Bilingualism, cognitive reserve and lexical learning

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1. Bilingualism: who's bilingual?

- Bloomfield (1933:55): '*native-like* control of two or more languages'
- Weinreich (1953:1): 'the practice of alternately using two languages'
- Grosjean (1997): 'the use of two (or more) languages in one's everyday life, **not** knowing two or more languages equally well and optimally'
- Important to remember that bilinguals may be competent in speaking and listening, but less competent in reading and writing

1.2. About half of the people in the world are at least somewhat bilingual (Fabbro, 1999)

- Some people live in bilingual regions: Québec, Catalonia, Belgium…
- Others become bilingual because their home language is not the language used for school and business (Tunis, US-Spaniards, some countries in Asia, etc.)

1.2. Bilingualism: hypotheses

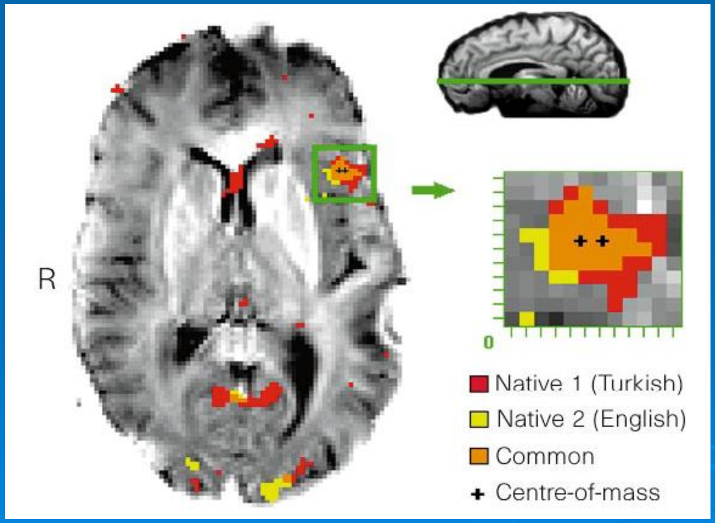
- **Single**-system hypothesis
  - The two languages are represented in just one system

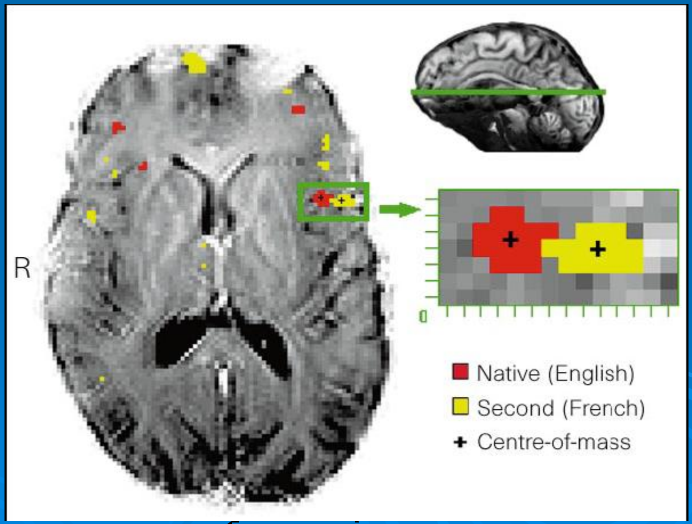
- **Dual**-system hypothesis
  - The two languages are represented somehow in separate systems in the mind
  - When recovery of language after trauma is studied, sometimes the first language recovers first, sometimes the second language recovers first

1.3. fMRI and bilingualism

•Some studies have found similar patterns in early and late bilinguals (Chee et al., 1999b)

•Some others have found different patterns of activation in sentence production in early and late bilinguals





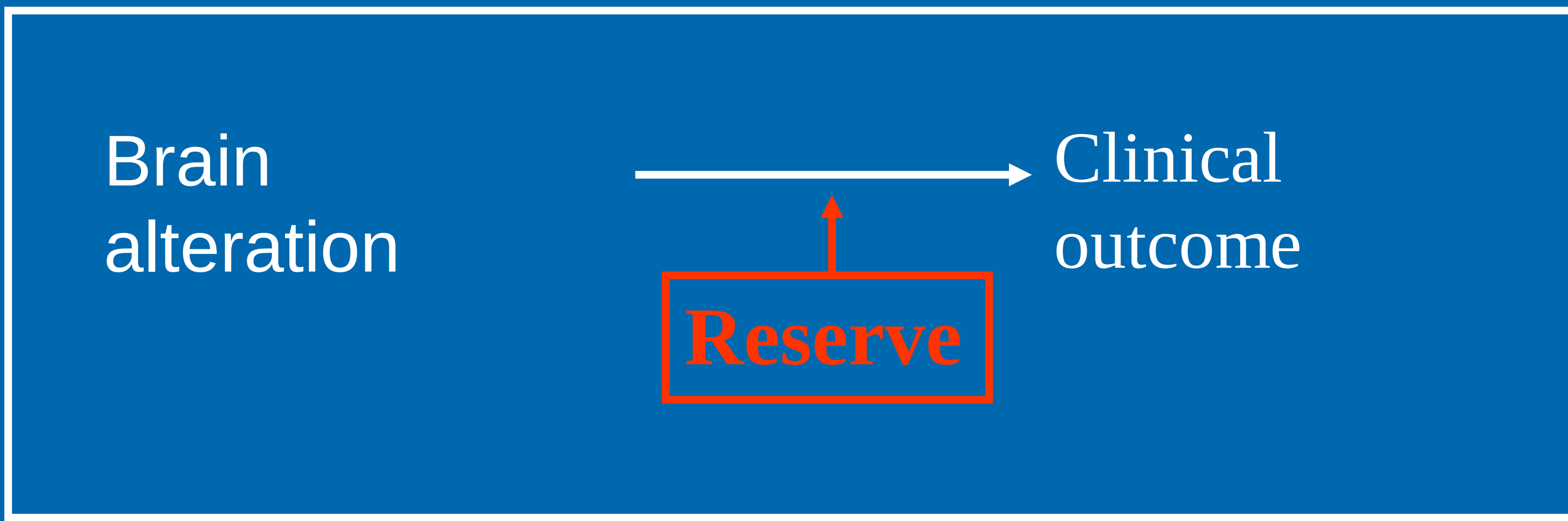
Kim et al, 1997

1.3.1. Research on bilingualism

- Early researchers thought that bilingualism entailed cognitive handicap: the brain having to manipulate two linguistic systems could involve less cognitive efficiency

- Impact by the first well-controlled study comparing monolinguals with bilinguals (Peal & Lambert, 1962):
  - more advanced in school
  - better on tests of first-language skills (grammar and syntax)
  - showed greater cognitive flexibility (or cognitive control)

2. Cognitive Reserve and ageing



Reserve can be explained as the discordance between the degree of brain alteration and its clinical symptoms

2.1.Passive Models

*Brain Reserve

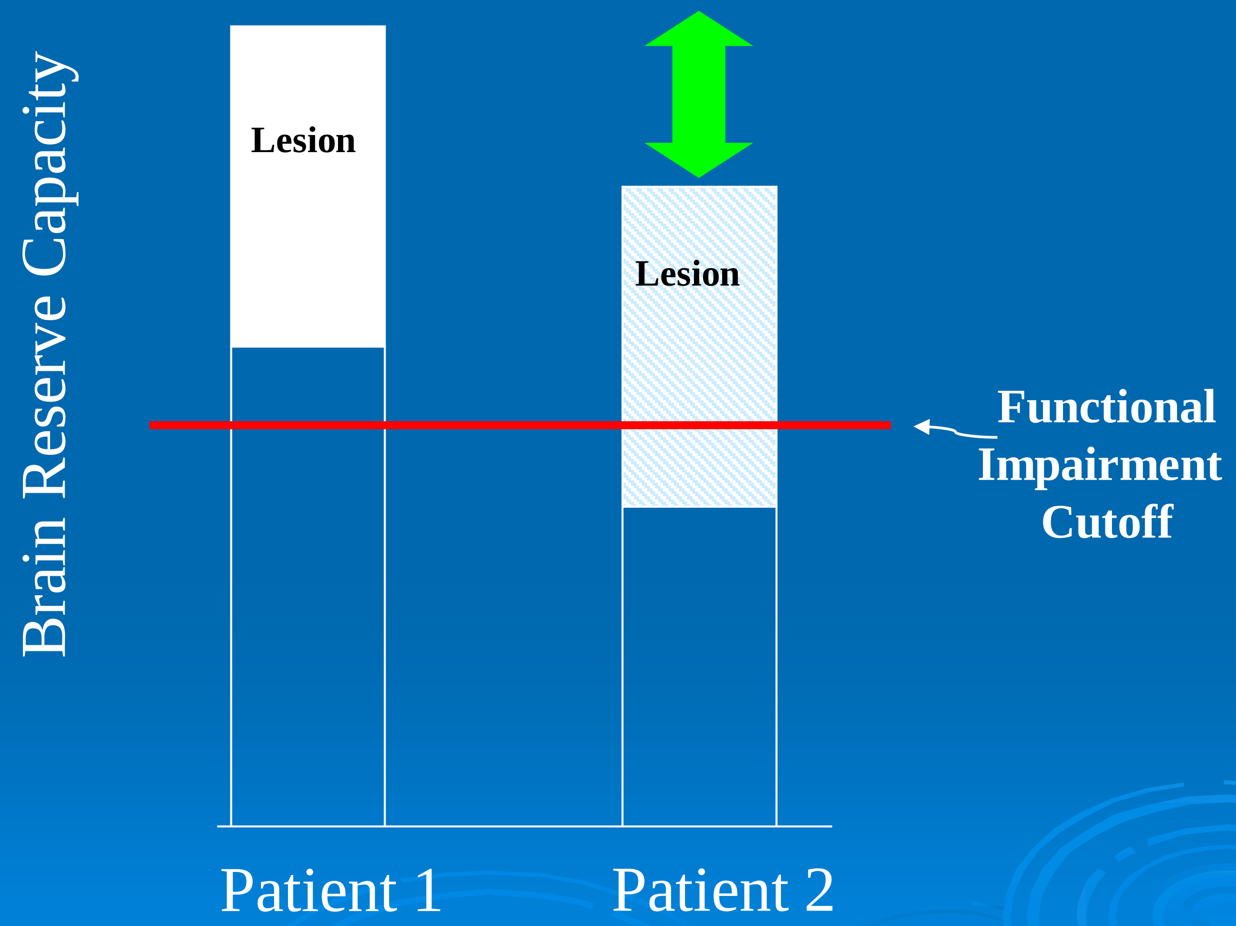
*Neuronal Reserve

Threshold hypotheses

2.1.1.Threshold (Satz,1993)

- Hypothetical construct: “Brain Reserve Capacity” (BRC)
- Concrete examples of BRC: brain size, **neuronal count**
- There is individual variation in BRC
- There is a critical threshold of BRC. Once depleted past this critical point, specific clinical or functional deficits emerge.
- Assumes that a specific type of brain damage will have the same effect in each person.
- Does not recognize individual differences in processing cognitive or functional tasks in the face of by brain damage.

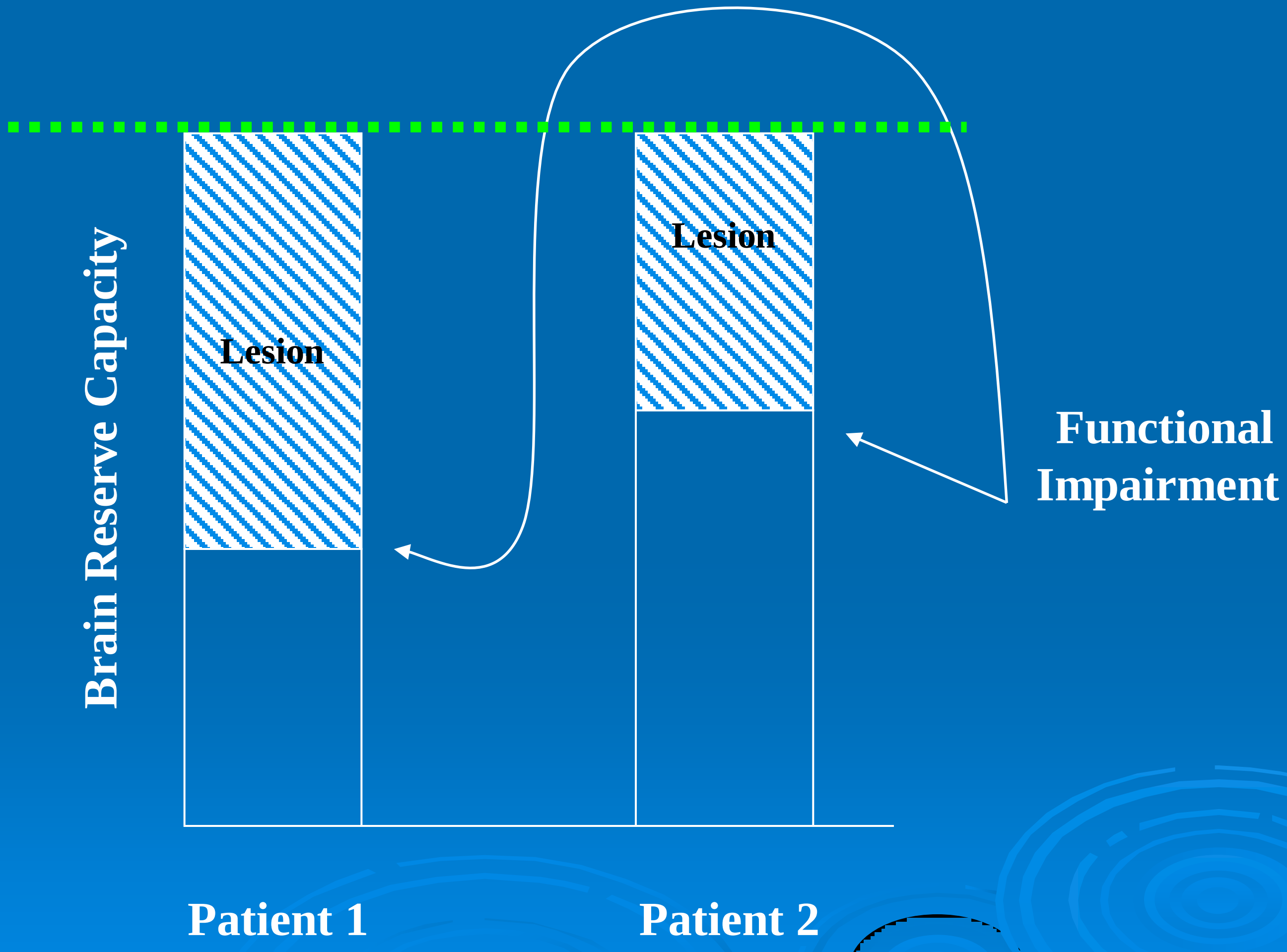
2.1.1.Passive, threshold model



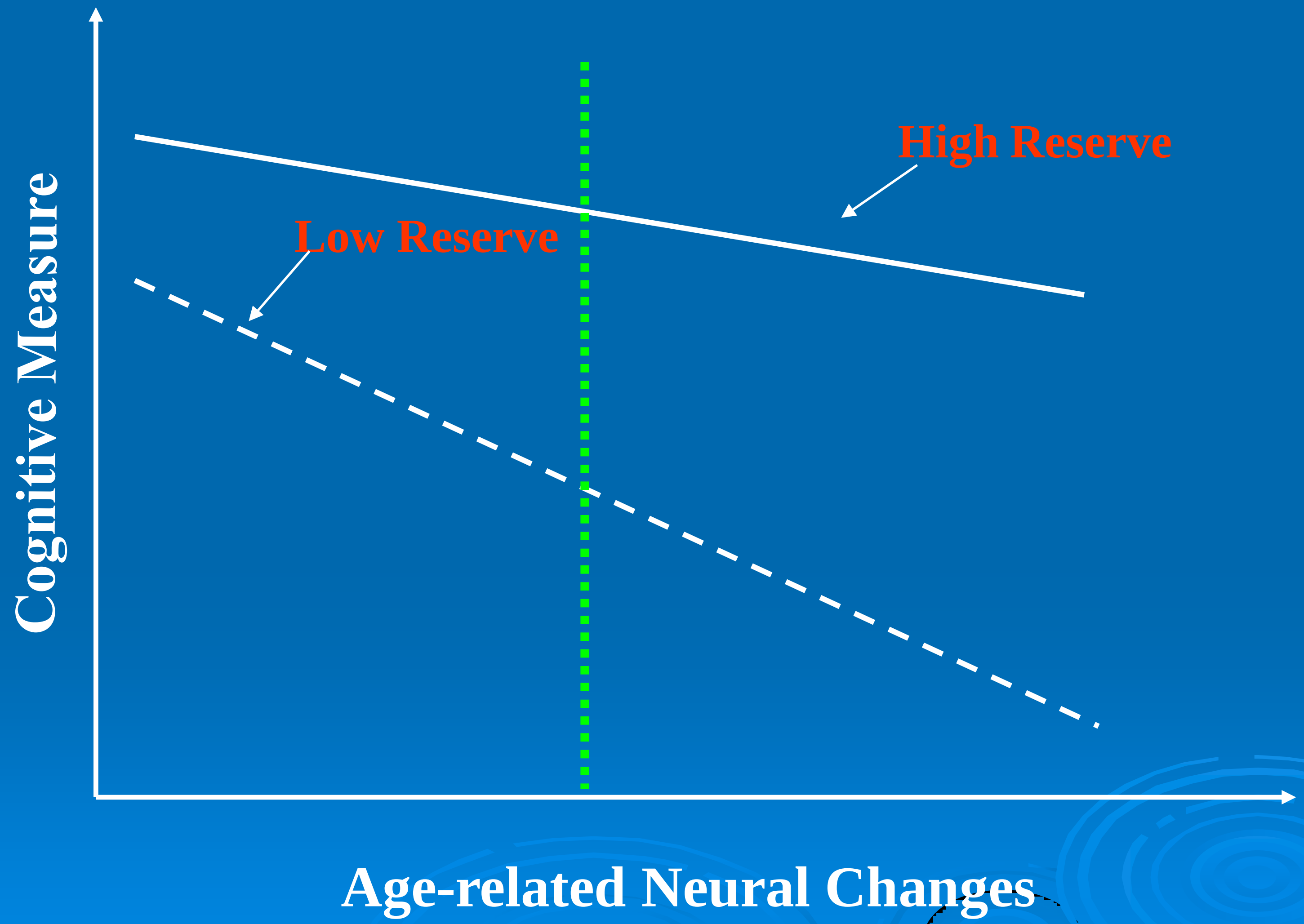
2.2. Active Model of Reserve

- Relies on the quality of the response -- not the amount of BRC.
- Relies more on the "software" than the "hardware"
- **Reserve can vary** when BRC is held constant

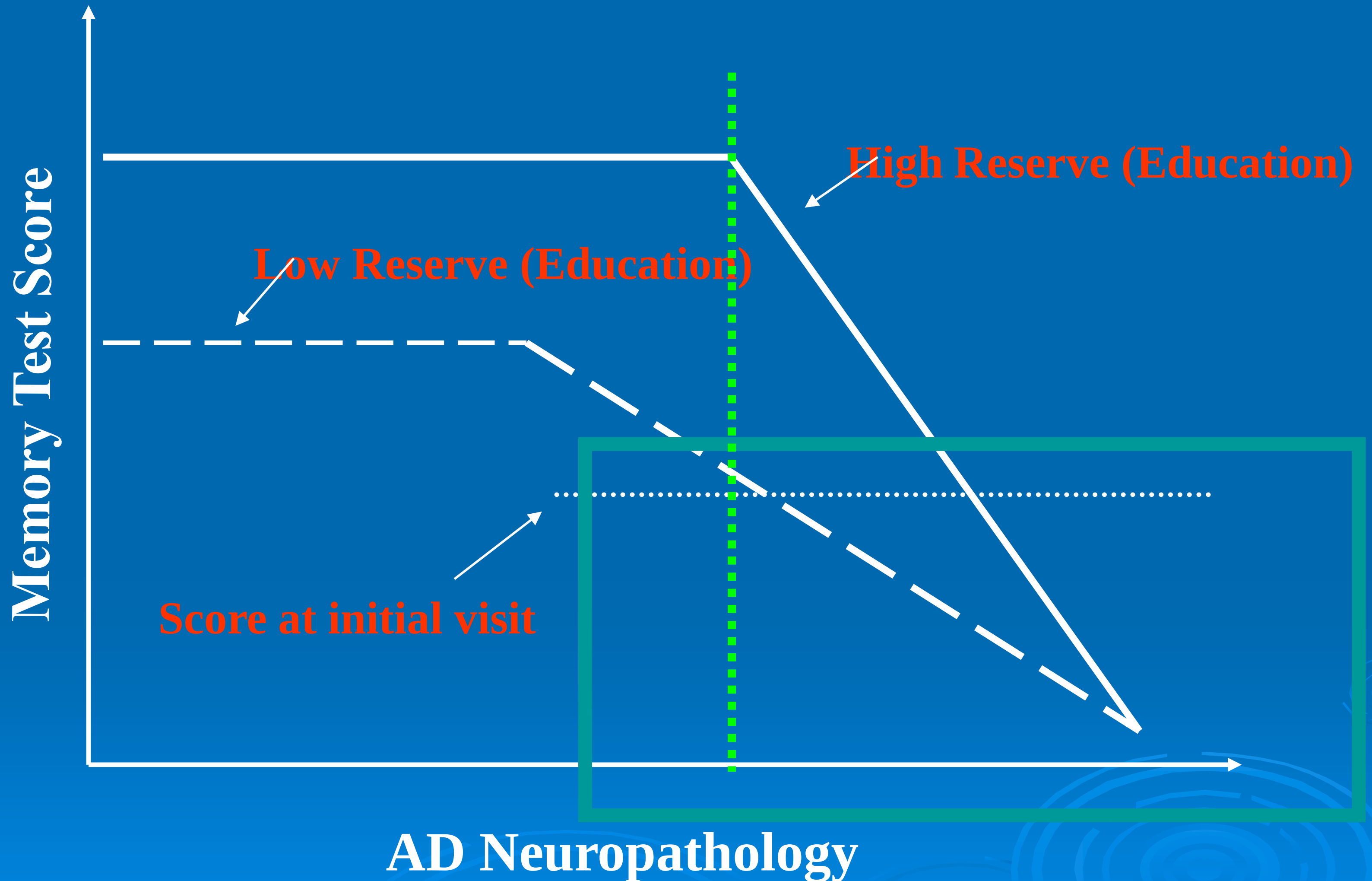
2.2. Active Model



2.3. Discordant cognitive profiles



2.3.1. High reserve = more abrupt decay



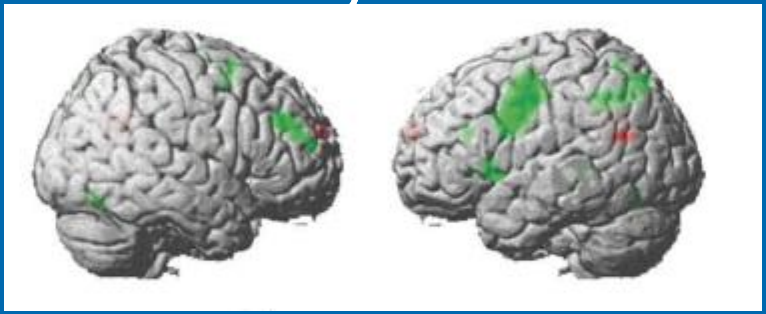
Stern et al Neurology 1999

2.4. Cognitive Reserve (CR)

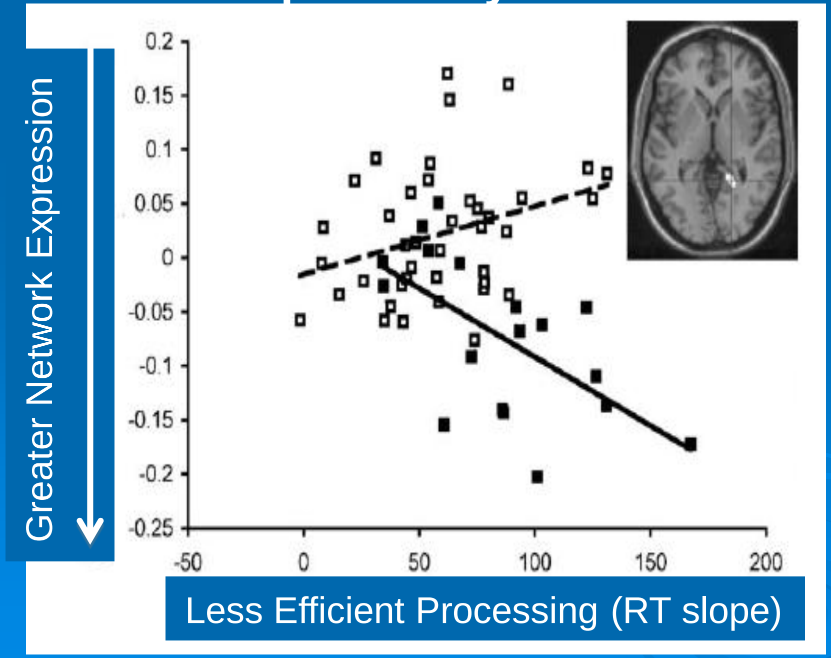
- Resilience/plasticity of cognitive networks in the face of disruption
- Exercise and cognitive stimulation can activate brain plasticity mechanisms and remodel neuronal circuitry in the brain.
- increase vascularization, neuronal survival and resistance to brain insult, BDNF, serotonin, dopamine, neurogenesis in the dentate
    - Neural Reserve: efficiency/capacity of existing brain networks
    - Neural Compensation: ability to adapt alternate networks or brain areas

2.4.1.Neural Reserve and Neural Compensation

Primary Network



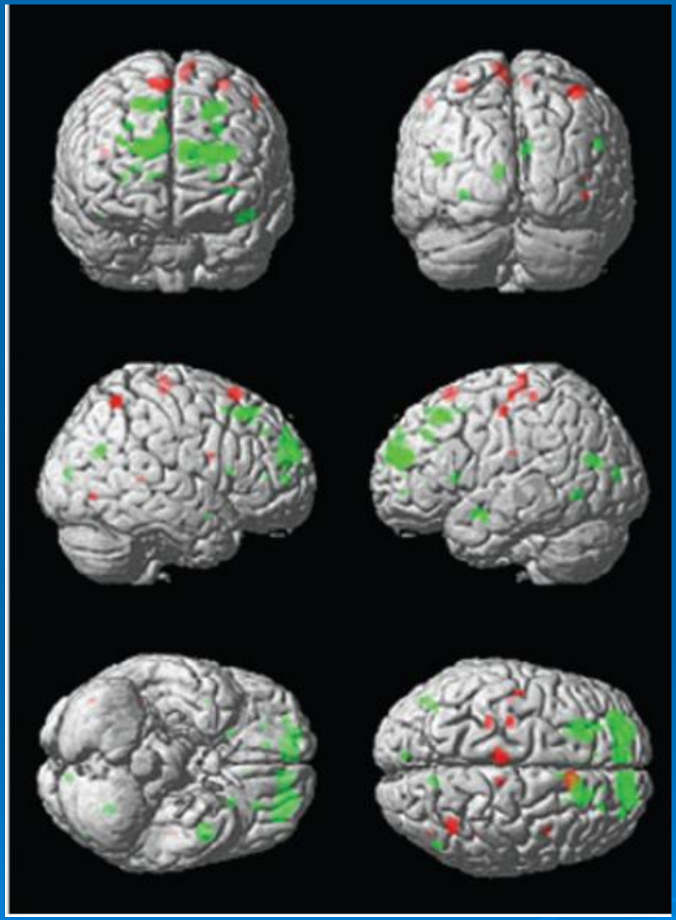
Compensatory Network



- The primary network was expressed by both young and old
- Higher expression of the primary network was associated with poorer performance in younger adults → Neural Reserve
- The "compensatory" network is expressed primarily by the elders; higher expression was associated with poorer performance

Zarahn et al., Neurobiol Aging 2007

2.4.2. Generalized representation of CR

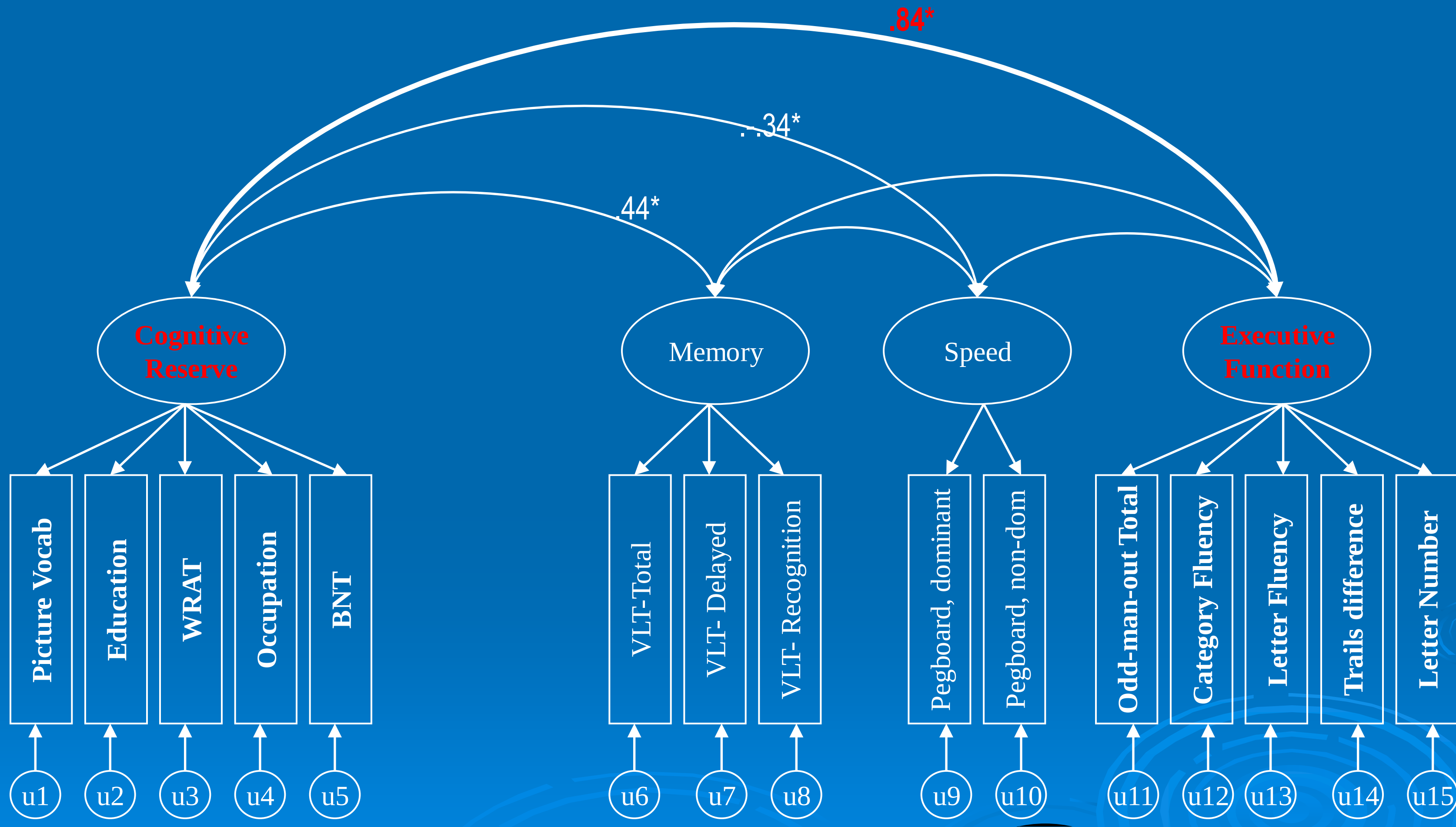


- In the context of complex tasks, the executive network represents the neural instantiation of CR

- *Areas in this CR-related network have been associated with executive and control processes*

Stern et al., Cerebral Cortex, 2007

2.4.3. CR and Executive Function



Siedlecki et al, JINS, in press

2.4.4. Concluding remarks

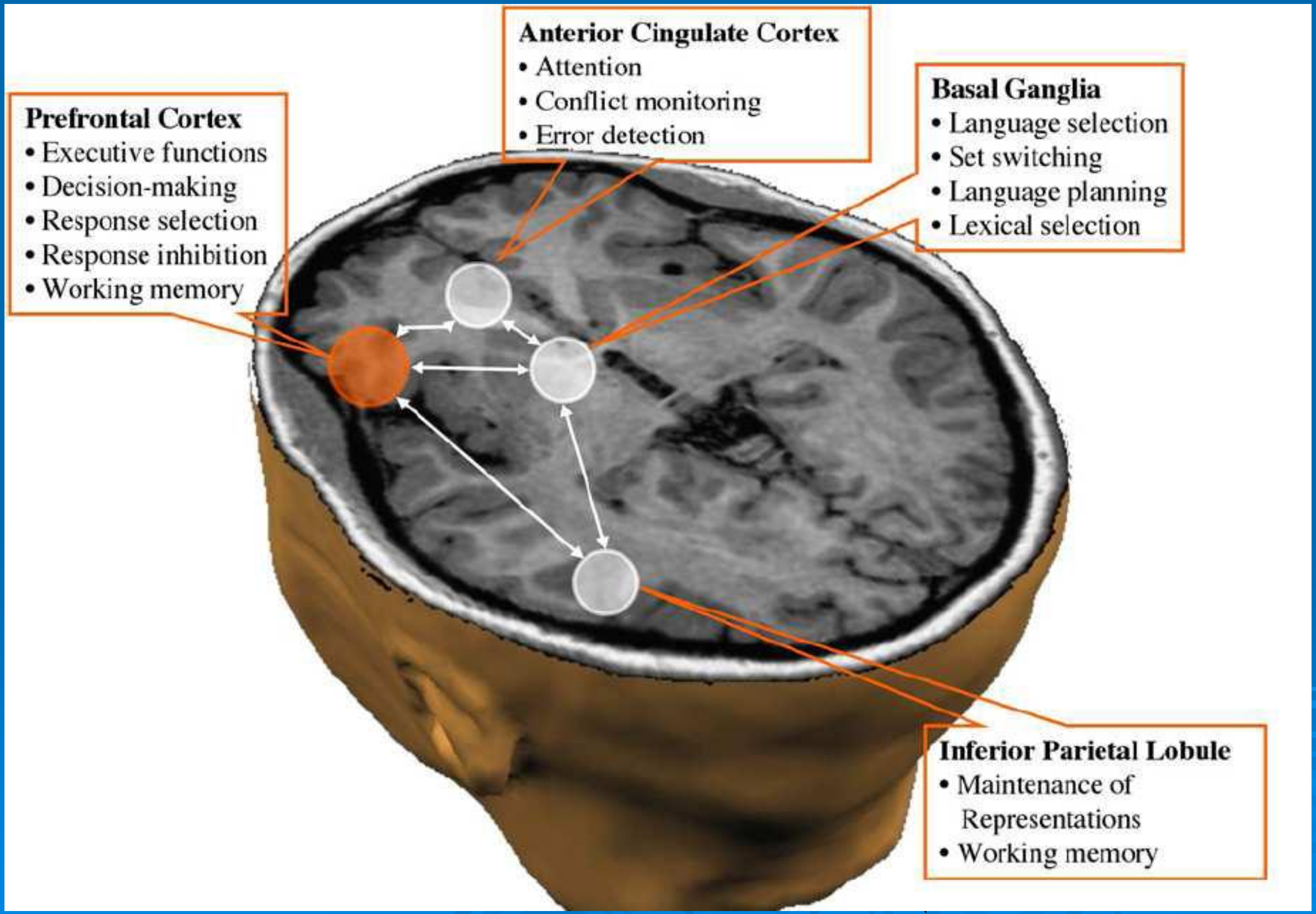
- Reserve is malleable: it is influenced by aspects of experience in every stage of life
- Cognitive reserve may be mediated by efficiency/capacity of existing brain networks, ability to enlist new, compensatory networks, or “pure” CR-related networks
- The concept of cognitive reserve is applicable to a wide range of conditions that impact on brain function at all ages, such as bilingualism???
- Influencing cognitive reserve may delay or reverse the effects of aging or brain pathology.

3. Bilingualism and Cognitive Reserve (I)

- dual task: older bilinguals are less disrupted by the secondary task (Bialystok, Craik and Ruocco, 2006)
- delayed onset of Alzheimer's disease (Bialystok, Craik and Freedman, 2007), but see (Meuter and Simmons, 2008)
- faster RTs during interference control – Simon Task (Bialystok et al., 2004; Meuter and Simmons, 2008)
- Simon task: **bilinguals were faster** than monolinguals **in each age group** specially in conditions with high **working memory** demands

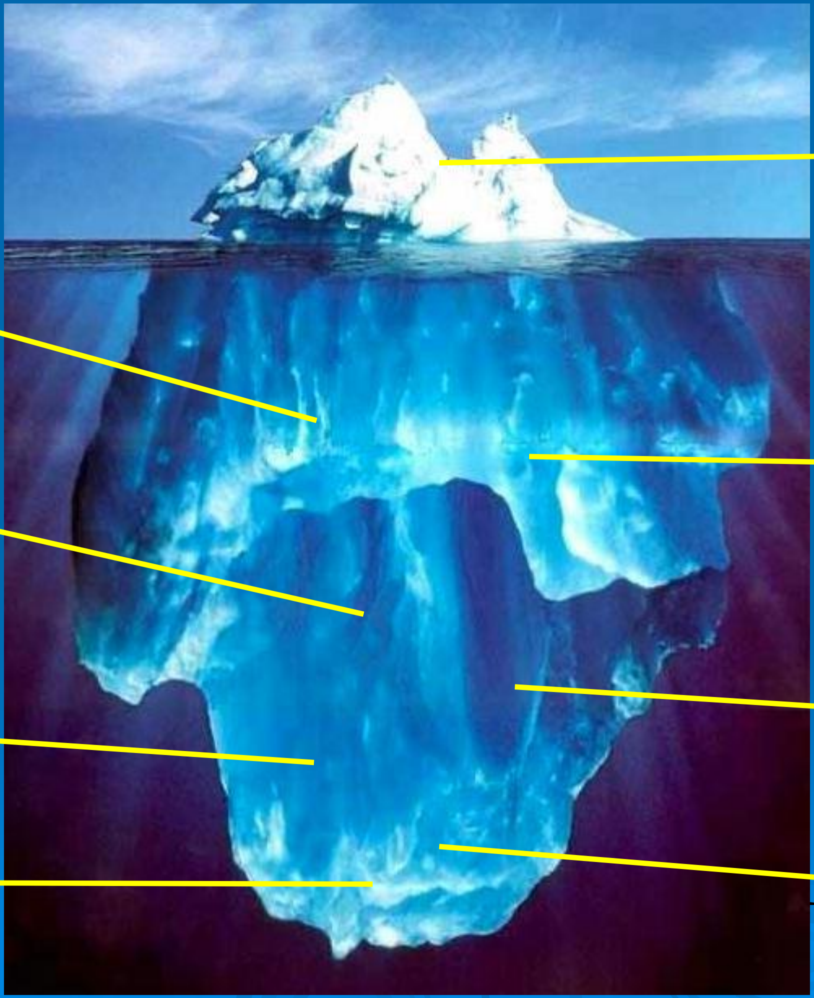
3. Bilingualism and Cognitive Reserve (II)

LIFG (Broca's area) and RIFG: task switching and language control



Proposed by Abulatebi and Green, 2007

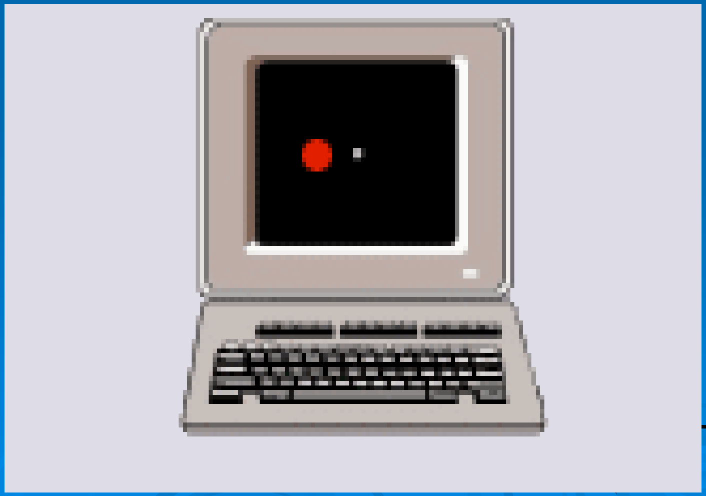
3. Bilingualism and Cognitive Reserve (III)



3.1. A task to explore interference control

Rule: **red** circle = left; **blue** circle = right

- The processing of the (irrelevant) location of the circle interferes with the processing of the colour (relevant)
- Simon effect: cost for incongruent trials

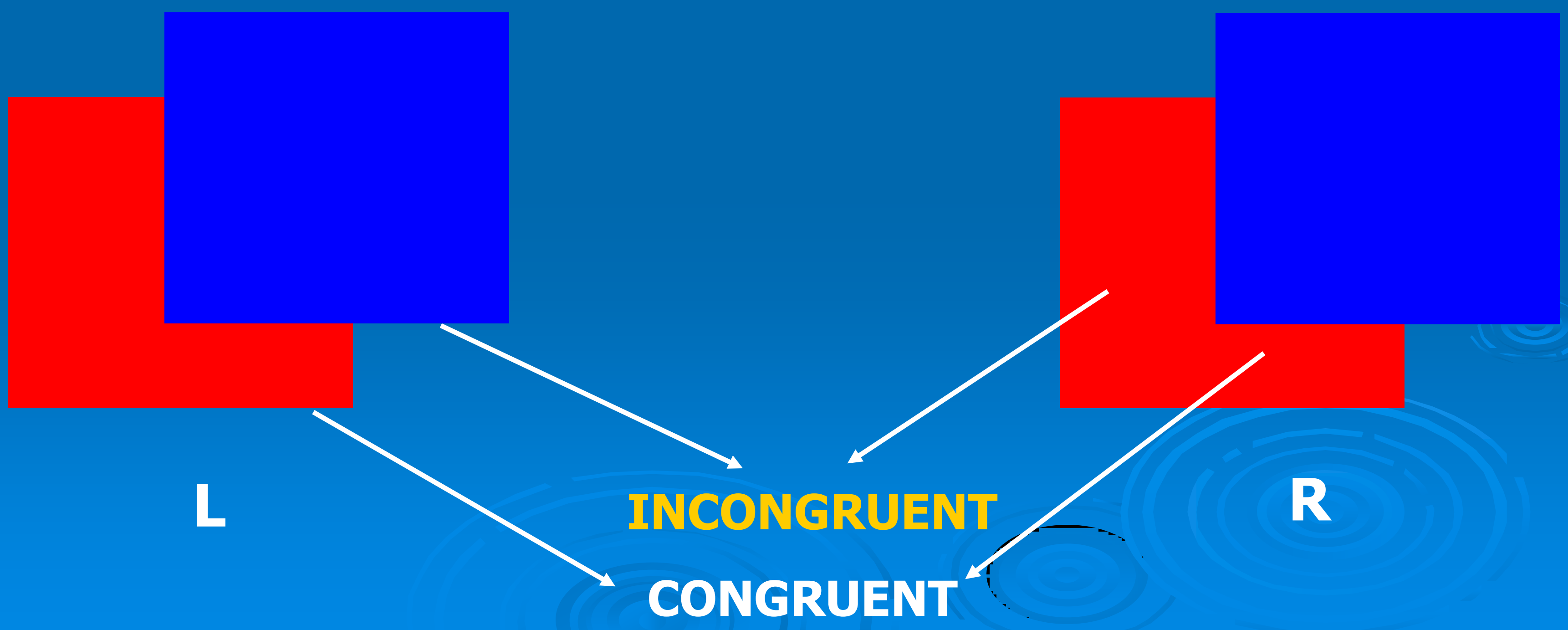


3.1. The Simon effect (SE)

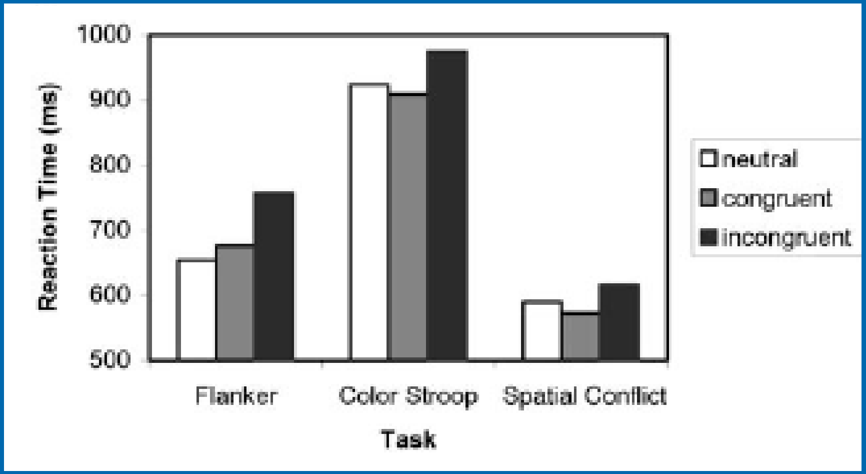
red square = left

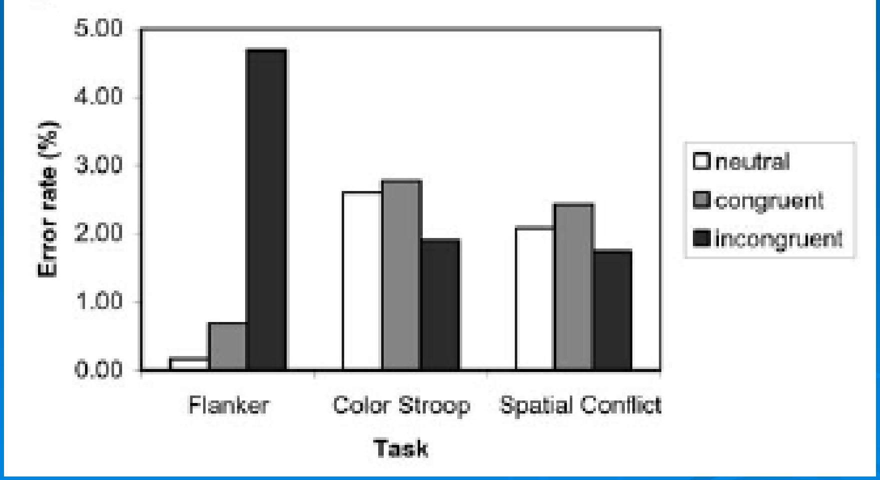
blue square = right

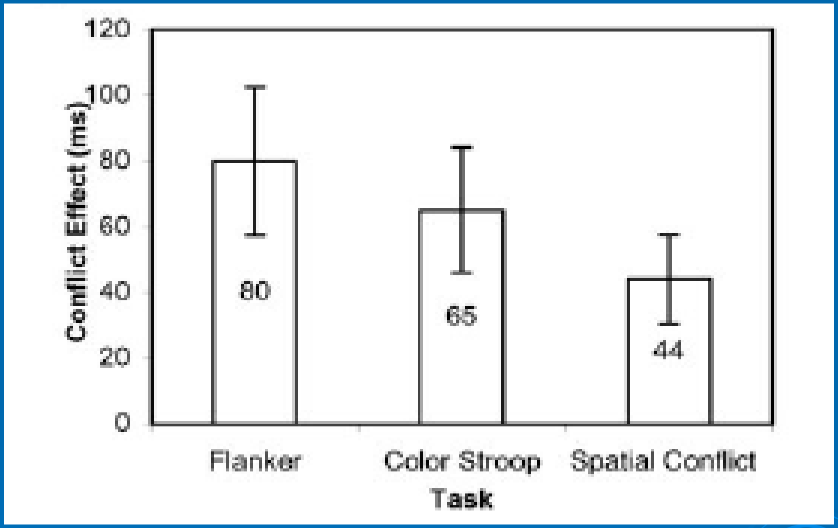
SE = incongruent - congruent



3.2. Interference control: behavior

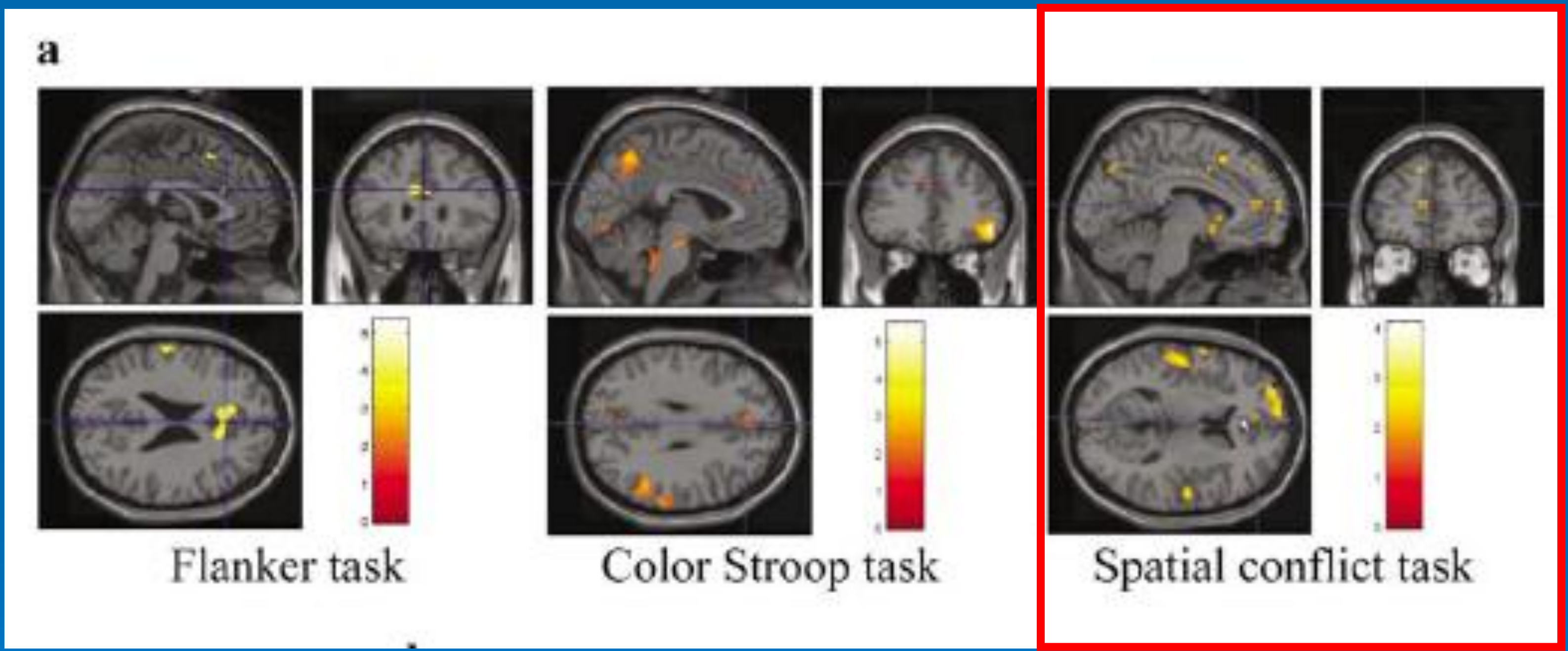






Fan et al.,2003

3.2. Interference control: neural correlates



Fan et al.,2003

3.3. Participants and neuropsychological testing

- 12 elderly French monolinguals
- 12 elderly French-English lifelong bilinguals
- Degree of bilingualism established on the basis of:
  - Language proficiency questionaire (LEAP-Q, Marian et al., 2007)
  - performance on a sensitive task (BAT, Paradis, 1989)
  - Bilingual switching task
- Handedness (Edinburgh; Oldfield, 1971)
- Cognitive status (Moca test) and mood (GDS, Brink & Yesavage, 1983)
- Other executive measures: source memory (Glisky et al., 1995) lexical retrieval (Boston Test and COWAT- FAS), TMT, Stroop, Digits and Brixton

3.4. Experimental Design

1. Neuropsychological testing (2 hours)

1 week

2. fMRI session (1 hour)

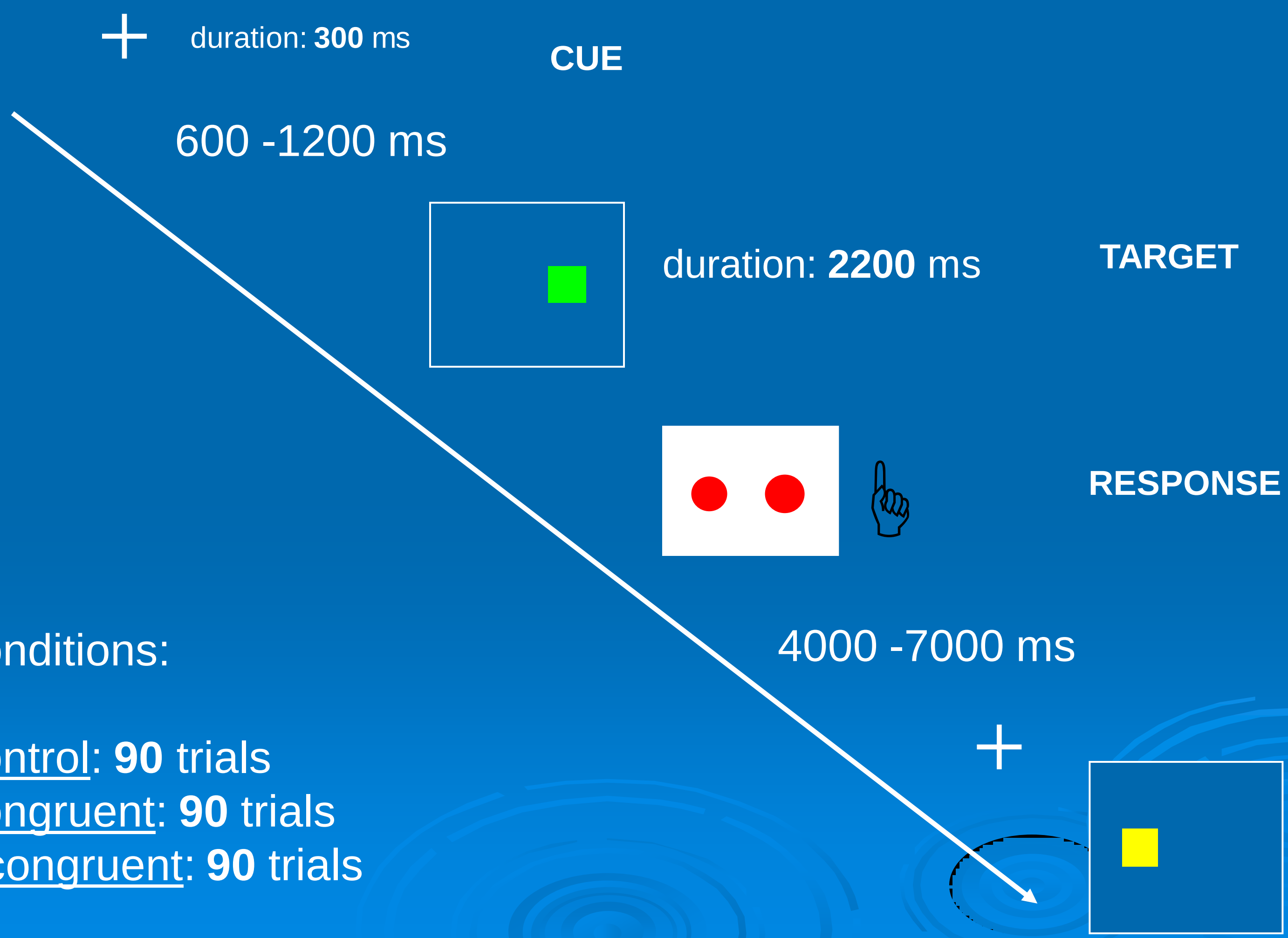
2 weeks

3. fNIRS session (1 hour)

Conditions:

Control: **90** trials
Congruent: **90** trials
Incongruent: **90** trials

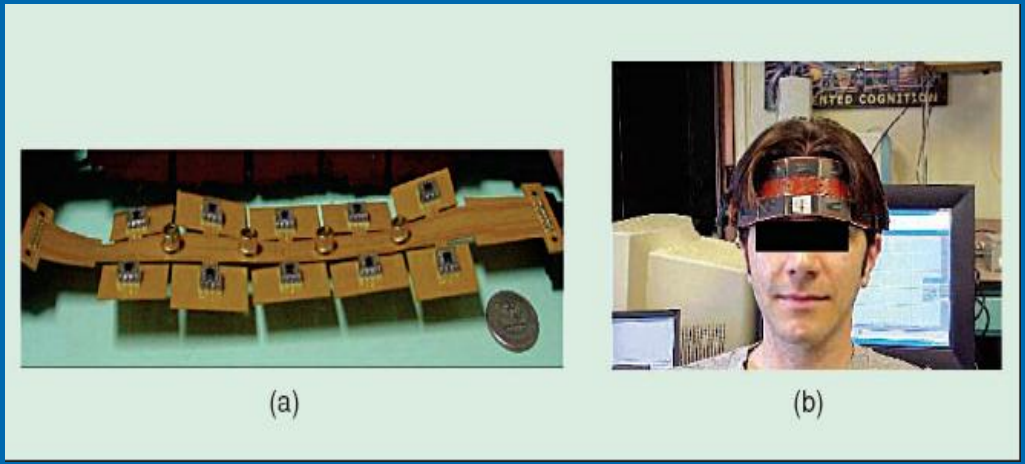
3.5. fMRI task timing

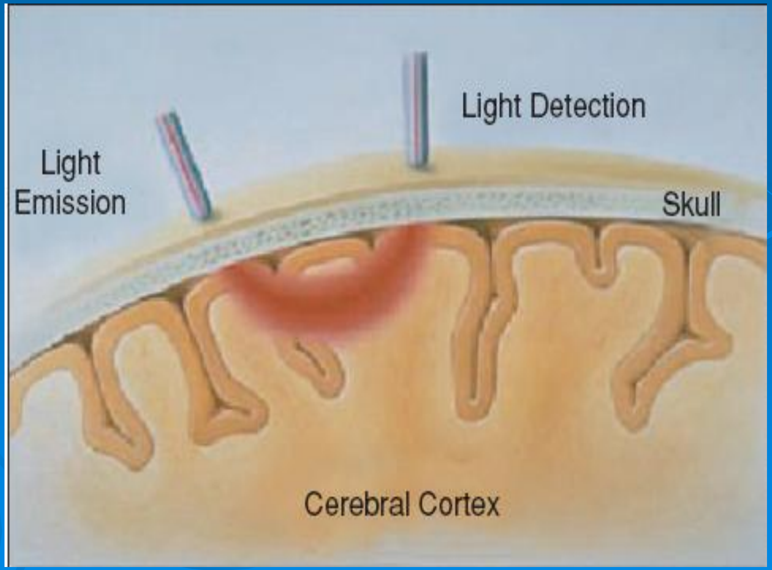


Conditions:

Control: **90** trials
Congruent: **90** trials
Incongruent: **90** trials

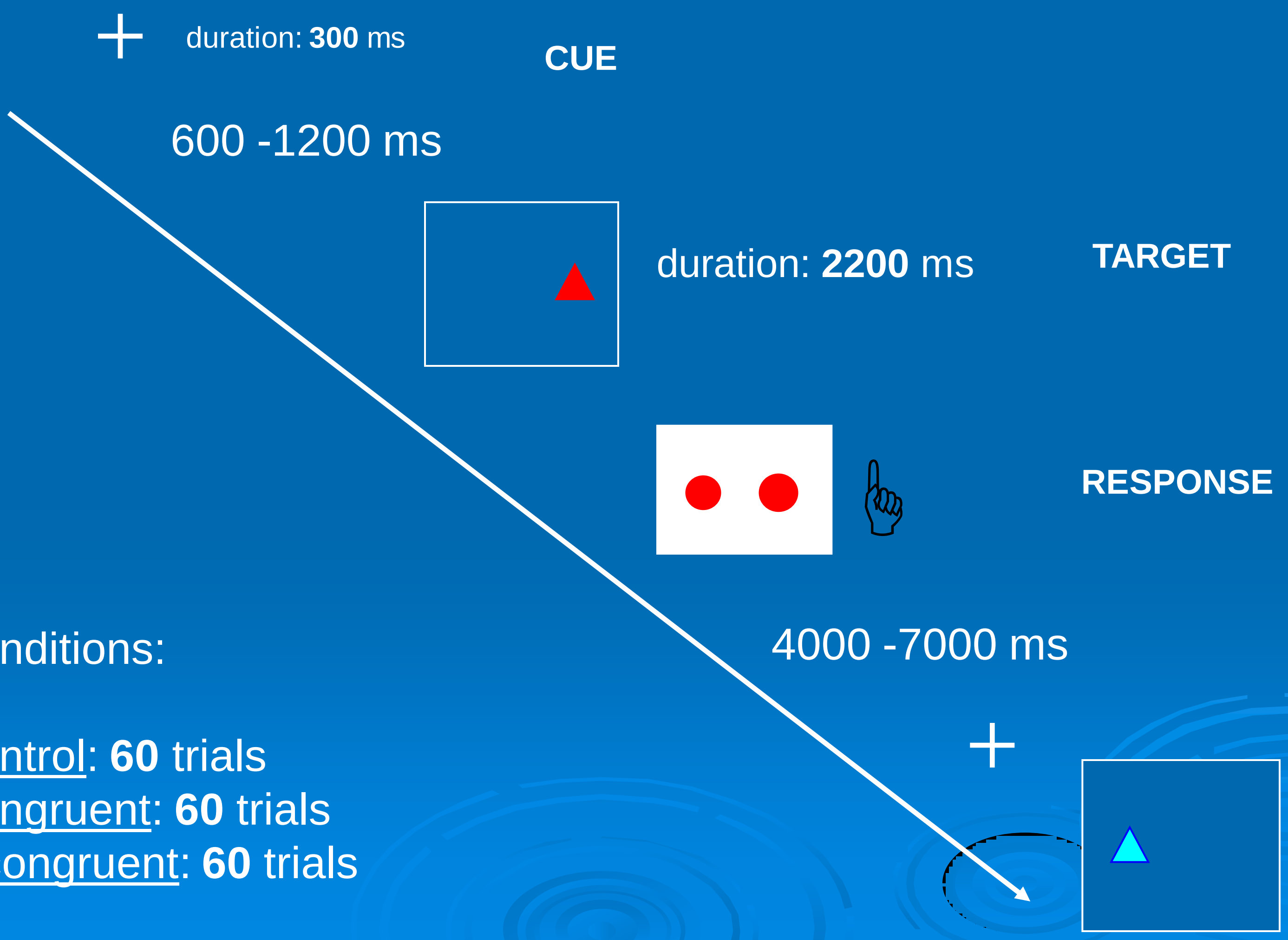
Functional near Infrared Spectroscopy (fNIRS)





- Oxy and de-oxy hemoglobin
- User friendly (elderly)
- Cheap
- Movement tolerance

3.6. fNIRS task timing



Conditions:

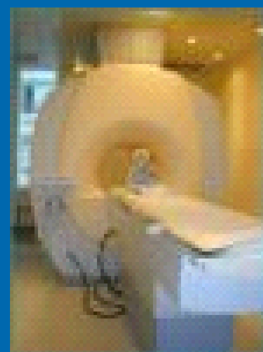
<u>Control</u>: **60** trials
<u>Congruent</u>: **60** trials
<u>Incongruent</u>: **60** trials

3.7. Future research

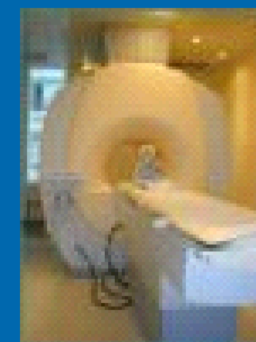
- Is there a difference between 'early' and 'late' bilinguals with respect to cognitive control in non-linguistic tasks?
- Role of linguistic distance?
- VBM (Brain reserve), cortical thickness & connectivity
- The answer will bring us closer to understanding the relationship between language and other cognitive faculties.

4. Lexical learning in young adults

5-day early learning phase



lexical learning



T0

T1

T2

First day of lexical learning

First Spanish naming task

Second fMRI session

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4.1. Cognate and non-cognate learning

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Contents lists available at ScienceDirect

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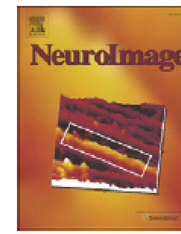

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Brain activation and lexical learning: The impact of learning phase and word type

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Raboyeau, G. Marcotte, K. Adrover-Roig, D. & Ansaldo,AI. 2009

4.1. Examples

Table 1
Examples of cognates and non-cognates (natural and manufactured items) in French, Spanish and their English translation.

Cognates			Non-cognates		
French	Spanish	English	French	Spanish	English
Abeille	Abeja	Bee	Ane	Burro	Donkey
Arbre	Árbol	Tree	Chenille	Oruga	Caterpillar
Serpent	Serpiente	Snake	Feuille	Hoja	Leave
Baleine	Ballena	Whale	Limace	Babosa	Slug
Vache	Vaca	Cow	Papillon	Mariposa	Butterfly
Armoire	Armario	Wardrobe	Bougie	Vela	Candle
Casserole	Cacerola	Pan	Balai	Escoba	Broom
Flèche	Flecha	Arrow	Casquette	Gorra	Cap
Marteau	Martillo	Hammer	Chaussure	Zapato	Shoe
Tambour	Tambor	Drum	Montre	Reloj	Clock

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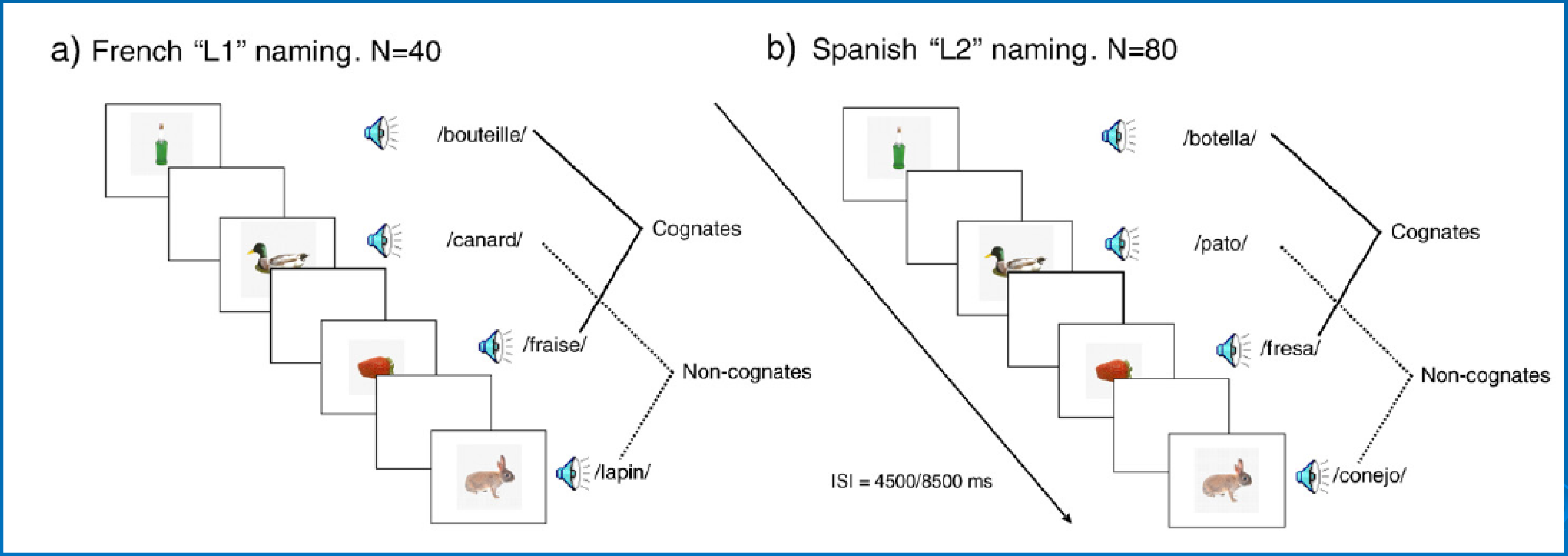
4.2. fMRI tasks



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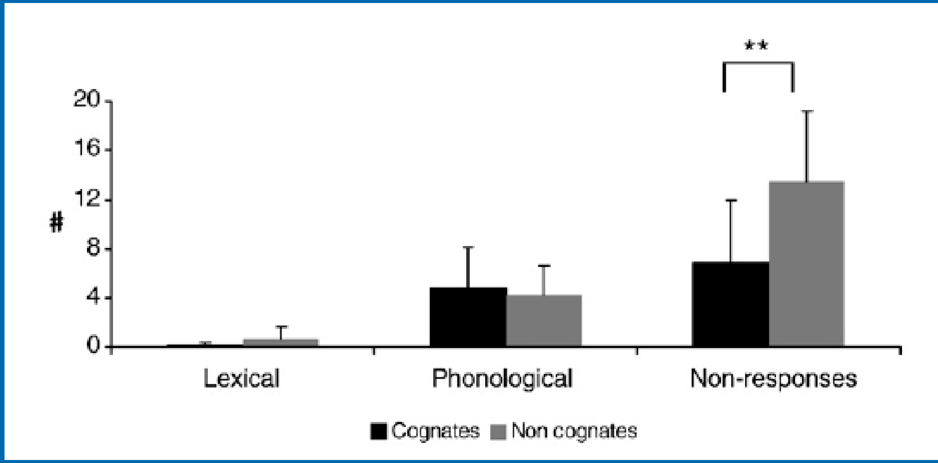
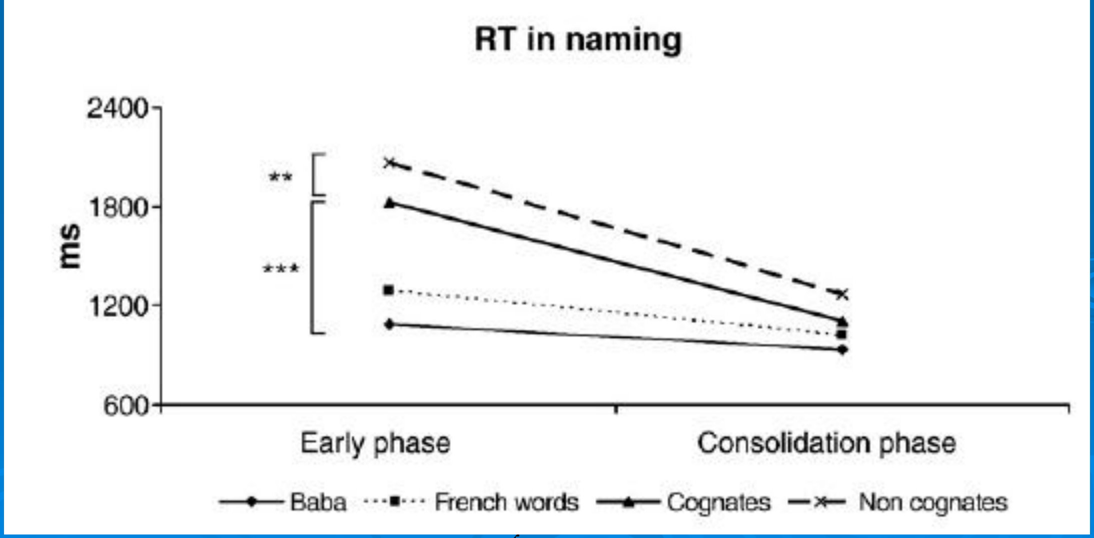
4.3. Cognate and non-cognate learning





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4.4 Time effect in younger adults

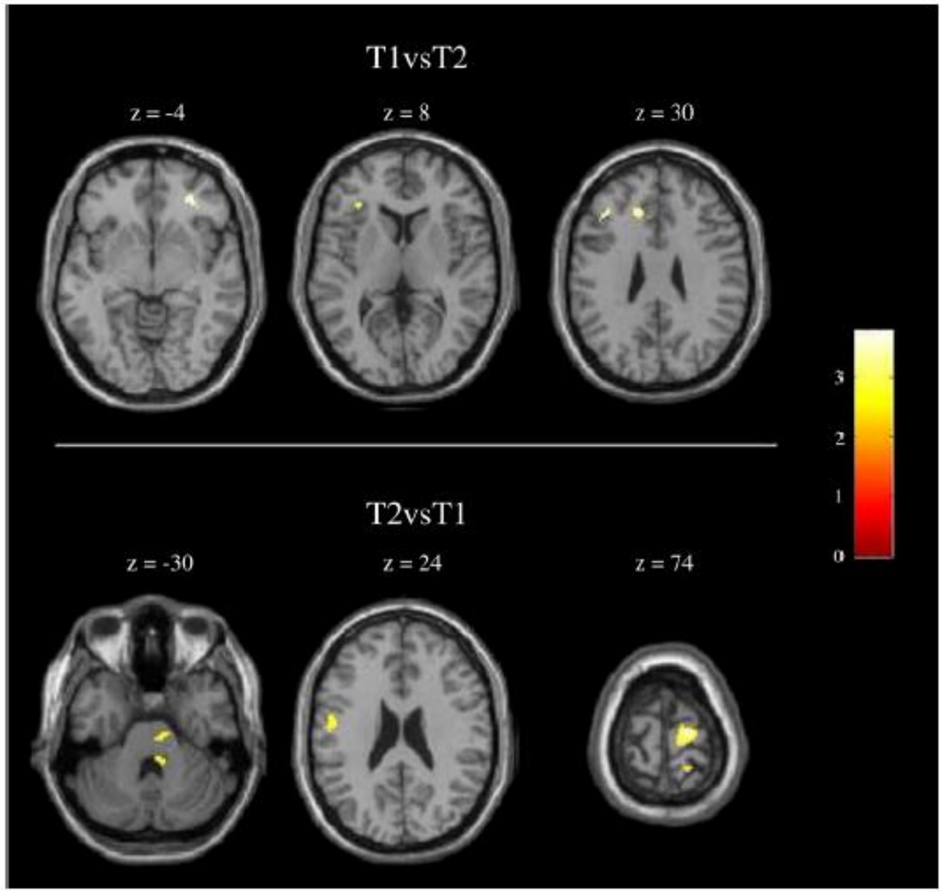

Fig. 5. Significant BOLD signal increase related to the learning phase. $p<0.005$, $k>10$. T1 vs. T2 comparison (upper panel) revealed significant increased activation in the right VLPFC (BA 47), the left and middle IFG (BAs 45 and 46), the left DLFC (BA 9), and ACC (BA 32). T2 vs. T1 comparison (lower panel) revealed significant increased activity in the left premotor cortex (BA 44/6), the right SMA and the right cerebellum. Statistical parametric maps overlaid onto the average T1-weighted anatomy of all subjects ($n=10$). See Table 4 for abbreviations.

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4.5 Non cognates – cognates in the younger

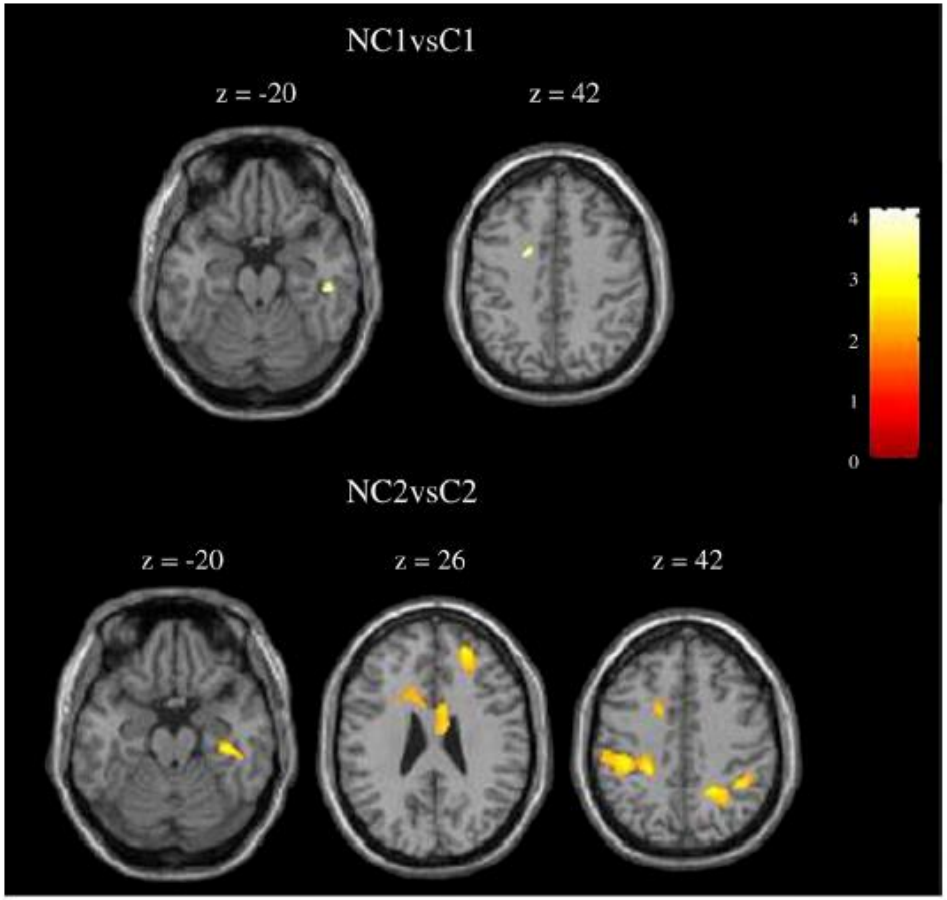

Fig. 6. Significant BOLD signal increases with non-cognates vs. cognates at either learning phase; $p < 0.005$, $k > 10$. Non-cognate vs. cognate comparisons at T1 (upper panel): increased activity in the ATG (BA 38), the right ITG (BA 20), the left ACC (BA 24). Non-cognate vs. cognate comparisons at T2: significant increased activity in the left occipito-temporal cortex (BA 37), the right ITG (BA 20), the ACC bilaterally (BA 32), the right superior and the IFG (BAs 45 and 10), the right precentral gyrus (BA 6), the SMA bilaterally (BA 6), the supramarginal gyrus (BA 40) bilaterally, and the right putamen. Statistical parametric maps overlaid onto the average T1-weighted anatomy of all subjects ($n = 10$). See Table 5 for abbreviations.

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4.6. Successful naming: correlational analysis

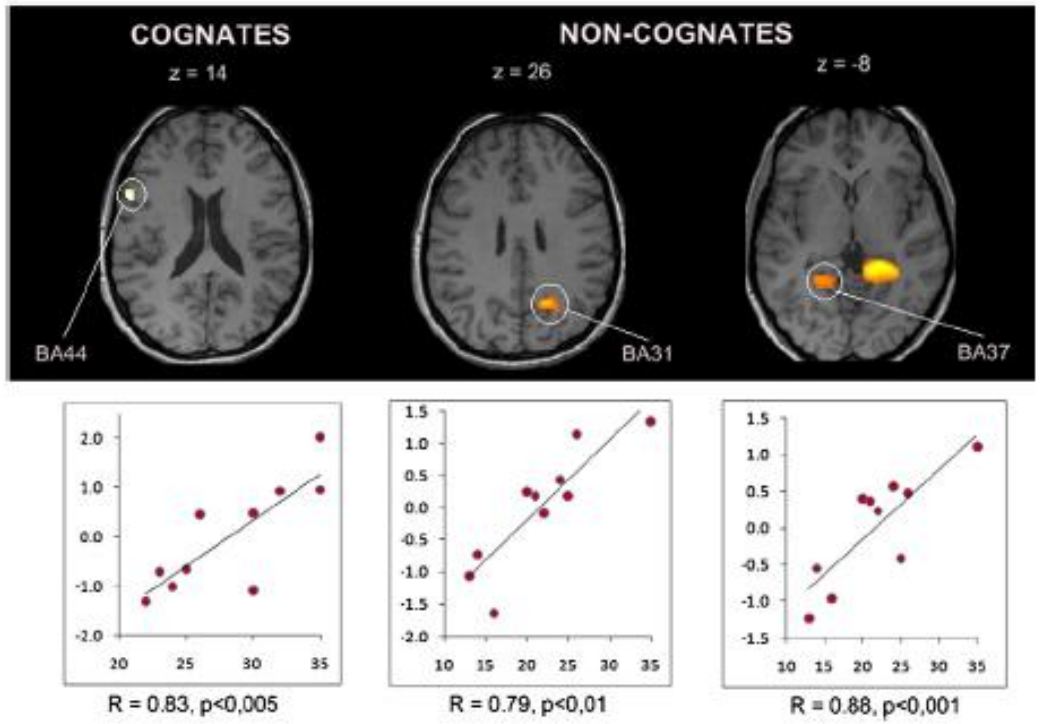

Fig. 7. Positive correlations between BOLD signal intensity and correct naming for cognates and non-cognates. $p<0.005$, $k>10$. Circled see significant activation in Broca's area (BA 44) during successful cognate naming (left panel). Activations in the posterior cingulate cortex (BA 31, middle panel), and the anterior-medial left fusiform gyrus (BA 37, right panel) were evident during successful non-cognate naming. Scatter plots depict the correlation between the average percent signal change and accuracy during cognate naming (left plot) and non-cognate naming (middle and right plots). Each dot represents data from one subject. The x-axis represents the accuracy rate. The y-axis represents the signal intensity. Only regions showing significant results after the Fisher's r to Z transform are represented.

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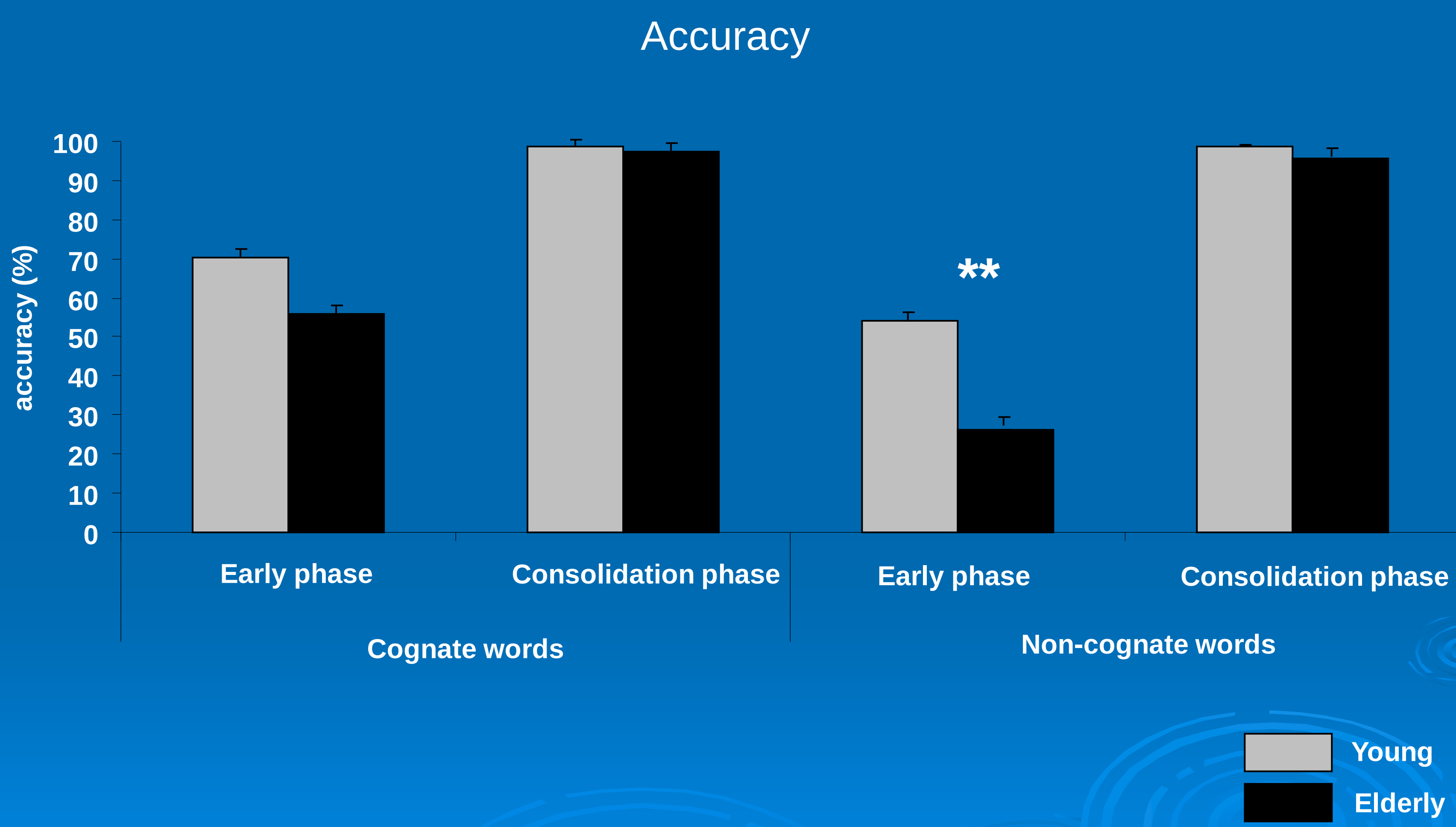
5. Age-related lexical learning (N=24)

		Young	Elderly	t (p)
	Age	22.7 (2.0)	70.2 (4)	33.8 (p<.0001)
	Education	16.3 (2.3)	16.4 (3.7)	ns
	MMSE	-	28.6(1.4)	-
Grober & Buscke	Free recall	14.4 (2)	12.4 (1.8)	2.3 (p<.033)
	Total recall	15.9 (.3)	15.9 (.3)	ns
	Del. free rec	14.8 (1.2)	12.7 (2.7)	2.2 (p<.04)
	Del. tot rec.	16.0 (.0)	15.7 (.4)	ns
	Dots	10.5 (2.1)	13.1 (2.1)	ns
Stroop	Words	11.9 (1.7)	17.1(3.5)	2.9 (p<.015)
	Dots-Words	17.4 (3.6)	26.6 (8.7)	2.3 (p<.06)
	Ordered	39.5 (3.1)	32.3 (5.9)	3.4 (p<.003)
Phonological Memory	Disordered	40.6 (2.6)	37.2 (5.6)	ns
	Span	3.6 (.51)	3.3 (.48)	ns

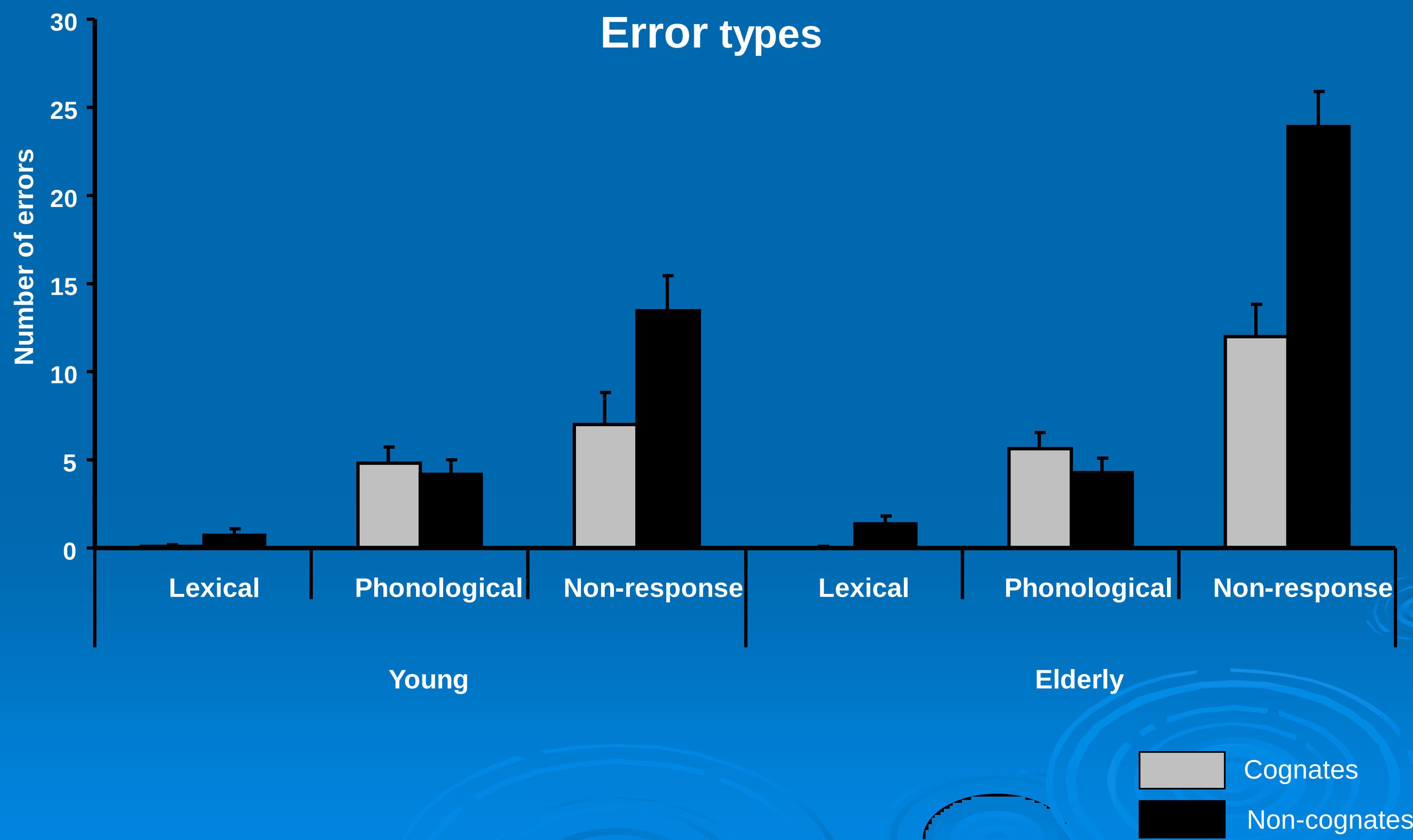
Adrover-Roig et al., in preparation

5.1. Age-related lexical learning (N=24)



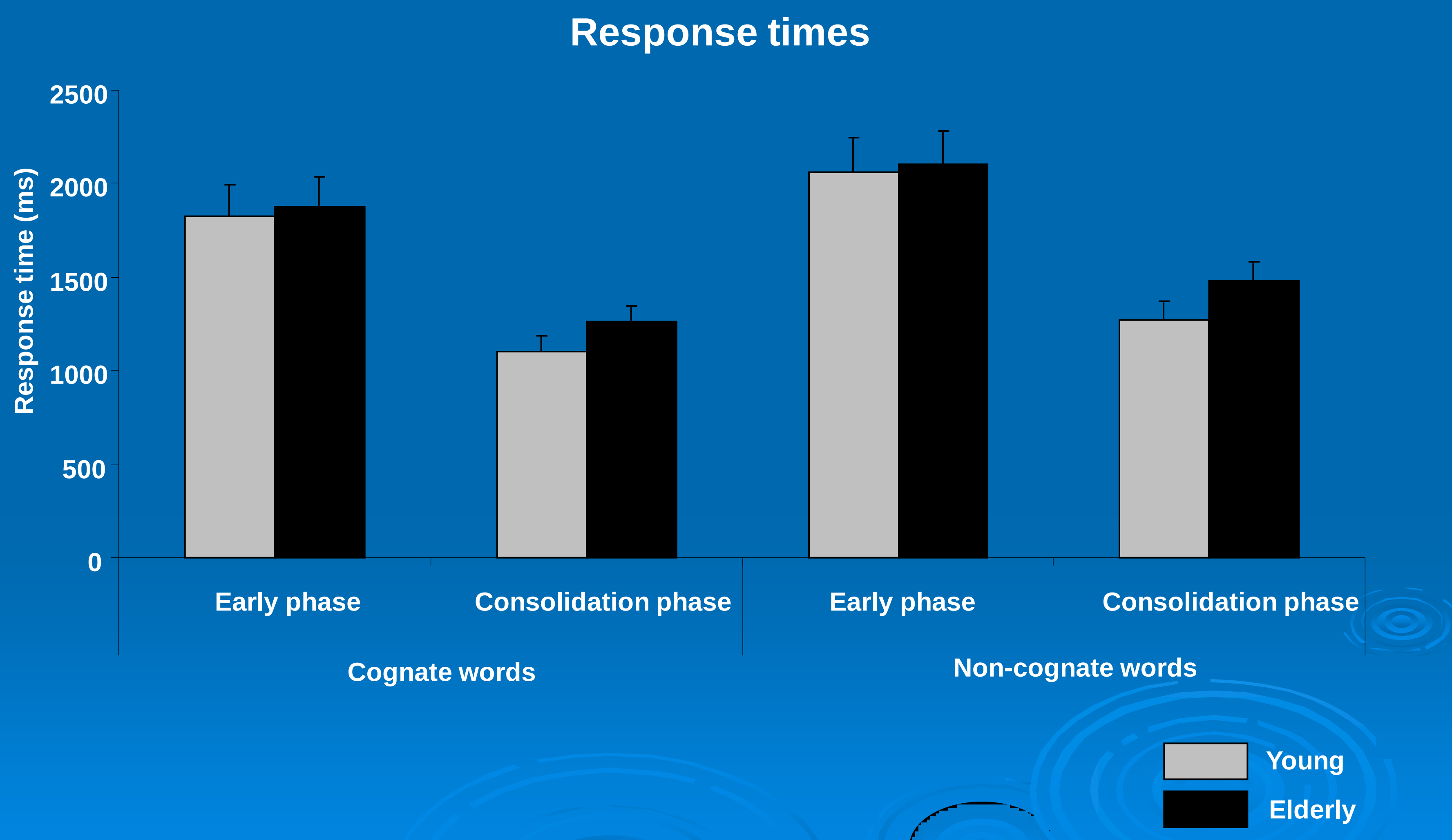
Adrover-Roig et al., in preparation

5.2. Age-related lexical learning (N=24)



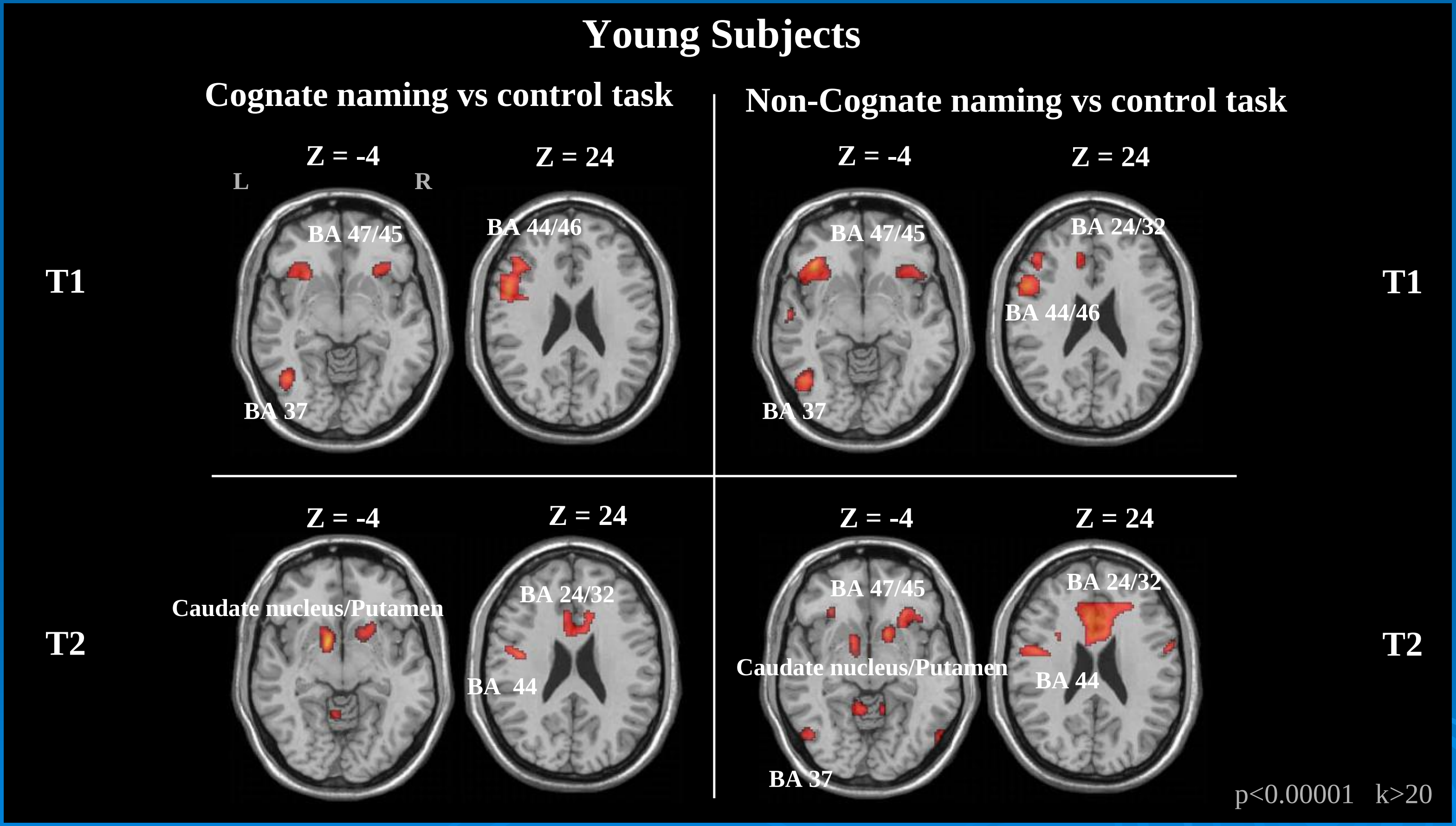
Adrover-Roig et al., in preparation

5.3. Lexical learning in the elderly



Adrover-Roig et al., submitted

5.4. T-tests in the younger sample



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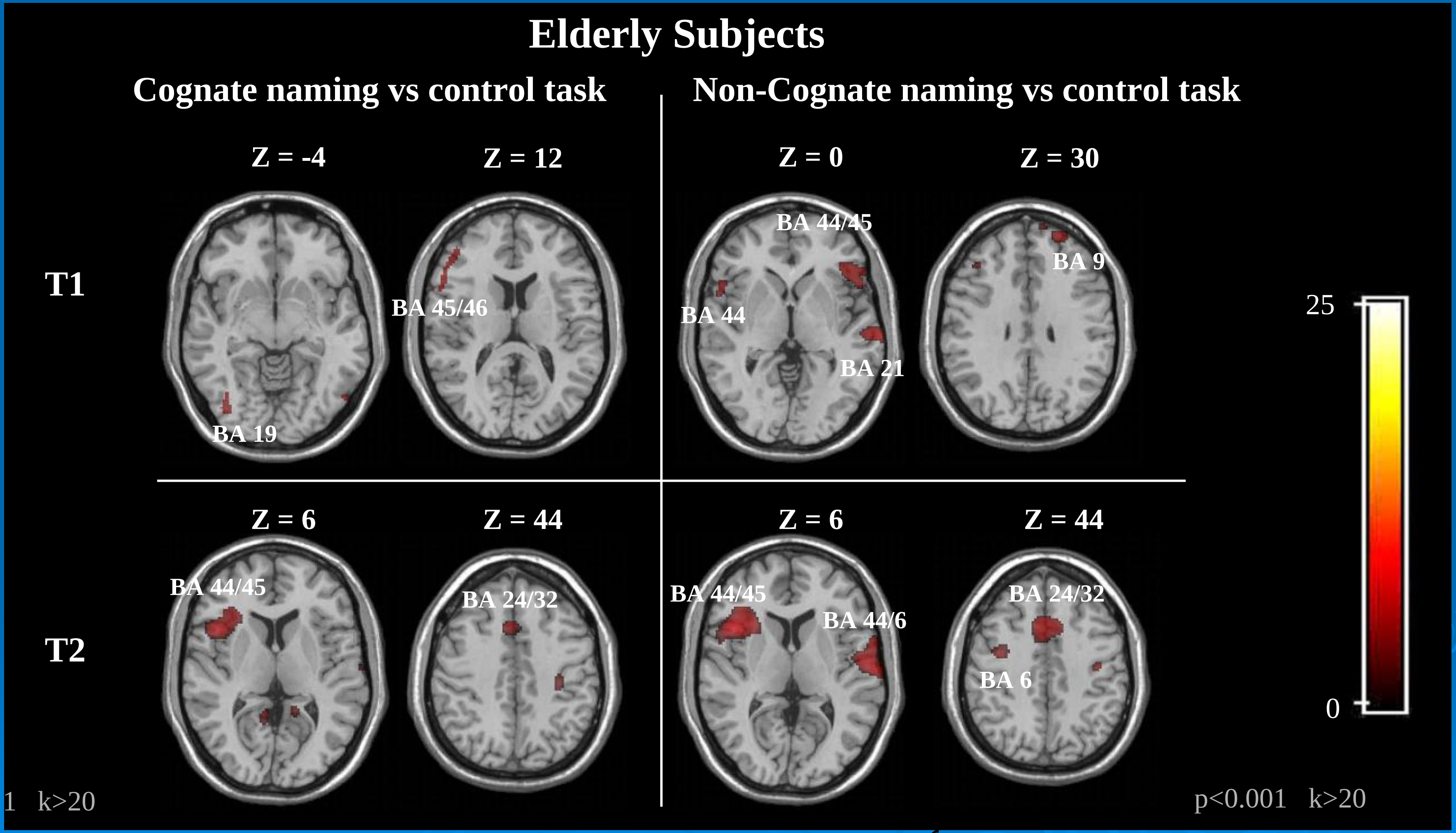
5.5. T-tests in the elderly sample



Adrover-Roig et al., in preparation

5.6. T-tests: substraction analysis

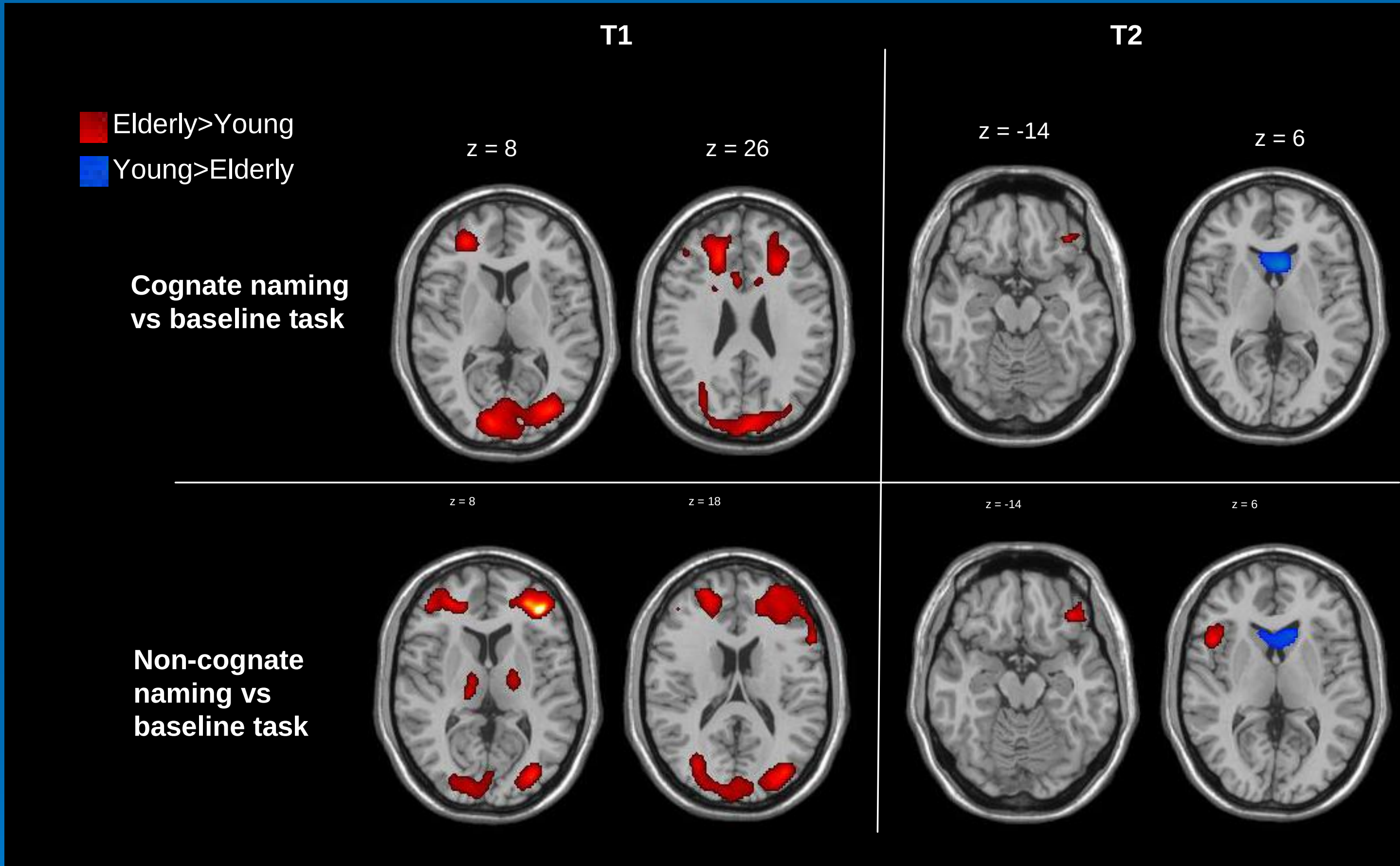
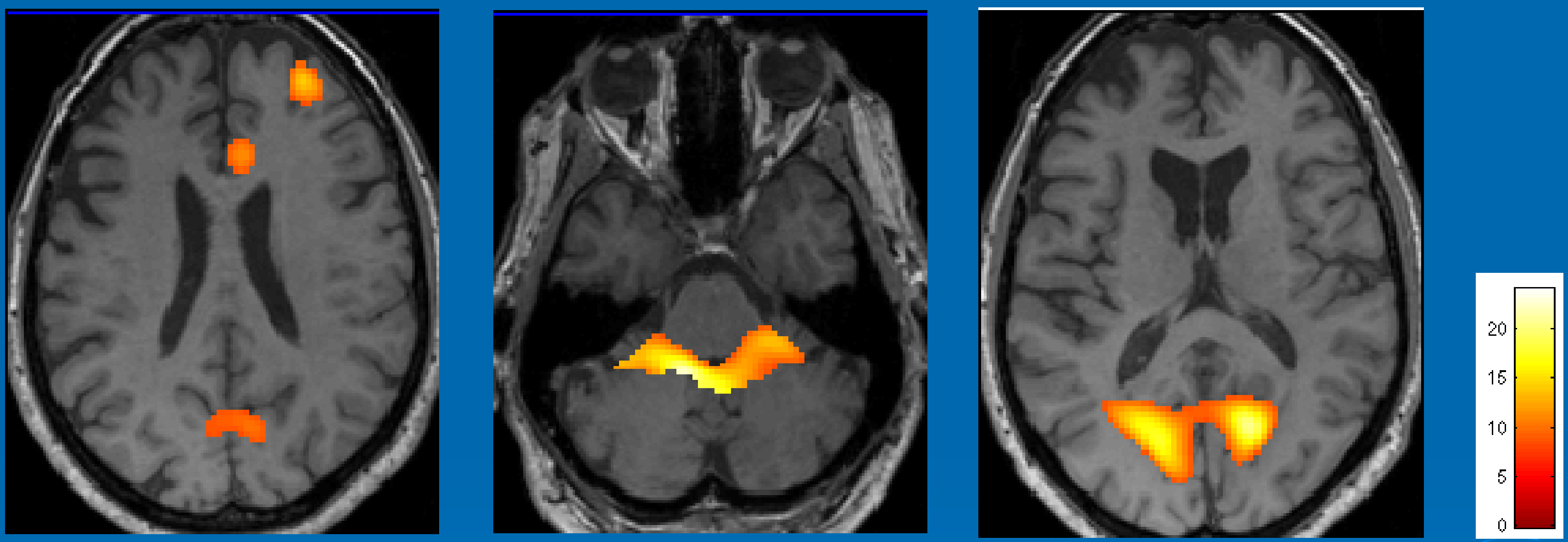


Figure 1 : Contrast comparing young and elderly subjects at T1 and T2 for cognate and non-cognate naming. p<0,001; k>20

Adrover-Roig et al., in prepration

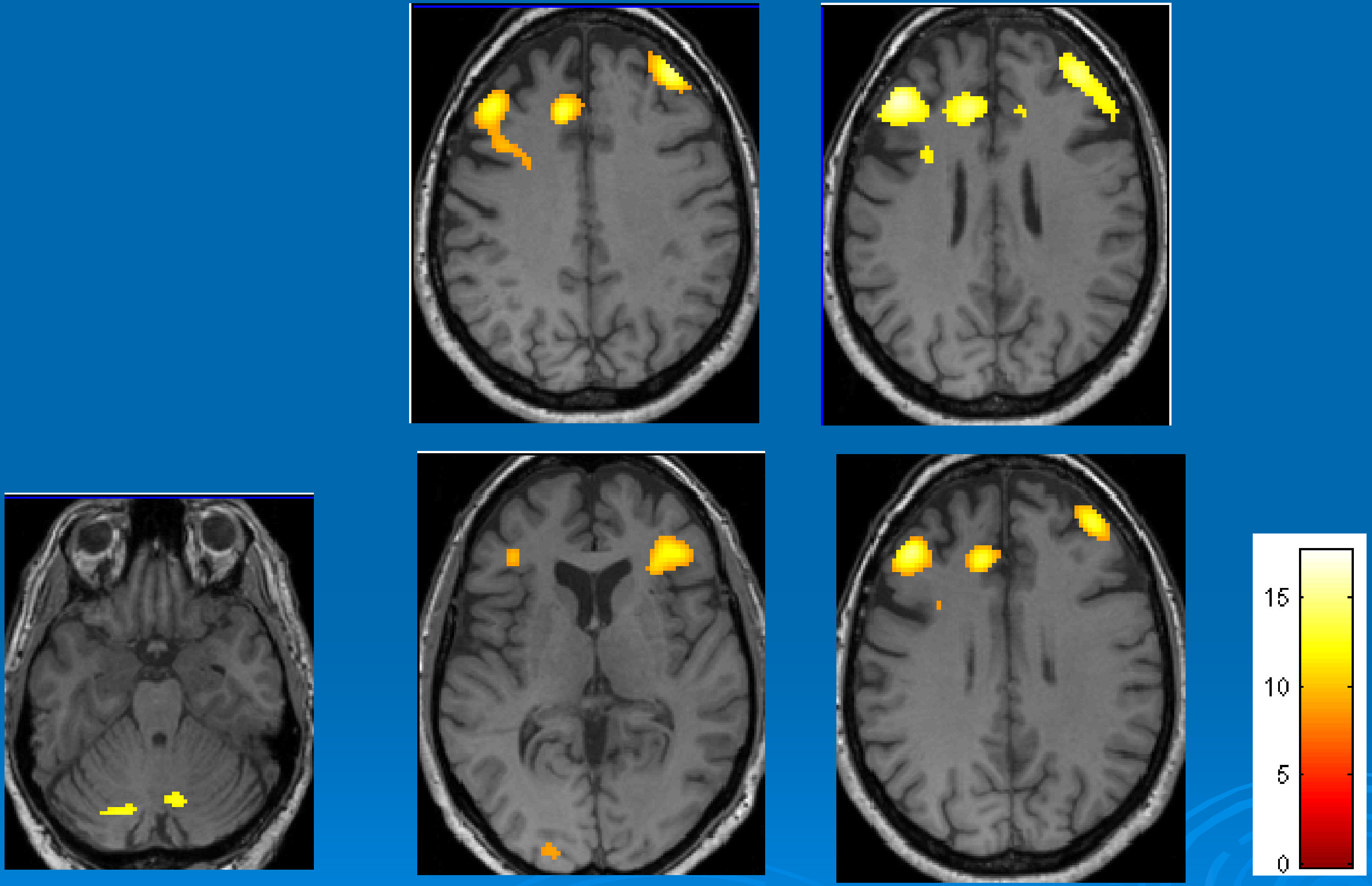
5.7. Factorial analysis: main effect word type



Main effect of word type (K>20; p<.00001)

Adrover-Roig et al., in prepration

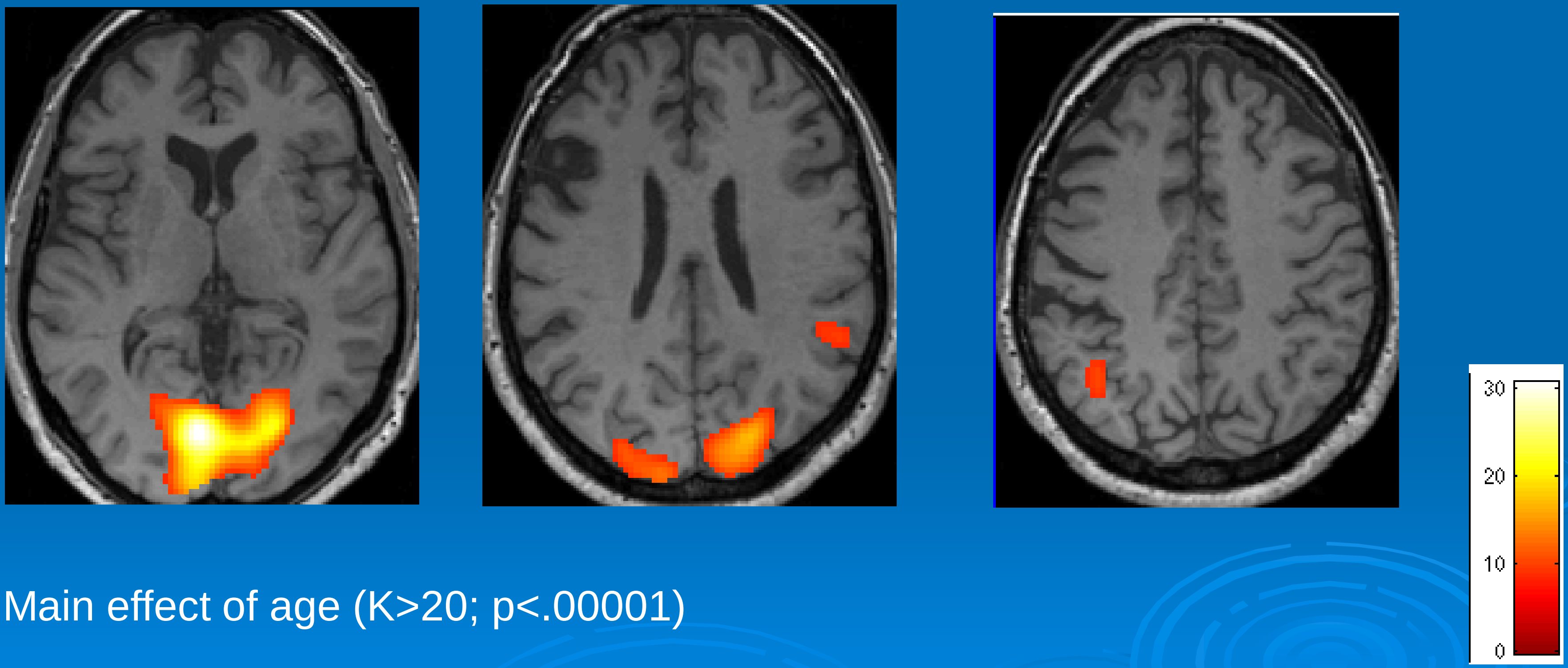
5.7.1. Main effect of Time



Main effect of time (K>20; p<.00001)

Adrover-Roig et al., in preparation

5.7.2 Main effect of age

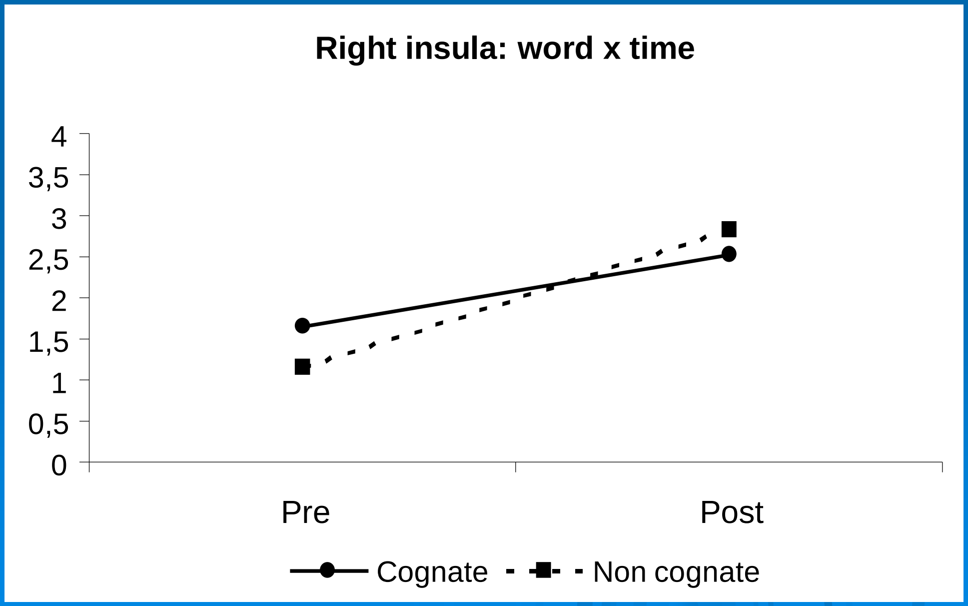


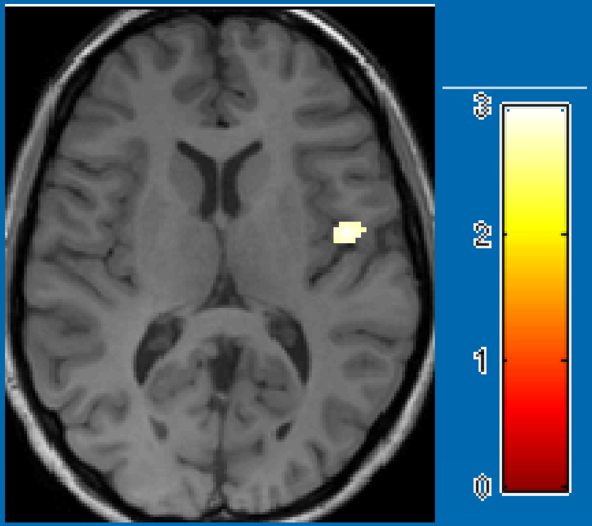
Main effect of age (K>20; p<.00001)

Adrover-Roig et al., in preparation

5.7.3. Word type x time interaction

Word type x time (K>20;p<.00001)

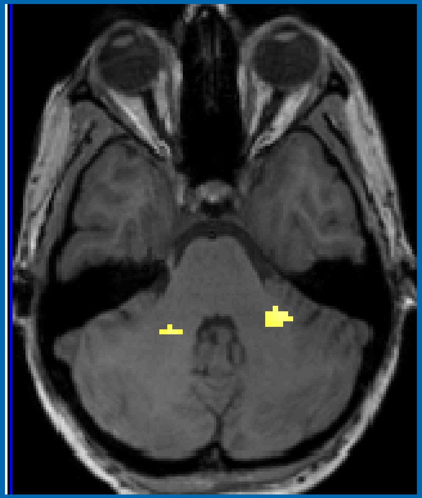


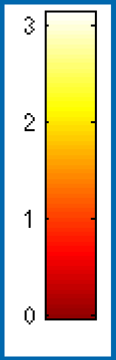


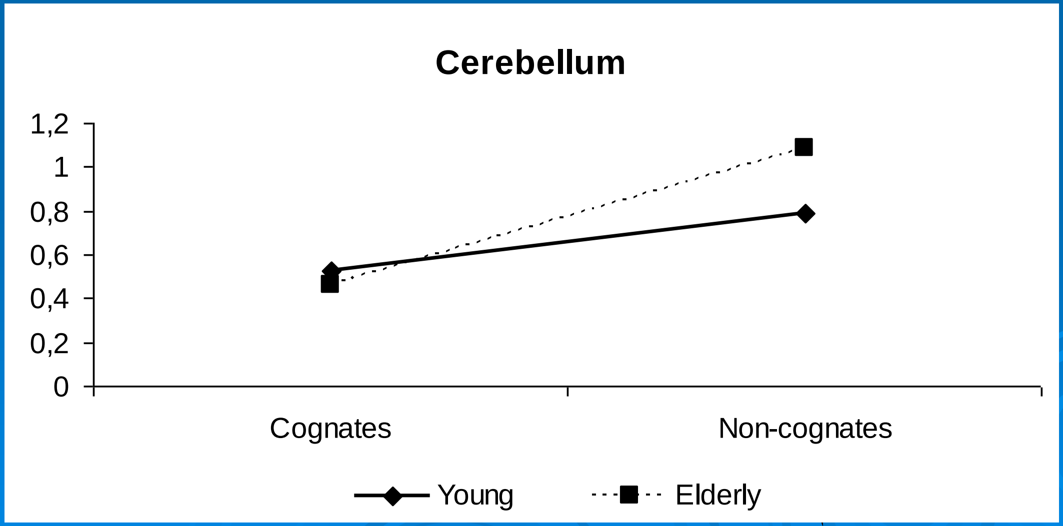
Adrover-Roig et al., in preparation

5.7.4. Word type x age interaction (I)

Word type x age
(K>20; p<.00001)

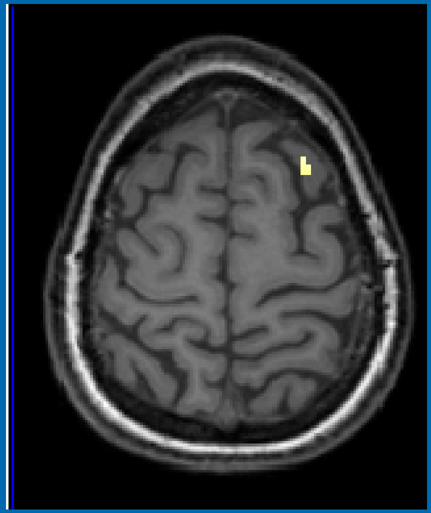


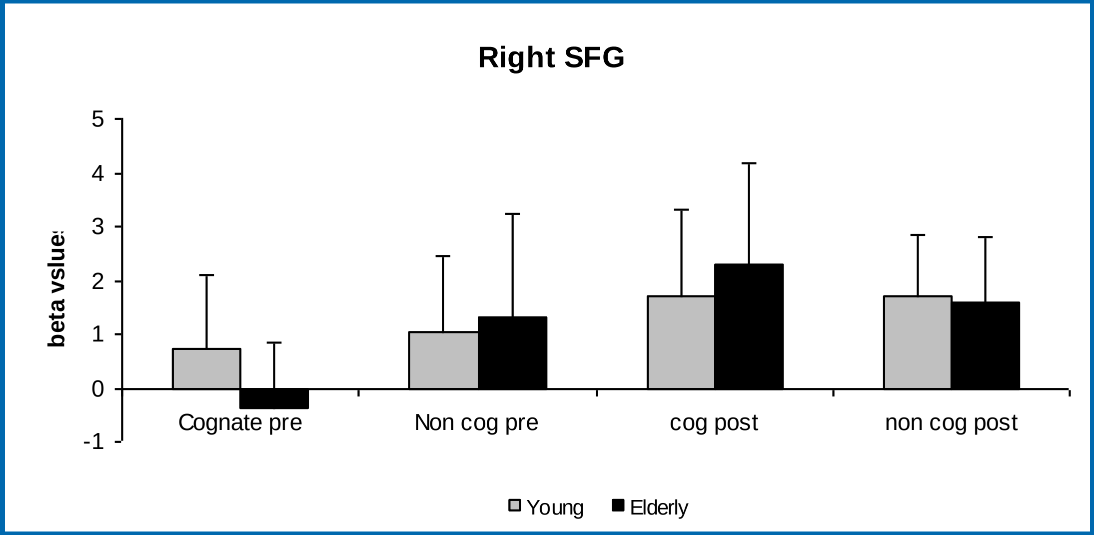


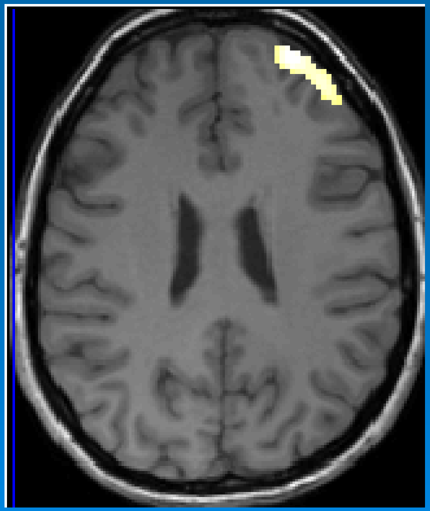


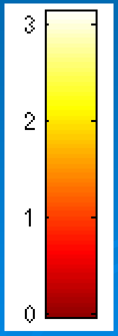
Adrover-Roig et al., in preparation

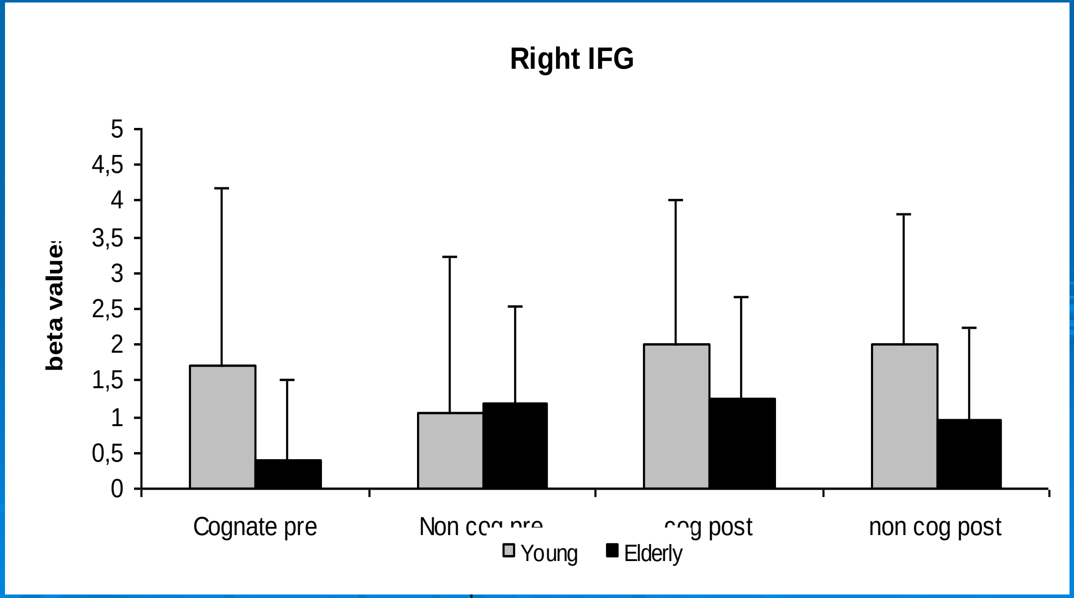
5.7.5. Word type x time x age interaction (I)





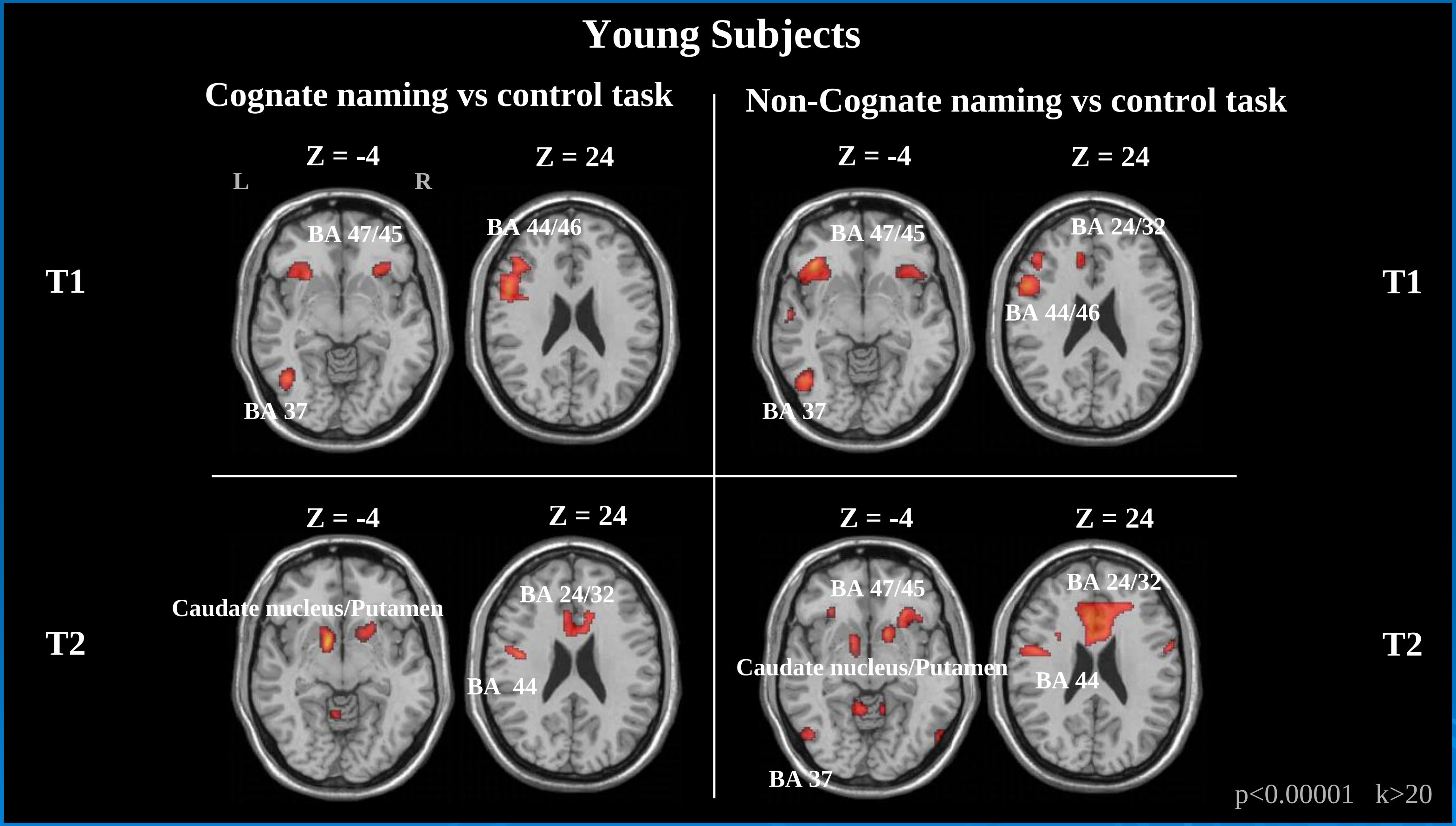






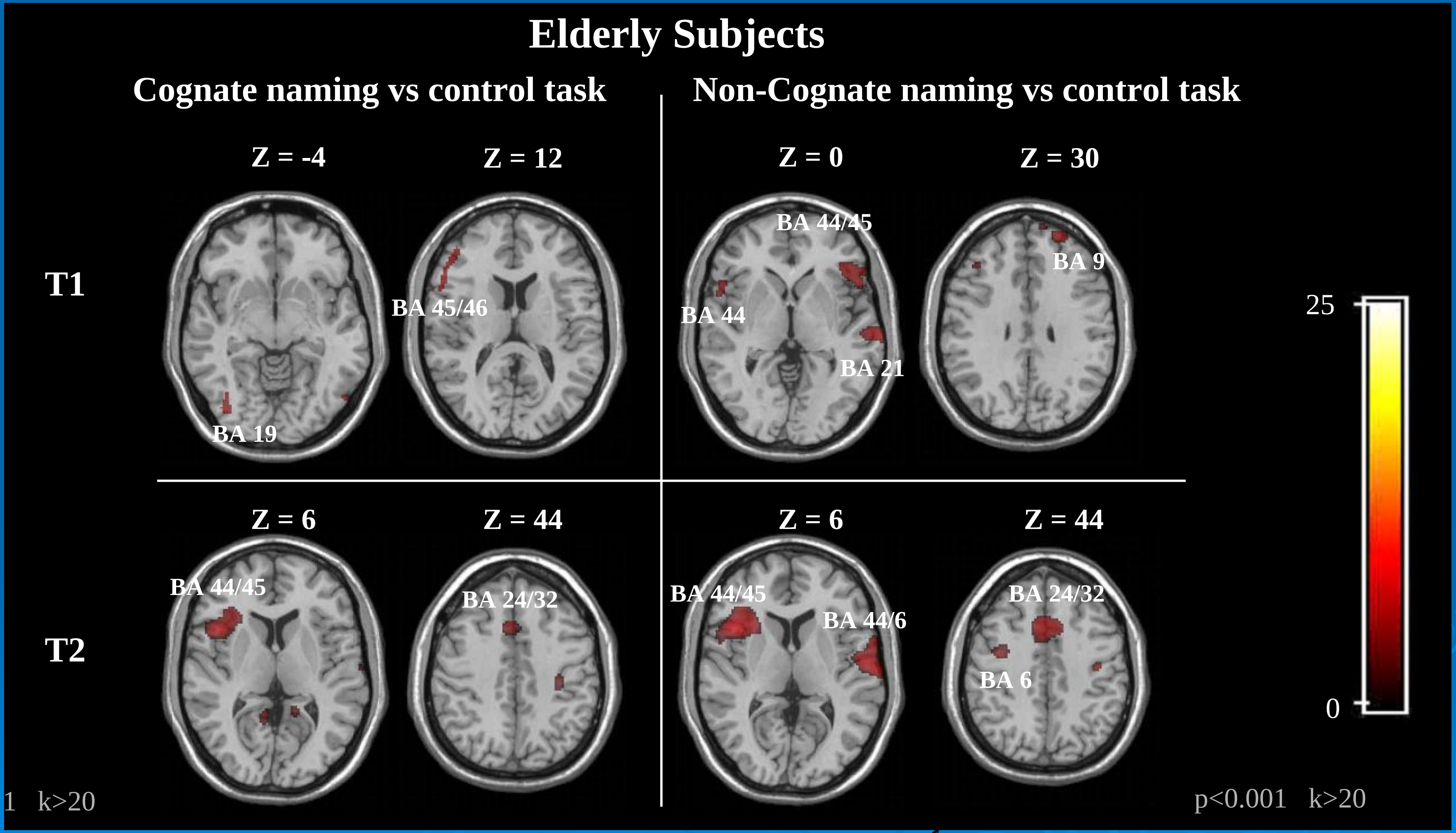
Adrover-Roig et al., in preparation

5.4. T-tests in the younger sample



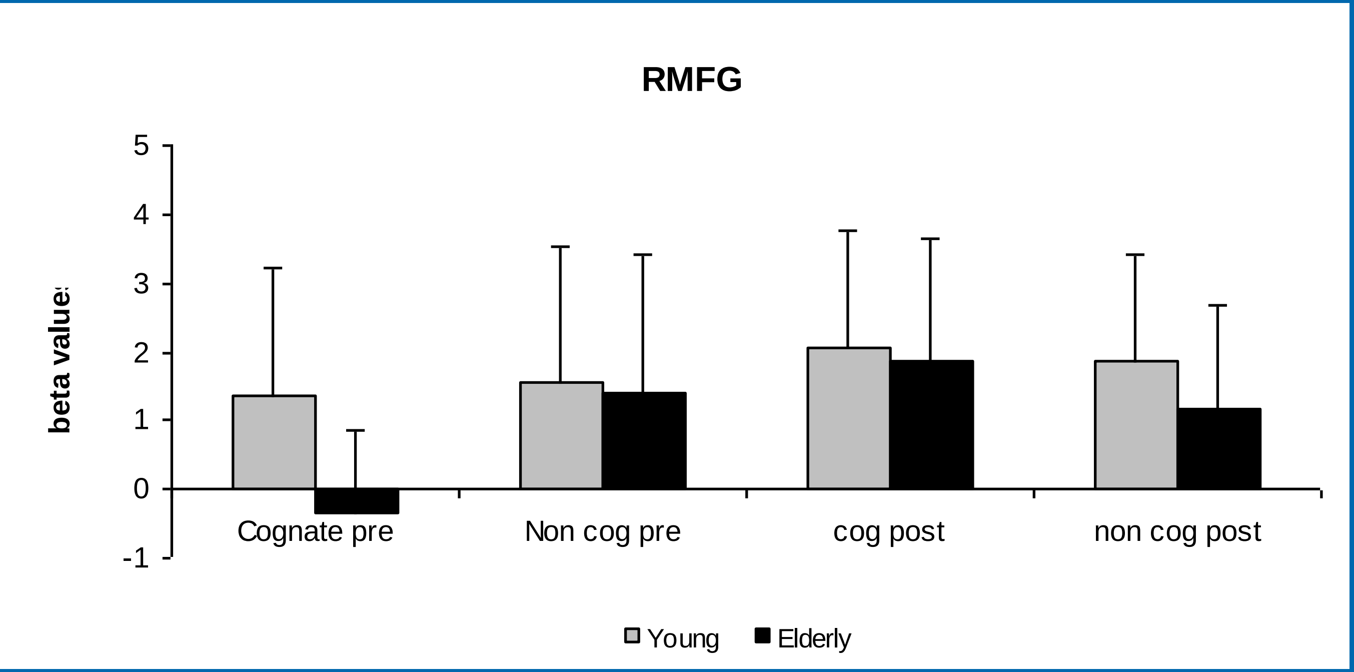
Adrover-Roig et al., in preparation

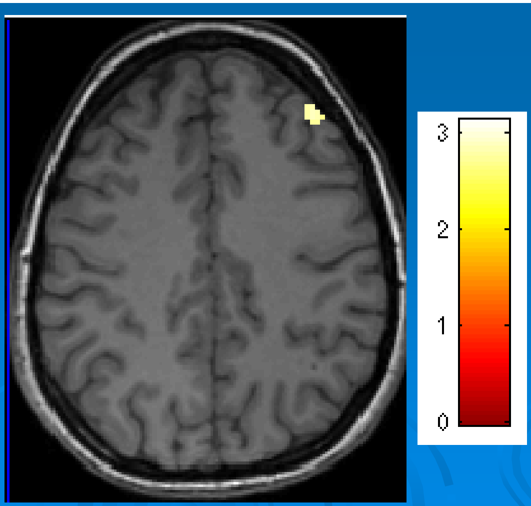
5.5. T-tests in the elderly sample



Adrover-Roig et al., in preparation

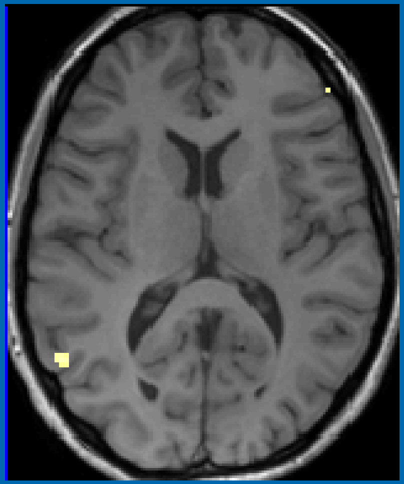
5.7.5. Word type x time x age interaction (II)

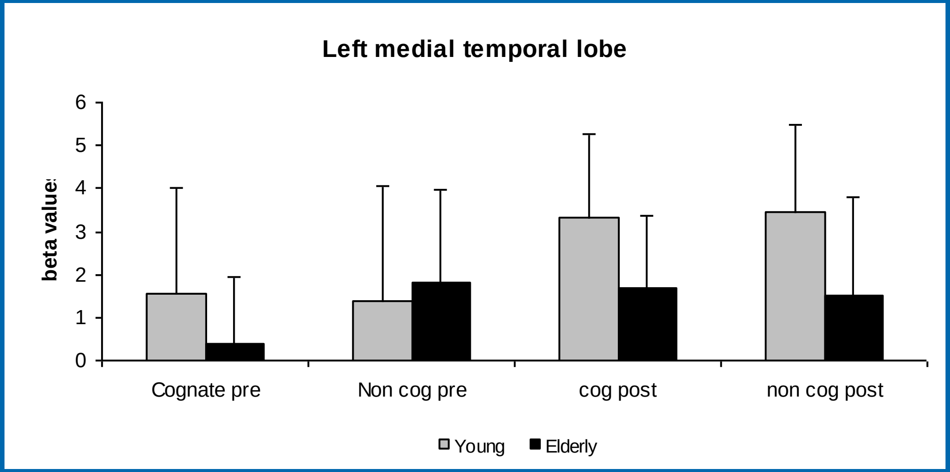


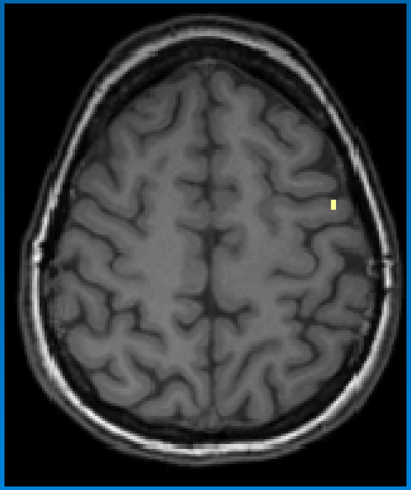


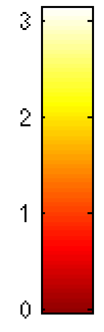
Adrover-Roig et al., in preparation

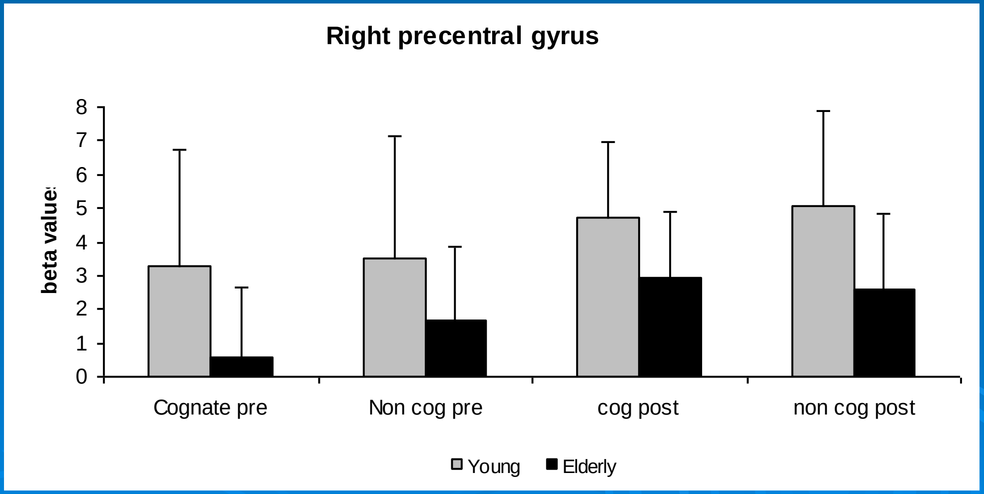
5.7.5. Word type x time x age interaction (III)











Adrover-Roig et al., in preparation

5.8. Conclusions

- The **early** phase of lexical learning involve mainly **frontal** activations while **consolidation** triggers larger **action**-related activity (cerebellum, premotor cortex, SMA)
- Cognate naming may relie on **phonological processing** areas while non cognate naming is more associated to **semantic** regions, in younger adults
- **Advancing age does not seem to disrupt the learning of cognates**, in terms of accuracy and reaction times
- Elderly adults show **down-regulated right-frontal activity when naming cognates** and **larger bilateral** activity when naming **non cognates.**
- **Non-cognate** learning is achievable for the elderly, though with **poorer initial accuracy** and **larger articulatory** demands
- The learning-related **frontal to subcortical switch** is not observed in the elderly during lexical learning

Suggested reading

- **Adrover Roig. D** & Ansaldo. AI (2009). Bilingualism and cognitive reserve. *SLAN*: 1-17.
- **Adrover-Roig, D**. & Barceló, F. (2009). Individual differences in aging and cognitive control modulate the neural indexes of context updating and maintenance during task switching. Cortex; *in press.*
- Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19,* 290-303.
- Raboyeau, G., Marcotte, K., **Adrover-Roig, D**., Ansaldo, AI. (2009). Brain activation and lexical learning:The impact of learning phase and word type. *NeuroImage*, 49, 2850–2861
- Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Can J Exp Psychol* 60(1): 68-79.
- Bialystok, E., F. I. Craik y M. Freedman (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neuropsychologia* 45(2): 459-64.
- Bialystok, E., F. I. Craik y A. C. Ruocco (2006). Dual-modality monitoring in a classification task: the effects of bilingualism and ageing. *Q J Exp Psychol (Colchester)* 59(11): 1968-8

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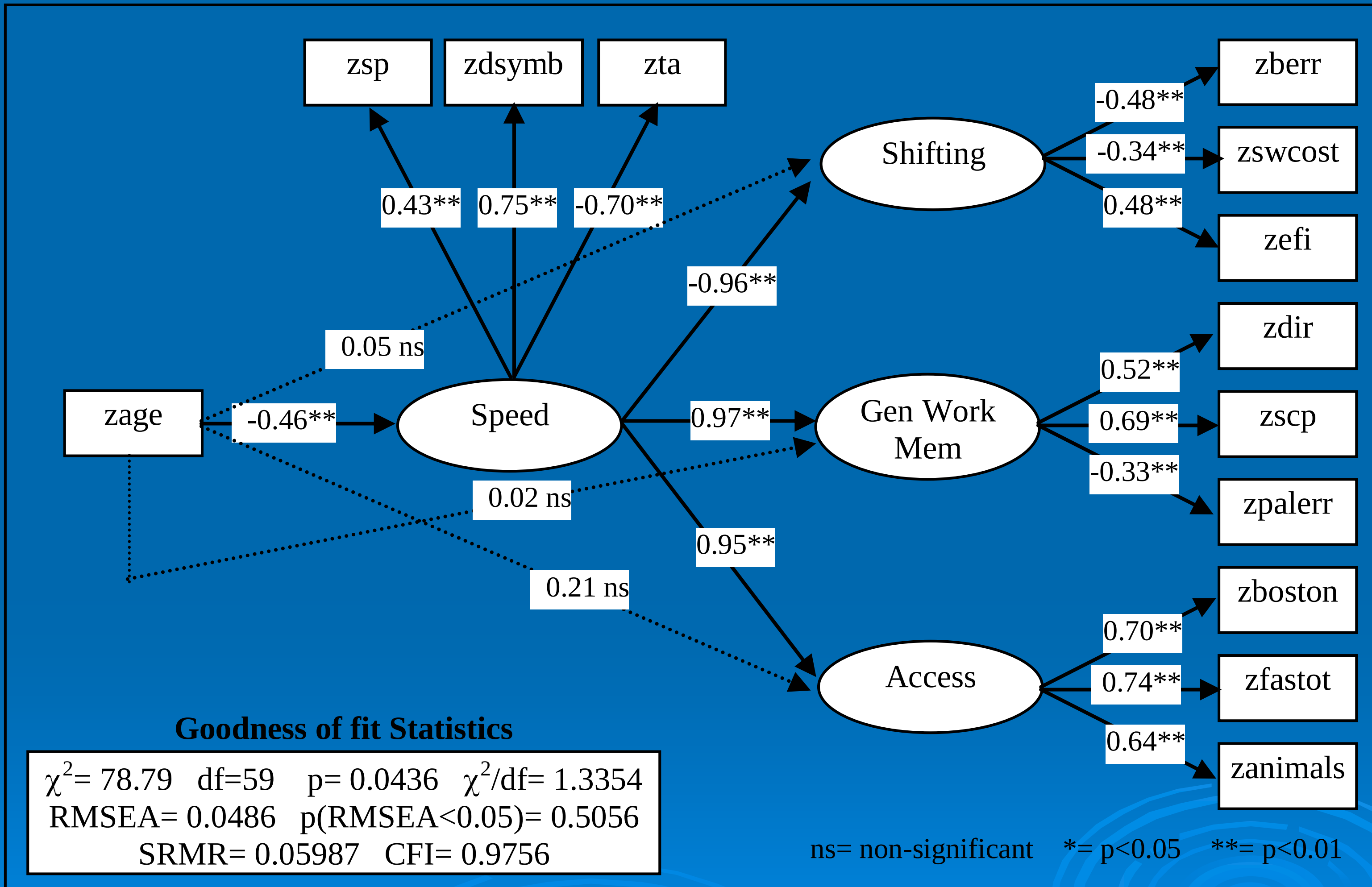
Gaëlle Raboyeau (Ph.D.)

Karine Marcotte (M.O.A)

Thank you very much

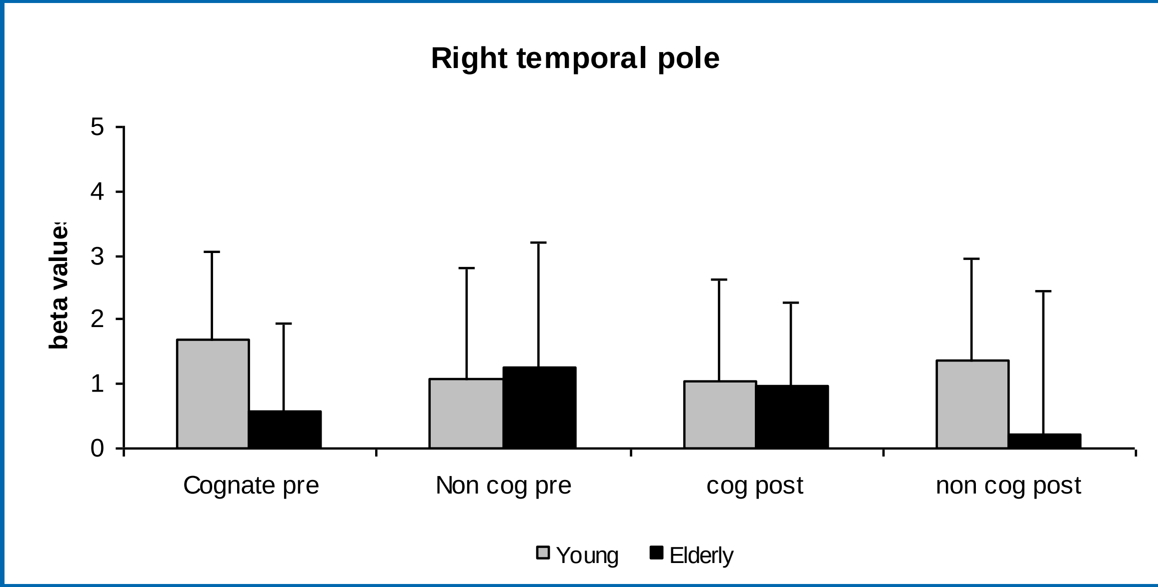
for your attention

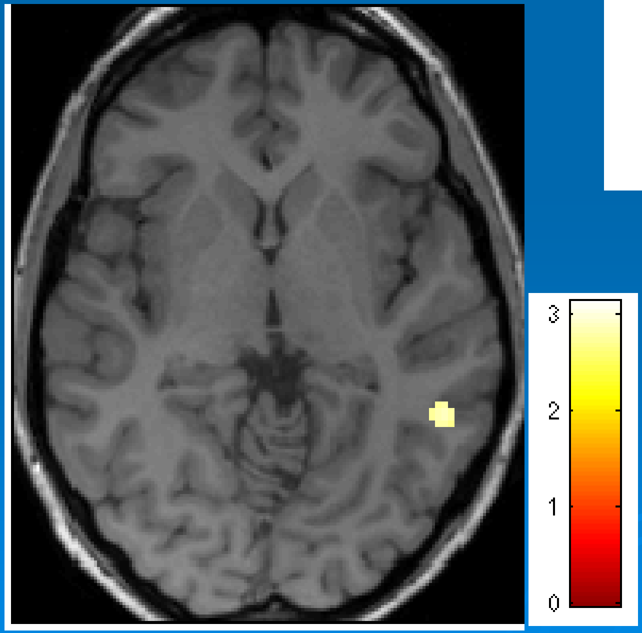
3.4. Executive control in bilinguals



Adrover-Roig et al., submitted

5.7.5. Word type x time x age interaction (IV)

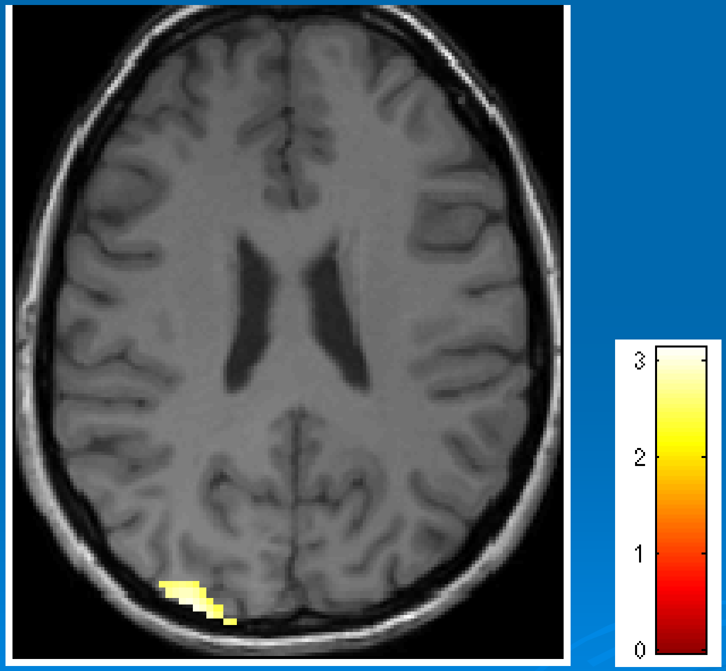


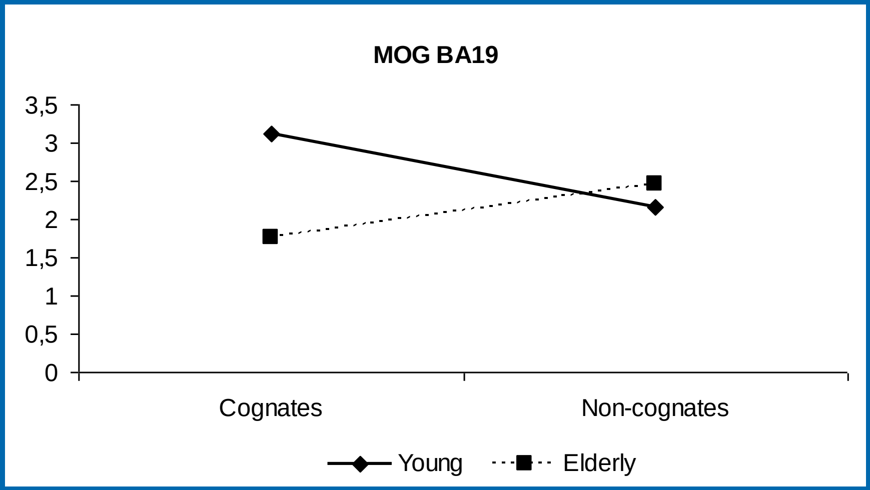


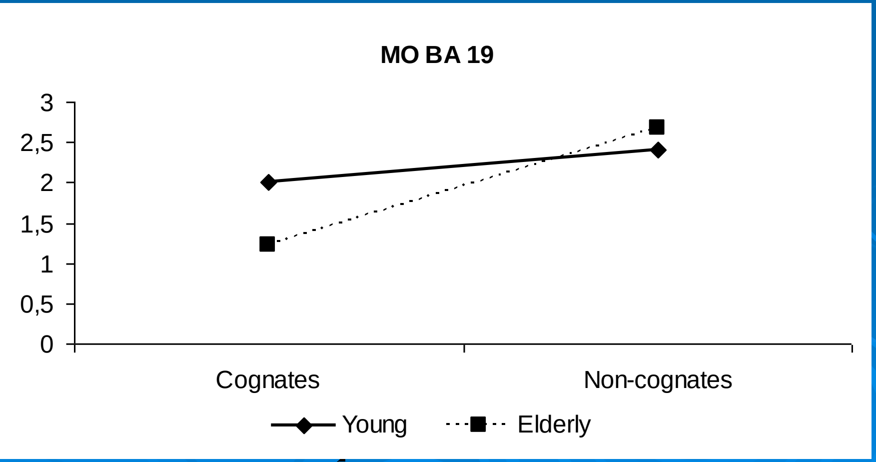
Adrover-Roig et al., in preparation

5.7.4. Word type x age interaction (II)

Word type x age
(K>20; p<.00001)

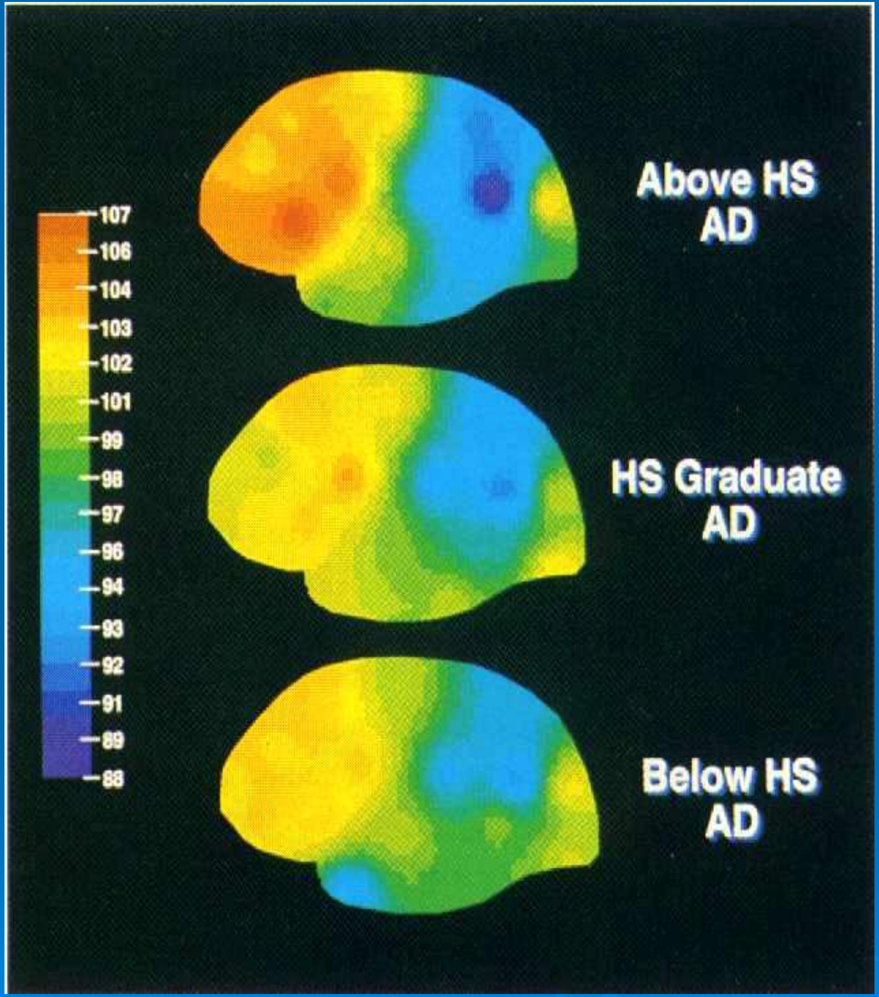






Adrover-Roig et al., in preparation

2.4.2. Education and rCBF



Stern et al, Ann Neurol 1992

Controlling for clinical disease severity, there is an **inverse relationship** between education and a functional imaging proxy for AD pathology

Similar findings have been noted for **occupational attainment** and **leisure** activities