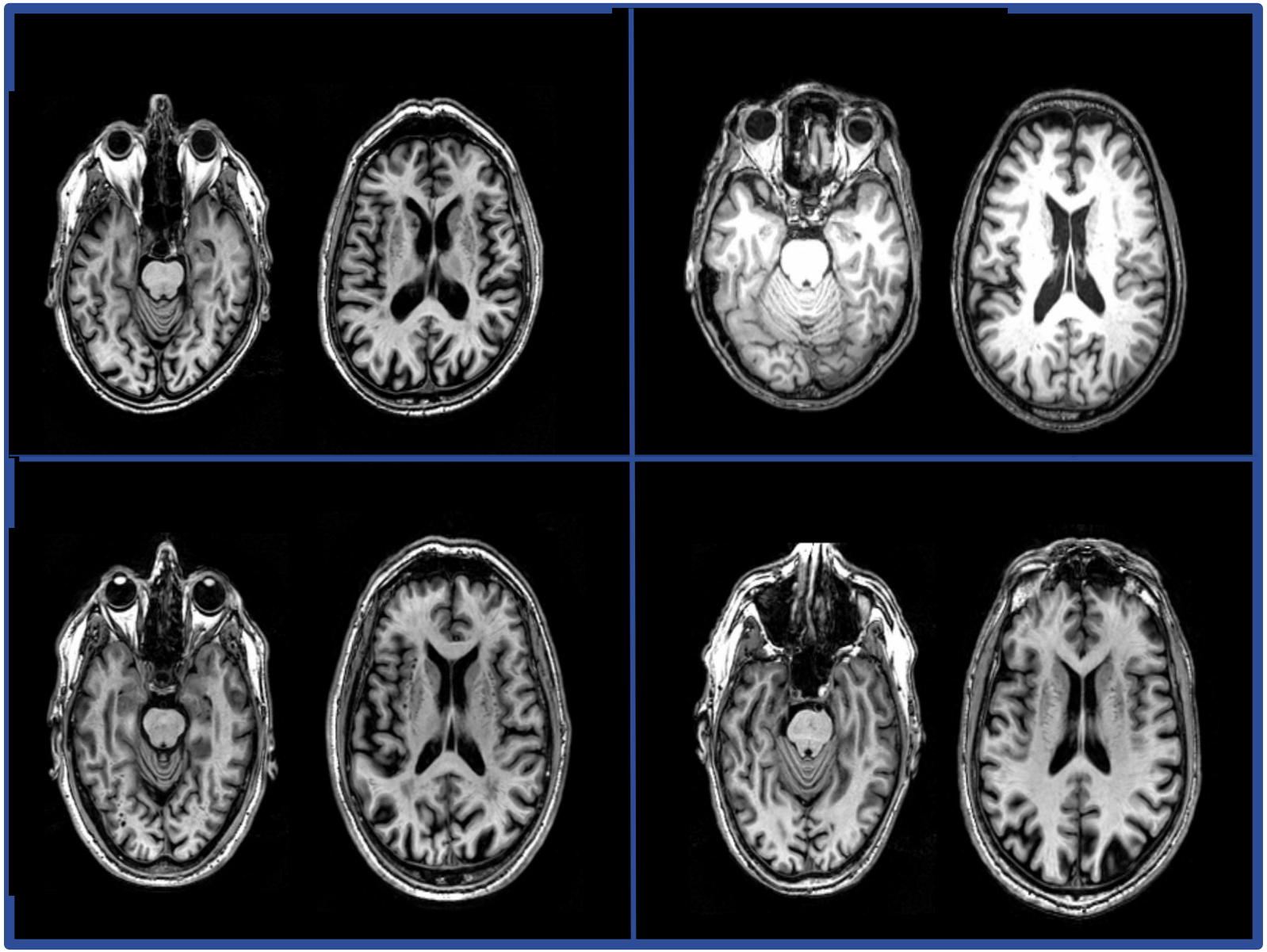

Neural compensation: individuals with loss of brain structure, such as brain atrophy in aging and neurodegeneration in diseases, are still able to almost function normally.

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Floor discussion about best learning methods for high school settings

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