The relationship between language and cognition

How bilingualism may enrich our cognitive abilities and change the brain structure

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Trondheim, 30/05/2013

What inspired my studies

What's Cognitive Psychology?

Cognition

The collection of mental processes and activities used in perceiving, learning, remembering, thinking, and understanding, and the act of using those processes (Ashcraft, 2002)

Cognitive Psychology

The study of how people perceive, learn, remember, and think.

Examples

- How people perceive various shapes
- Why they remember some facts and forget others
- How they learn language

Methods in Cognitive Psychology

Laboratory experiments - Aim: to measure behaviour

Behavioural measures

Reaction time (Msecs to perform a task)
Accuracy (Number of correct responses)
Verbal protocols (Tape recordings)
Behavioural measures

Physiological measures

Heart Rate
Blood pressure
Respiration rate
Skin Conductance
EEG (Electroencephalogram)

Neuroimaging

MRI and fMRI (Magnetic Resonance Imaging)
PET (Positron Emission Tomography)
NIRS (Near Infrared Spectroscopy)
Others

The Computer Metaphor

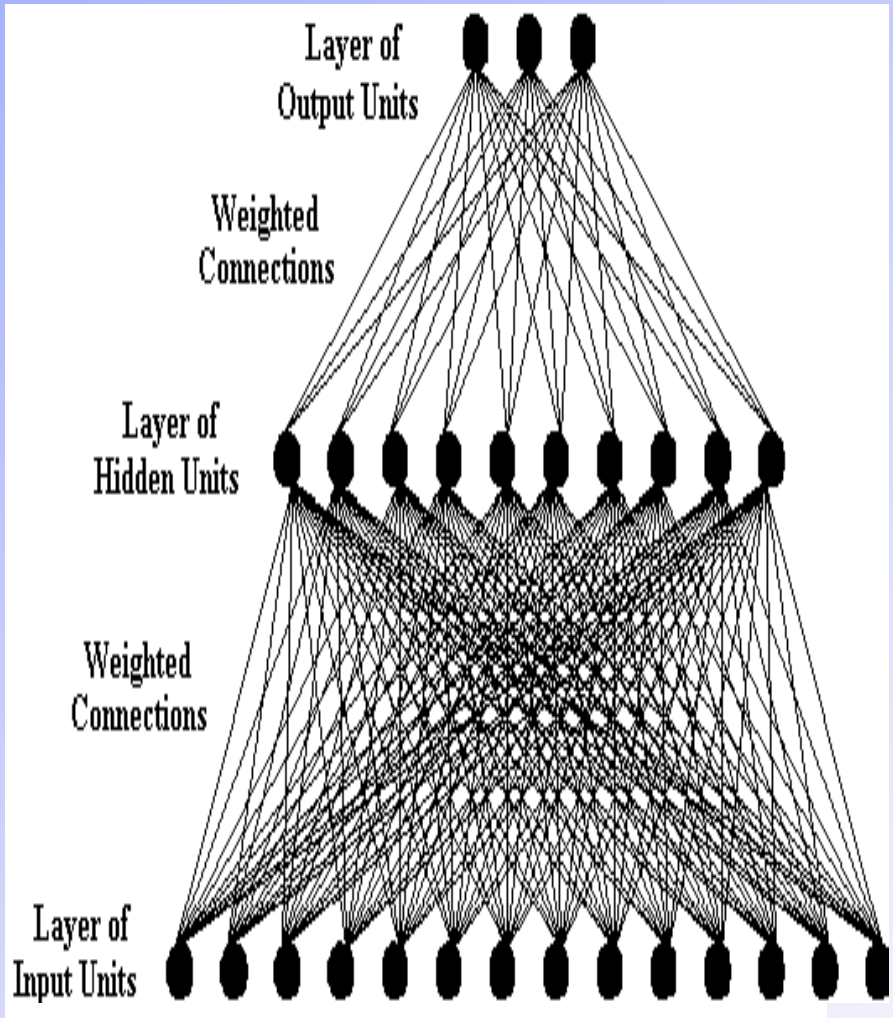
Cognitive Psychology influenced by Information Processing Theory

The human mind as a processor of information like a computer

But human mind is more complex than a computer

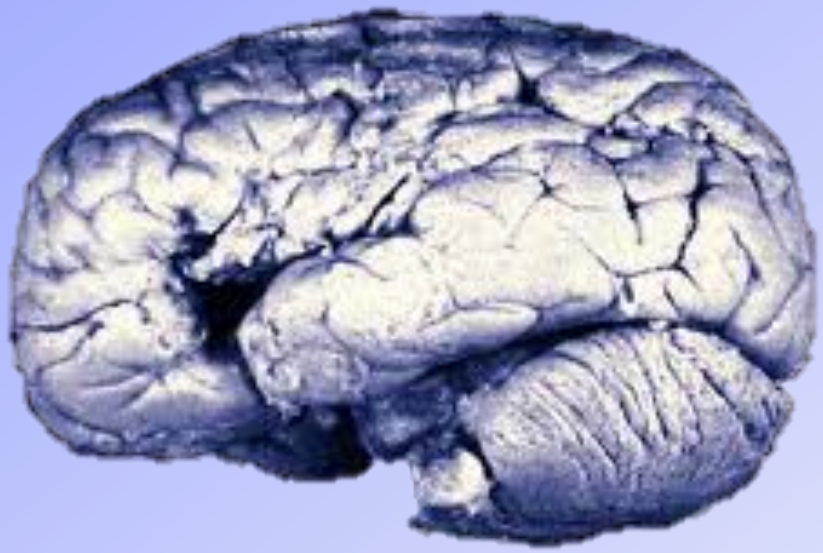
For example: is information processed in a modular, "serial" fashion?

Or can our brain also process information interactively, in "parallel"?



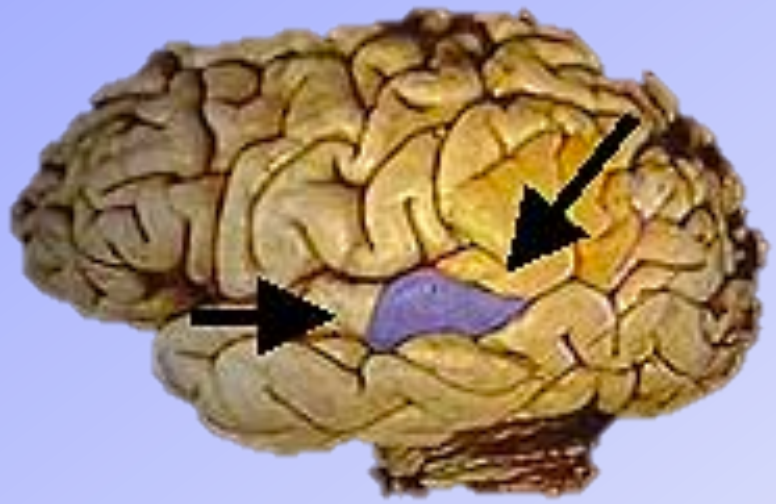
A (very) brief history of Language and Cognition

1861 – Paul Broca



- Patient (Mr. Leborgne) had a stroke
- Impaired speech production
- Intact speech comprehension
- Frontal lesion in the Left Hemisphere was associated to loss of language (Broca's area)

1874 - Carl Wernicke

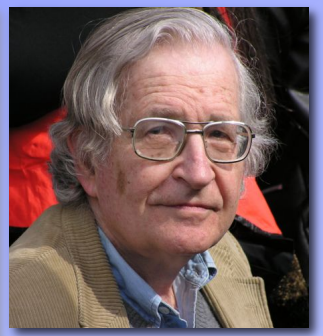


- Impaired speech comprehension
- Intact speech production
- Posterior region of the superior temporal lobe of the left hemisphere (Wernicke's area)

Nativism vs. Non-Nativism

Language is separated from the rest of Cognition.

We are born with the ability to build grammatical structures (UG) and specialized language-learning mechanisms.



Noam Chomsky
Nativist Theory

There is nothing unique about language learning.

Cognitive development and general learning mechanisms apply to language

Jean Piaget
Cognitive Development Theory

A long-standing debate that has characterised more than 60 years in psychological research

Two examples

1: Nicaraguan Sign Language
(Senghas & Coppola, 2001)

1970s: deaf children from different villages (they didn't know each other) went to a new school in Managua to learn lip-reading

They soon began to communicate with signs on the buses and at school

They created a rudimentary sign language **(NSL)**

NSL developed rapidly.

Researchers are studying this case as a prove of innate ability to create grammar

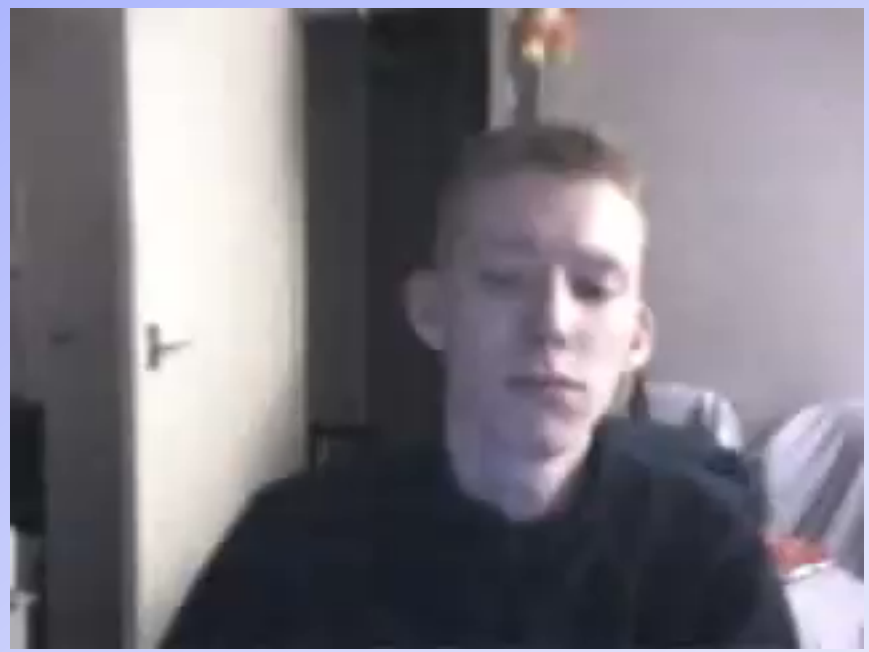
Two examples

2: The K.E. Family

- Half of the family members have Specific Language Impairment **(SLI)**

- Mutation of the **FOXP2** gene in chromosome 7

(Lai, Fisher, Hurst, Vargha-Khadem & Monaco, 2001)



BUT…

NSL signers, however, in touch with many researchers and experts in American Sign Language: how much does this matter to the development of NSL?

FOXP2 is present also in other species (chimps, rats, snakes). They don't have language…

Its general contribution involves the rapid planning, coordination and timing of sequential movements

In humans, FOXP2 is critical for planning, rapidly changing sequential mouth movements for speech, and would thus subsequently impact on language
(Filippi & Karmiloff-Smith, 2012)

EXECUTIVE FUNCTION (EF)

A key cognitive system that allows us to:

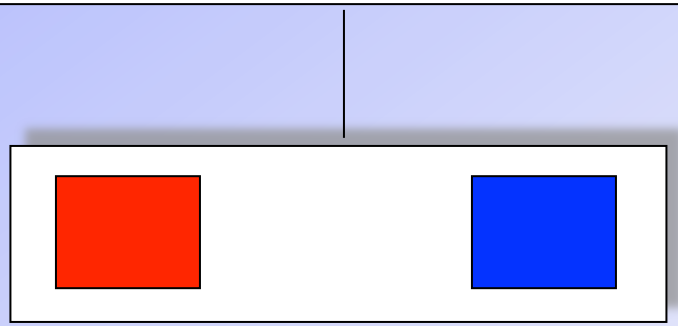
- **Learn**
- **Adapt to new rules/tasks,**
- **Ignore/suppress irrelevant information and keep the focus on the target**
- **Switch rapidly and efficiently between two tasks**

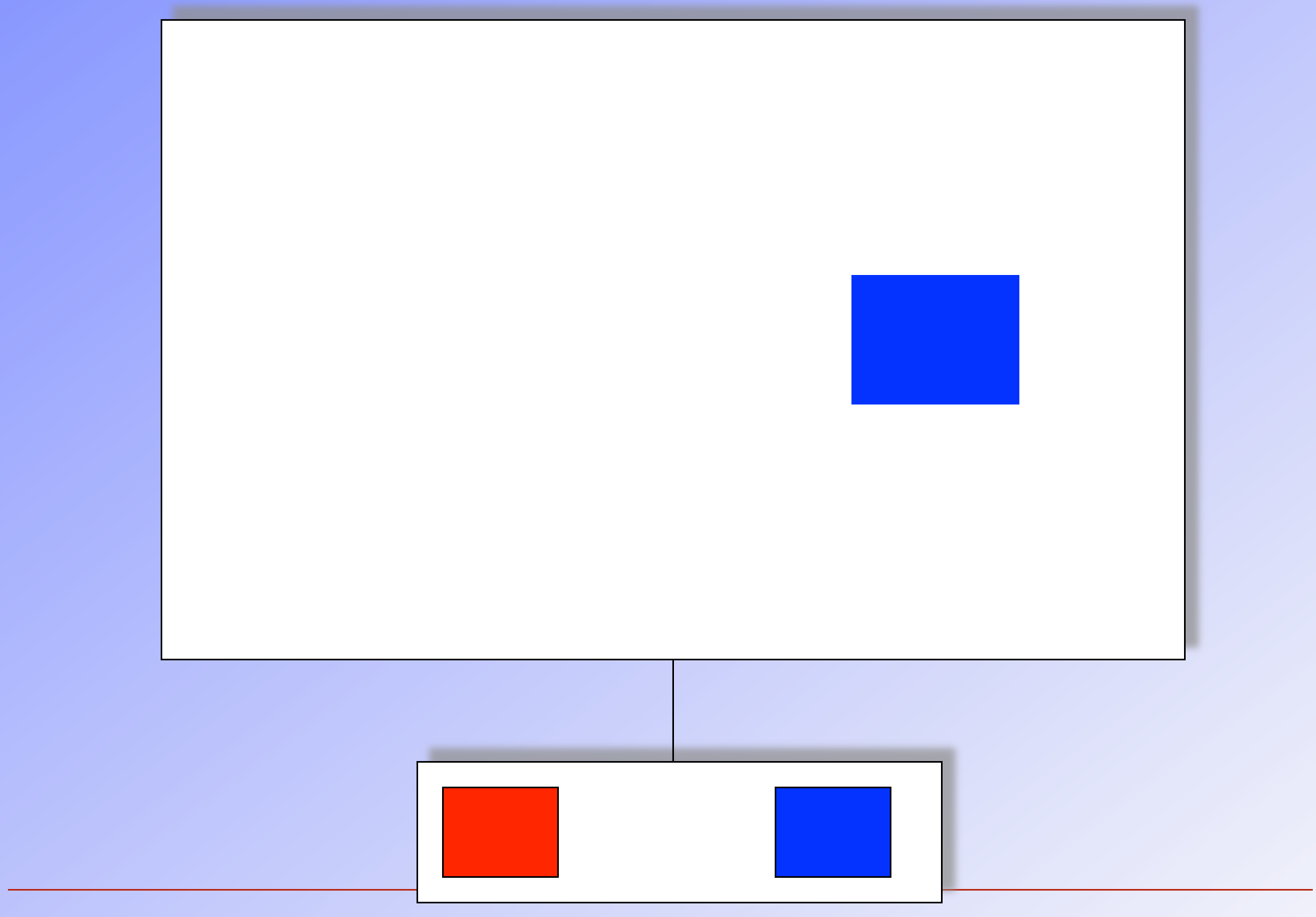
These processes need deliberate or *controlled* attentional resources

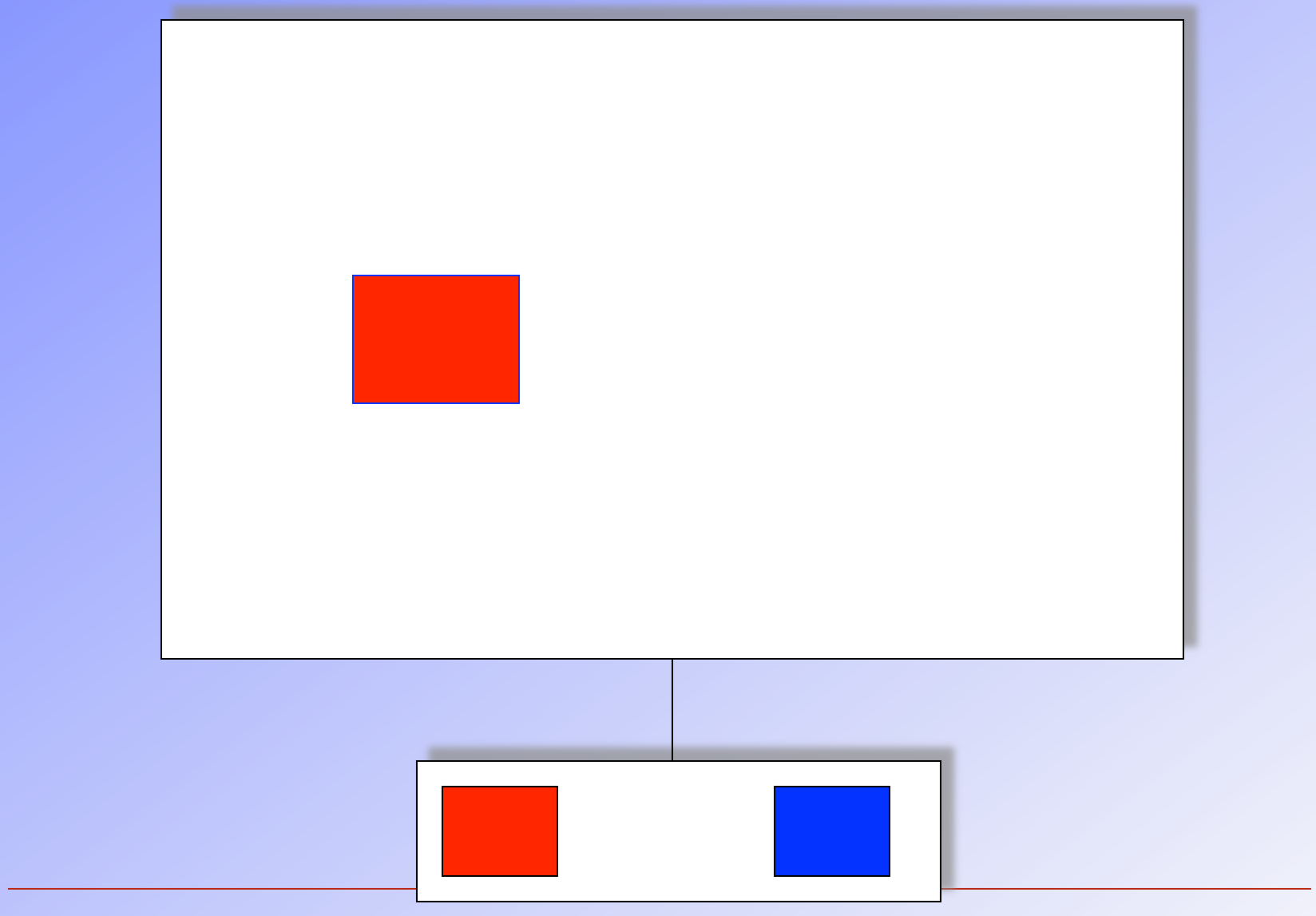
Let's try an EF task together!

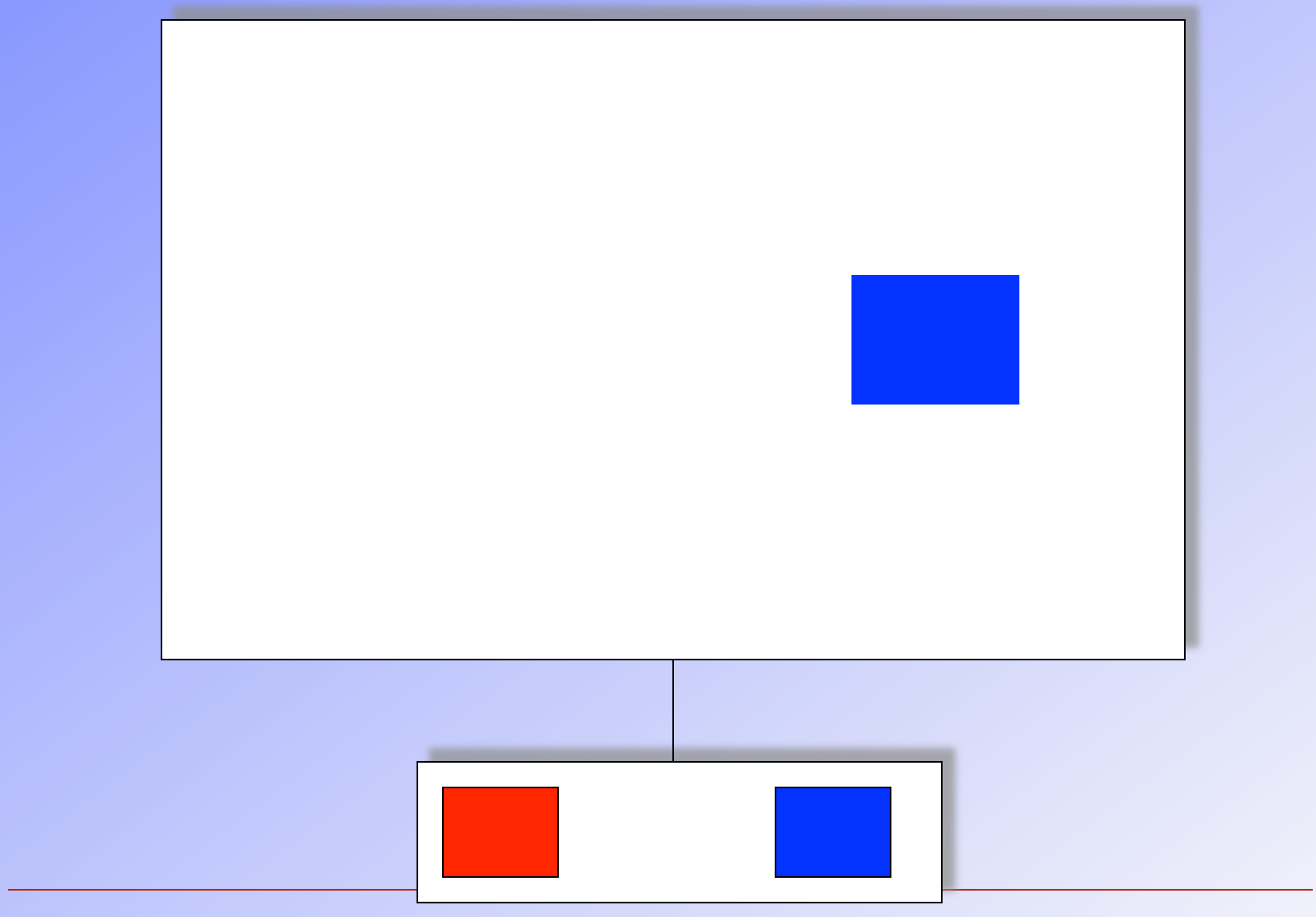
When you see a BLUE square
tap your right hand on the table

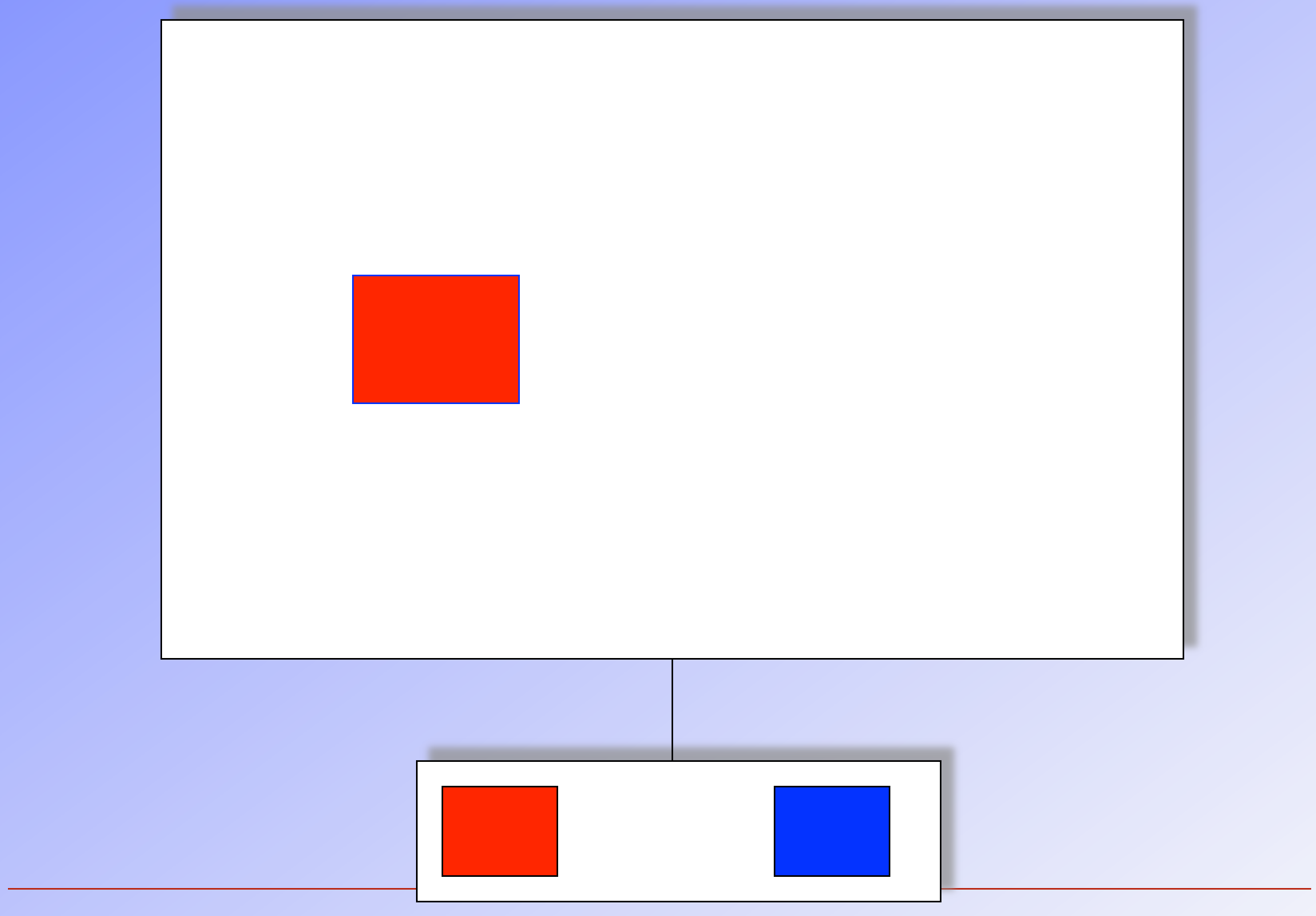
When you see a RED square
tap your left hand on the table

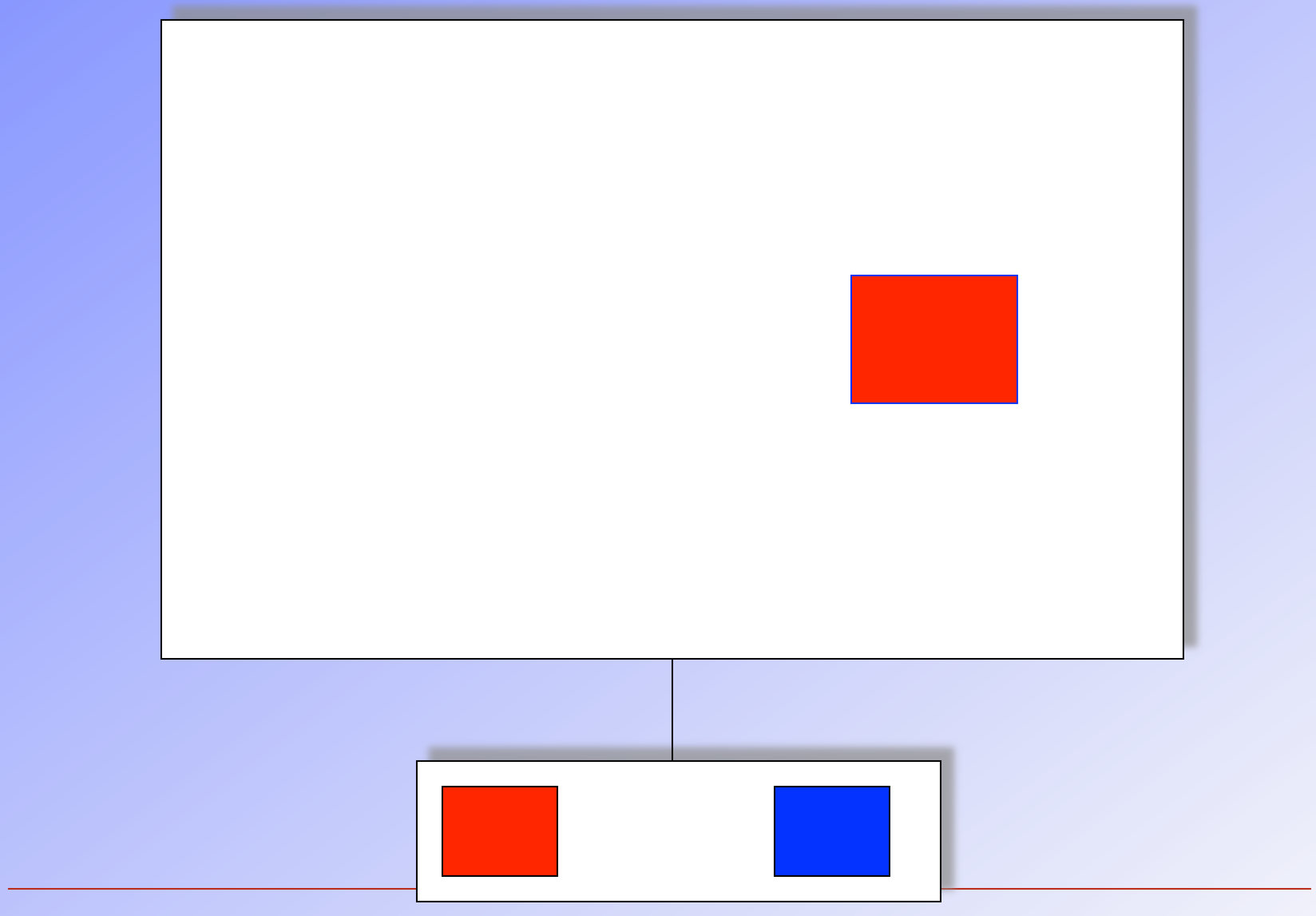


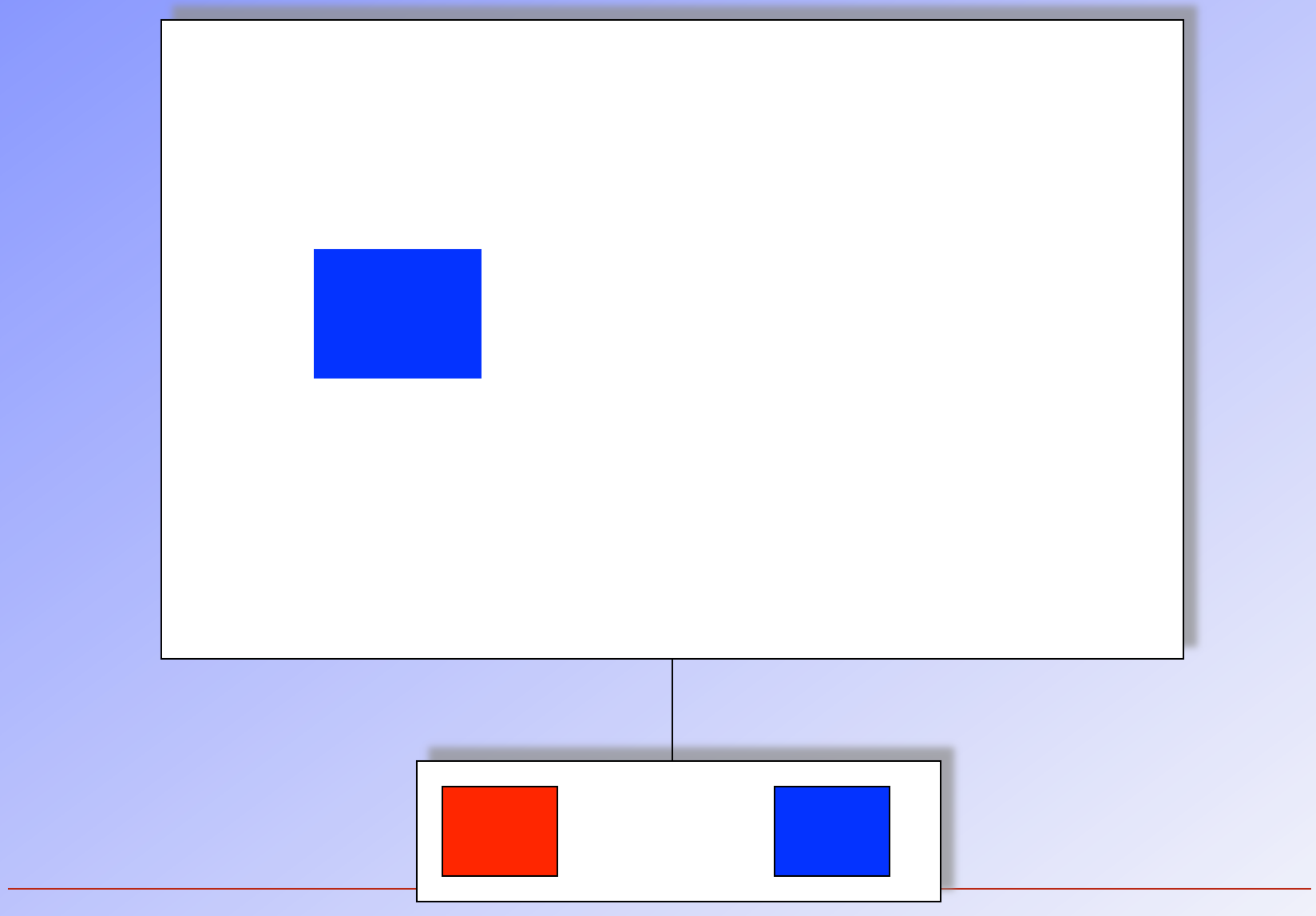




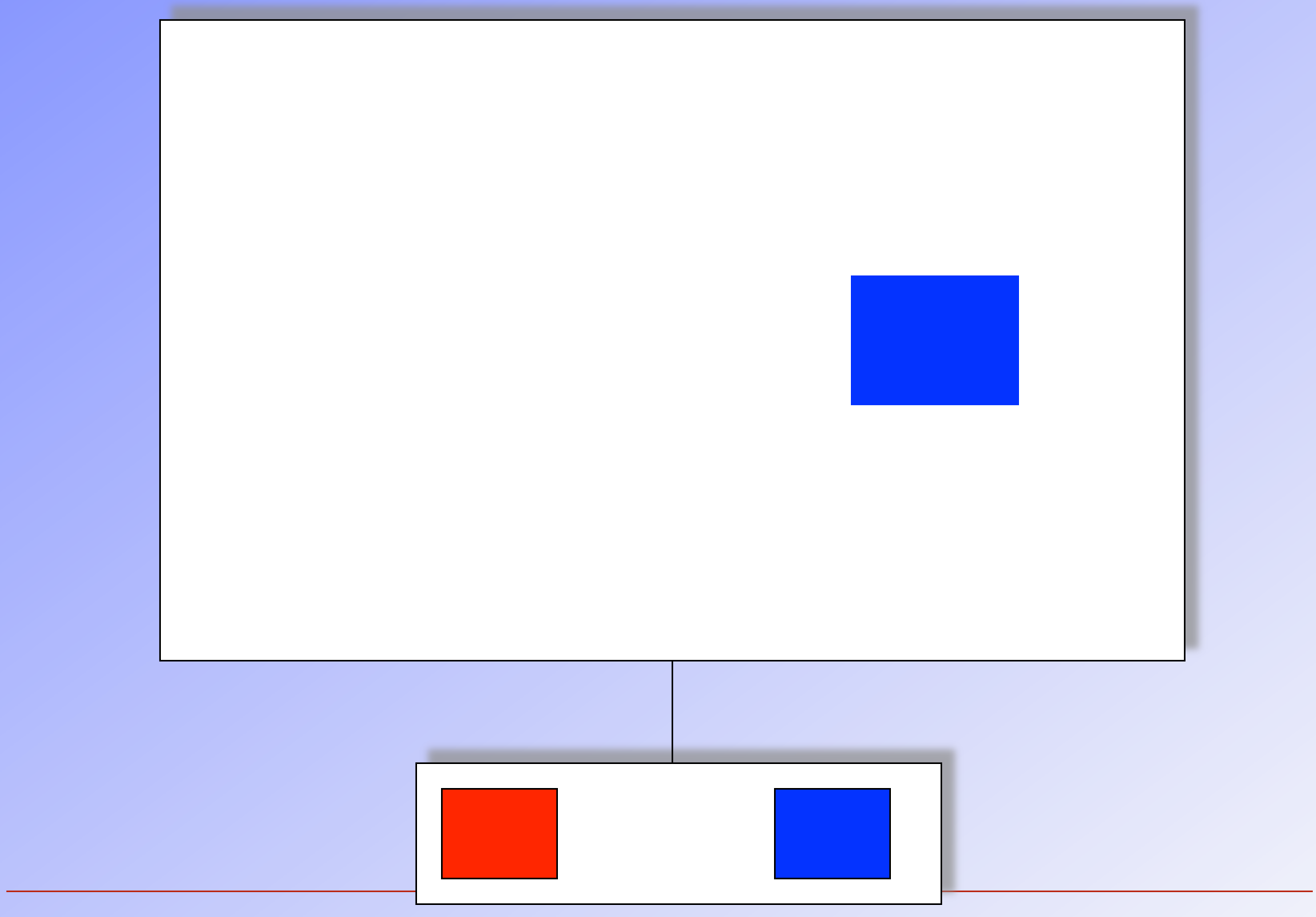




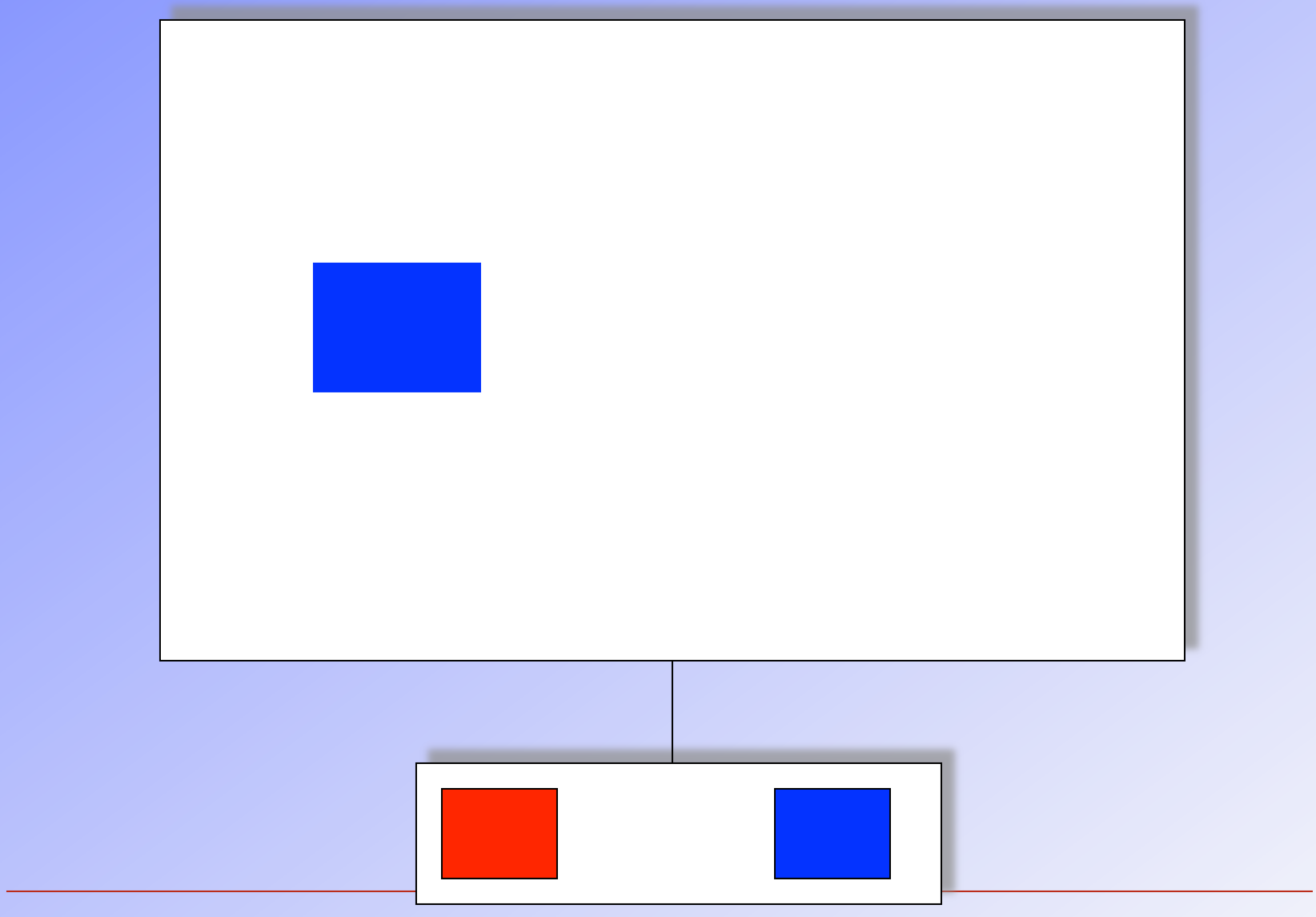




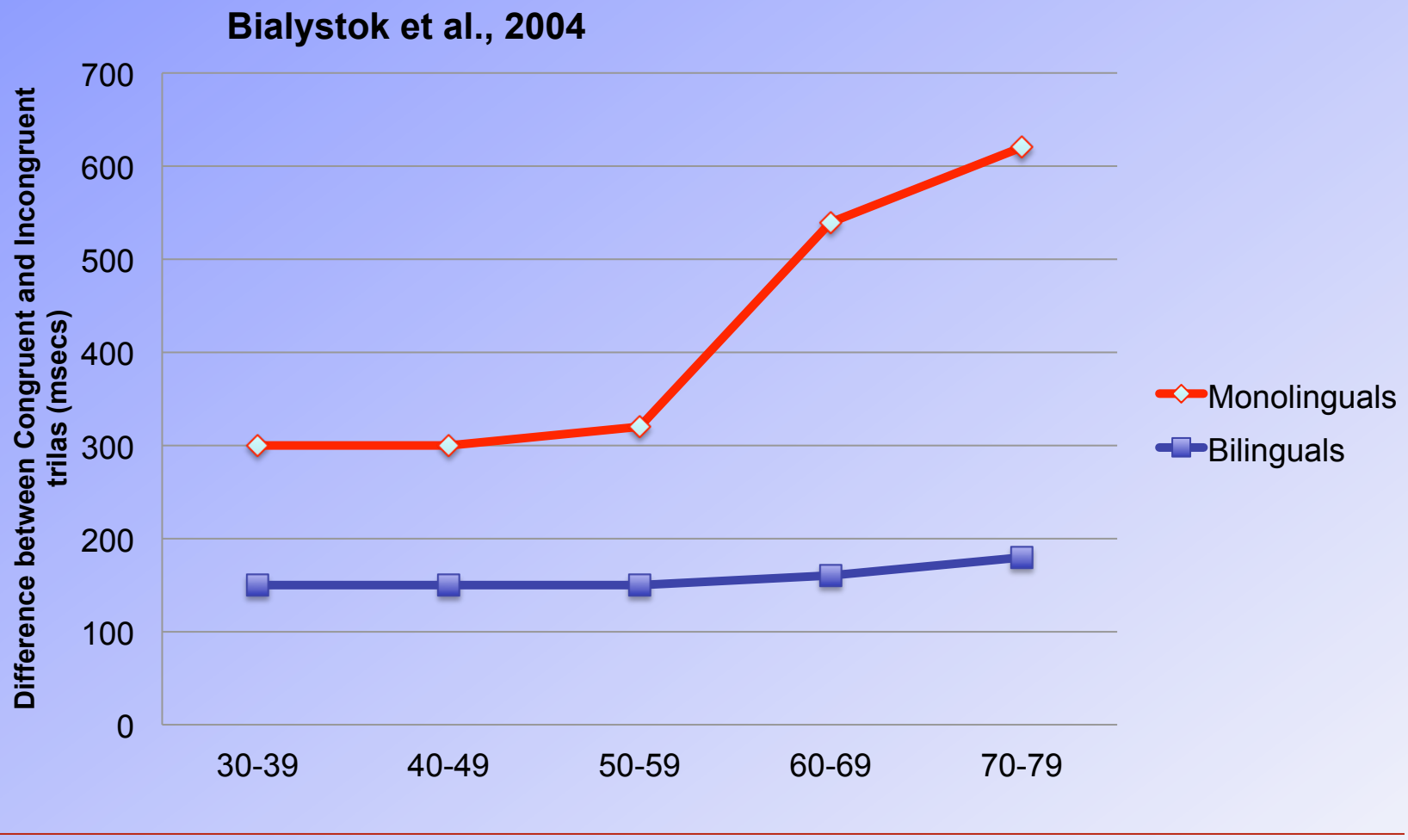
Congruent Trials



Incongruent Trials



Can Language affect Executive Function?



A possible explanation

Bilinguals switch between languages
They need to inhibit one language to produce speech in the other

Daily brain "work-out" may produce a benefit in resolving conflict between competing information beyond the language system

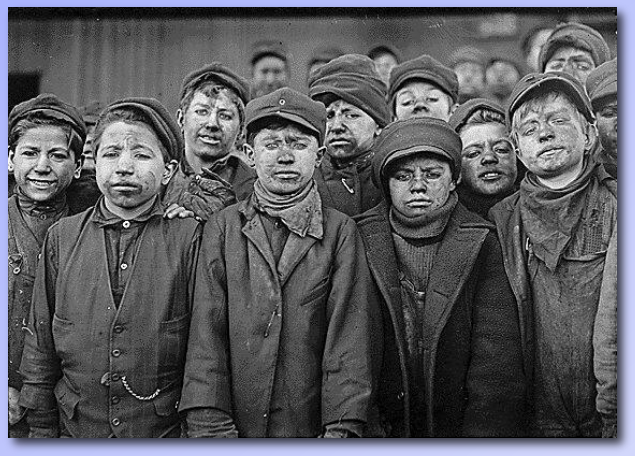
Evidence that language and general cognitive abilities are "interactively" working together (?)

Early research: Bilingualism is BAD!

Up to the 1960s: bilingualism seen as a **handicap** (e.g. Saer, 1923)

Monolingual children outperformed bilingual children on a range of **IQ** measures

Serious methodological issues



No, bilingualism is good!

When Socio-economic status is properly controlled, **bilinguals outperformed monolinguals** in a wide range of cognitive tasks and may protect the brain from the effects of ageing (Bialystok, 2008)

A world of multi-lingual speakers

Estimate of bilinguals in the world

~ 3 billions (Grosjean, 2010)

(50% of the world population!)

Europe

56% bilinguals

Great Britain

38% can speak a second language

(European Commission, 2006)

Who is bilingual?

Bilinguals are people who speak at least two languages (or *dialects*) in their everyday life (Grosjean, 2010)

But there are several levels of bilingualism, for example:

- **Native (early) bilinguals (those who learnt two languages since birth)**

- **Late bilinguals (those who started to learn a second language in adolescence)**

My research

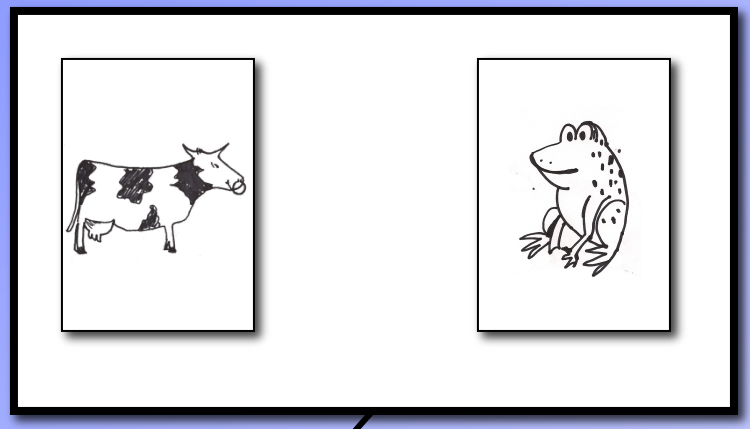
- How does the bilingual brain deal with speech interference?
- Are there any differences between adult “late” bilinguals and “early” bilingual children?
- Does the brain structure change in function of increase control of interference?

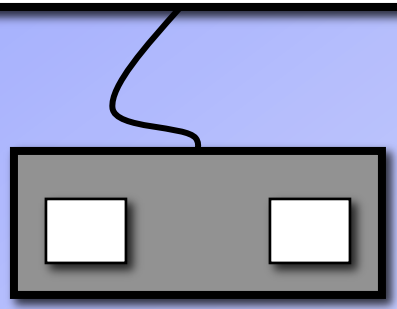
Outline of 3 studies

1. Italian/English bilingual adults vs. Italian monolinguals
2. Magnetic Resonance Imaging with bilingual adults
3. Multi-cultural bilingual children vs. English monolinguals

Main task:

Speech-in-speech, dichotic listening paradigm





Target Sentence
Woman's voice
"The frog is hit by the cow"

Interference
Man's voice
"Il pappagallo morde il toro"

Stimuli

Canonical sentences - Subject-Verb-Object (low comprehension demand):

The Cow is pushing the Frog
La Mucca spinge la Rana
It's the Cow that is pushing the Frog
E' la Mucca che spinge la Rana

Non-canonical sentences - Object-Subject-Verb/ Object-Verb-Subject (high comprehension demand):

The Frog is pushed by the Cow
La Rana e' spinta dalla Mucca
It's the Frog that the Cow is pushing
E' la Rana che la Mucca spinge

Bates, E., & MacWhinney, B. (1987); Dick et al. (2001; 2004); Leech et al. (2007)

Procedure

Participants' task:

• Focus on the **target** sentence and ignore the **interfering** sentence (always spoken by opposite gender)

• Identify the animal doing the "**bad action**" (agent)

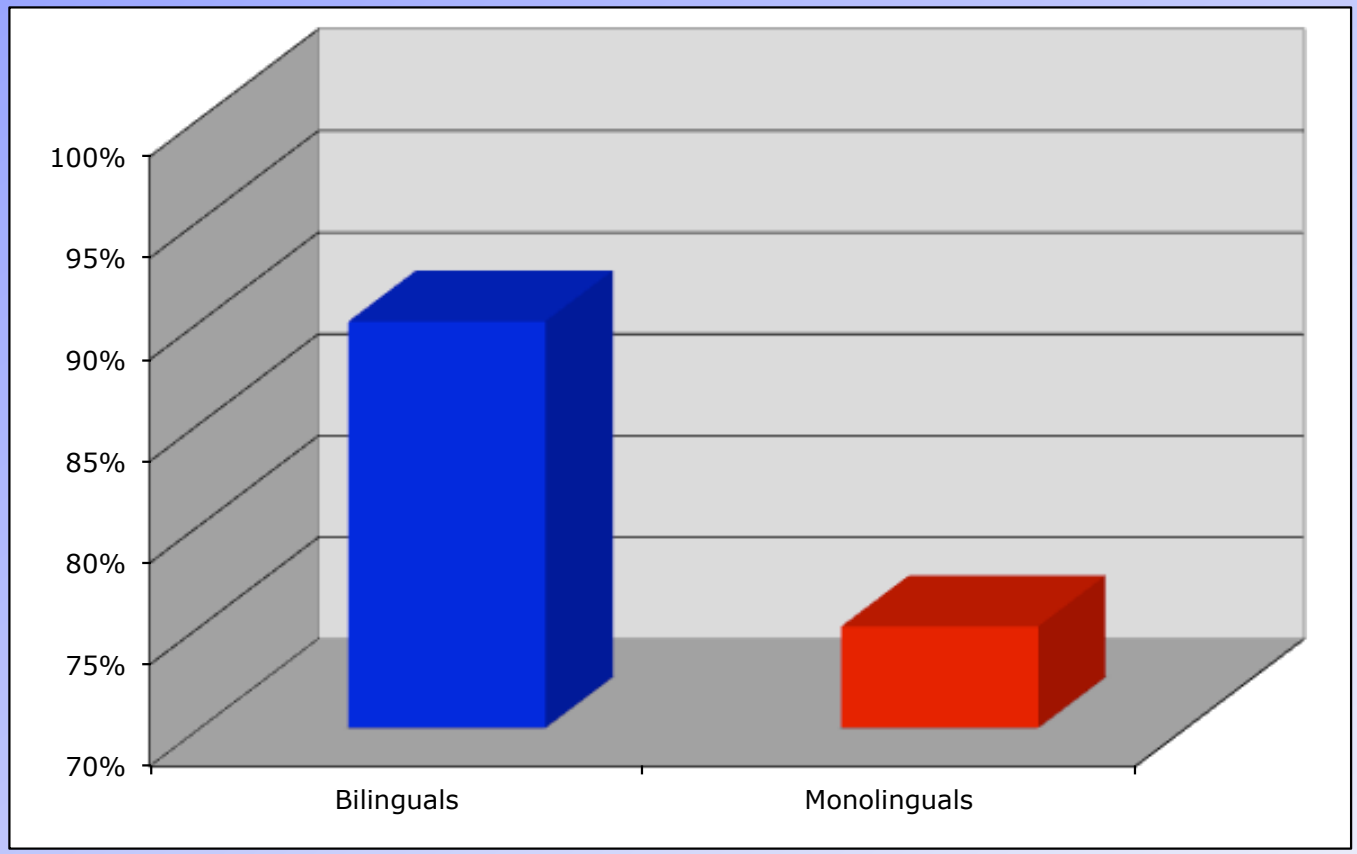
Conditions:

Target sentences	Interference
ITALIAN	ITALIAN ENGLISH

Control condition with **no interference**

Study 1: Adults
Main Results

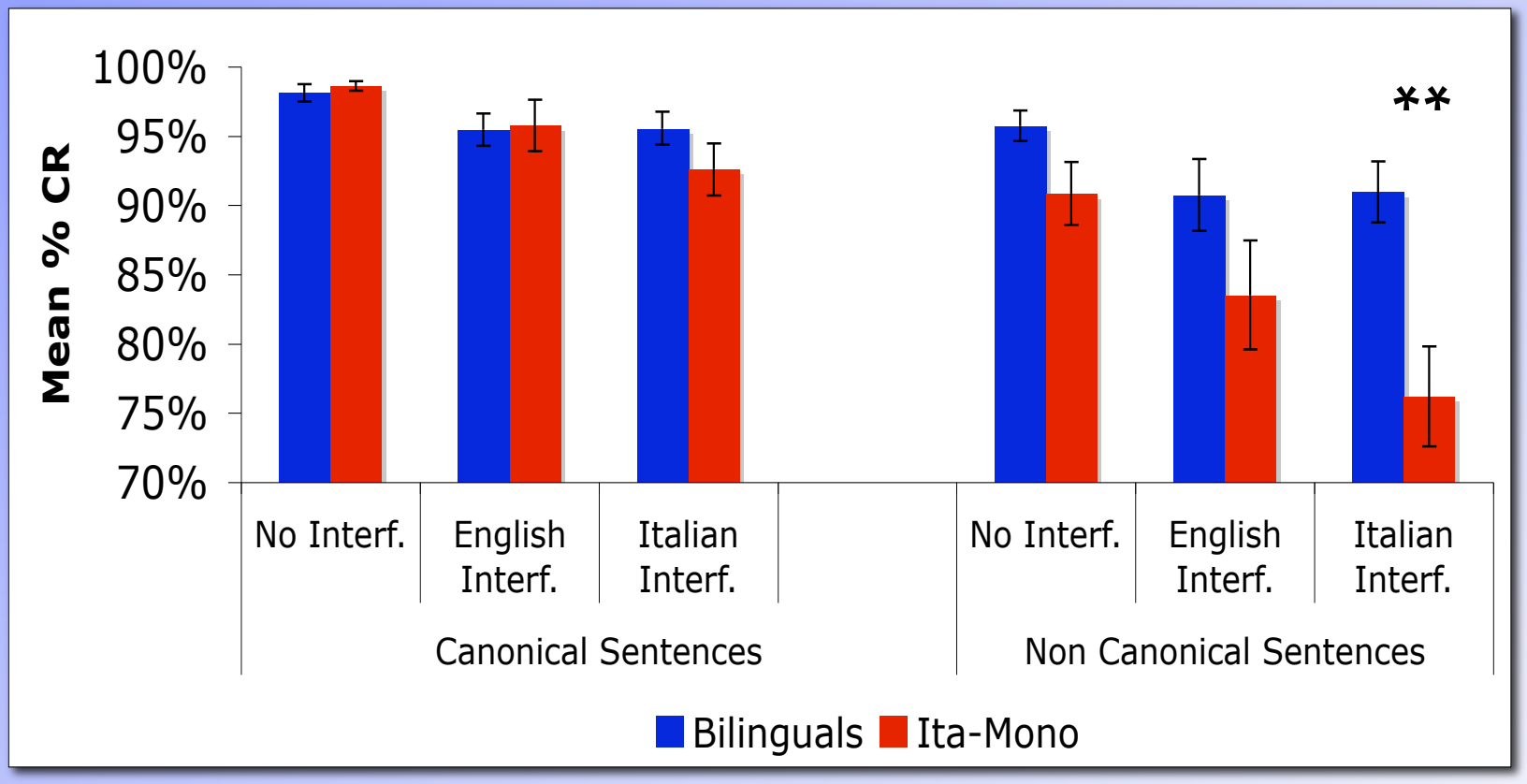
Compared to monolinguals, bilinguals are more efficient in ignoring the interference and comprehend the sentence correctly



(Filippi et al., 2012)

Study 1: Adults

Better in comprehension of more complex sentences



Study 2: The brain and control of interference

Does brain structure change as a function of increased ability to control both languages?

Magnetic Resonance Imaging (MRI) and Voxel-Based Morphometry (VBM) study

Wellcome Trust Centre for Neuroimaging

UCL

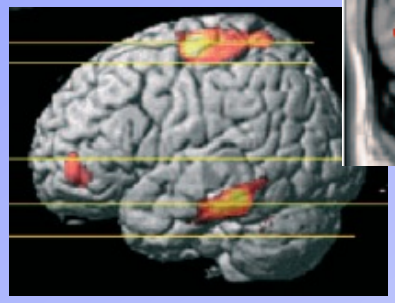
What does VBM do?

- Voxel Based Morphometry (VBM) identifies local differences whilst discounting large scale differences in gross anatomy
  - **i.e. regional differences/changes in grey matter**
- An unbiased analysis technique
- Possible to analyse the whole brain
- Identify precise locations
  - **i.e. [x,y,z] co-ordinates which can be compared with functional studies**

VBM studies

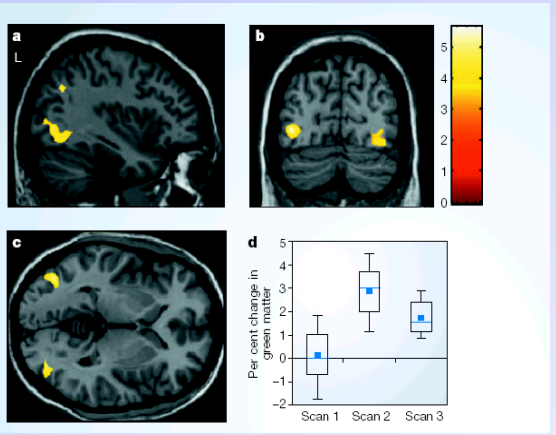
Taxi drivers have more grey matter in the posterior hippocampi

Maguire *et al.* (2000) Science



Brain regions with more grey matter in professional keyboard players

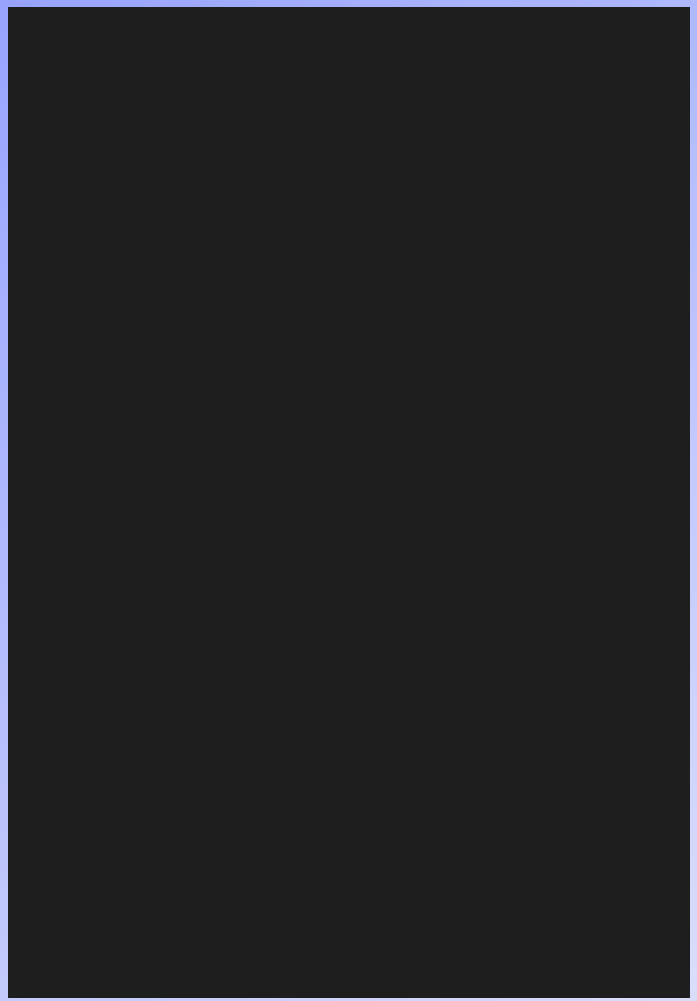
Gaser & Schlaug (2003) Journal of Neuroscience



The acquisition of juggling skill

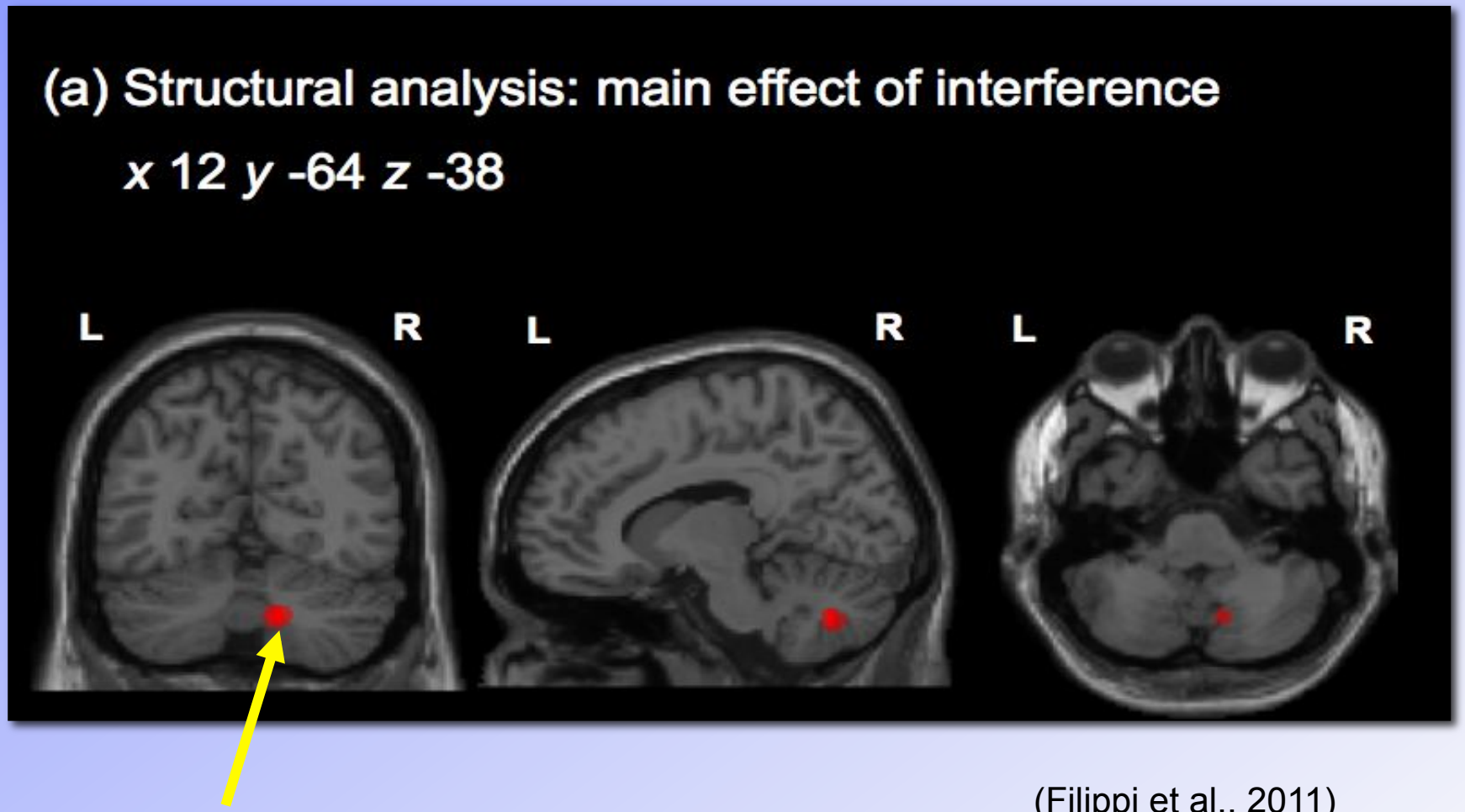
Draganski *et al.* (2004) Nature

Structural Brain Imaging



Study 2: Main Results

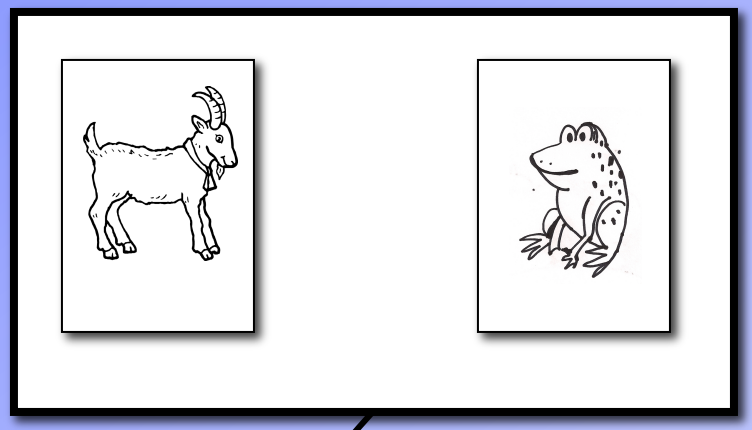
Neuroplasticity and control of interference



(Filippi et al., 2011)

Right-Posterior Paravermis

Study 3: Children

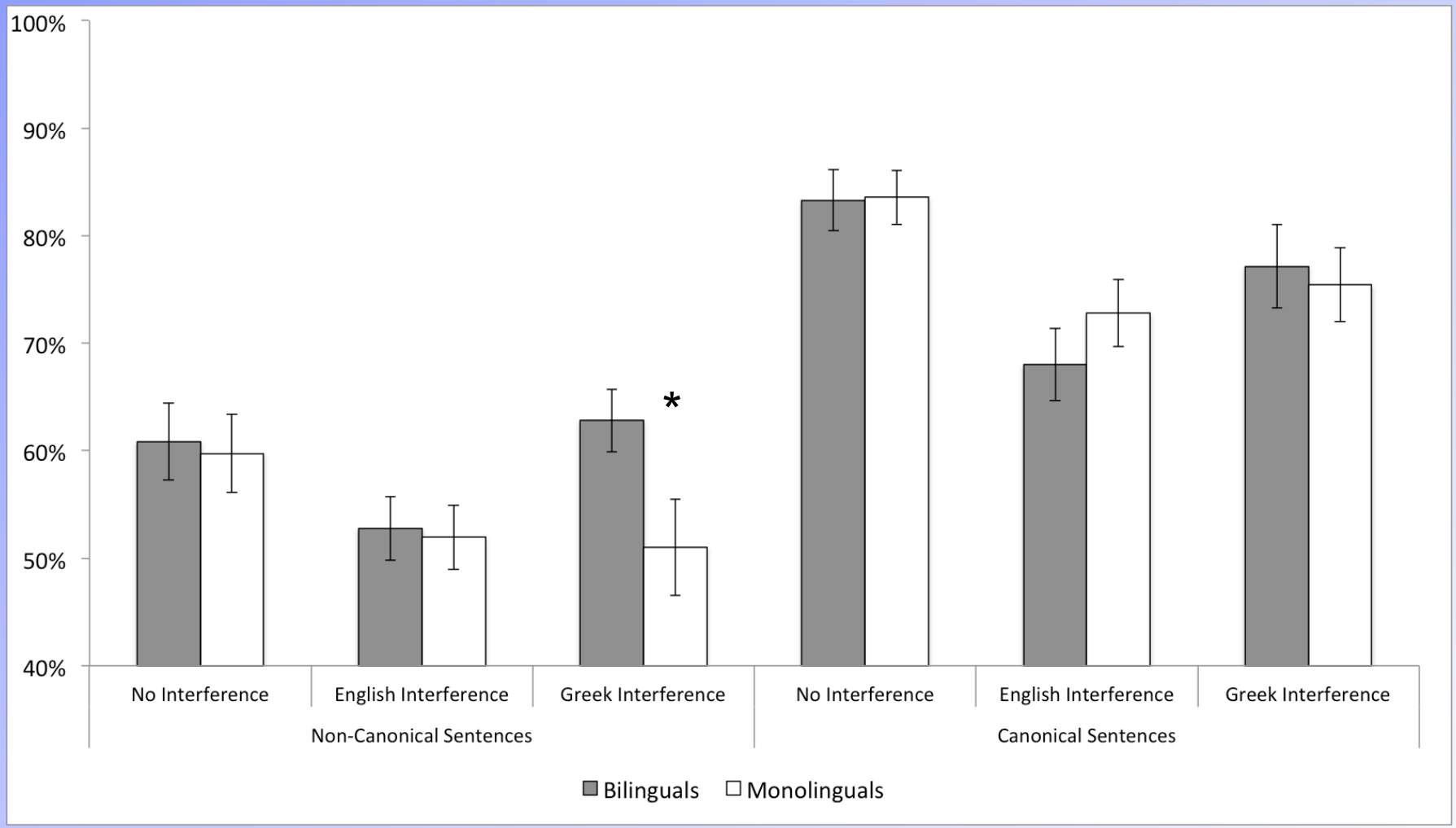


Target Sentence
Woman's voice
"It's the goat that is hitting the frog"

Interference
English
Greek
No Interference

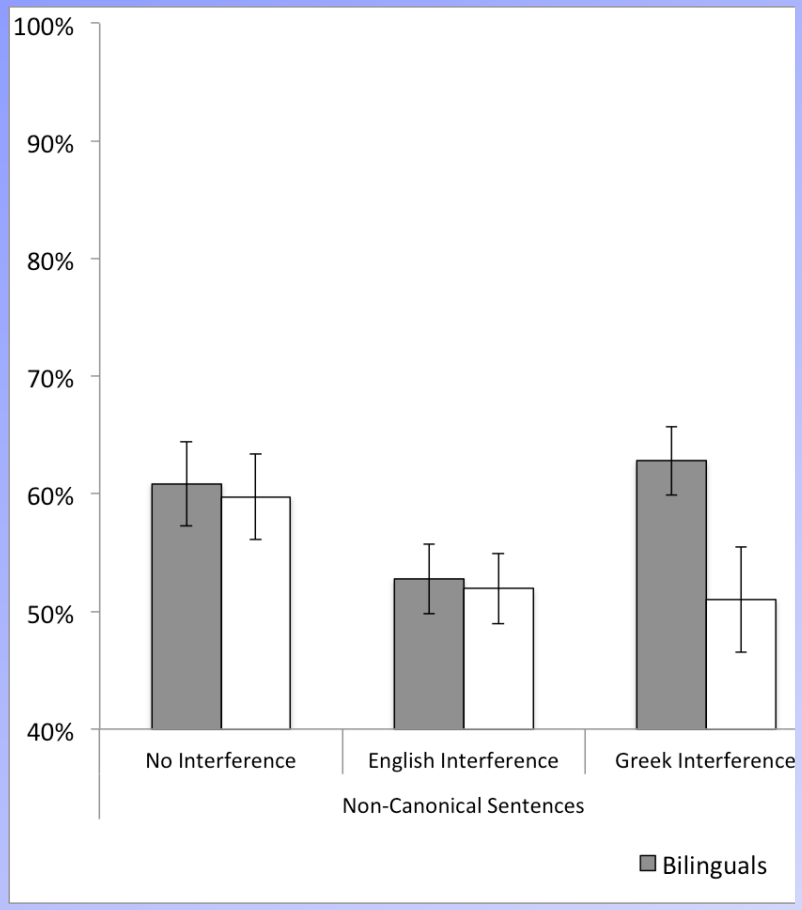
Study 3: Main results

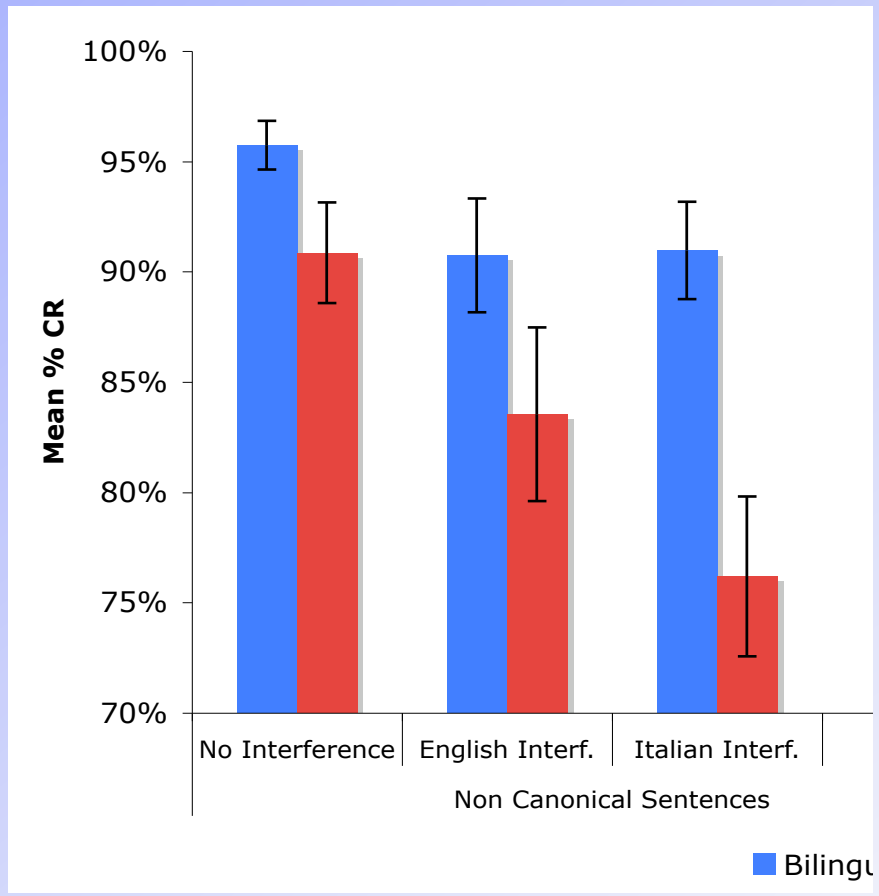
Bilingual children better than monolinguals in comprehension of complex sentences when interference was meaningless



Early vs. Late bilinguals

Early monolinguals less efficient than late bilinguals in screening out native language interference





Conclusions

The combined used of behavioural and neuroimaging techiques provided new evidence for:

1) An enhanced bilingual ability to resist sentence-level interference when comprehension demands were high (both in childhood and adulthood)

(Filippi et al., 2012, Bilingualism: Language & Cognition; Filippi et al., in preparation)

2) Novel finding: involvement of Cerebellum in the control of verbal interference

(Filippi et al., 2011, Journal of Neuroscience)

General Conclusions

The study of bilingualism has provided interesting findings

Growing evidence that language and general cognitive functions work together

Has cleared up previous convictions that learning a second language is bad for cognitive development

More research is required to draw definite conclusions

THANKS TO

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