Cognitive Neuroscience and Addiction

Giuseppe Sartori

Professor of Cognitive Neuroscience
University of Padua

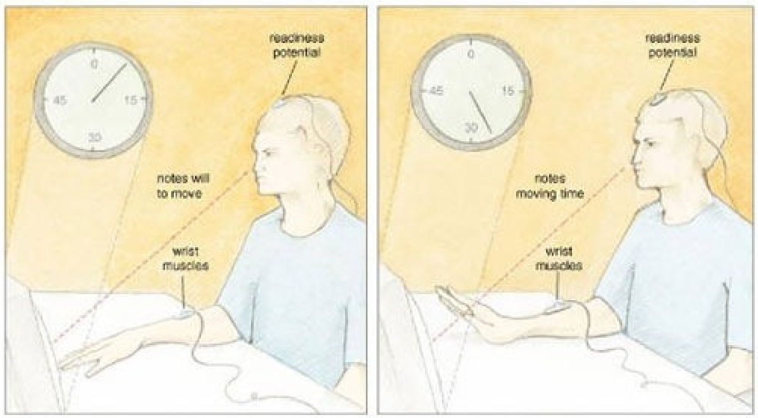
Consciousness and free will

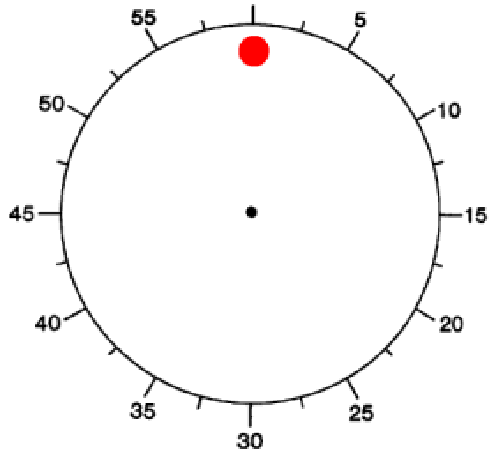
Libet *et al* (1983)

Conscious experiences related to actions are preceded by <u>**unconscious**</u> brain electrical activity – the *readiness potentials* – which begins about 500-1000 milliseconds before the action

Method

Subjects had to move their wrists while observing a rotating clock hand. After each trial, they had to determine the clock position when they formed the intention to act (the so-called *W judgment*)





Consciousness and free will

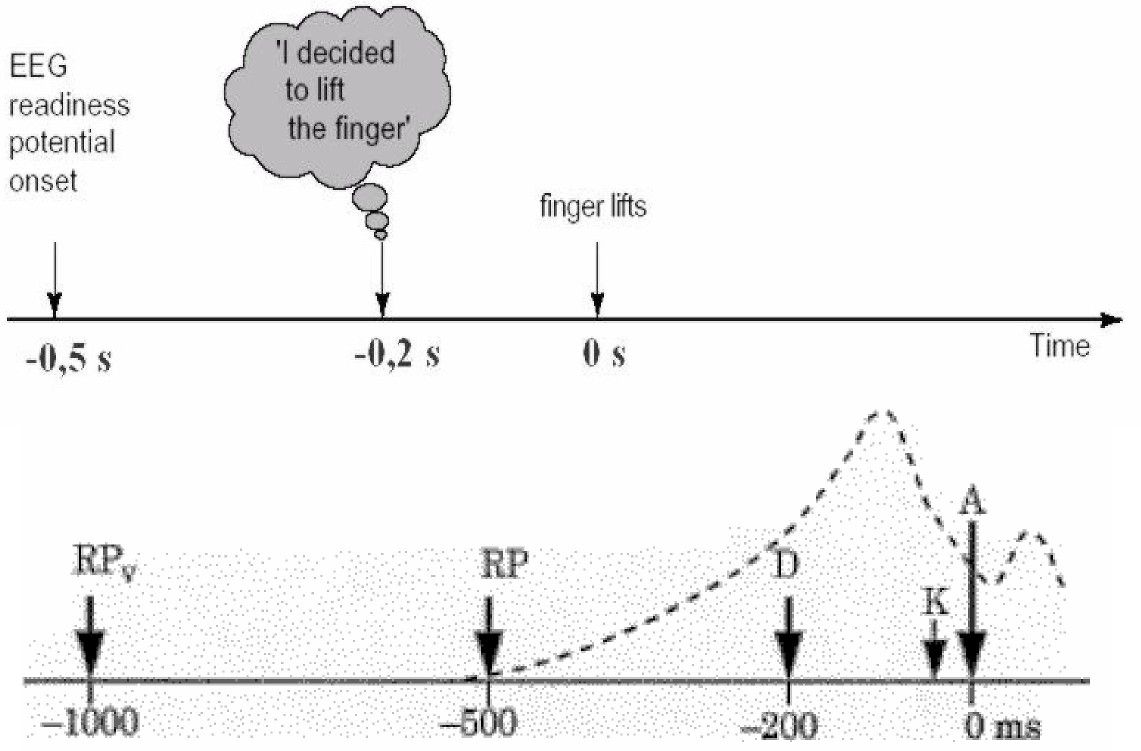
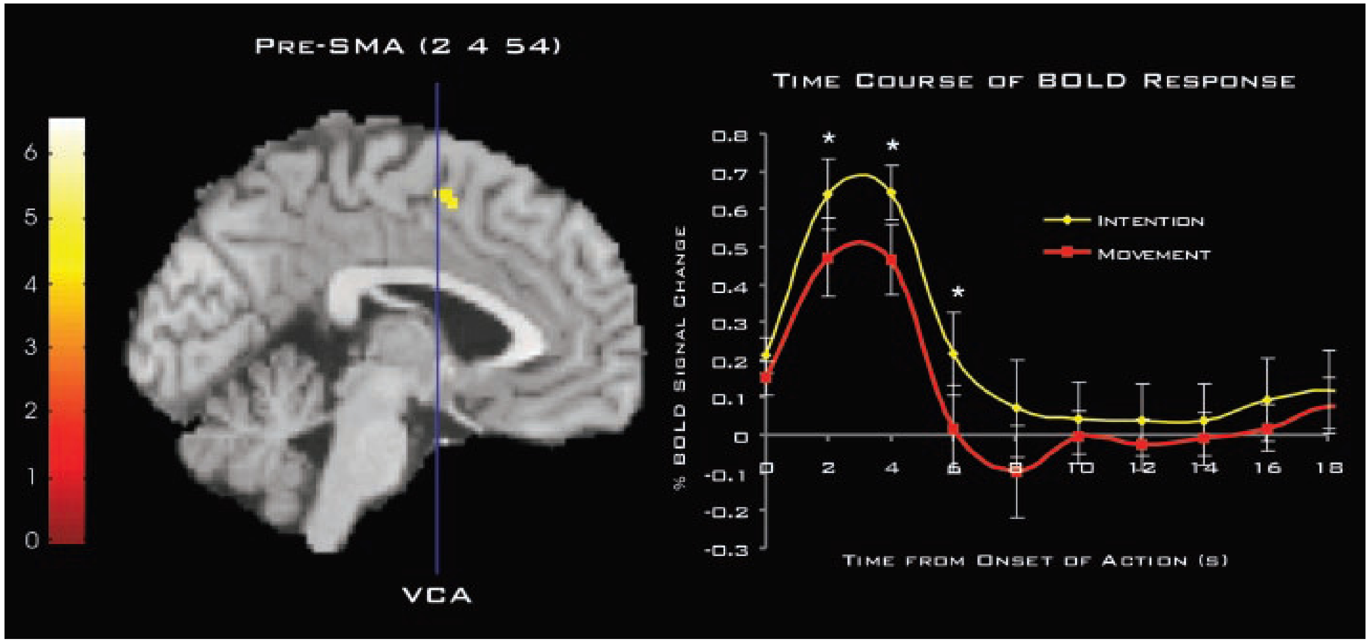


Fig. 1: Sequence of readiness potential (RP), volitional decision (D), and onset of action (A), as well as the control stimulus on the skin (K). If the action is planned ahead, the readiness potential starts already at time RP_v. After Libet (1985).

Consciousness and free will

- Lau *et al* (2004)
  - Intention to act reflects the activity in the supplementary motor area (*pre-SMA*)



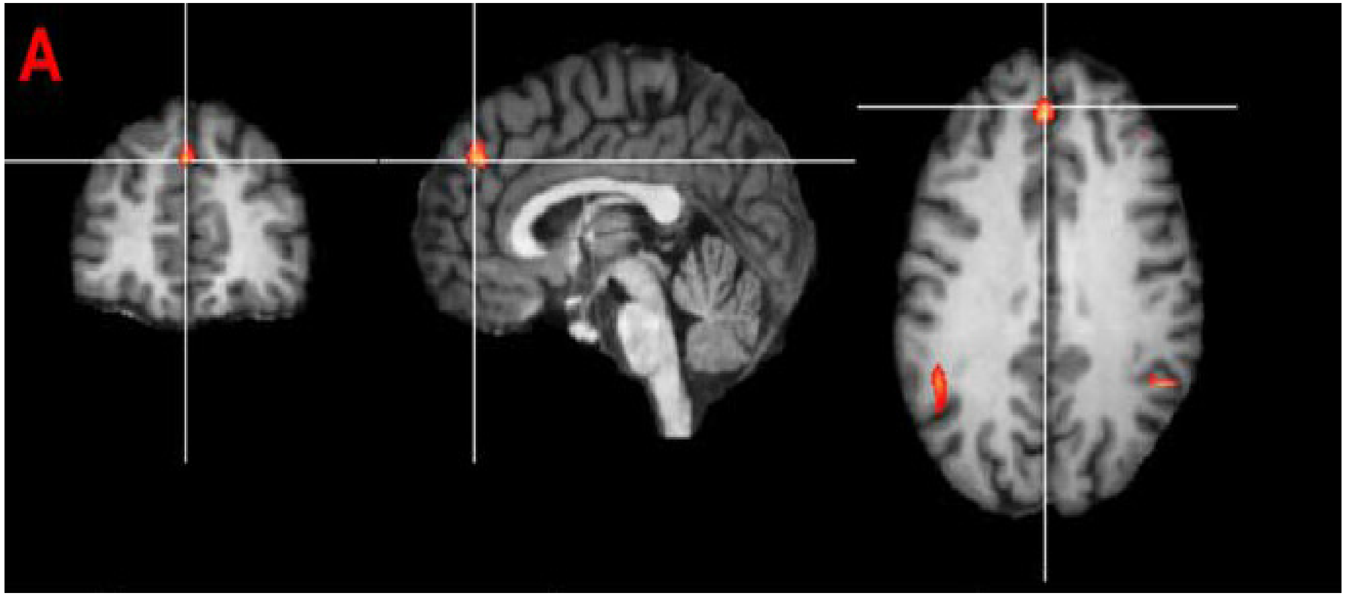
Inhibition of intentions to act

The Journal of Neuroscience, August 22, 2007 • 27(34):9141–9145 • **9141**

To Do or Not to Do: The Neural Signature of Self-Control

Marcel Brass[1,2] and Patrick Haggard[3]
[1]Max Planck Institute for Human Cognitive and Brain Sciences, 04103 Leipzig, Germany, [2]Department of Experimental Psychology, Ghent University, 9000 Ghent, Belgium, and [3]Institute of Cognitive Neuroscience and Department of Psychology, University College London, London WC1N 3AR, United Kingdom

Fundamental role played by dorsomedial frontal cortex in actions inhibition

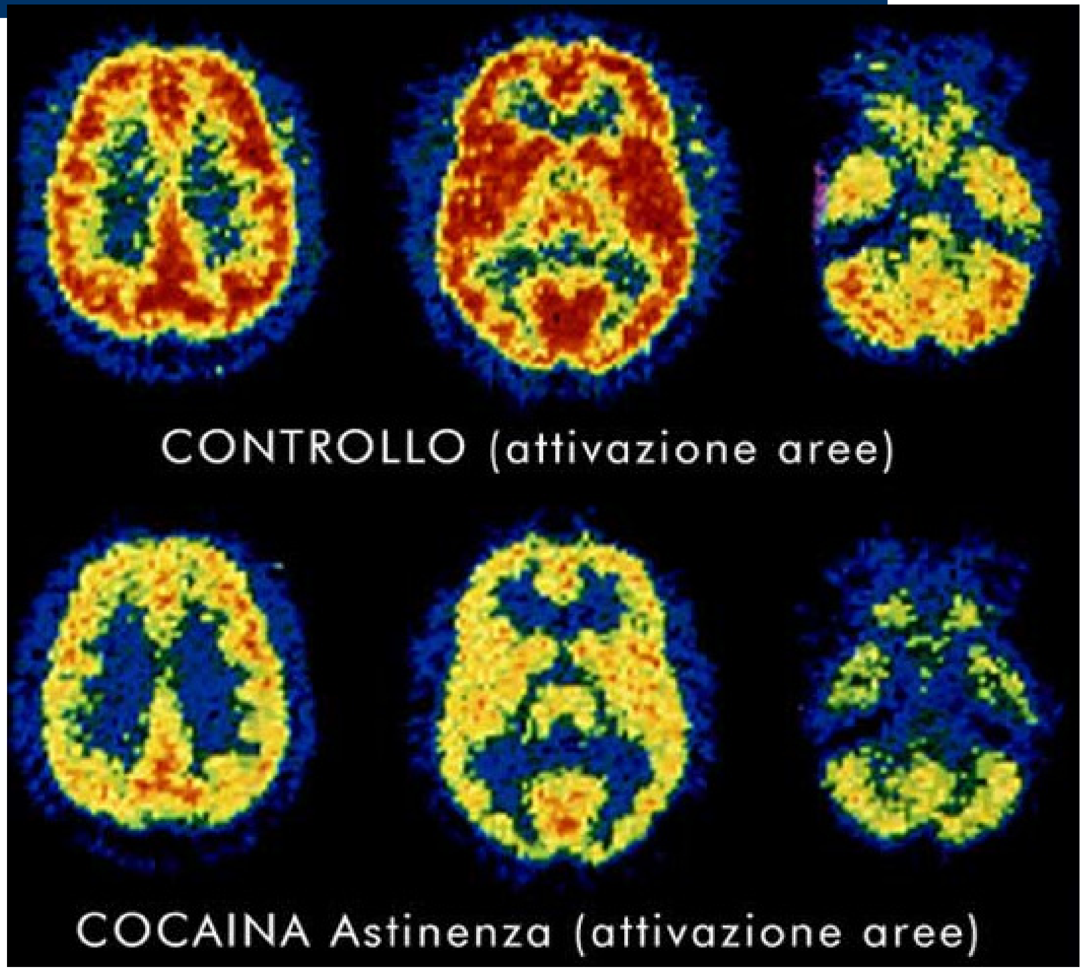


Methods in cognitive neuroscience

- Tools for measuring electric cerebral activity
  - Event related Potentials (ERPs)
- Neuroimaging
  - Magnetic Neuroscience (MR), Voxel-Based Morphometry (VBM)
- Functional neuroimaging
  - Functional MRI (fMRI), Positron Emission Tomography (PET)

Positron Emission Tomography

PET images showing activity reduction in brain regions of a cocaine abuser with respect to a normal subject. Red areas are related to greater brain activity



Reward system

doi:10.1093/brain/awn011 *Brain* (2008),

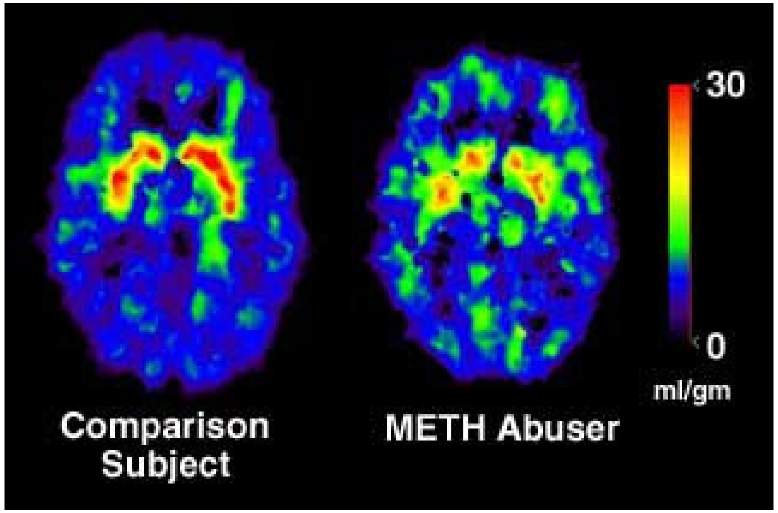
Focal basal ganglia lesions are associated with impairments in reward-based reversal learning

Christian Bellebaum,[1] Benno Koch,[2] Michael Schwarz[2] and Irene Daum[1]

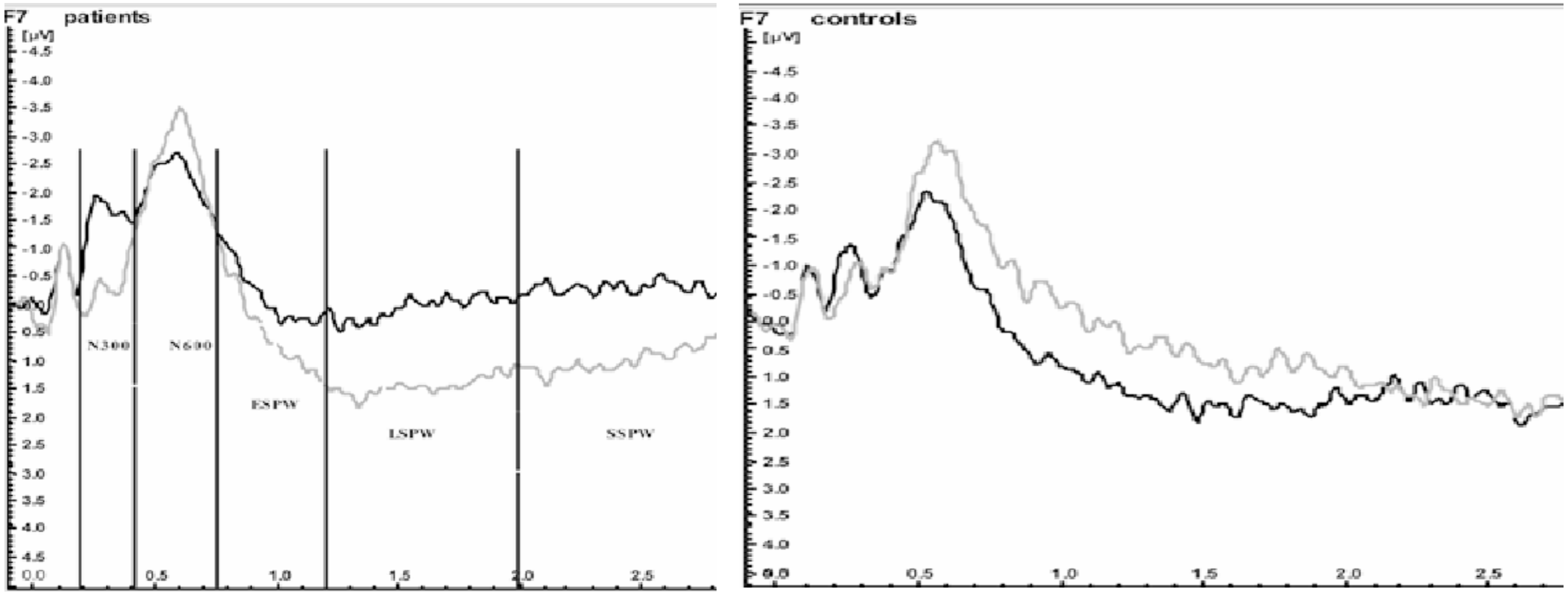
Positron Emission Tomography

- Pet is a nuclear medicine imaging technique which produces a three-dimensional image or map of functional processes in the brain

Dopaminergic reduction in metamphetamine abusers (Volkow et al, 2001)



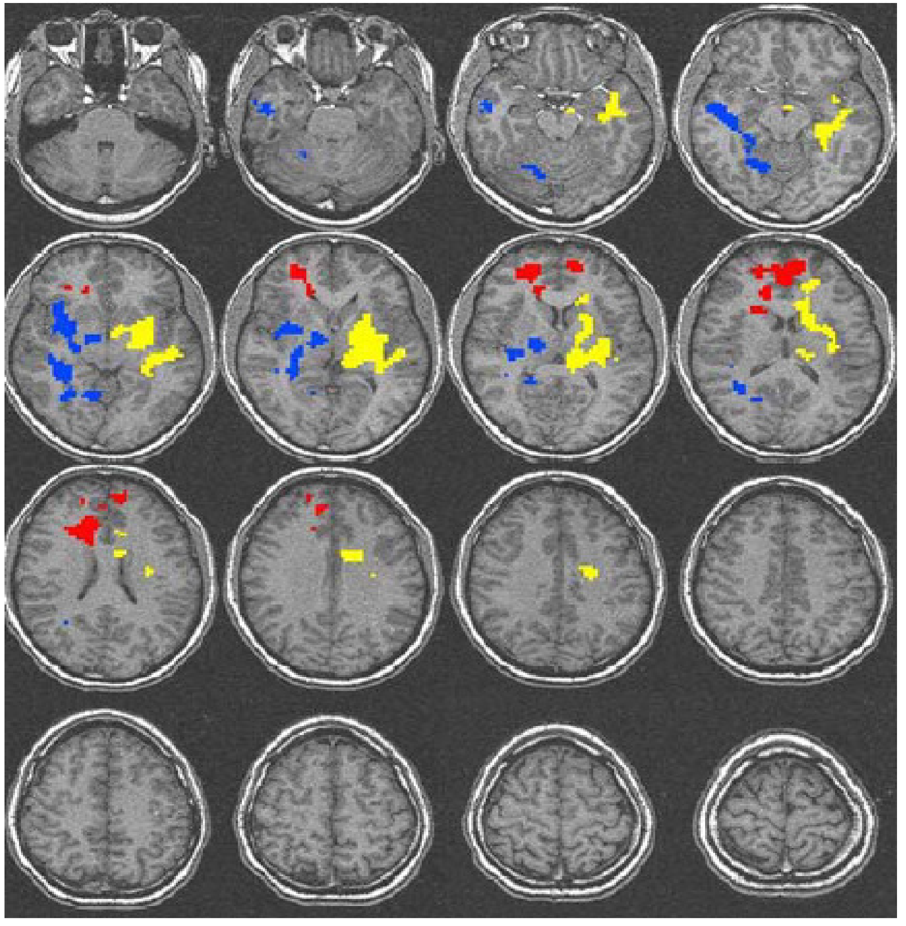
Event-related Potentials



- Electrical brain activity in cocaine addicted and normal subjects during the presentation of neutral stimuli (black line) and cocaine-related stimuli (grey line) (van de Laar et al, 2004)

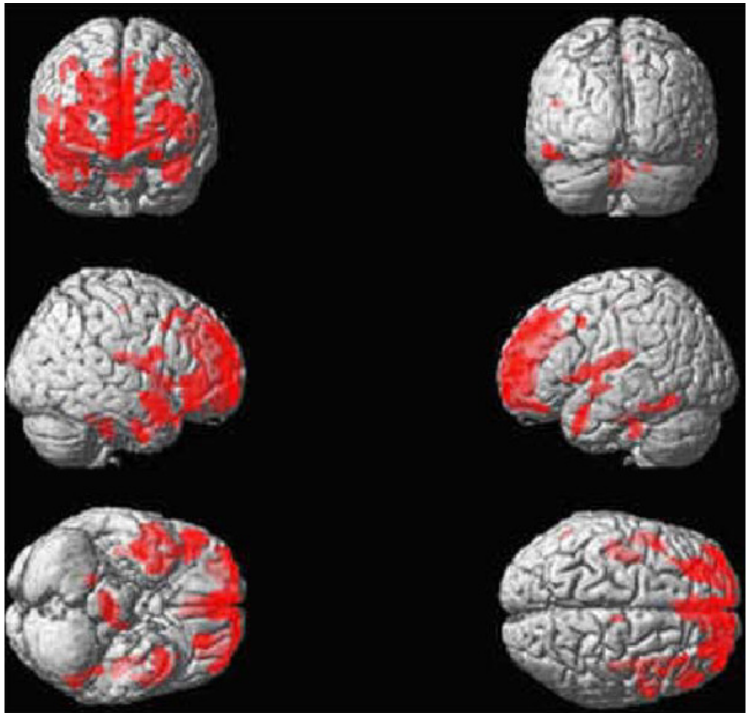
Functional Magnetic Resonance

Hyperactive brain regions in MDMA abusers as compared with healthy subjects during a working memory task (Moeller et al, 2004)



Voxel-Based Morphometry

- It provides a measure of brain density through the whole brain



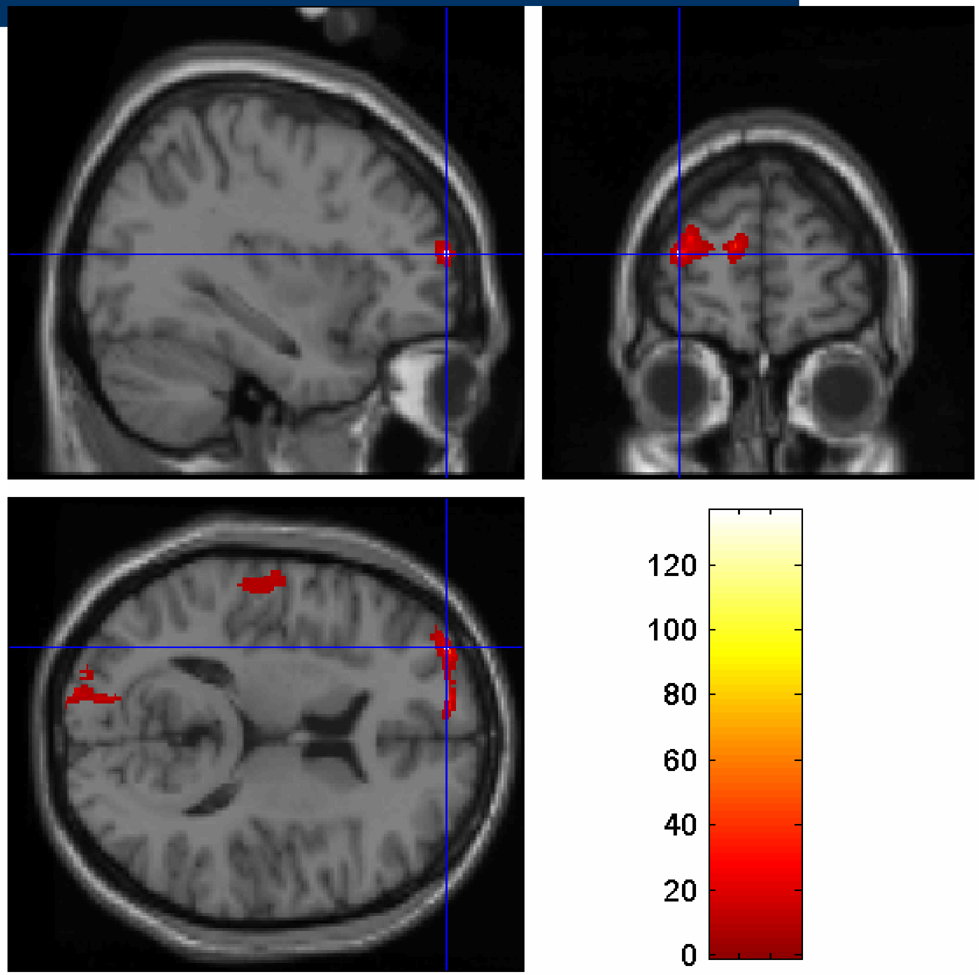
Heroin addicted subjects show frontal and bilateral temporal hypodensity as compared with healthy subjects (Lyoo et al, 2006)

Case report – J F

- 25 years old
- Long lasting multidrug abuser
  - Heroin, alcohol, cocaine, MDMA
- ERPs investigation
- VBM analysis
- Neuropsychological testing

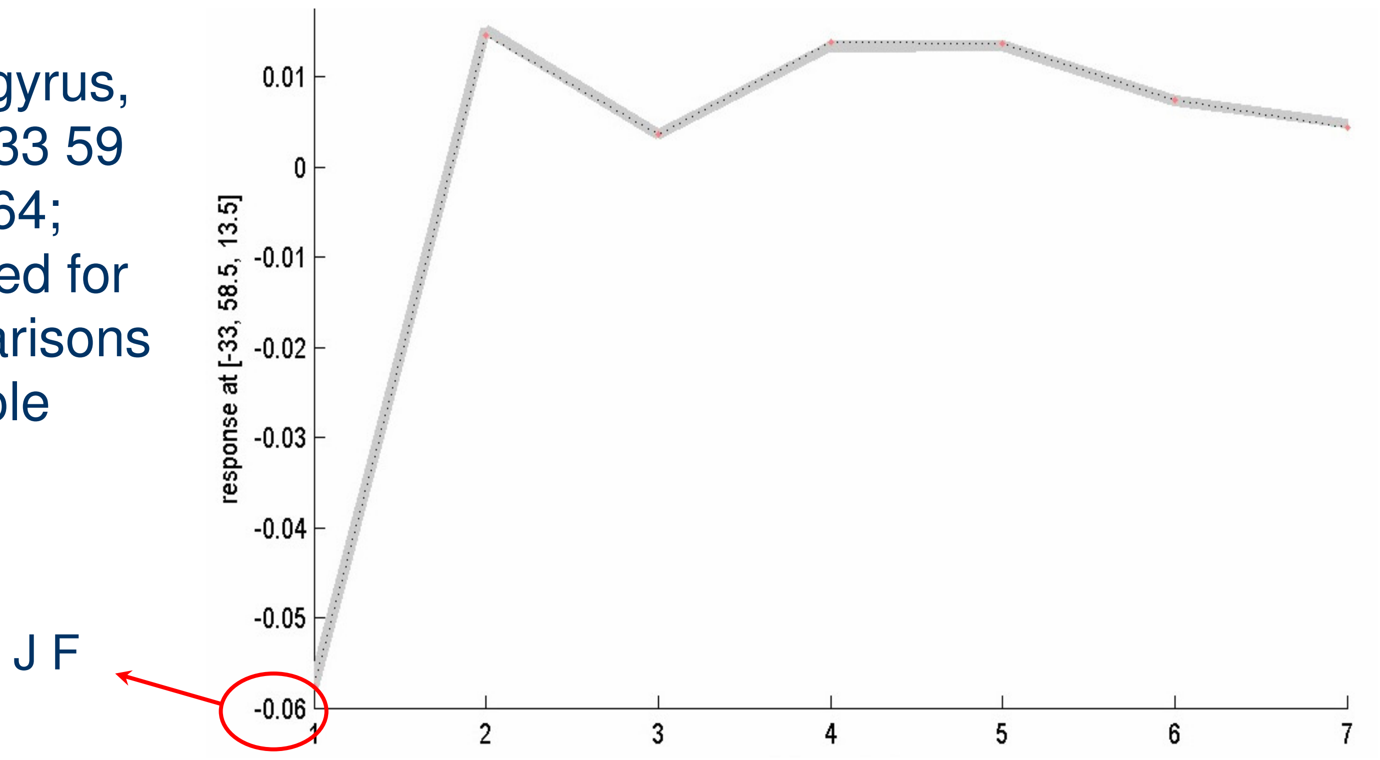
Case report – J F

Middle frontal gyrus, co-ordinates: -33 59 14; z-score: 5.64; $p<0.05$ corrected for multiple comparisons across the whole brain.



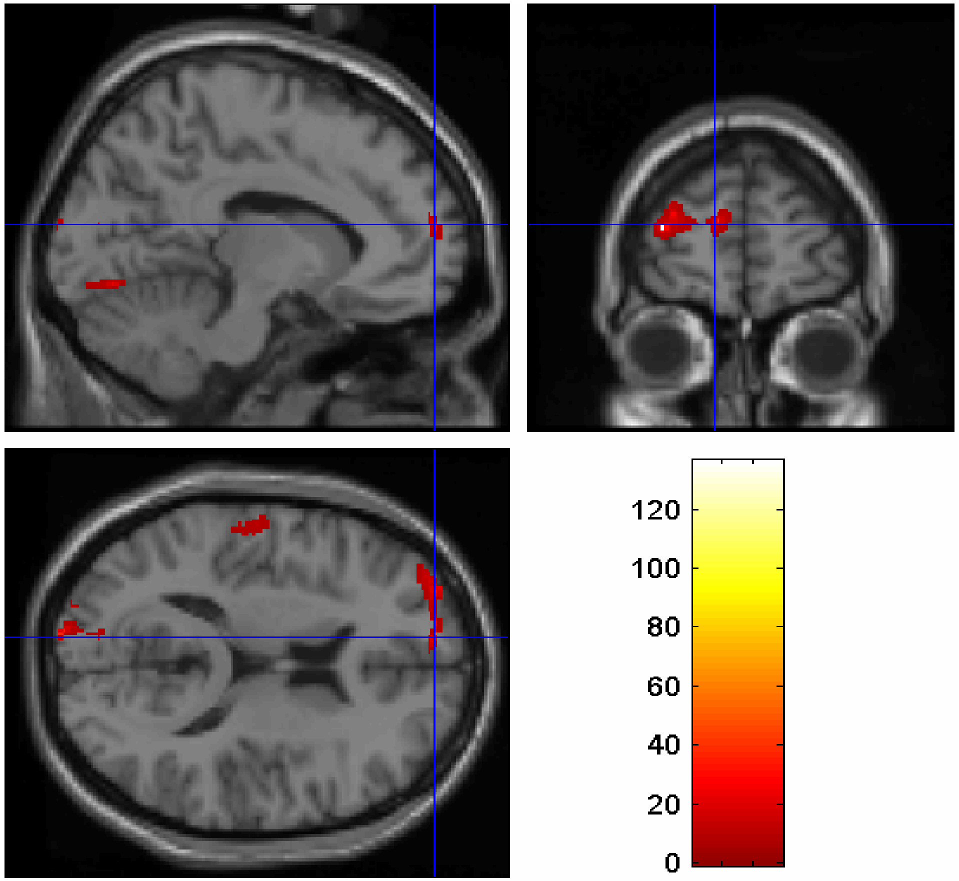
Case report – J F

Middle frontal gyrus, co-ordinates: -33 59 14; z-score: 5.64; p<0.05 corrected for multiple comparisons across the whole brain



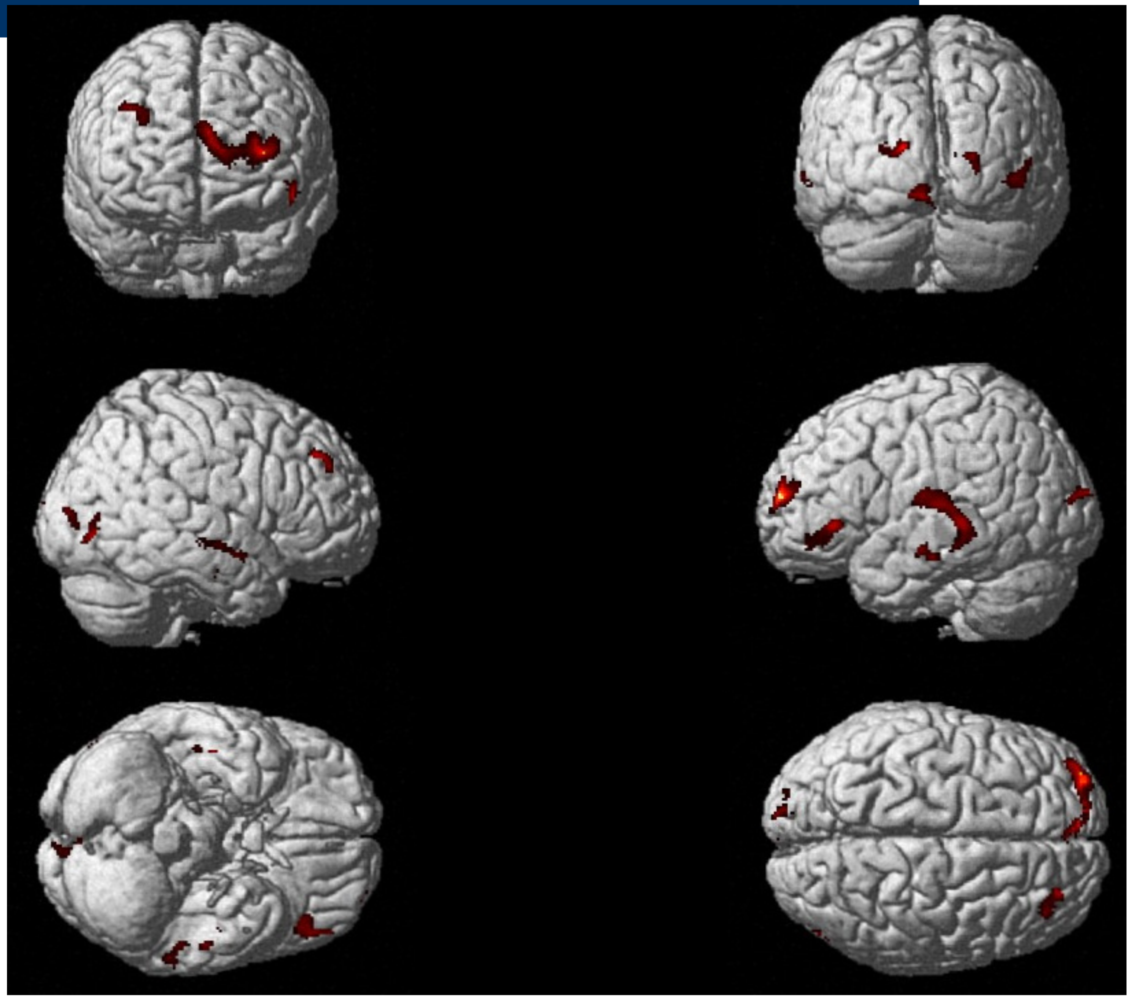
Case report – J F

Superior frontal gyrus, co-ordinates: -12 60 15; z-score: 4.92; $p<0.05$ corrected for multiple comparisons across the whole brain.



Case report – J F

3D images of differences in gray matter density

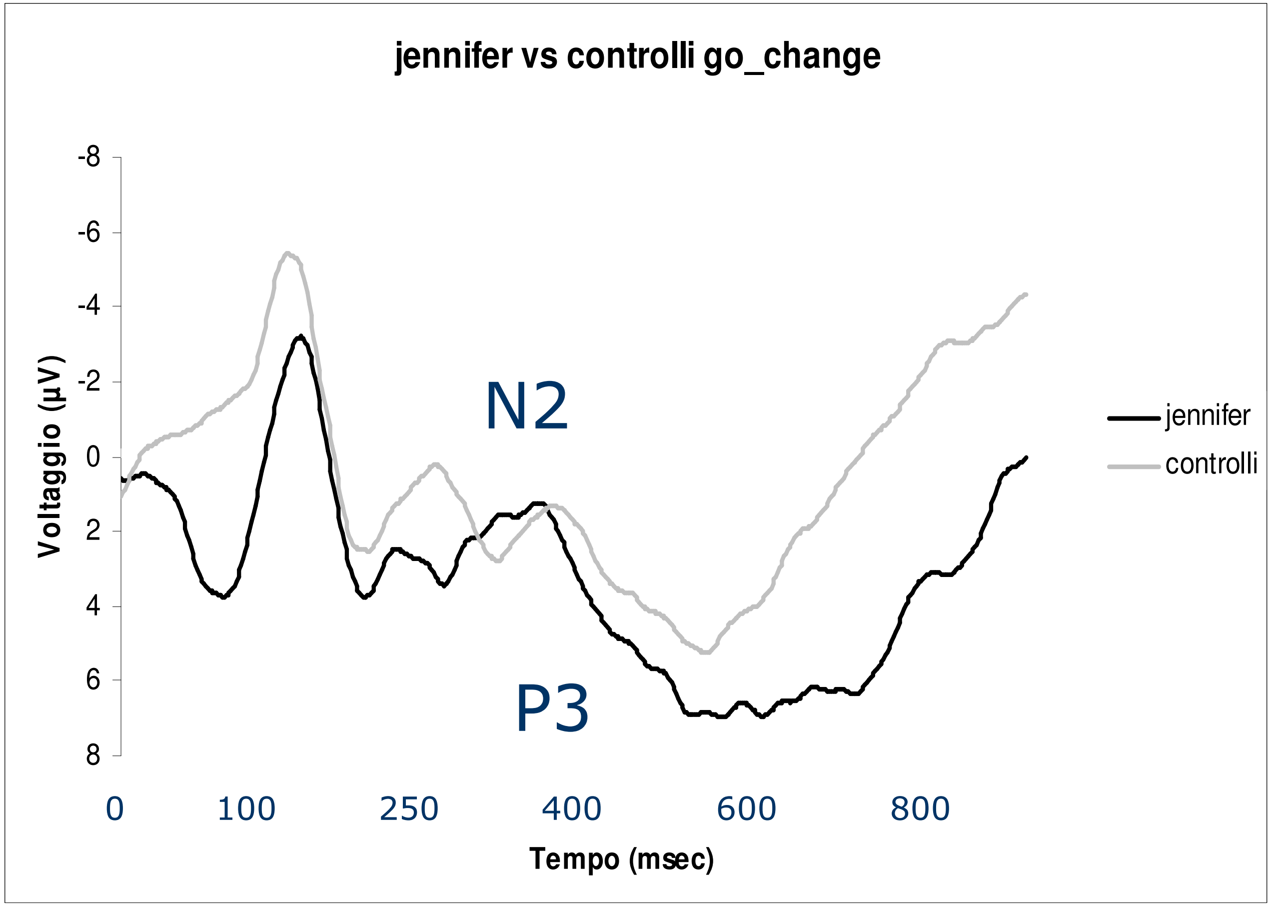


Case report – J F

- Stop-signal task
  - Requires subjects to perform speeded responses on GO trials and to inhibit their response on STOP trials
  - Useful in assessing impulsivity
  - N2-P3 complex greater on STOP than on GO trials → marker of response inhibition

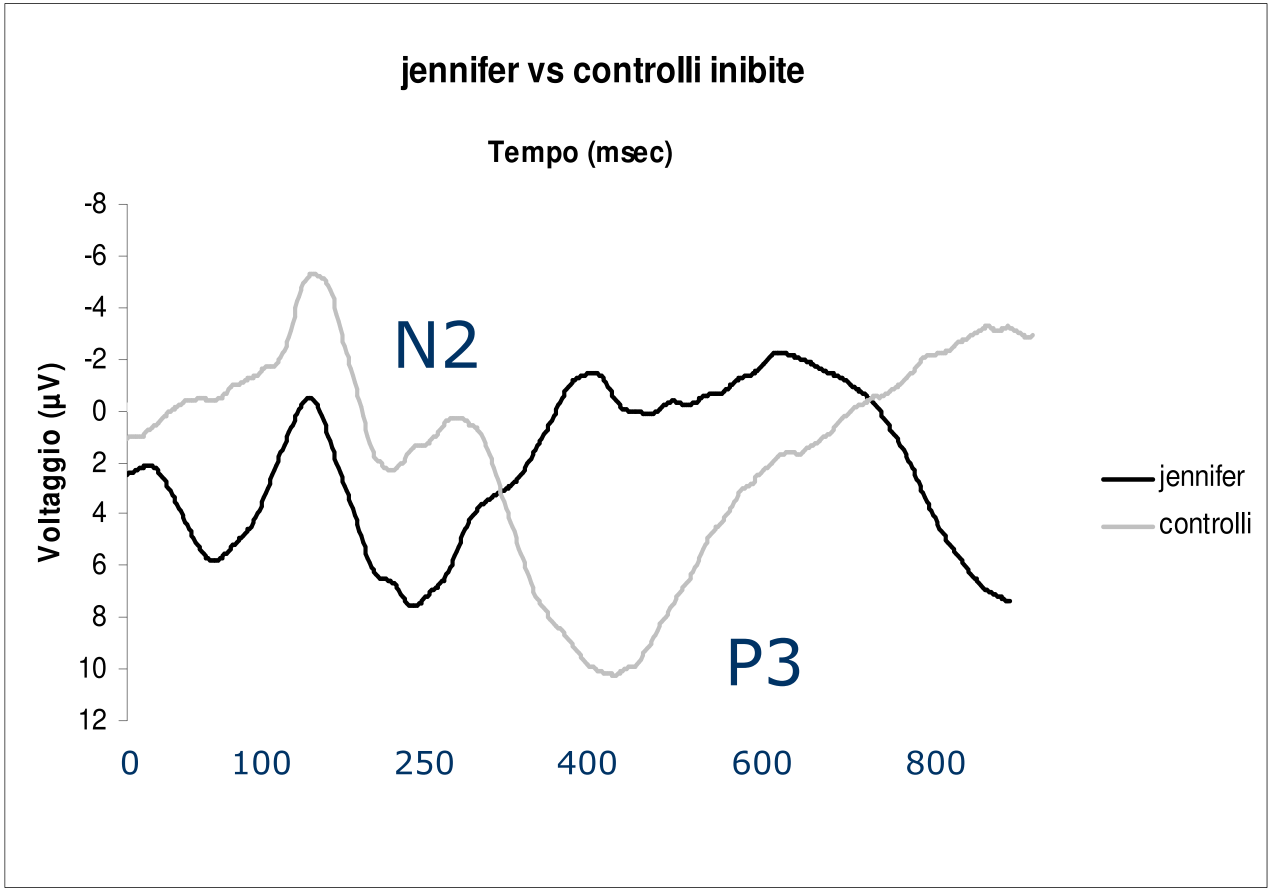
Case report – J F

ERP components showing no differences between J F and control subjects on GO trials



Case report – J F

ERP components showing great differences between J F and control subjects in those trials requiring response inhibition (STOP trials)



Case report – J F

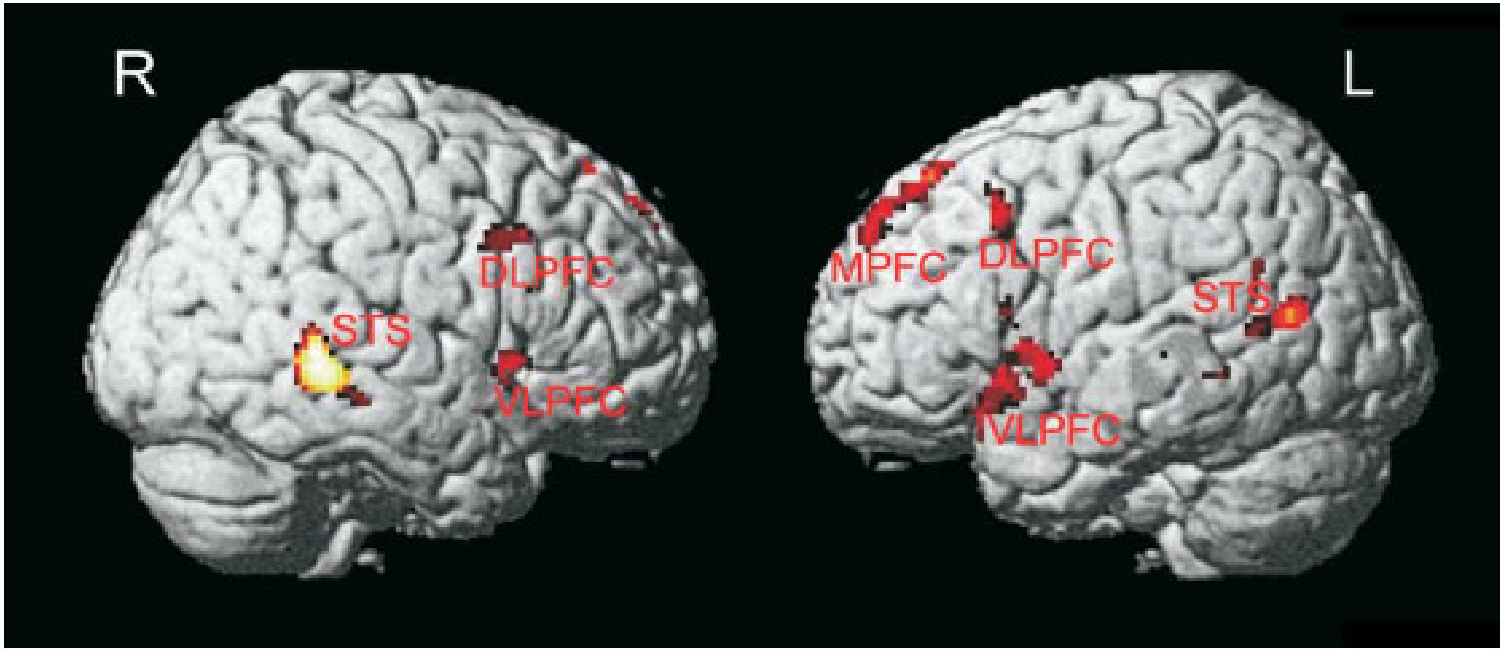
- Hayling test: sentences with the last word missing
  - Section A: sentence to be completed with a semantically related word ('The Captain wanted to stay with the sinking _________' *boat, ship*)
  - Section B: sentence to be completed with a completely unconnected word ('London is a very busy ______' *tomato, mouse, window* etc.)
- Impulsive individuals have difficult in inhibiting the semantically connected response in section B

	Section A	%ile	Section B	%ile	B-A	%ile	Errors	%ile
J F	19.67 s	14	59.21 s	5°	39.54 s	5°	13	6
Controls	12.6 s		26.4 s		13.8 s		4.2	

Polygraph

CATHERINE If I were guilty, and if I wanted to beat that machine, it wouldn't be tiring. It wouldn't be tiring at all. NICK Why not? CATHERINE Because I'm a professional liar. I spend most of my waking hours dwelling on my lies.

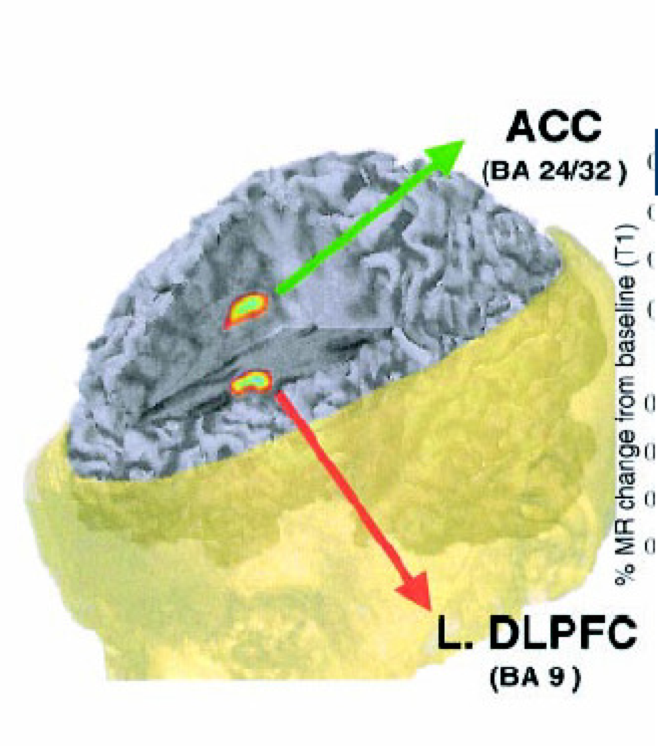
fMRI & Lie Detection



NEURAL CORRELATES OF TELLING LIES: A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY AT 4 TESLA

Phan, K., Magalhaes, A., Ziemlewicz, T., Fitzgerald, A., Green, C., Smith, W., 2005

fMRI & Lie Detection



DETECTING DECEPTION USING FUNCTIONAL MAGNETIC RESONANCE IMAGING

F. Andrew Kozel, Kevin A. Johnson, Qiwen Mu, Emily L. Grenesko, Steven J. Laken, and Mark S. George

Forensic IAT

- Accuracy
- Built on a grounded theoretical framework
- Sentences
- Short administration time
- Low tech
- Unmanned analysis
- Measures autobiographical memory

Implicit Association Test

- The Implicit Association Test (IAT) is an indirect measure – based on latency – of the strength of the association between two concepts
- Items related to four different concepts are displayed in a randomised order
- The subject gives only two types of responses

Implicit Association Test

- If two concepts that are **strongly connected** require the same response, subjects' reaction times are expected to be **very fast**

- Besides, when these two concepts require a different response, subjects' reaction times will be **slower**

Implicit Association Test

Flowers/ Unpleasant		Insects/ Pleasant
	leech	
	rose	
	happy	
	ugly	
A key		L key

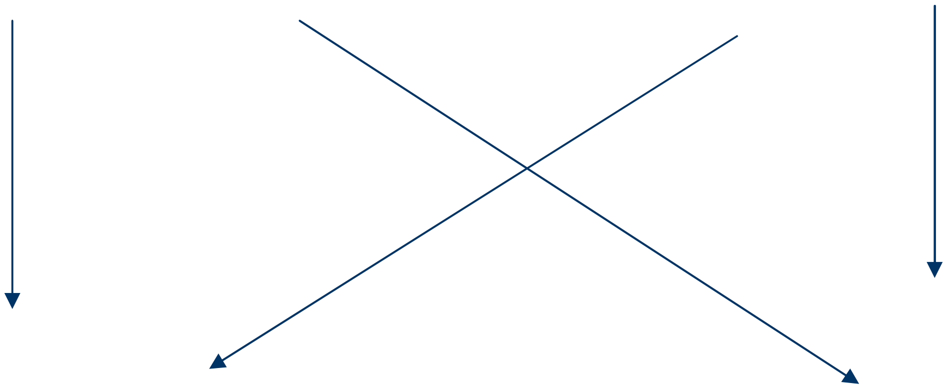
Forensic IAT

- Main objective: Forensic IAT as a **lie detector**
  - Does the IAT work with sentences?
  - Does the IAT discriminate between subjects on the basis of their different episodic memory?
  - Can the IAT be faked?

Drug users F-IAT

TRUE
"I am doing a psychological experiment"

FALSE
"I am climbing a cliff"



I HAVE TAKEN COCAINE

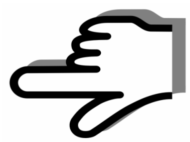
"I have taken cocaine"

I HAVE NOT TAKEN COCAINE

"I have not taken cocaine"

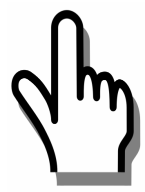
Drug users F-IAT: results

I have taken heroin	**1431 ms**	TRUE
2067 ms		**2213 ms**
FALSE	**1464 ms**	I have not taken heroin



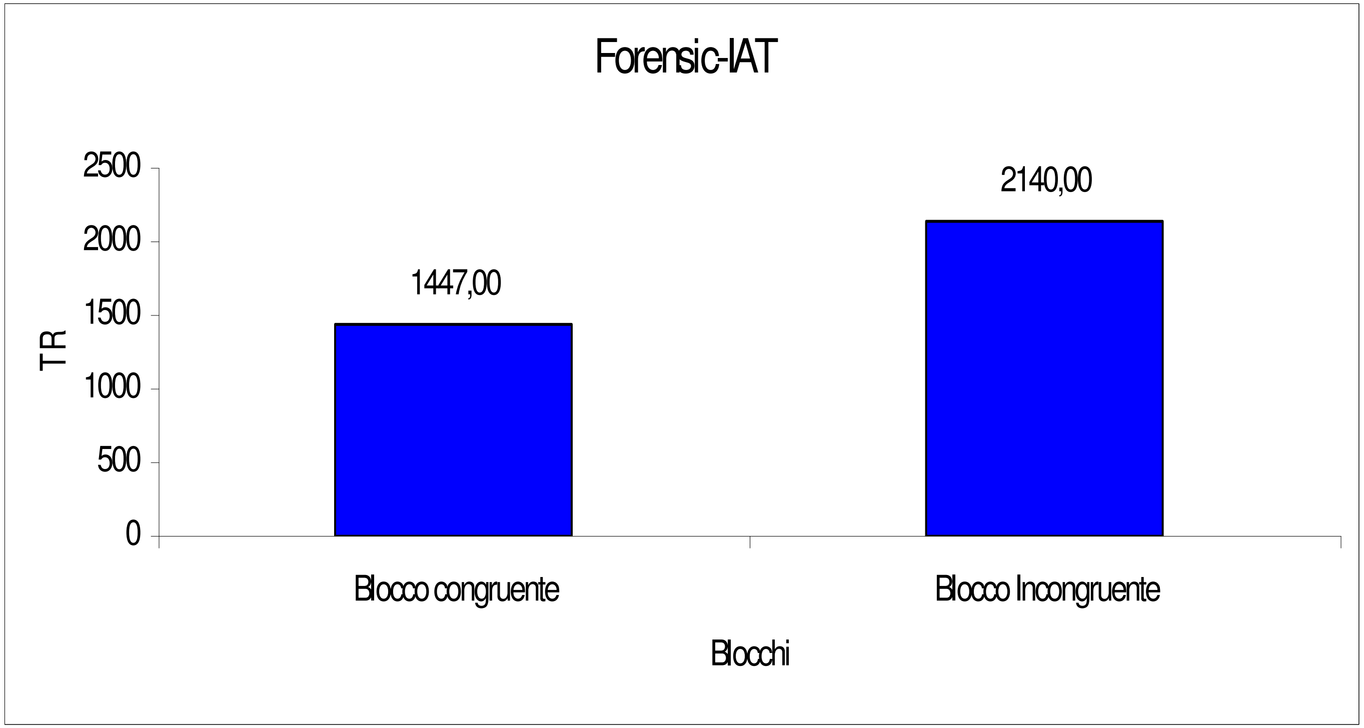
CONGRUENT

INCONGRUENT

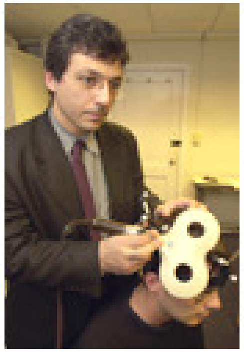


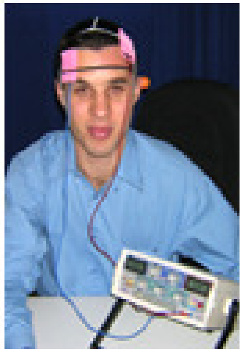
Drug users F-IAT: results

Correct classification → 13/14



LIE BLOCKING





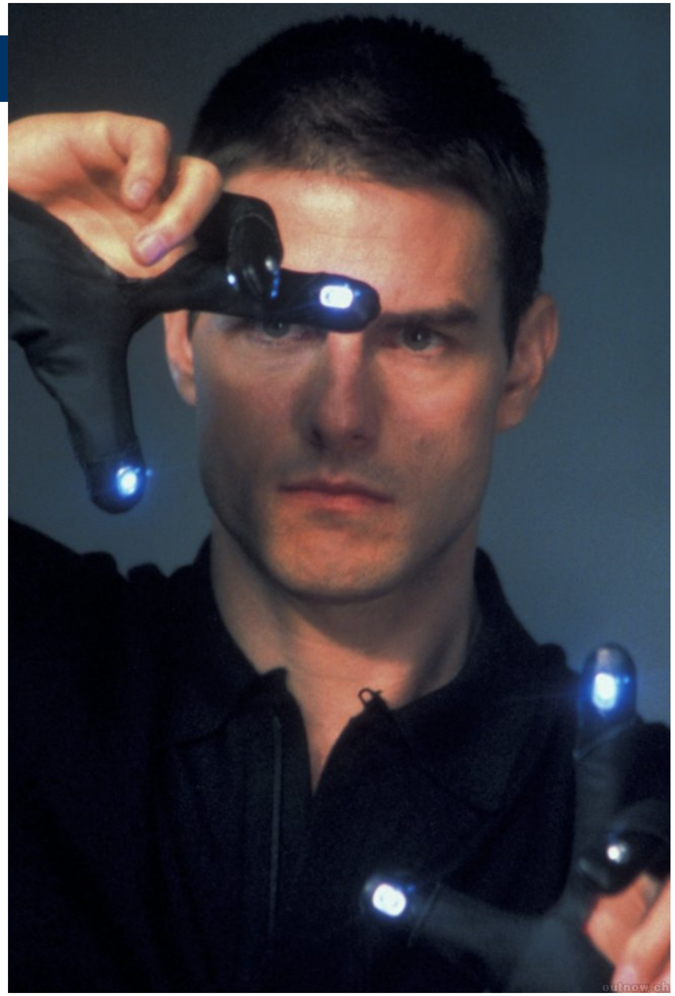
Cerebral Cortex
doi:10.1093/cercor/bhm088

Lie-Specific Involvement of Dorsolateral Prefrontal Cortex in Deception

Alberto Priori[1], F. Mameli[1], F. Cogiamanian[1], S. Marceglia[1], M. Tiriticco[1], S. Mrakic-Sposta[1], R. Ferrucci[1], S. Zago[1], D. Polezzi[2] and G. Sartori[2]

[1]Department of Neurological Sciences, University of Milan, Fondazione IRCCS Ospedale Maggiore Policlinico, Mangiagalli e Regina Elena, Italy and [2]Department of General Psychology, University of Padua, Italy

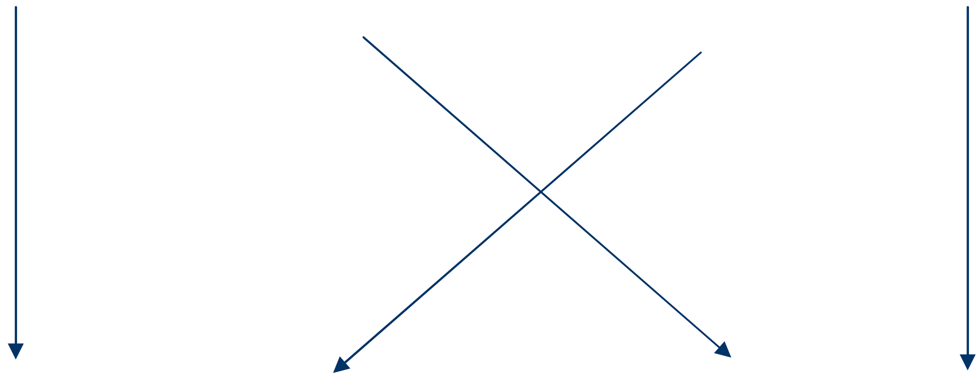
Intention detection



Intention detection

TRUE
"I am in front of a computer"

FALSE
"I am climbing a cliff"



REAL INTENTION

"I'm going to sleep in Padua "

FALSE INTENTION

"I'm going to sleep in New York"

Correct classification > 92%

Conclusions

- Congitive neuroscience may help in:
  - Highlighting the endophenotype of addiction
  - Explaining the origin of the symptoms
  - Detecting intentions for future actions and past behaviors

Collaborators

- Sara Agosta
- Cristina Zogmaister
- Umberto Castiello
- Davide Rigoni