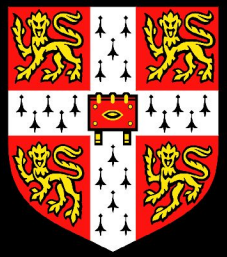
NST II Psychology
NST II Neuroscience (Module 5)

Brain Mechanisms of Memory and Cognition – 6

The prefrontal cortex

Rudolf Cardinal
Department of Experimental Psychology



Monday 13, 20, 27 Jan; 3, 10, 24 Feb 2003; 10 am
Physiology Main Lecture Theatre

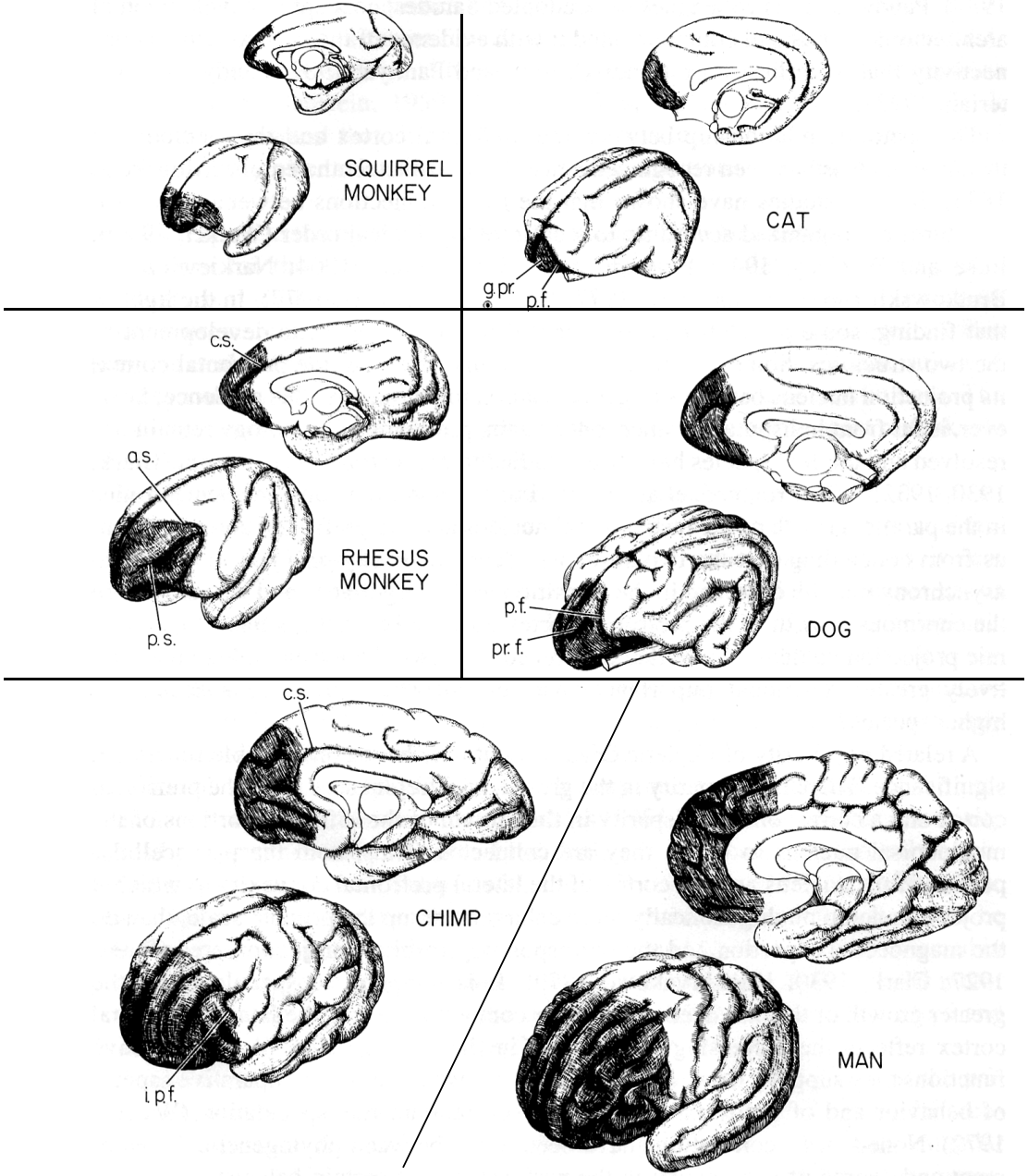
Chess and morality

Bergman (1957): 'Det Sjunde Inseglet' (The Seventh Seal)

The prefrontal cortex

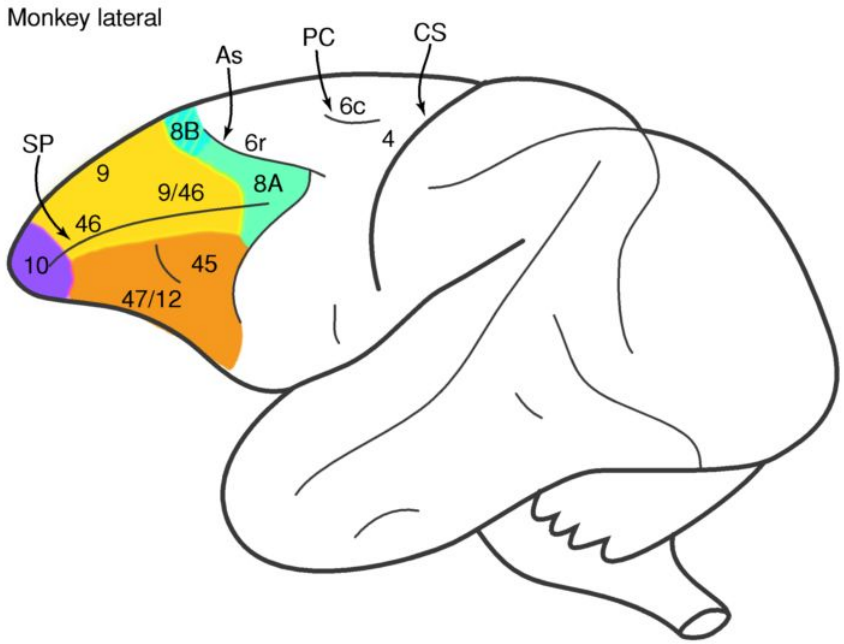
von Hagens (1996–): 'Bodyworlds'

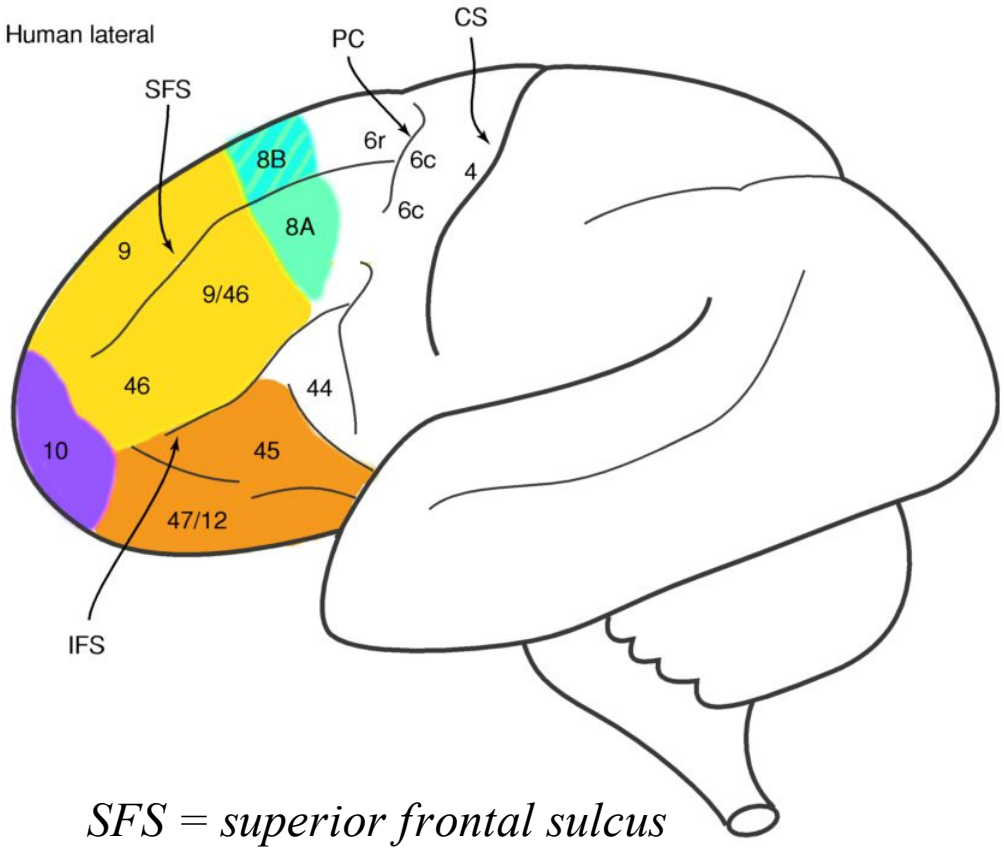
The prefrontal cortex across species



Fuster (1997)

Lateral PFC regions

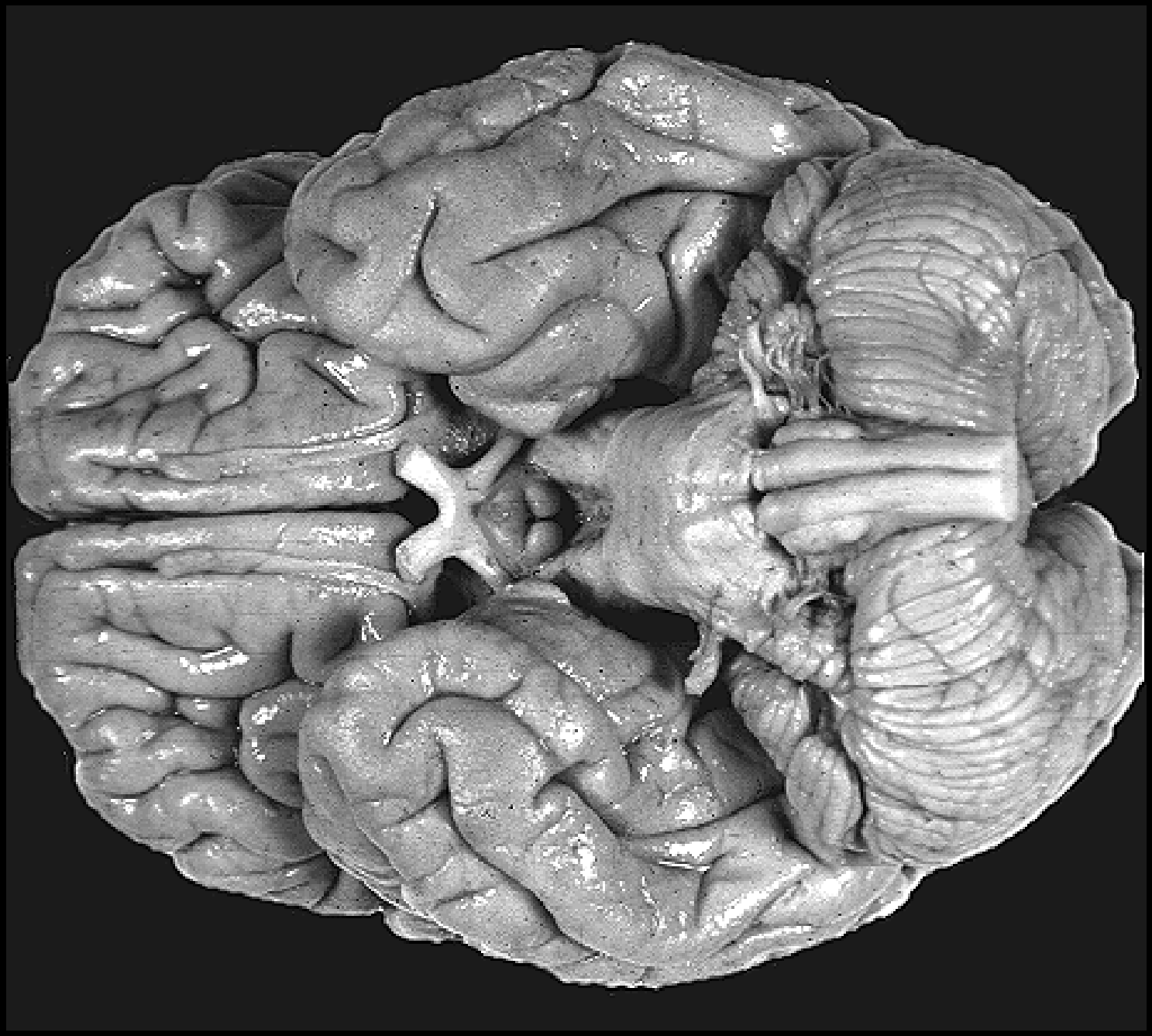




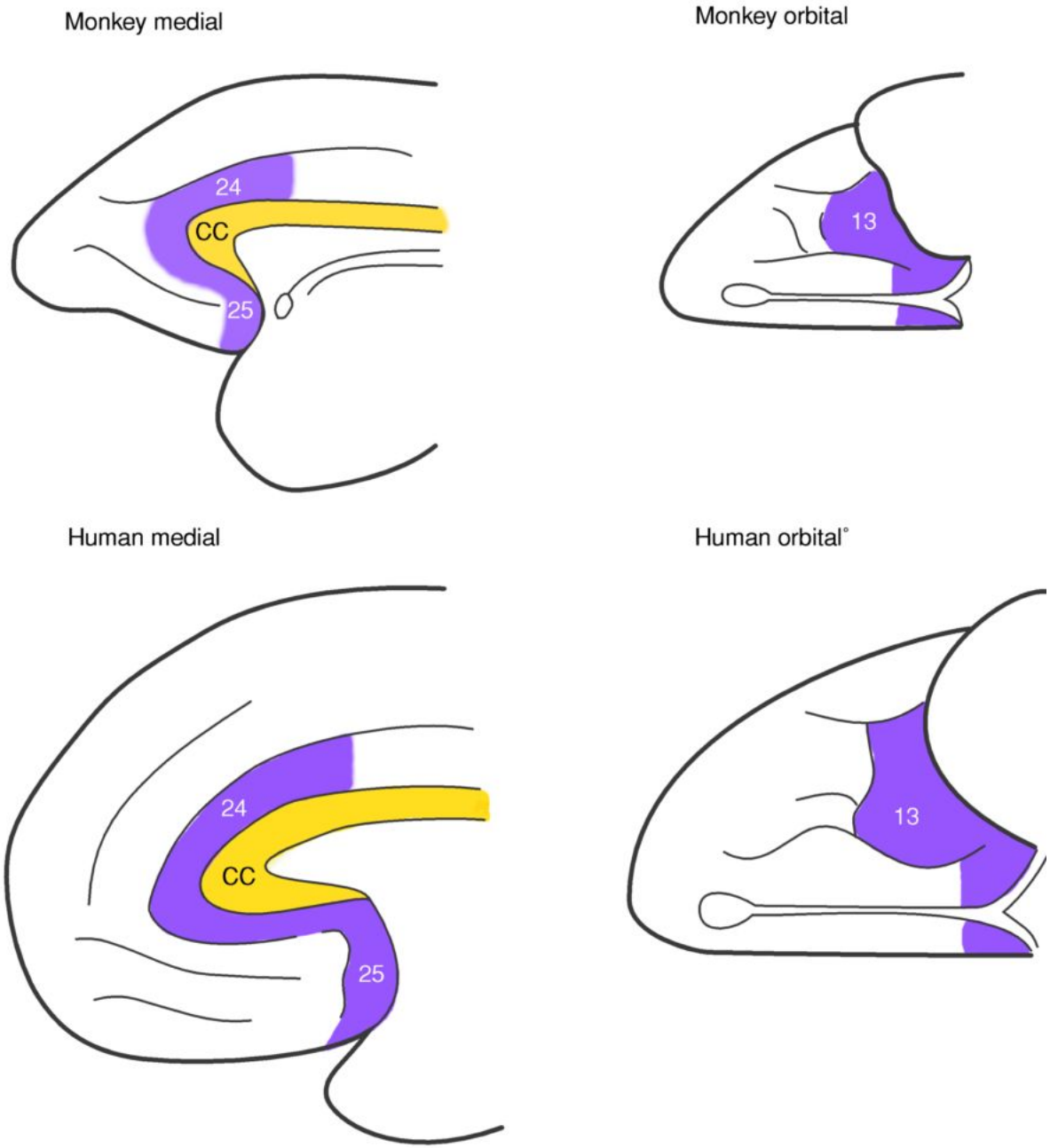
SP = sulcus principalis
As = arcuate sulcus

PC = precentral sulcus
CS = central sulcus

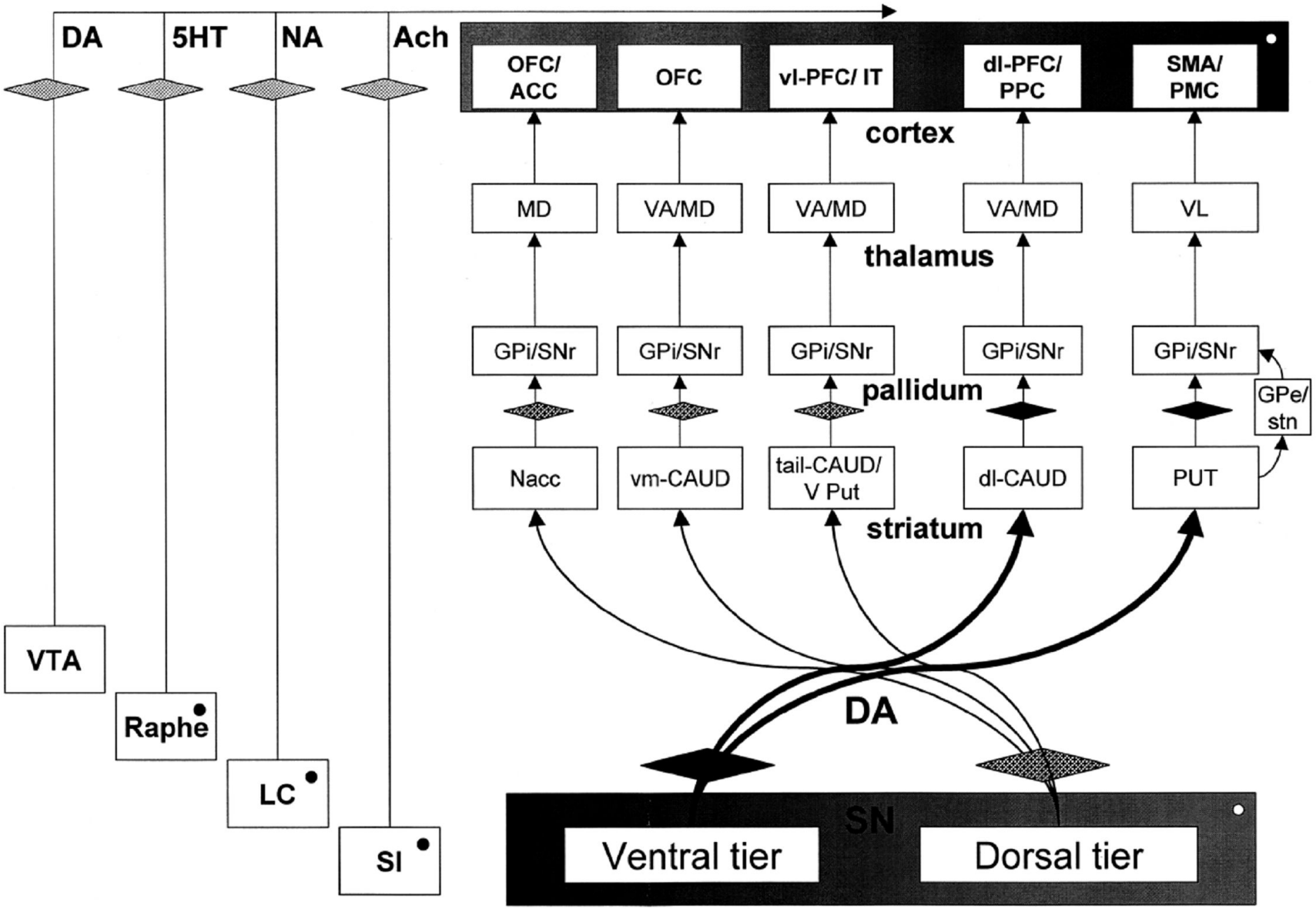
SFS = superior frontal sulcus
IFS = inferior frontal sulcus



Medial and orbital PFC regions



Connections of PFC subregions differ. Example: striatal loops



Frontal lobe lesions in humans

Poor judgement
Poor planning
Poor decision-making
Lack of initiative

Disturbed attention
Increased distractibility
Perseveration

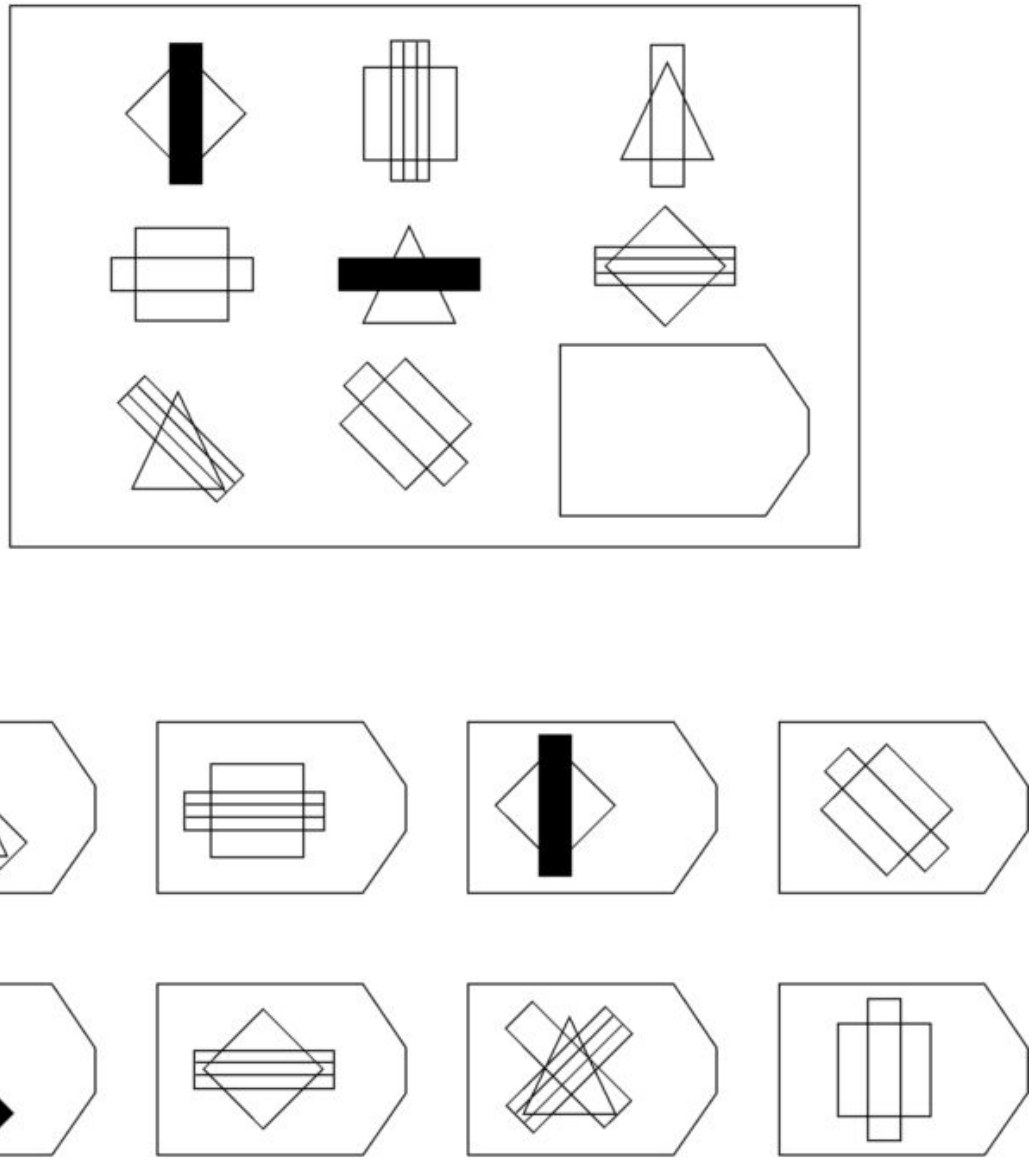
Disinhibition (inc. socially and emotionally)

Release of primitive reflexes

Disordered 'executive function'
Impaired 'higher cognitive processing'

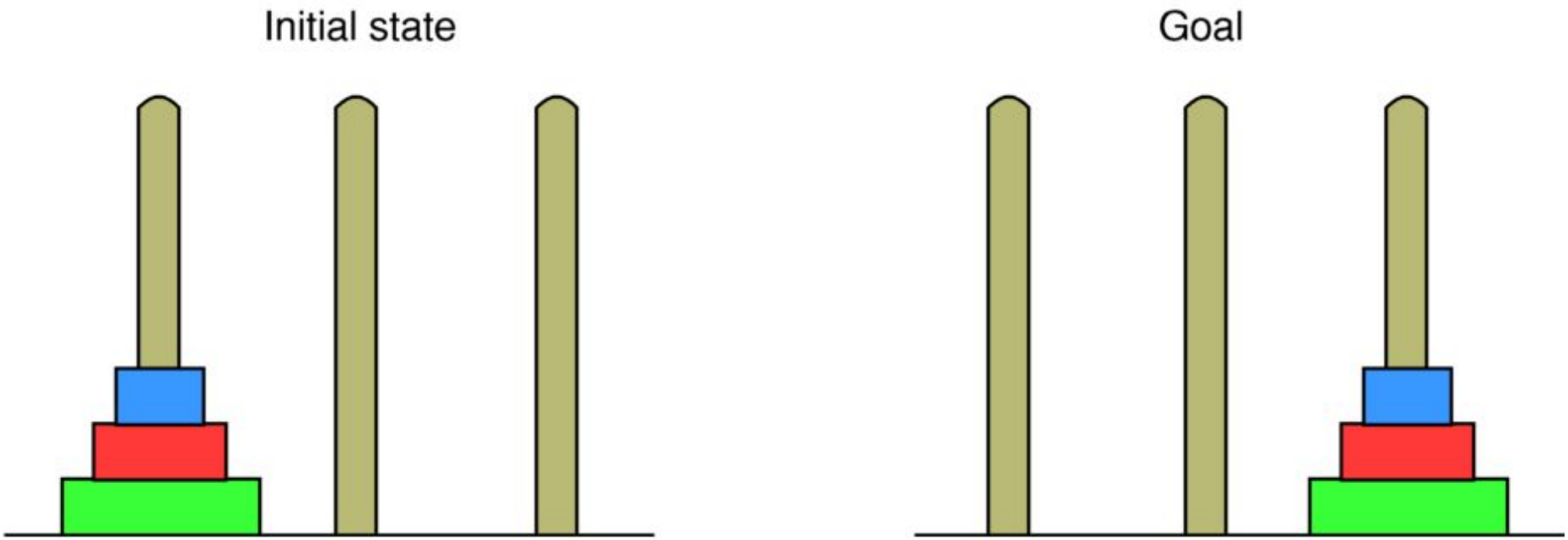
Dorsolateral prefrontal cortex

Raven's *Progressive Matrices* — geometric analogy



Penrose & Raven (1936); Raven (1938); Prabharakan et al. (1997) — DLPFC activation

The Tower of Hanoi



"Legend says that at the beginning of time the priests in a Hindu temple were given a stack of 64 gold disks, each one a little smaller than the one beneath it. Their assignment was to transfer the 64 disks from one of the three poles to another, with one important proviso — a large disk could never be placed on top of a smaller one. The priests worked very efficiently, day and night. When they finished their work, the myth said, the temple would crumble into dust and the world would vanish."

(At one move per second, and 2^{64}–1 moves, this task would take 580 billion years.)

Invented by Edouard Lucas (1883); activates PFC (Morris et al. 1993; Baker et al. 1996)

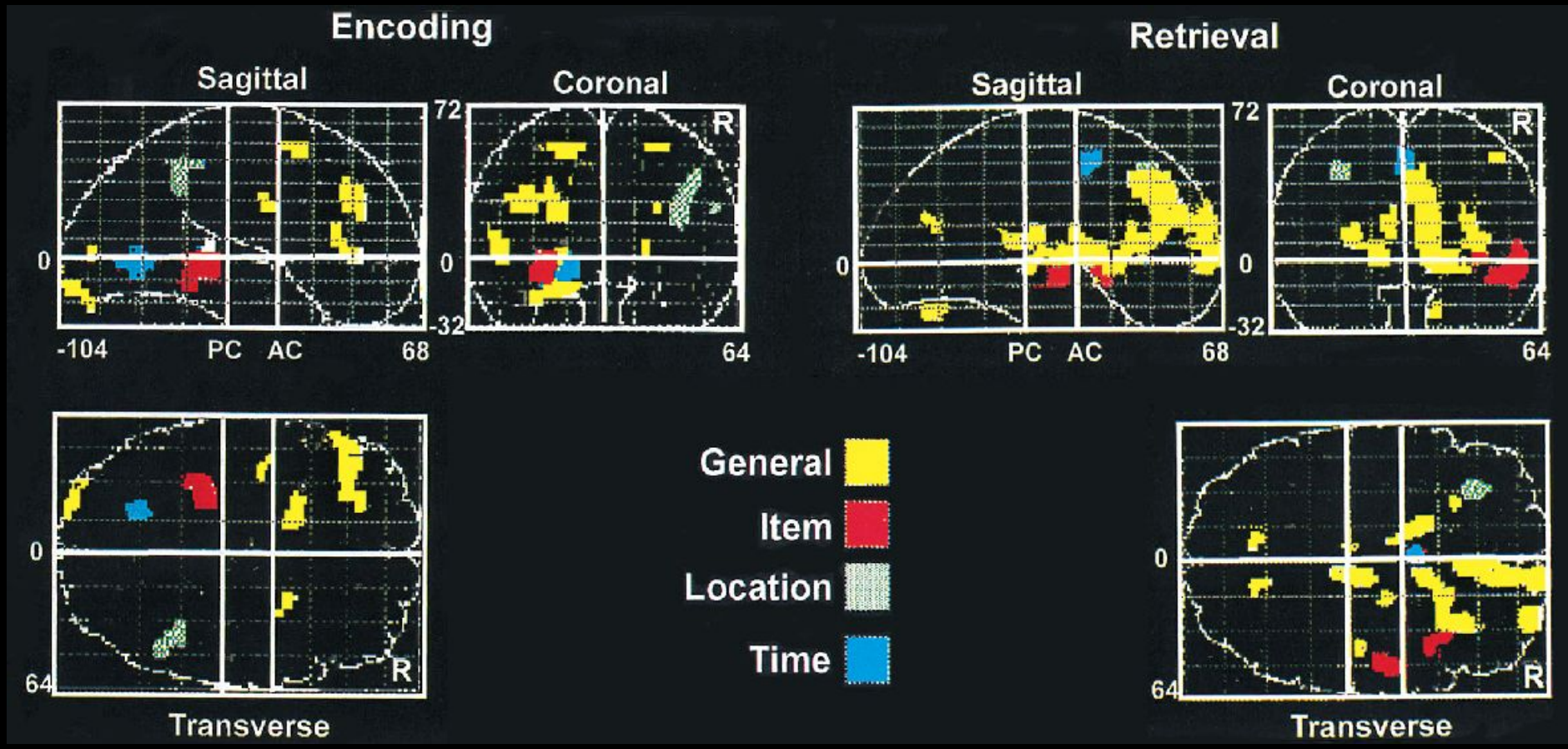
The Wisconsin Card Sorting Task

Grant & Berg (1948); impaired after DLPFC lesions (Milner, 1963)

Memory encoding and retrieval (1)

'Hemispheric asymmetric in encoding and retrieval' (HERA) model.

Passive perception is a typical control for 'encoding'.



Tulving et al. (1994); Nyberg et al. (1996; 1998)

Memory encoding and retrieval (2)

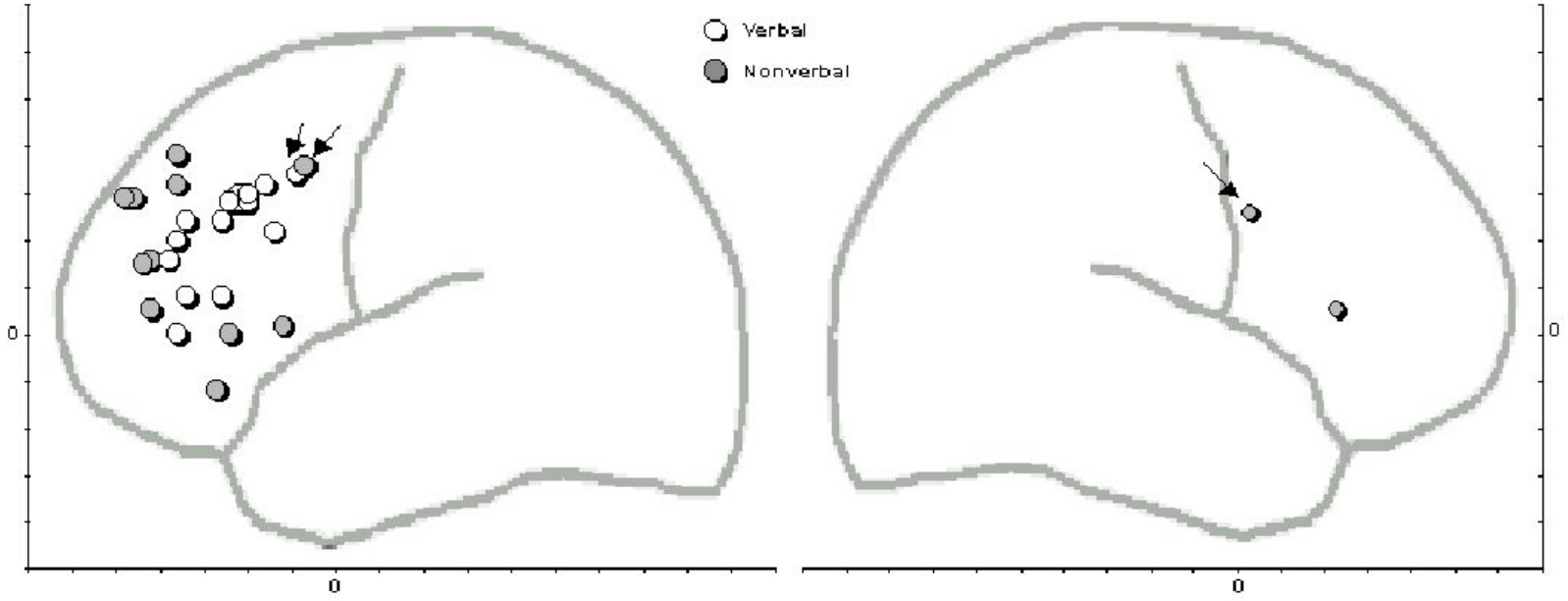
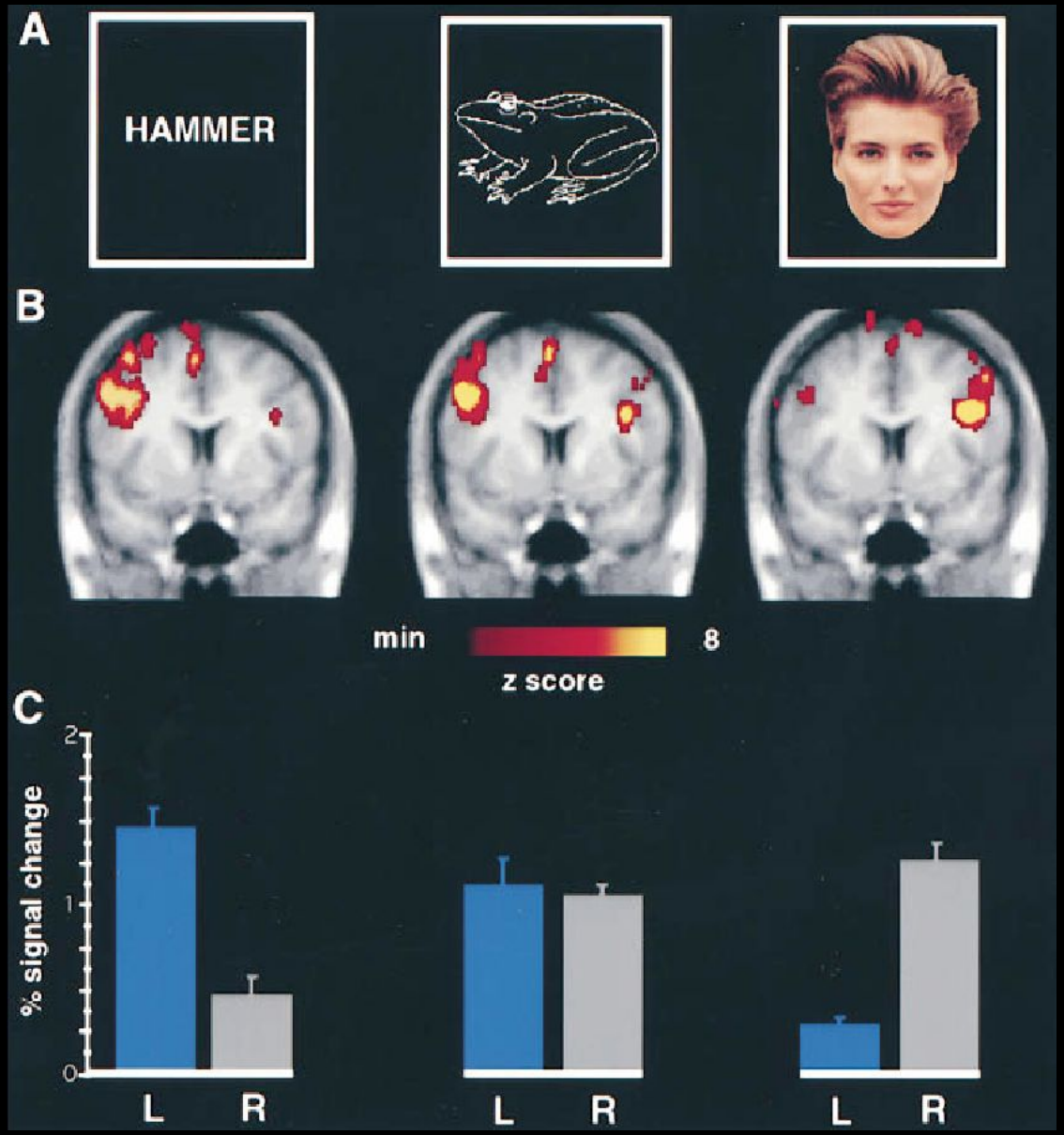


Fig. 1 Frontal cortical activation peaks from multiple neuroimaging studies of episodic memory encoding. Significant frontal activation peaks from studies involving intentional encoding of verbal[7,15–17] and non-verbal[6,14,18,19] information.

Nyberg et al. (1998)

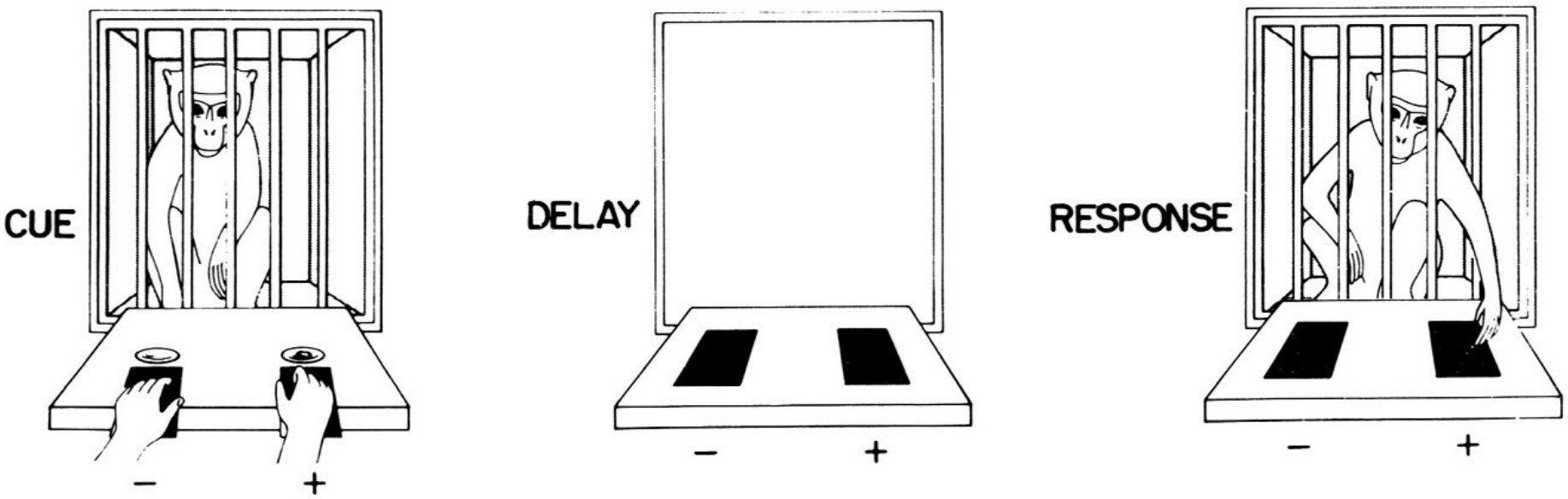
Memory encoding and retrieval (3)

Encoding material activates different regions of the PFC depending on the material encoded.



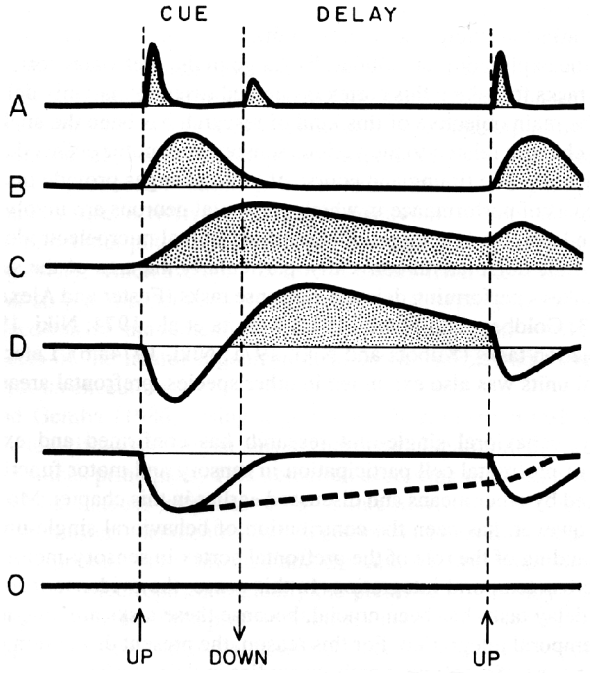
Kelley et al. (1998)

Delayed response task (1)



Friedman & Goldman-Rakic (1988); task originally by Hunter (1913)

Delayed response task (2)



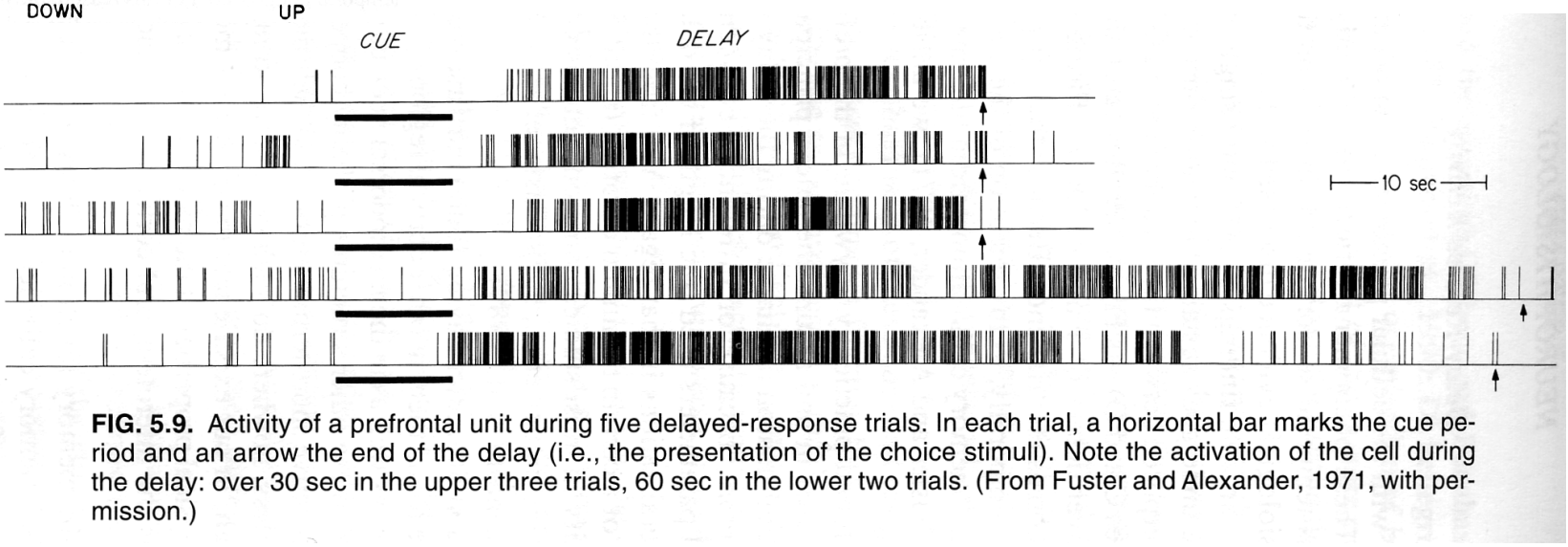
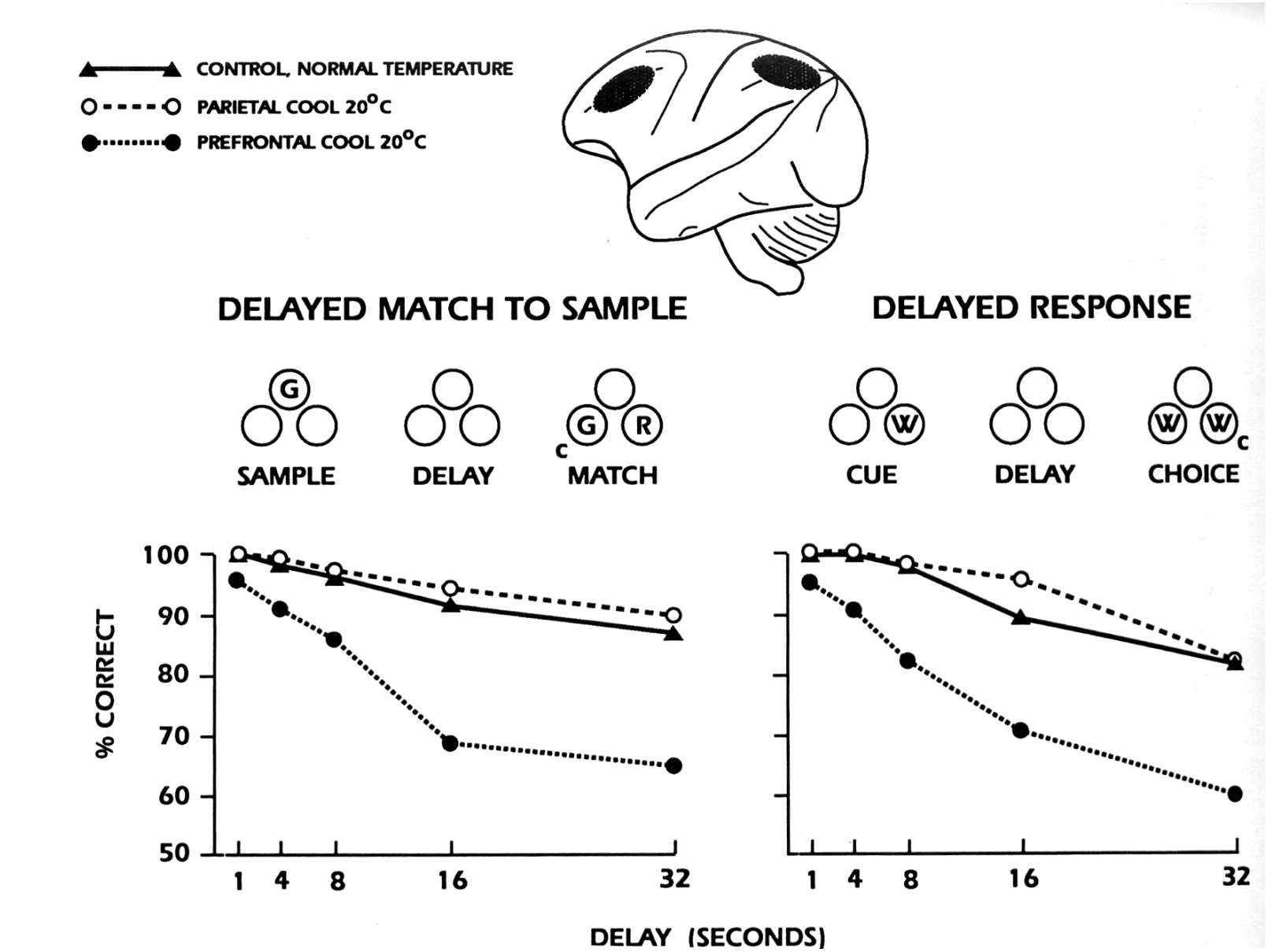


FIG. 5.9. Activity of a prefrontal unit during five delayed-response trials. In each trial, a horizontal bar marks the cue period and an arrow the end of the delay (i.e., the presentation of the choice stimuli). Note the activation of the cell during the delay: over 30 sec in the upper three trials, 60 sec in the lower two trials. (From Fuster and Alexander, 1971, with permission.)

Fuster & Alexander (1971)

Delayed response task (3)

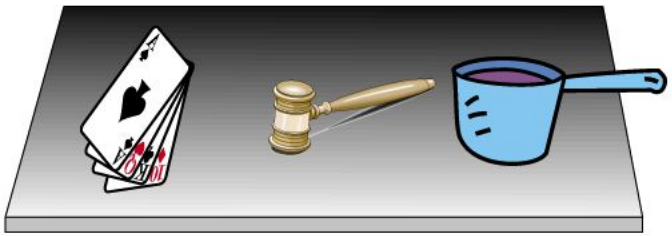


Fuster & Alexander (1970); Fuster (1995)

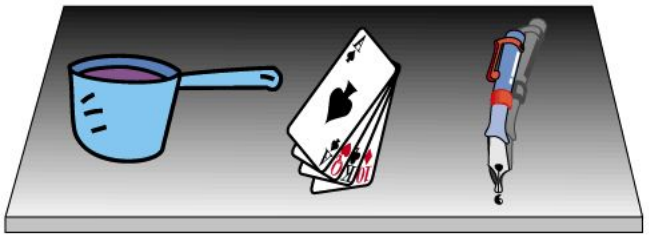
Self-ordered monitoring tasks

A

No effect of DLPFC lesion.

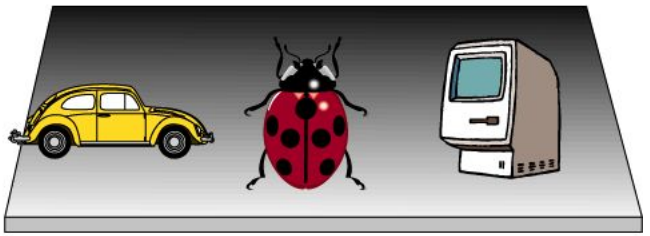


Recognition

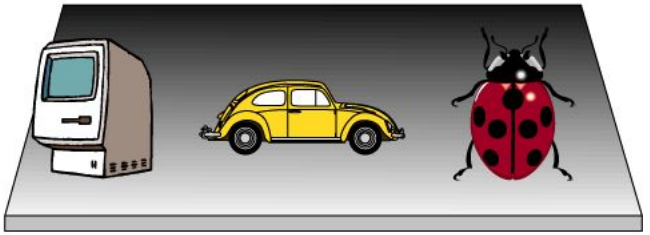


Choose novel object.

DLPFC lesions impair monkeys.

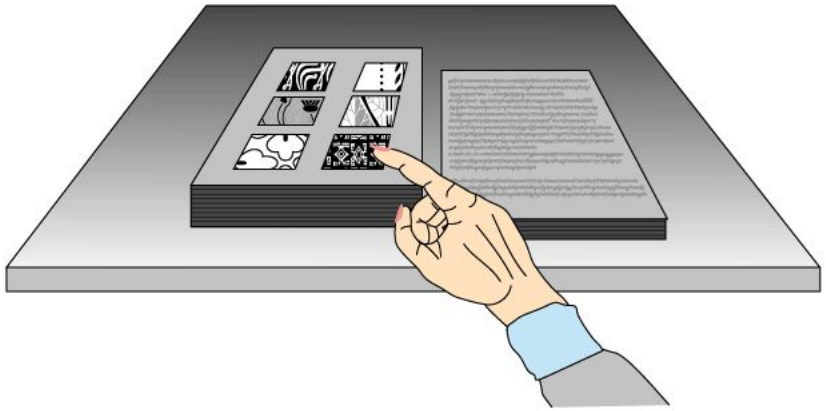


Monitoring



Choose object not previously chosen.

B

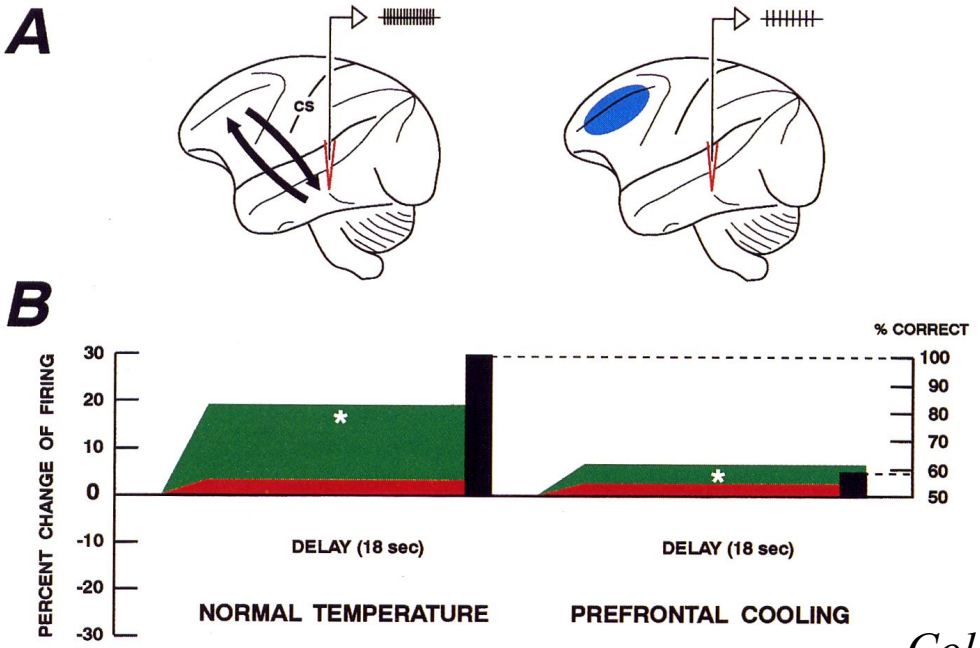


Pick one of the six stimuli; turn to the next card; pick another stimulus (until all six have been selected). ***DLPFC lesions impair humans.***

Petrides & Milner (1982); Petrides (1996)

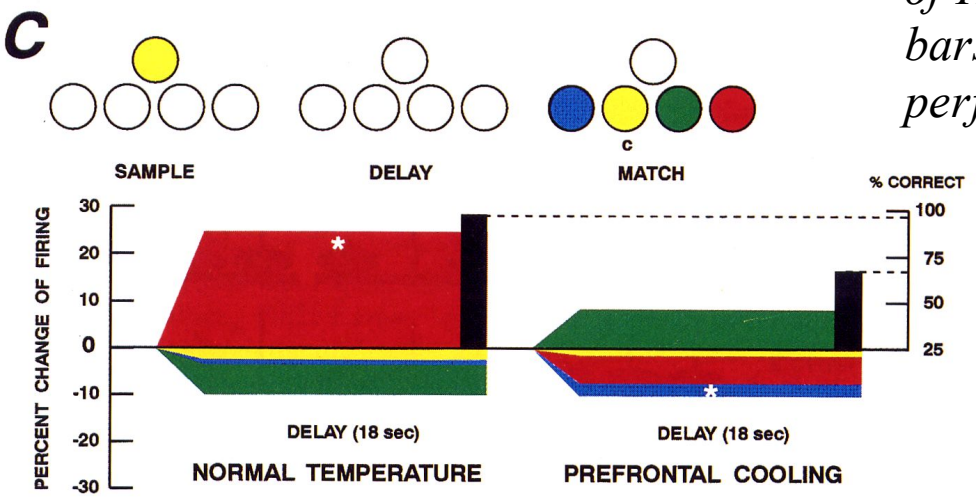
Working memory: PFC maintains posterior cortex activity?

Two-colour DMTS



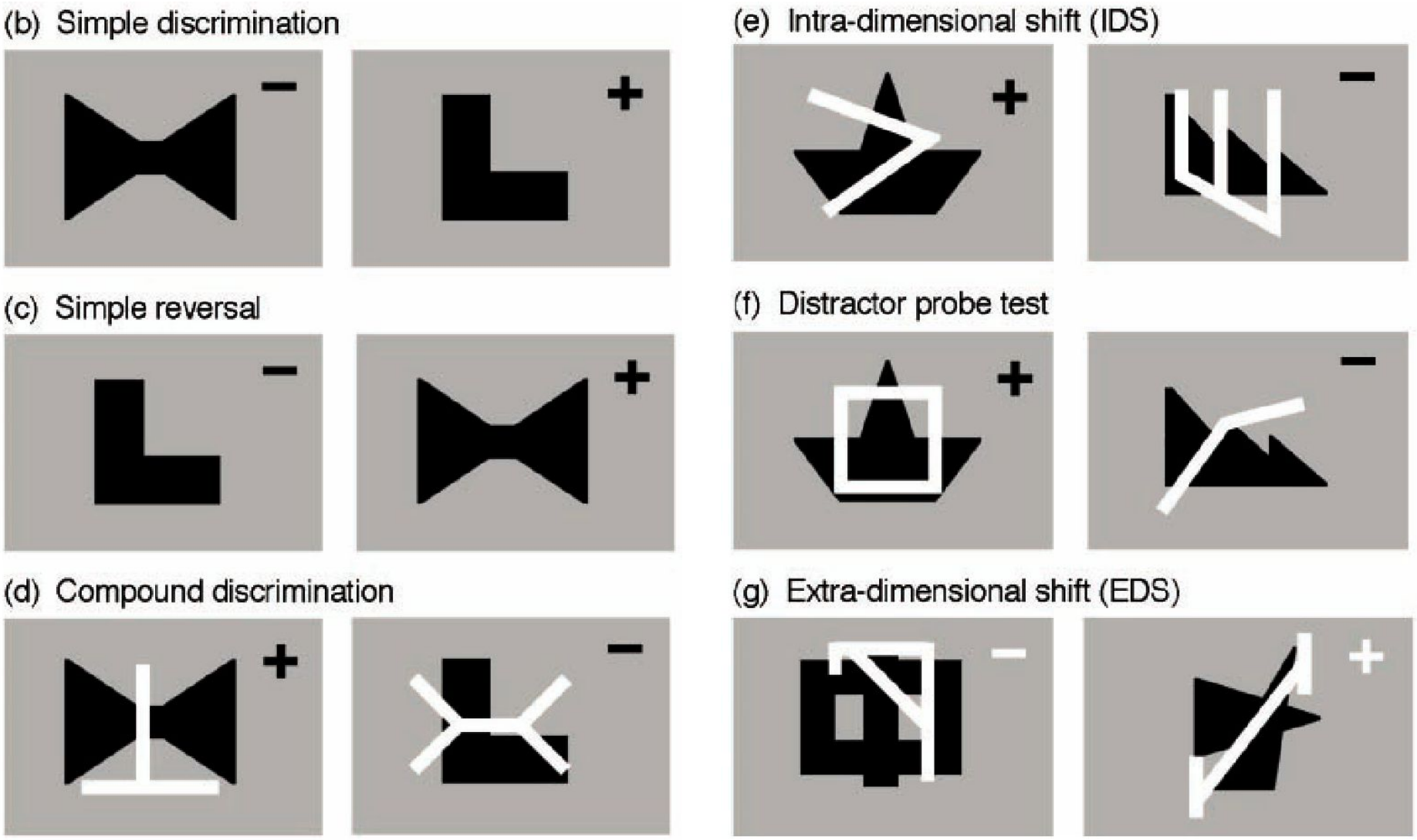
Coloured areas: activity of IT neurons. Black bars: behavioural performance.

Four-colour DMTS



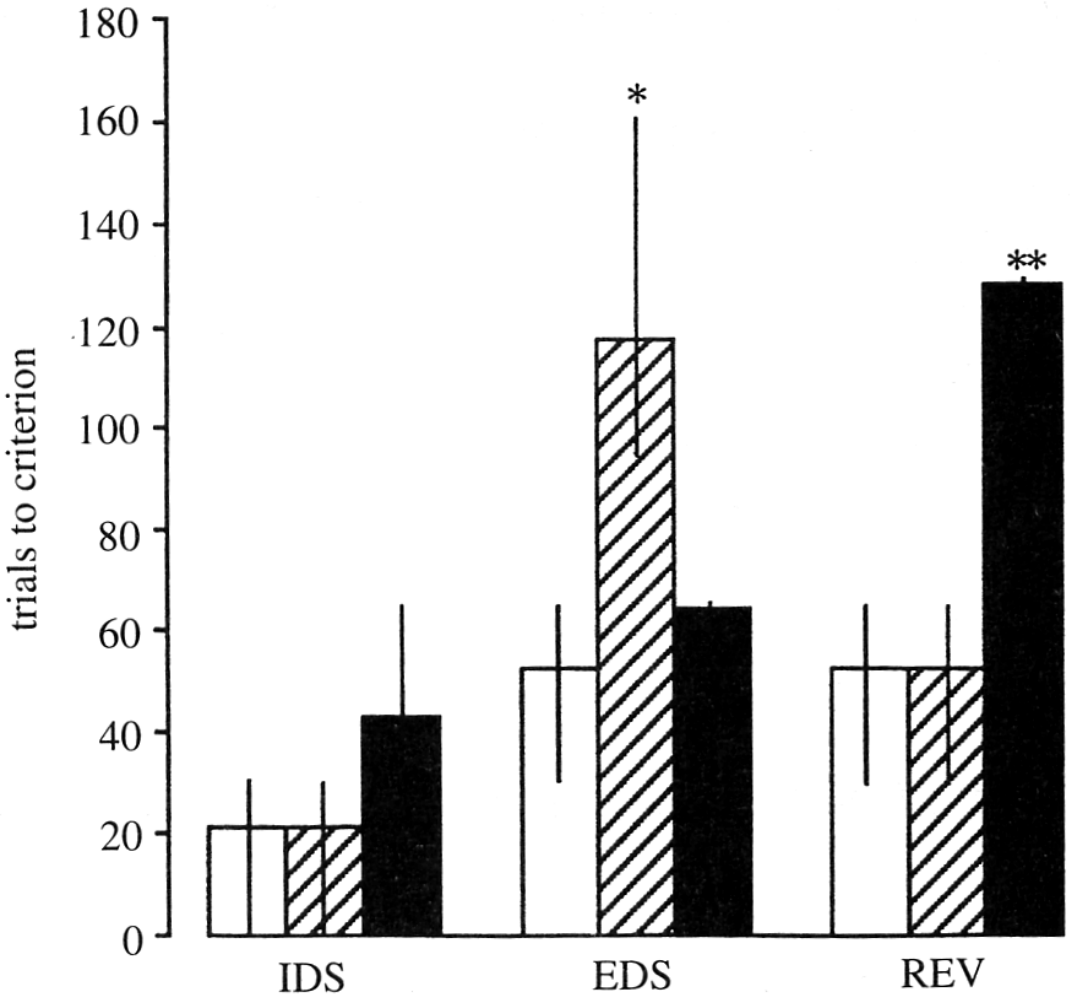
Fuster & Alexander (1970); Fuster (1995)

Attentional set and set-shifting



from Crofts et al. (2001)

Extradimensional set shifts impaired by DLPFC lesions



Open = sham-operated controls.
Hatched = DLPFC lesion (area 9).
Filled = OFC lesion.

Dias et al. (1996)

Extradimensional set shifts impaired by parietal lesions in rats

Table 1. Example of a possible combination of stimulus pairs for a rat shifting from digging medium to odor as the relevant dimension

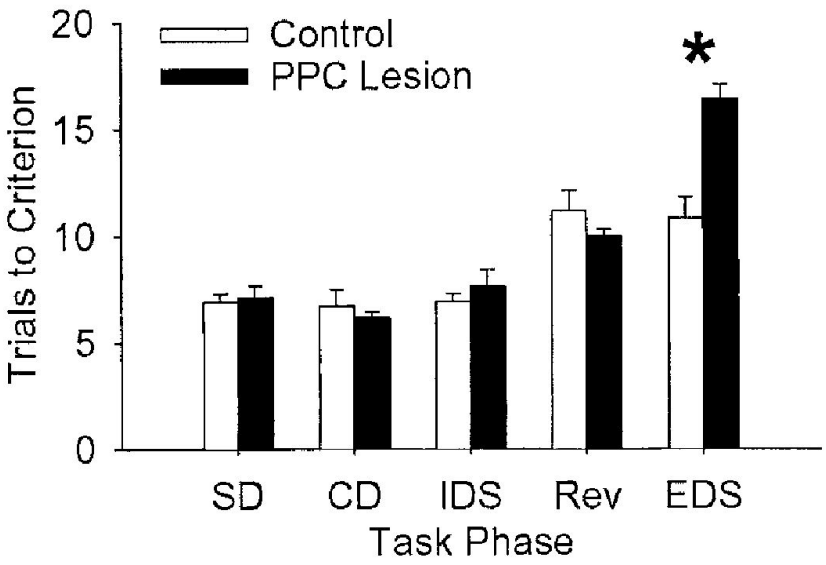
	Dimensions		Exemplar combinations	
Discrimination	Relevant	Irrelevant	S+	S−
SD	Medium		**M1**	M2
CD	Medium	Odor	**M1**/01	M2/02
			M1/02	M2/01
IDS	Medium	Odor	**M3**/03	M4/04
			M3/04	M4/03
Reversal	Medium	Odor	**M4**/03	M3/04
			M4/04	M3/03
EDS	Odor	Medium	**05**/M5	06/M6
			05/M6	06/M5

Half of the rats switched from medium to odor, and half switched from odor to medium. The correct exemplar is shown in bold and can be paired with either exemplar from the irrelevant dimension. In the IDS and EDS, the stimuli were novel exemplars of each dimension.

Table 2. Stimulus pairs used

Odor pairs	Medium pairs
Jasmine versus vanilla	Foam rubber versus plastic beads
Mulberry versus patchouli	Gravel versus BBs
Cinnamon versus gardenia	Pine shavings versus shredded manila folders

The exemplars within a dimension were always used in pairs. That is, for example, whenever jasmine appeared as one odor within a discrimination, the other odor was vanilla. No two rats within the same group received the same combinations, but the lesion and control groups were matched. The order of presentation of exemplars and the combination of exemplars into positive (+) and negative (−) stimuli were determined by a pseudorandom series generated before testing.



Fox et al. (2003)

Neuropsychiatric links: schizophrenia? (1)

• *Some symptoms of schizophrenia are successfully treated by antipsychotics; their efficacy correlates with their potency as* ***dopamine D2 receptor antagonists.*** *The PFC is regulated by dopamine (directly and at the level of the striatum via corticostriatal loops).*

• *Schizophrenics may be impaired on the* ***Wisconsin Card Sorting Task*** *(Goldberg et al. 1987) and spatial working memory tasks (Park & Holzman, 1992). DLPFC blood flow doesn't increase normally when schizophrenics perform the WCST (Weinberger et al., 1992) — but note* ***controversy.***

• *Schizophrenia has a strong genetic component (e.g. MZ twin concordance 45–50%; DZ twin concordance 5–15%). Asymptomatic relatives of schizophrenics are impaired on spatial working memory tasks (Park & Holzman, 1995).*

• *Are* ***hallucinations*** *a deficit in perceiving internally-generated auditory and visual images as self-generated? Imagery uses many of the same cortical regions as perception (Farah, 2000).*

• *Schizophrenics are impaired at perceiving whether images of moving hands are their own hand or somebody else's (Franck et al., 2001).*

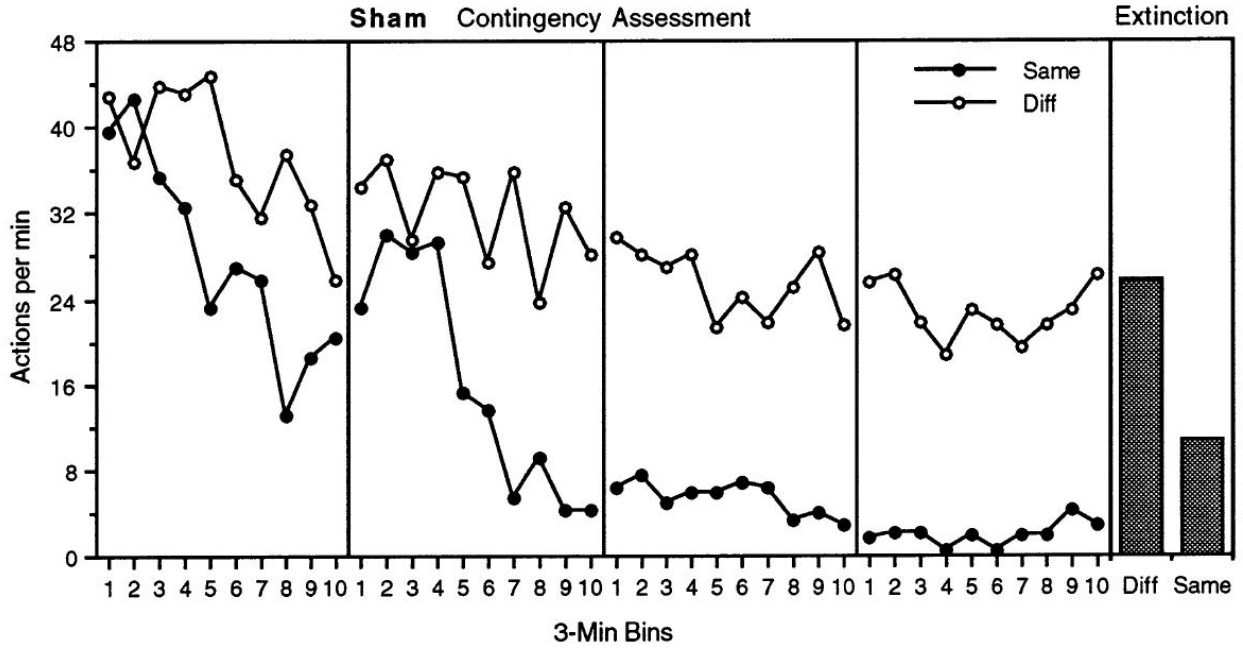
• *Lesions of the DLPFC in rats (prelimbic cortex) impair their ability to perceive that their actions cause a certain outcome.*

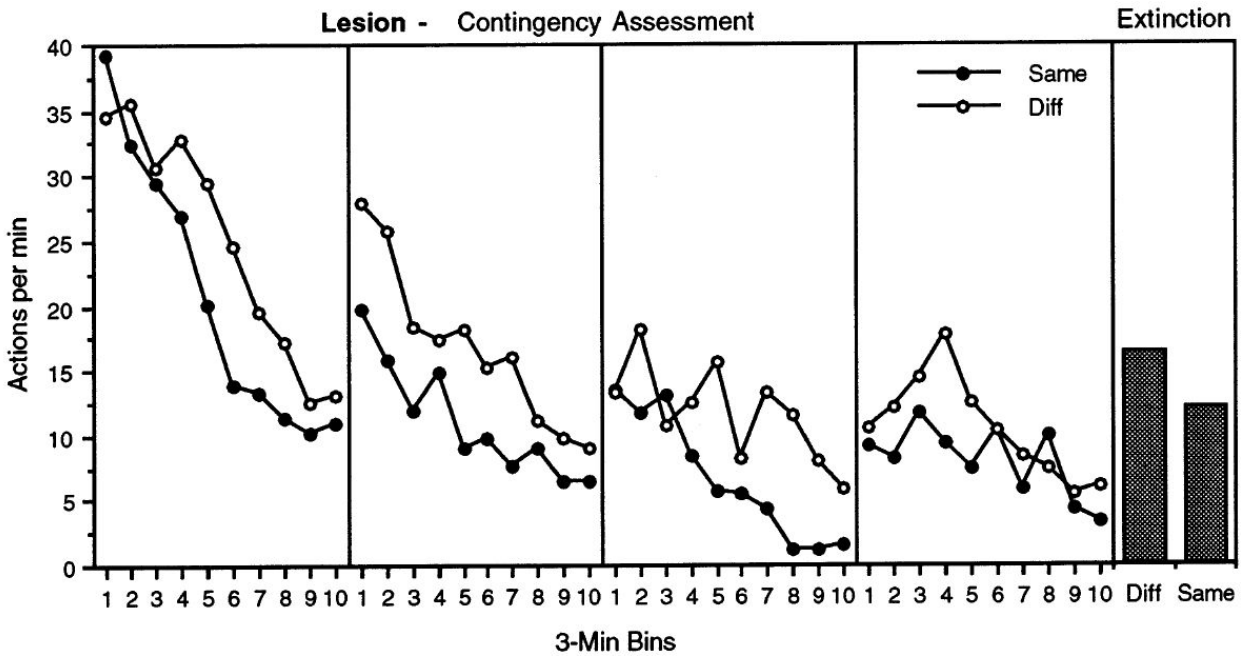
Neuropsychiatric links: schizophrenia? (2)

sham-operated rats

Test of action–outcome contingency knowledge

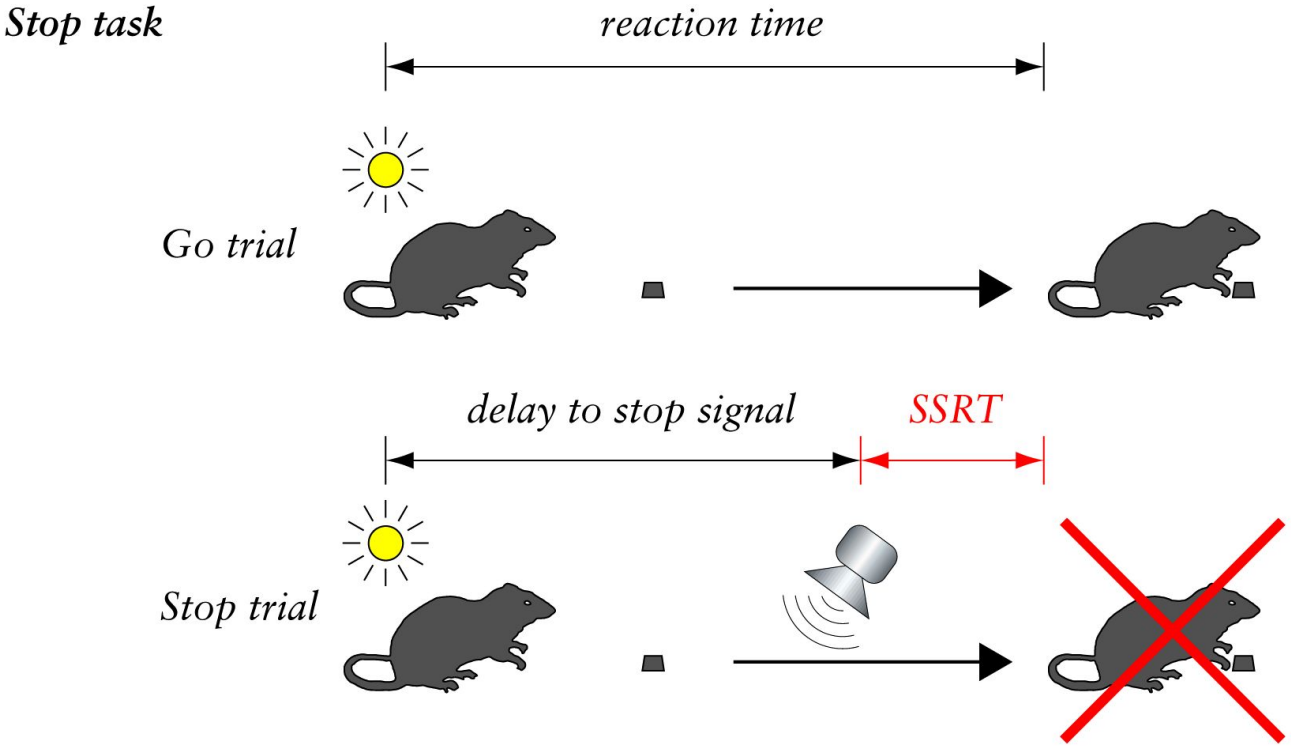
prelimbic (~ DLPFC)-lesioned rats





Balleine & Dickinson (1998)

Inhibition: a central function of the PFC?

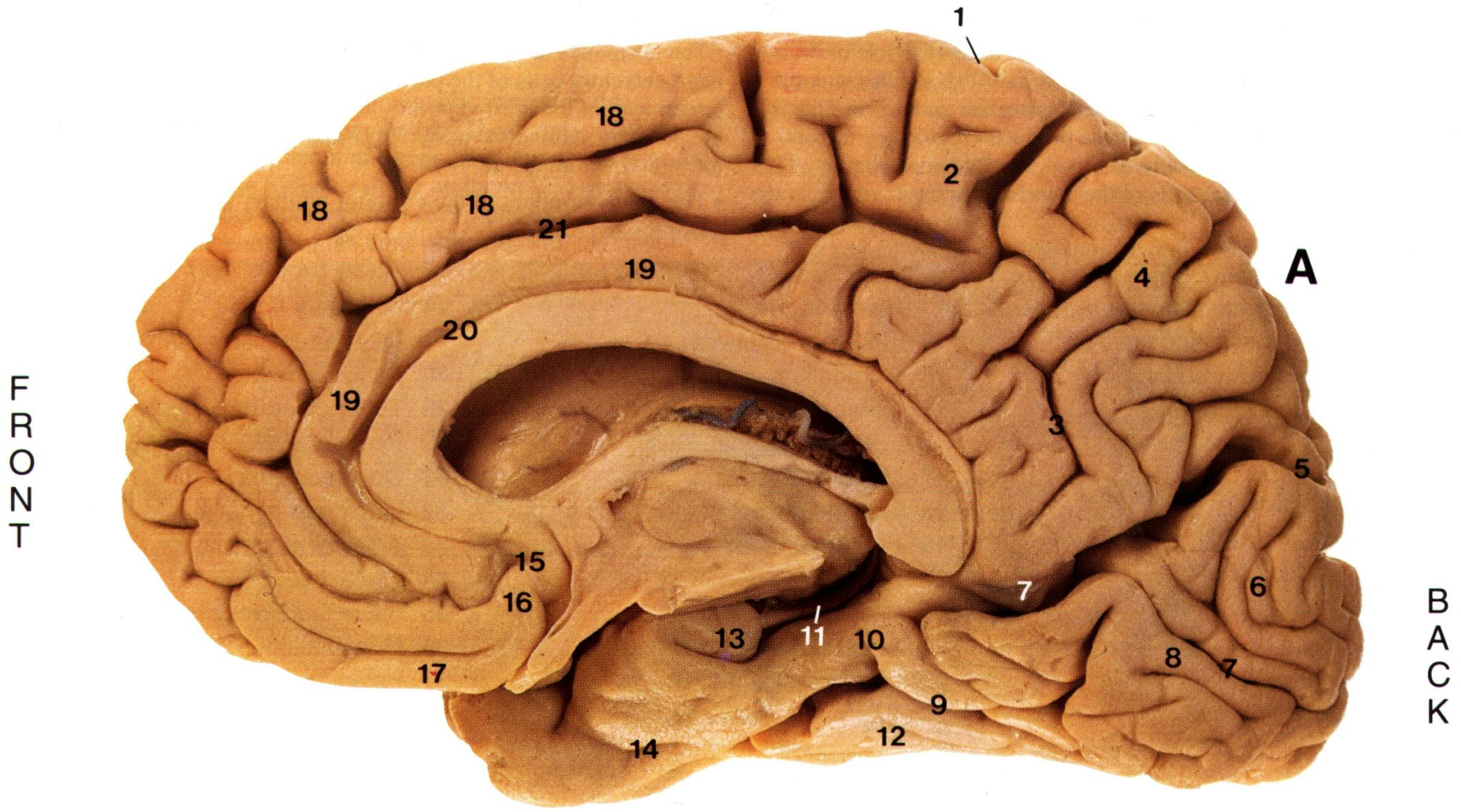


1. Go trials are more frequent than stop trials.
2. The median reaction time on go trials is calculated.
*3. The time between the **go** and **stop** stimuli is adjusted until p(successful inhibition on stop trials) = 0.5. This means that the effects of the **stop** signal are fast enough to cancel 50% of initiated responses, i.e. the **stop** signal influences responding on average at the same time as the **go** signal.*
4. The stop signal reaction time (SSRT) is then calculated as the time between the onset of the stop signal and the median response time on go trials.

Stop tasks activate the right inferior frontal gyrus in humans.
Right inferior frontal gyrus lesions increase the SSRT in humans *(Aron et al. 2003).*

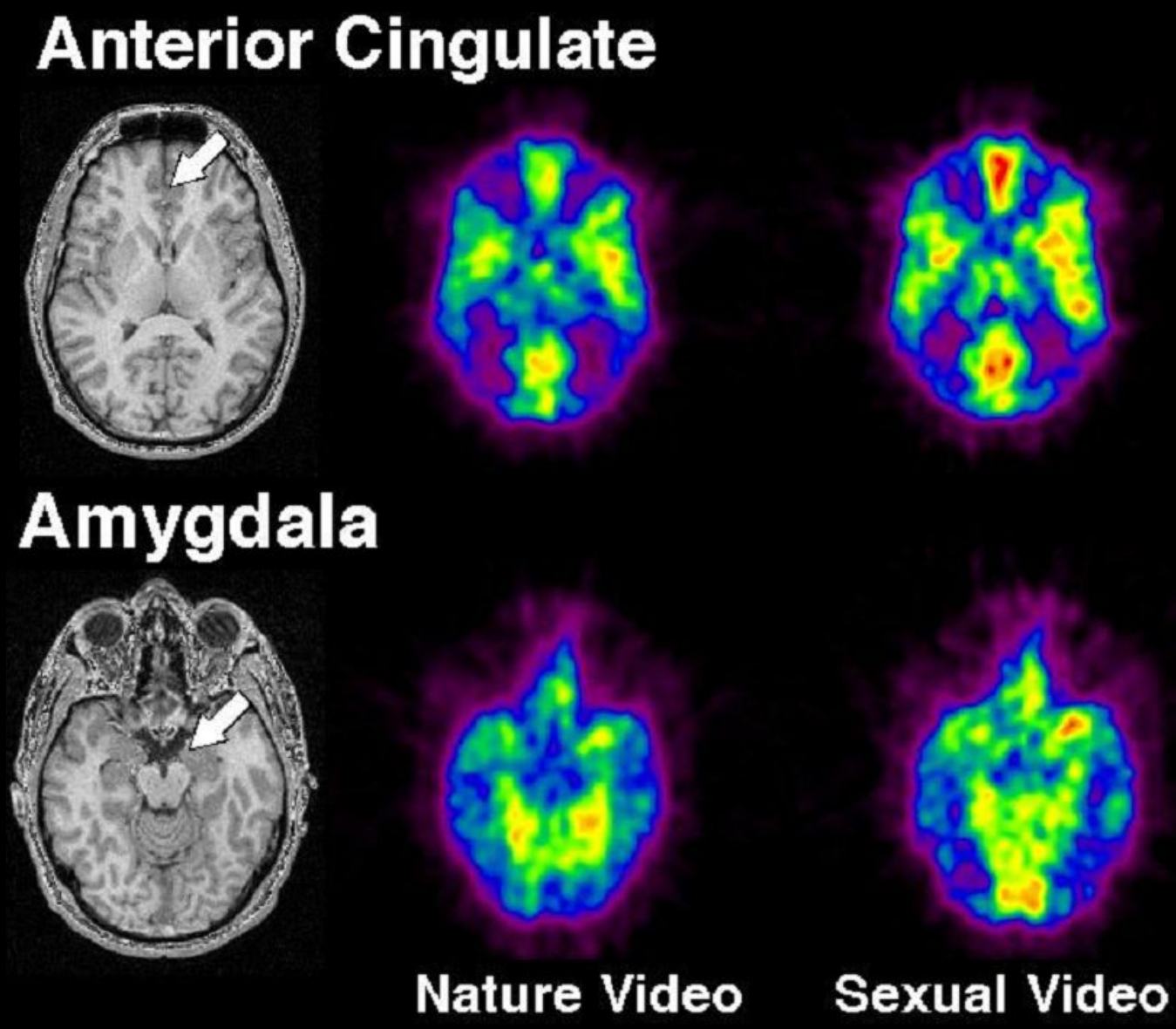
Anterior cingulate cortex

Cingulate cortex



(The numbers don't mean anything!)

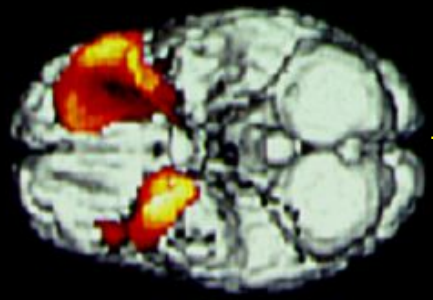
Sexual stimuli activate the ACC



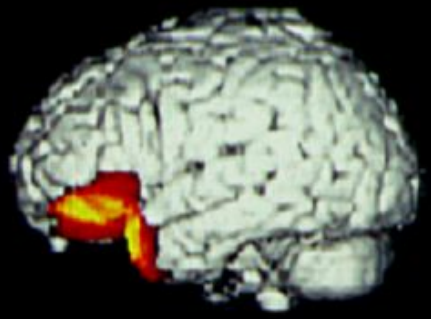
Childress et al. (1999→); see also Garavan et al. (2000)

Cue-induced cocaine craving activates the ACC and OFC

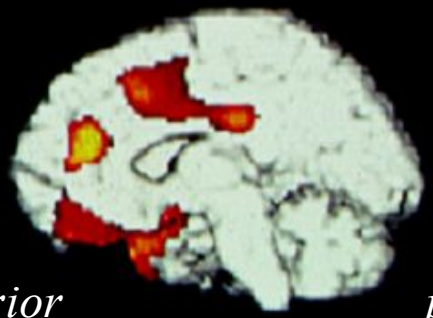
Cocaine addicts watching a cocaine video; activations correlated with subjective reports of craving



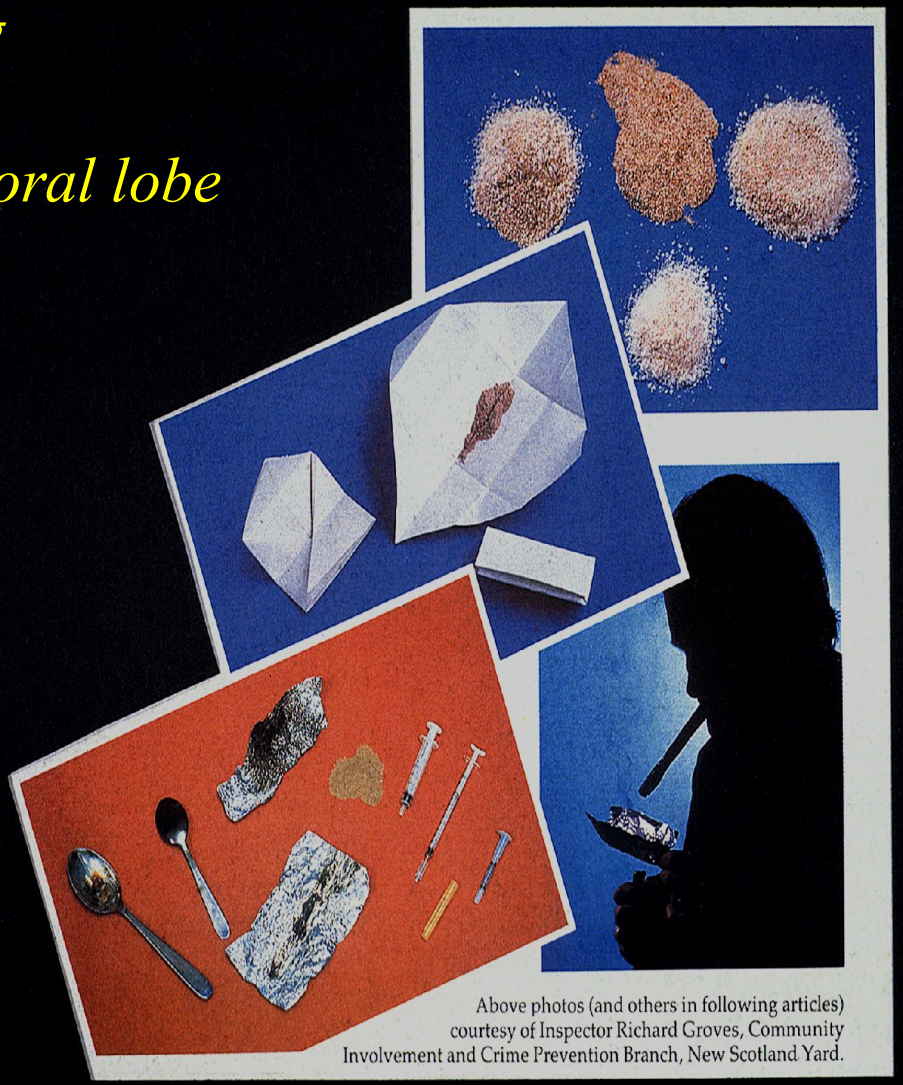
medial temporal lobe — amygdala



OFC



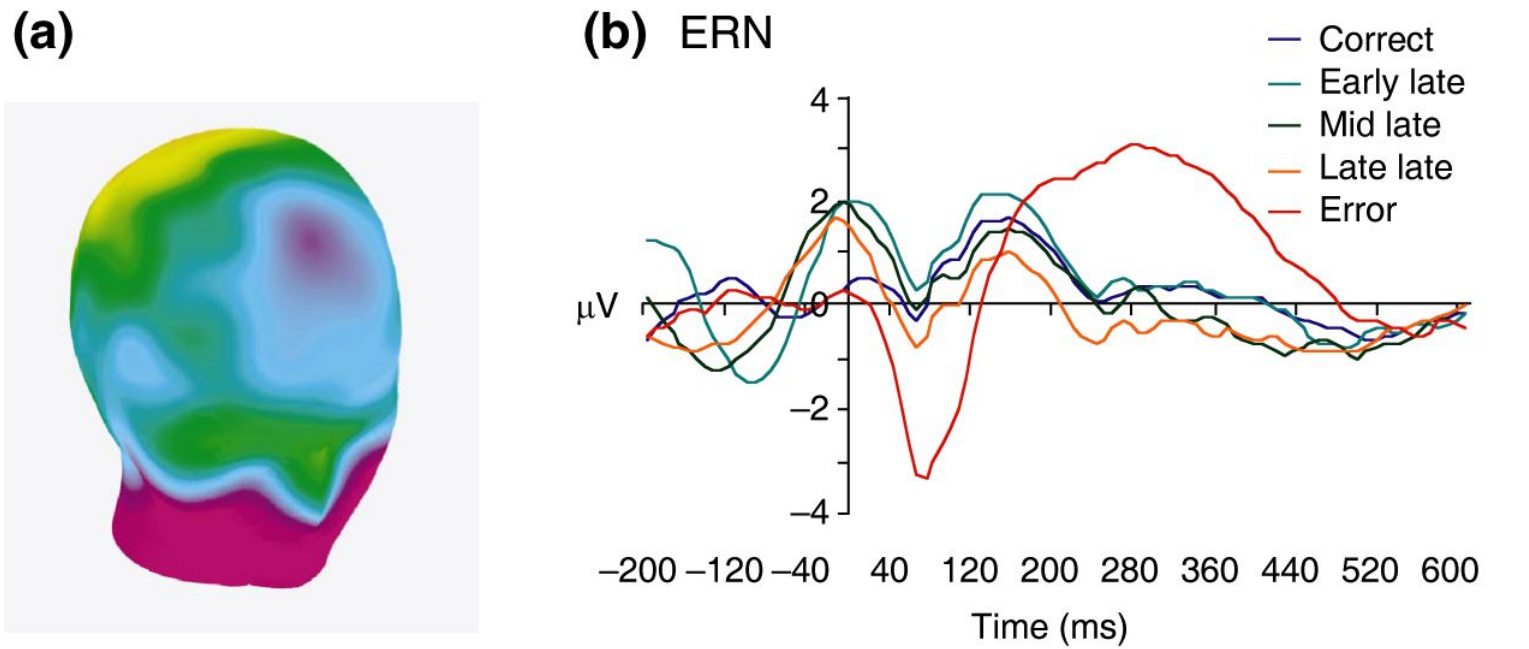
ACC



anterior *posterior*

Childress et al. (2000)

Errors in responding produce an EEG signal localized to ACC



Electrical studies of error-related negativity (ERN).
(a) Scalp distribution of the ERN (the purple area shows the centre of scalp negativity).
(b) Responses that are in error produce an ERN.

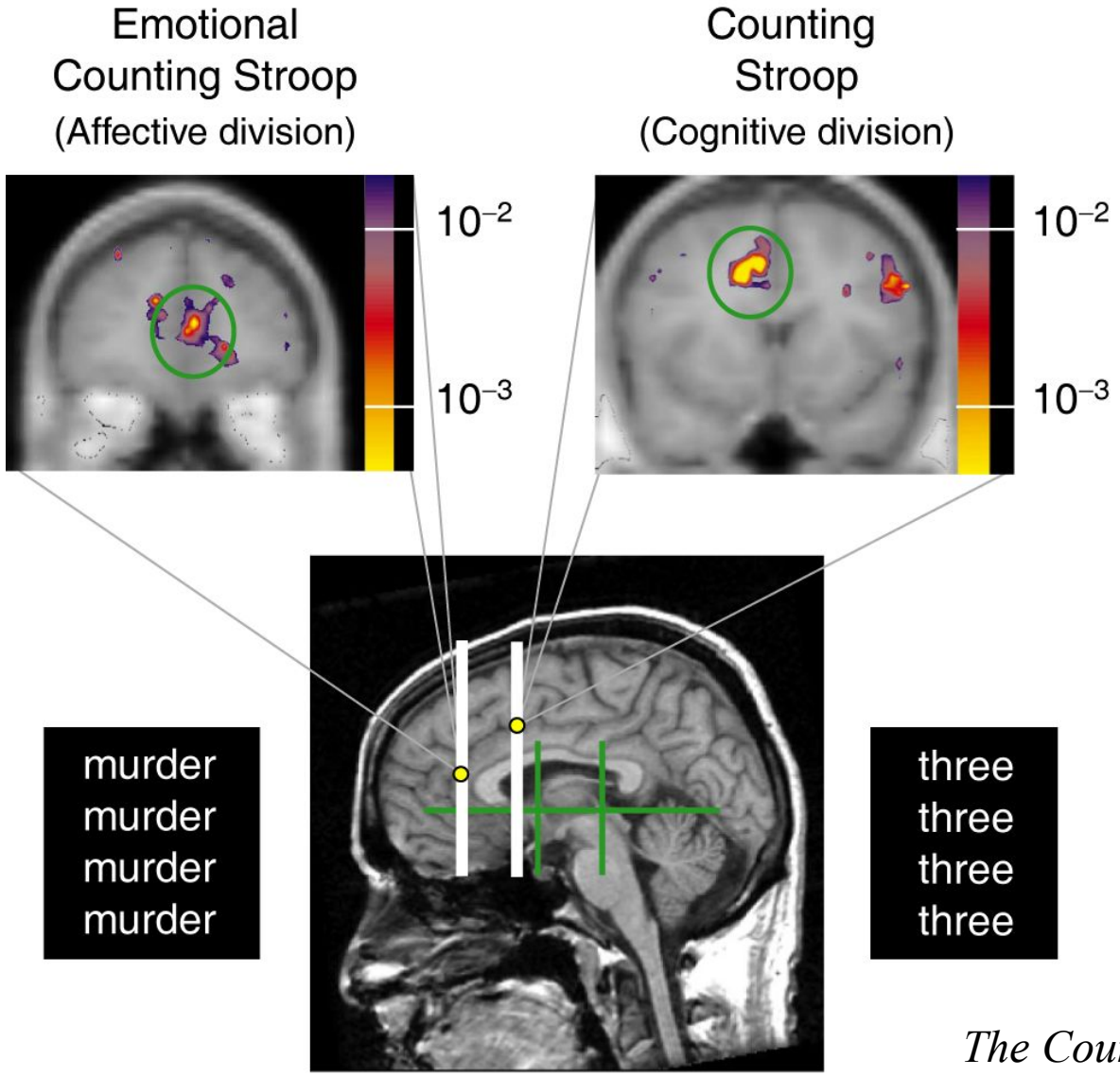
from Bush (2000)

The Stroop test

congruent	*neutral*	*incongruent*
blue	willow	red
yellow	trek	green
red	armchair	blue
green	prefect	yellow
blue	felicitous	blue
green	destructive	green
yellow	milk	yellow
blue	bore	blue
red	selection	red
yellow	karyotype	green

Stroop (1935)

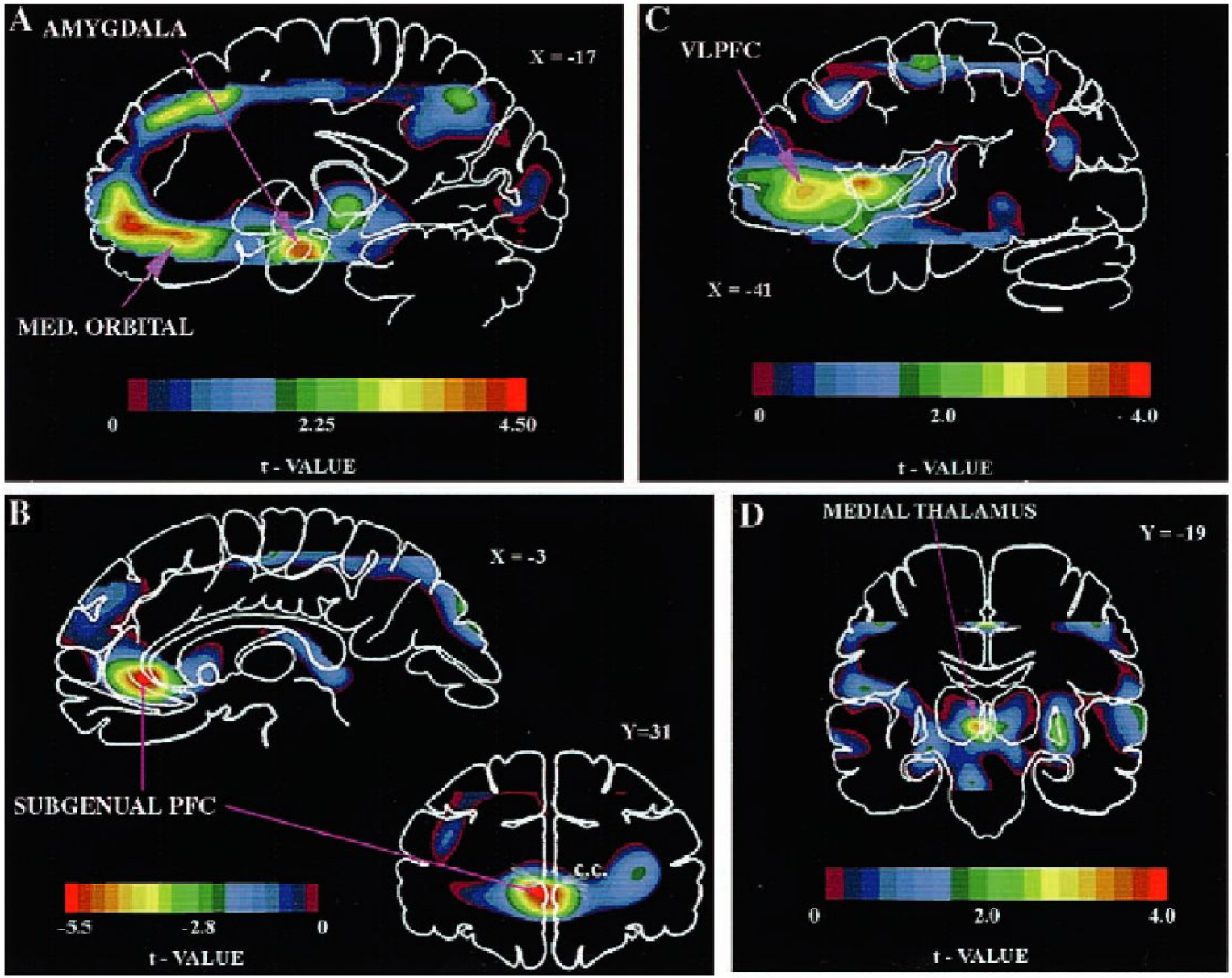
The Stroop test activates the ACC



The Counting Stroop: count the number of words present.

from Bush (2000)

ACC hyperactivity in depression

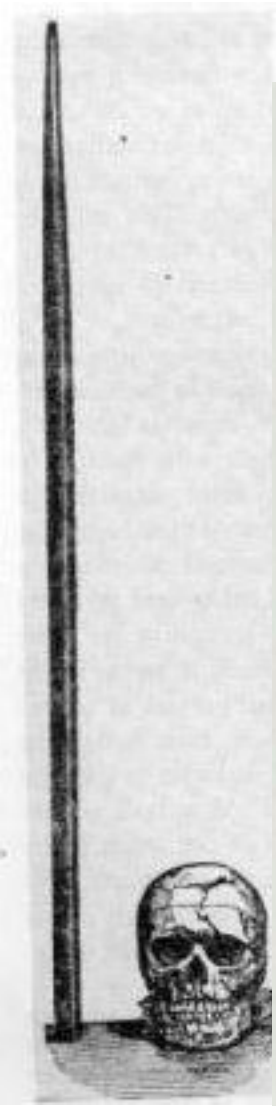


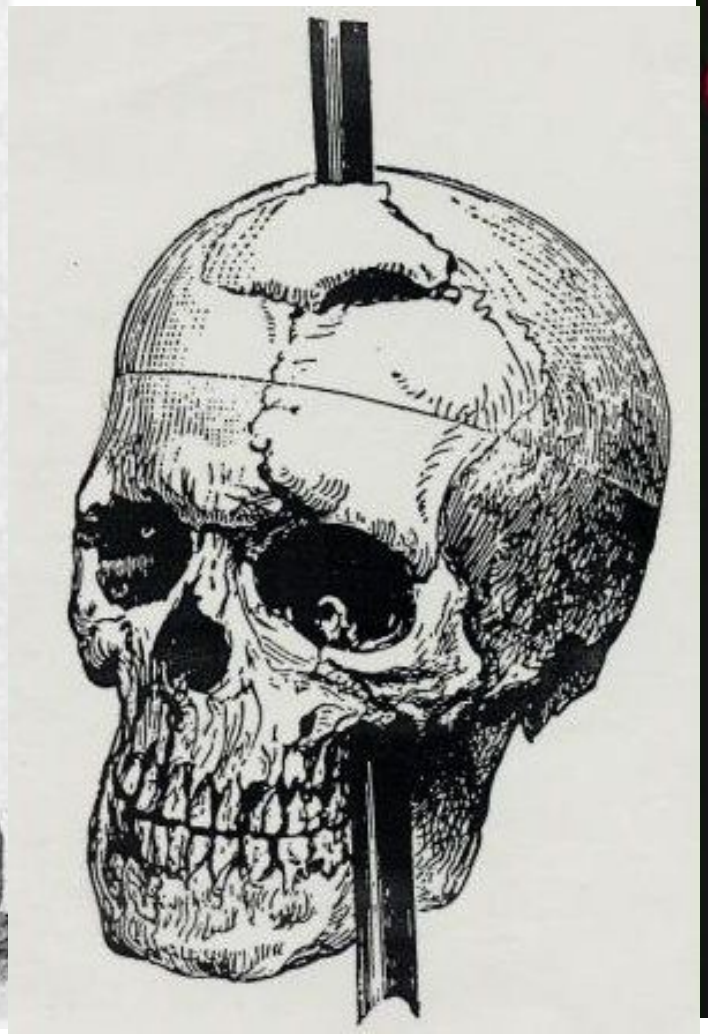
ACC

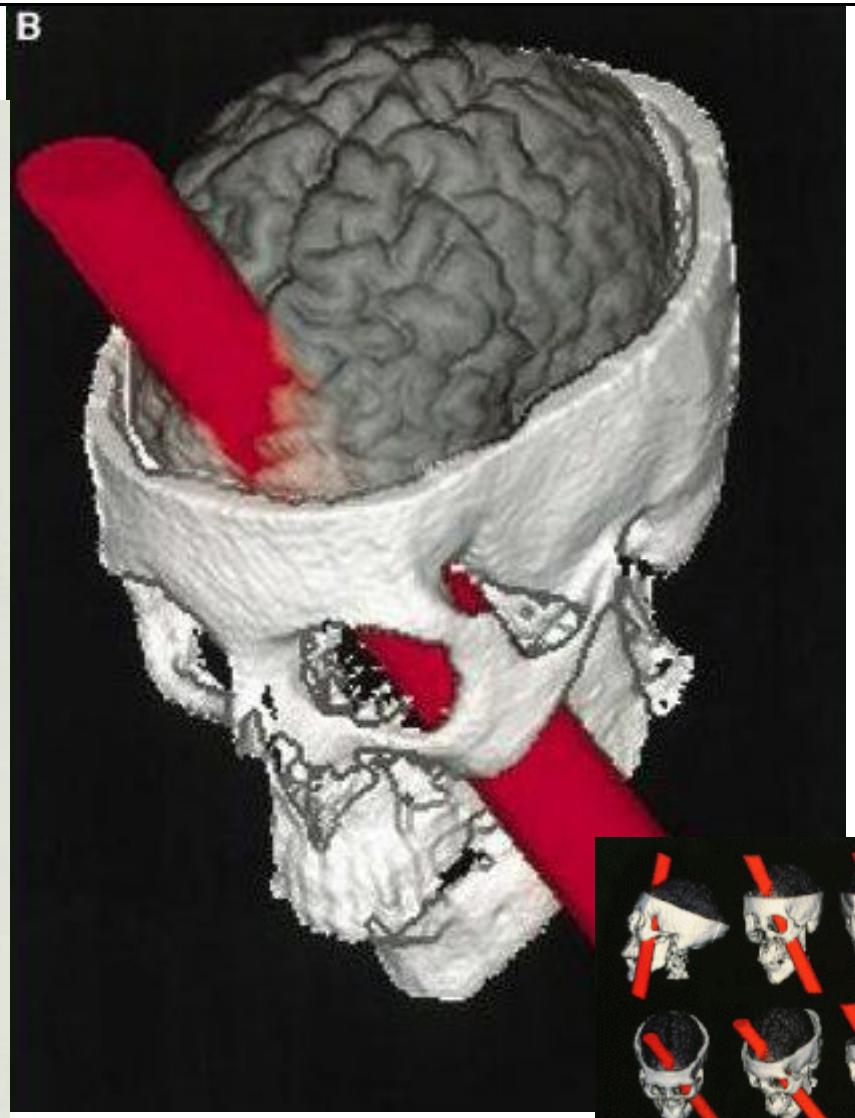
from Drevets (2000)

Orbitofrontal cortex

Orbitofrontal damage: the case of Phineas Gage







Harlow (1848; 1868); Damasio et al. (1994)

Orbitofrontal damage: the case of Phineas Gage

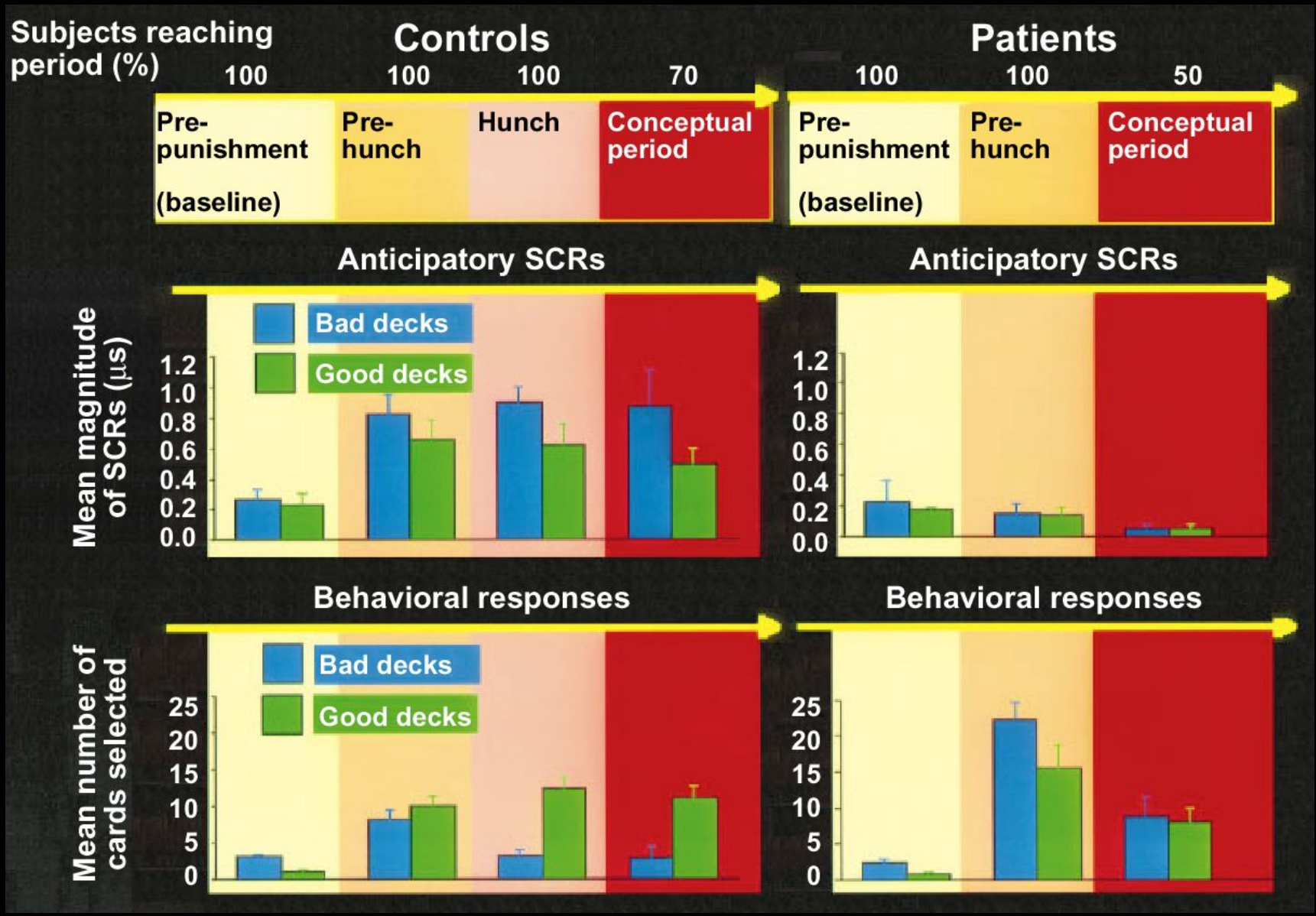
Orbitofrontal damage: the case of Phineas Gage

Earl Miller (a prefrontal cortex researcher) with the tamping iron

The Iowa gambling task

Bechara et al. (1994)

Anticipatory SCRs precedes knowledge

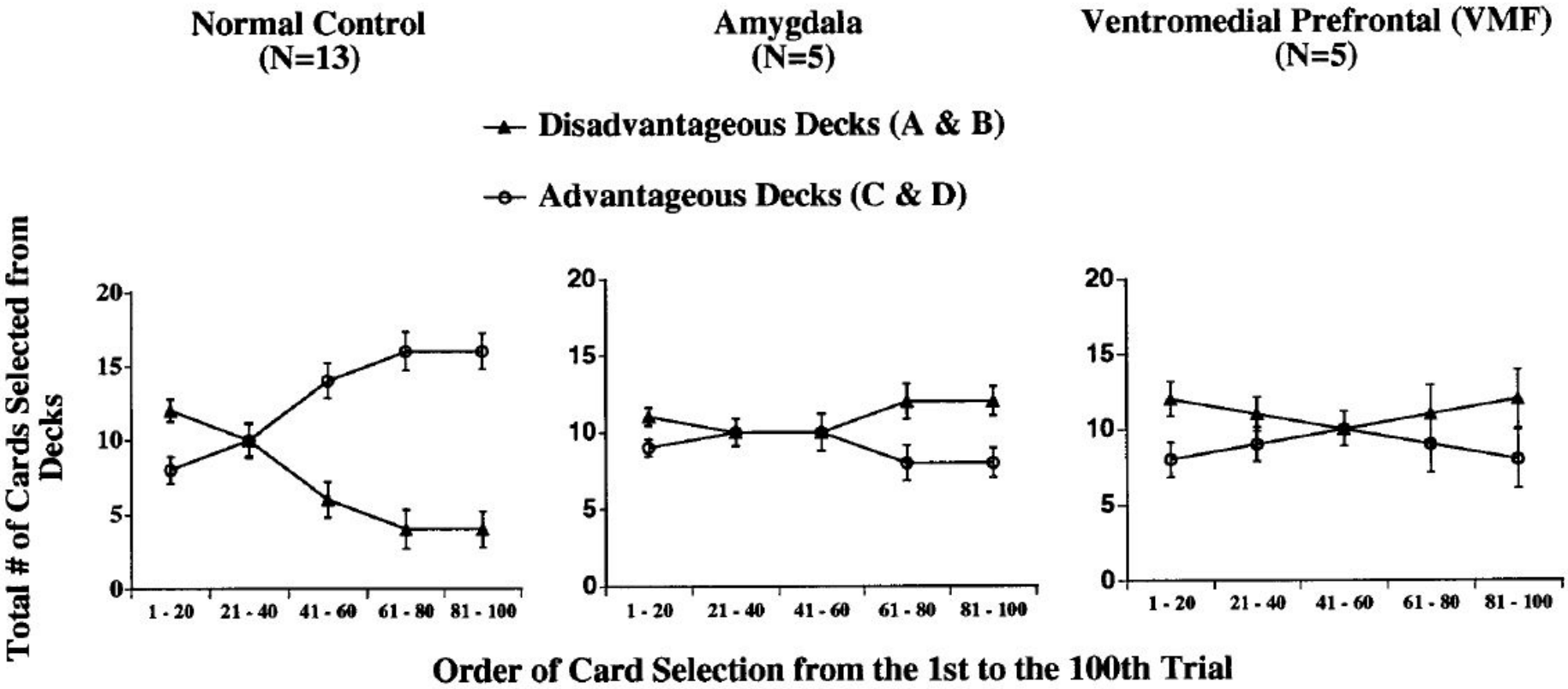


Bechara et al. (1997); normals and patients with ventromedial PFC (OFC) damage

“He chose poorly.”

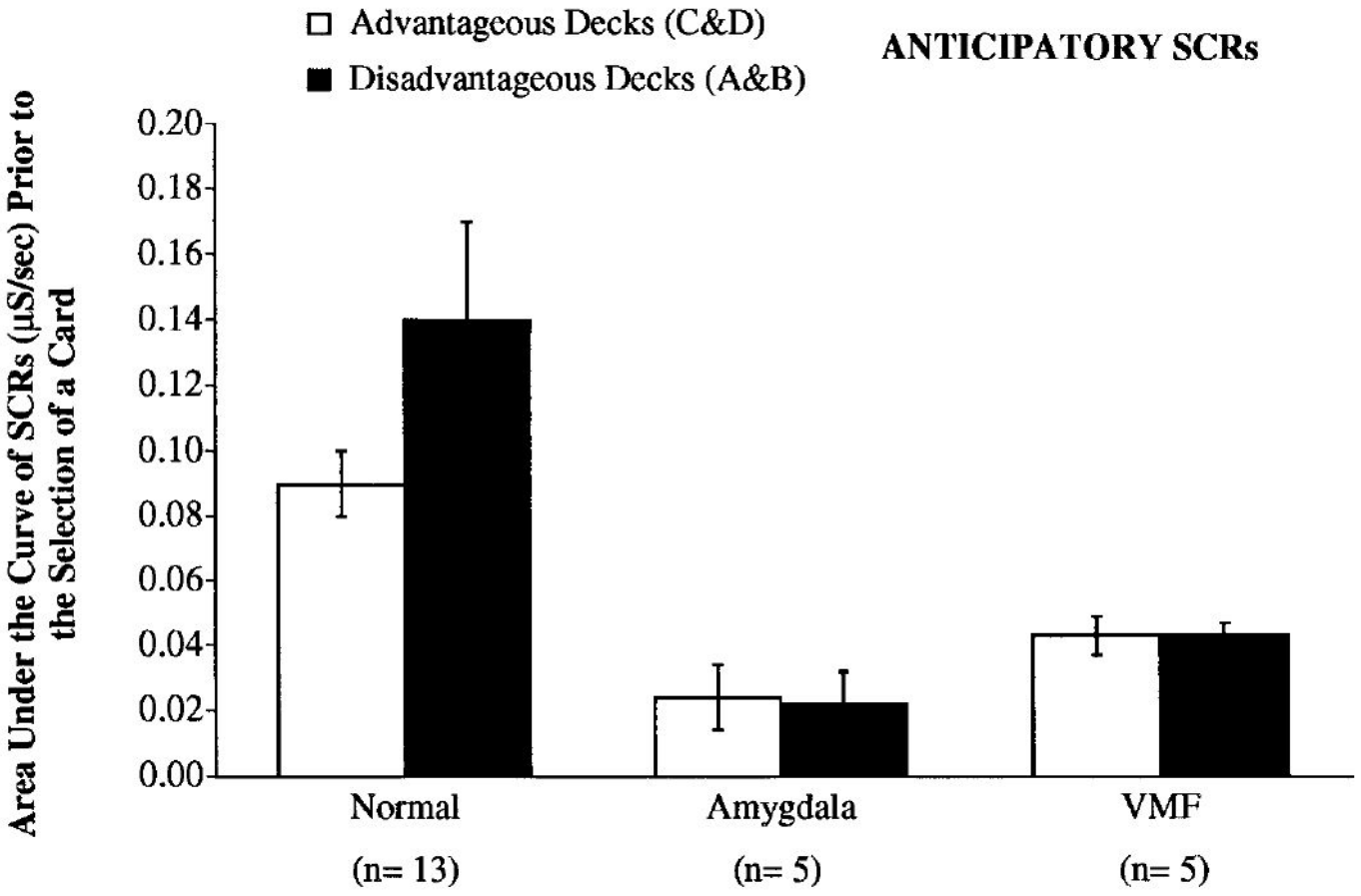
Spielberg (1989): ‘Indiana Jones and the Last Crusade’

OFC and amygdala lesions on the Iowa gambling task (1)



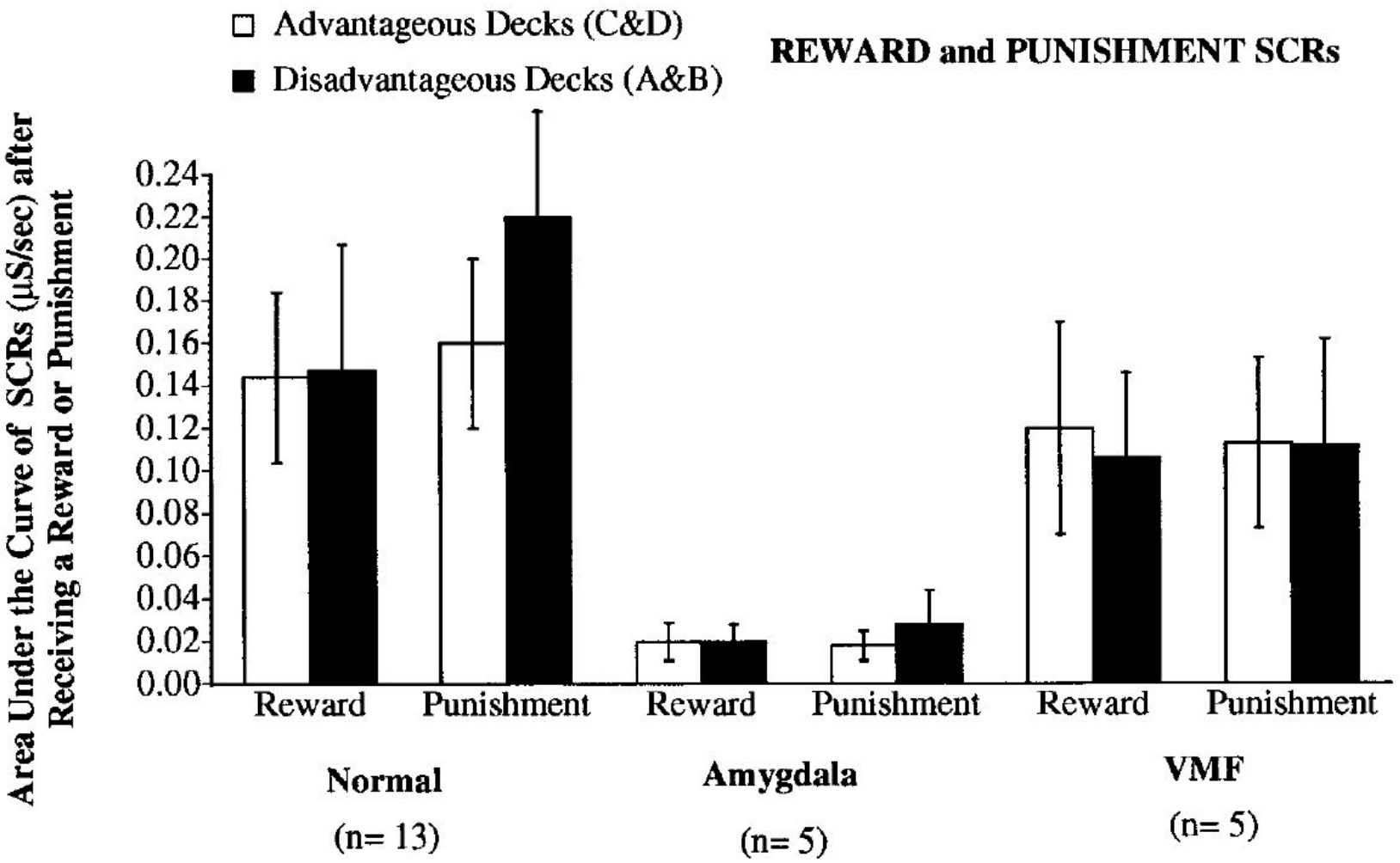
Bechara et al. (1999)

OFC and amygdala lesions on the Iowa gambling task (2)



Bechara et al. (1999)

OFC and amygdala lesions on the Iowa gambling task (3)



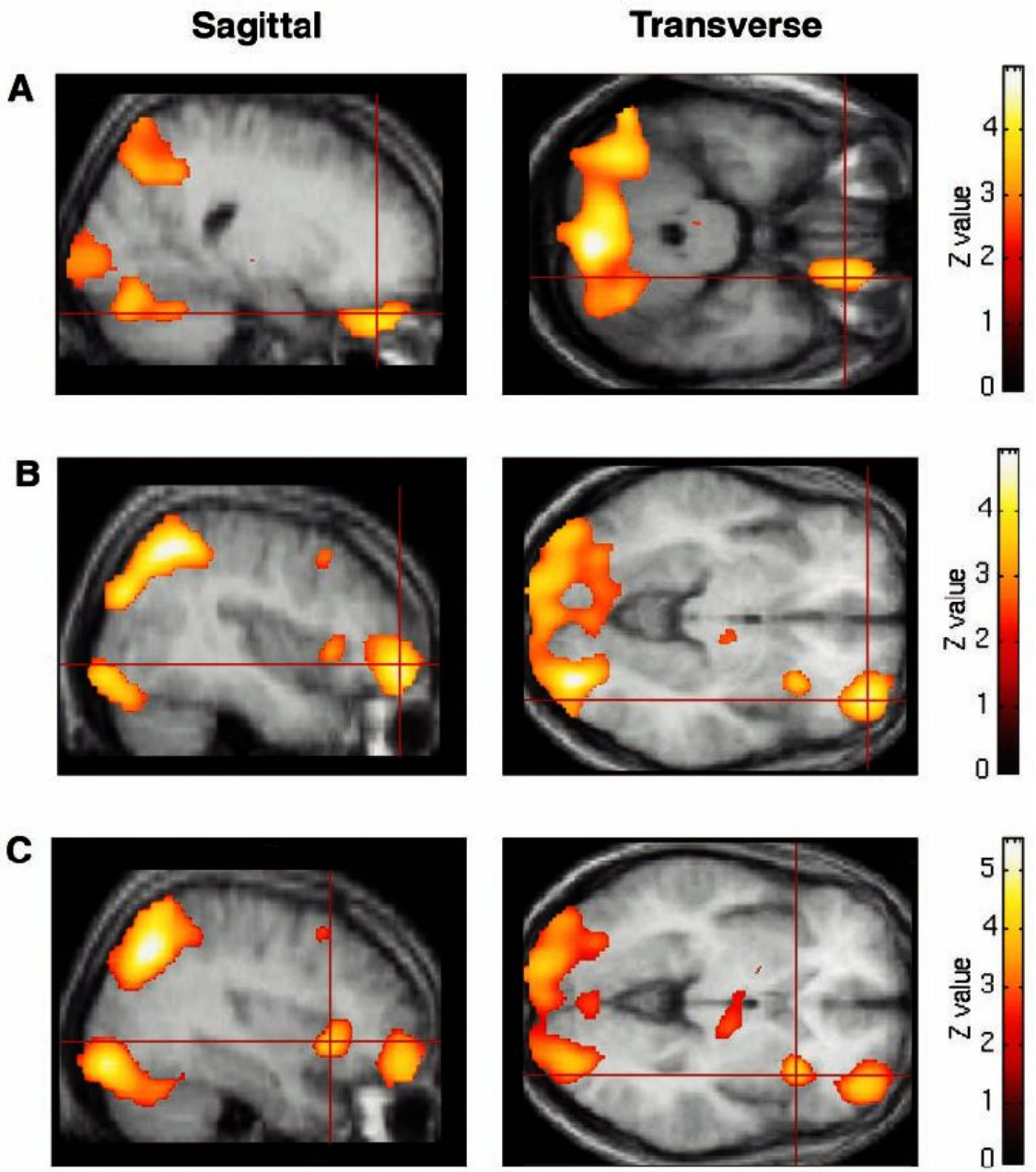
Bechara et al. (1999)

Choosing between small/likely and large/unlikely rewards

orbitomedial (11)

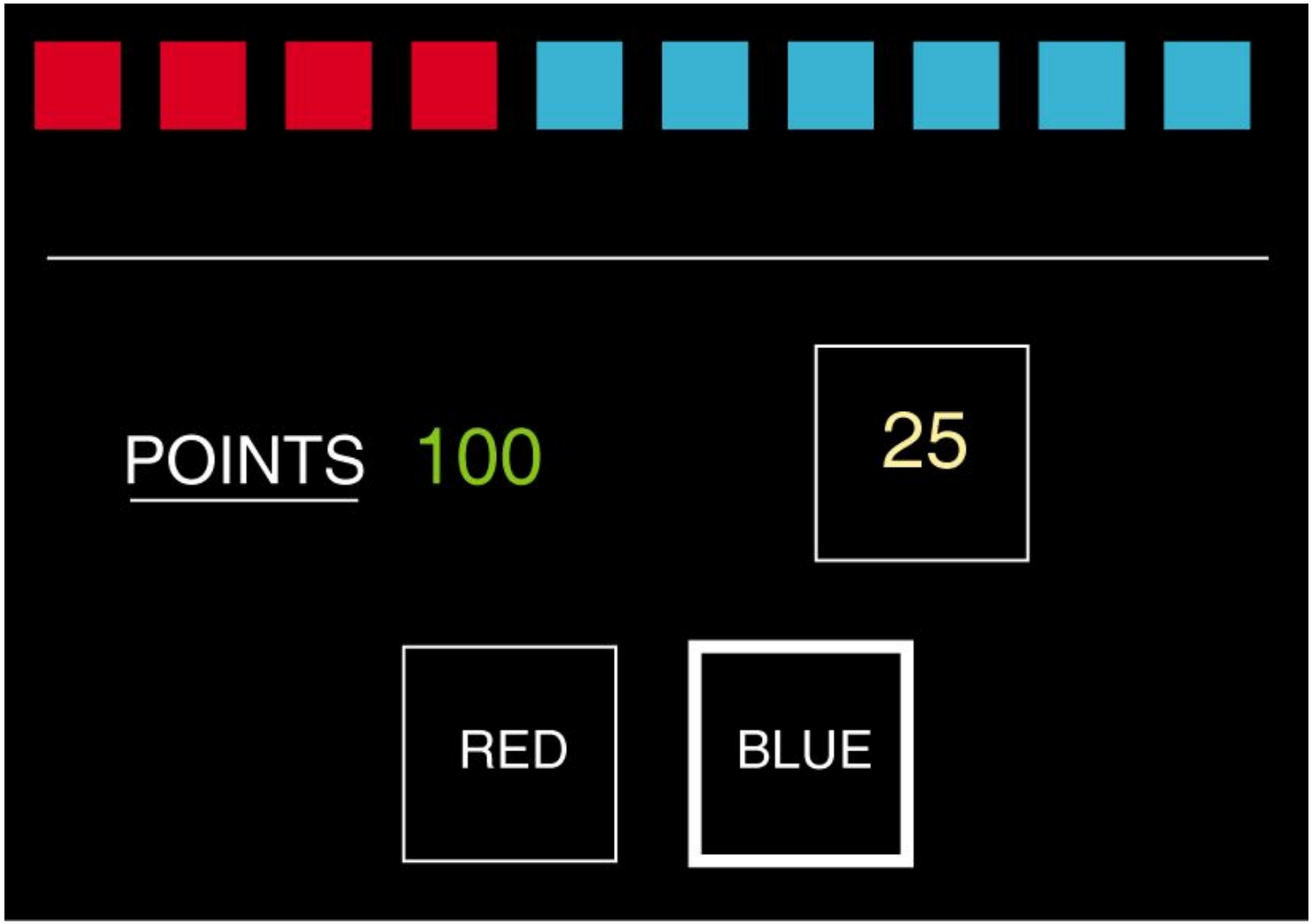
orbitolateral (10)

inferior convexity (47)



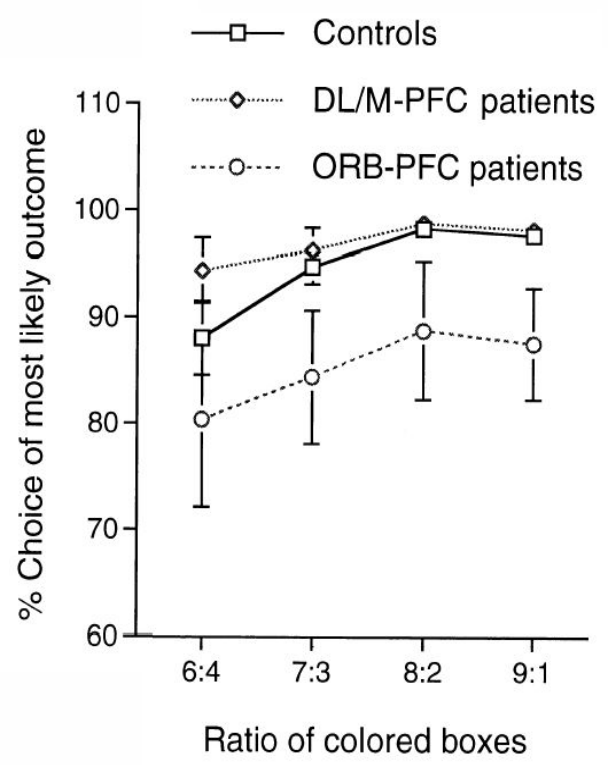
Rogers et al. (1999) J. Neuro.

Another gambling task...

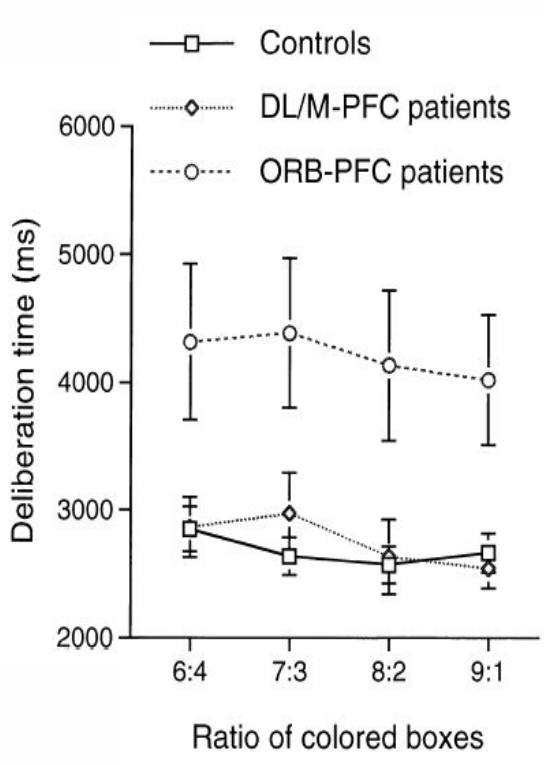


Rogers et al. (1999) Neuropsychopharm.

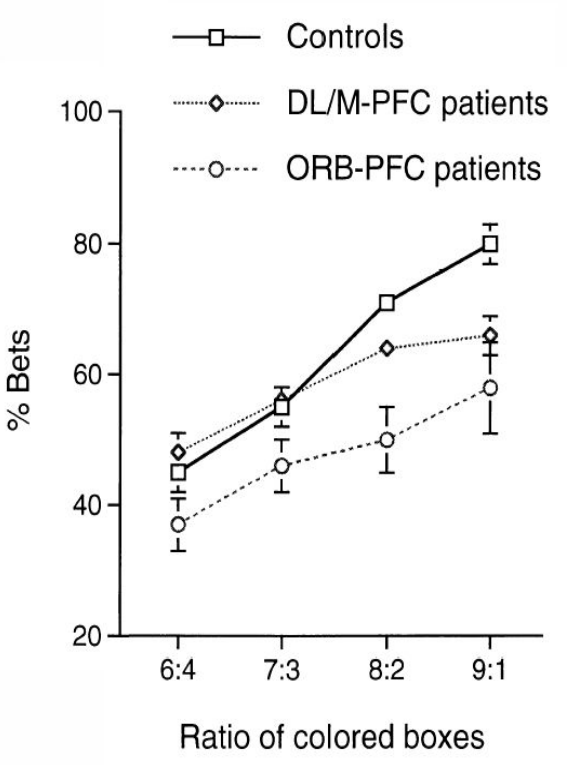
OFC lesions: wrong, slow, but not 'risk-taking'



% choice of most likely outcome



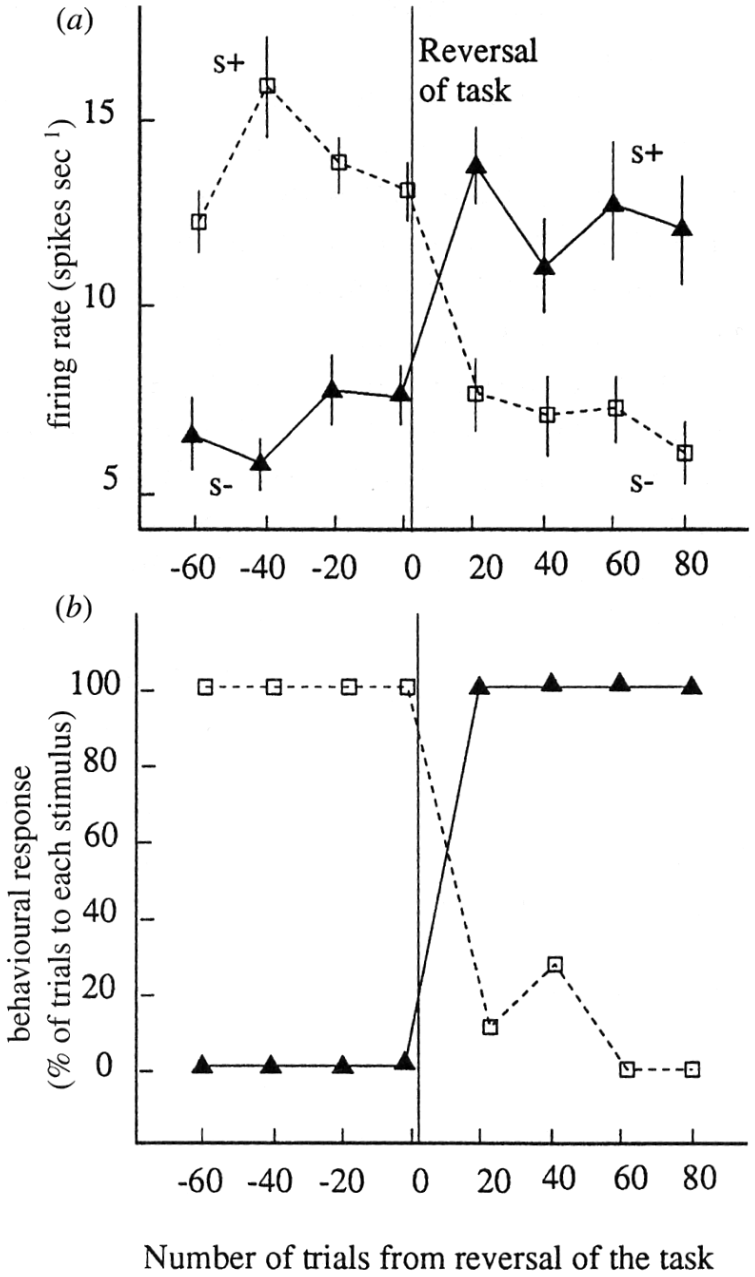
deliberation time



% of available points bet

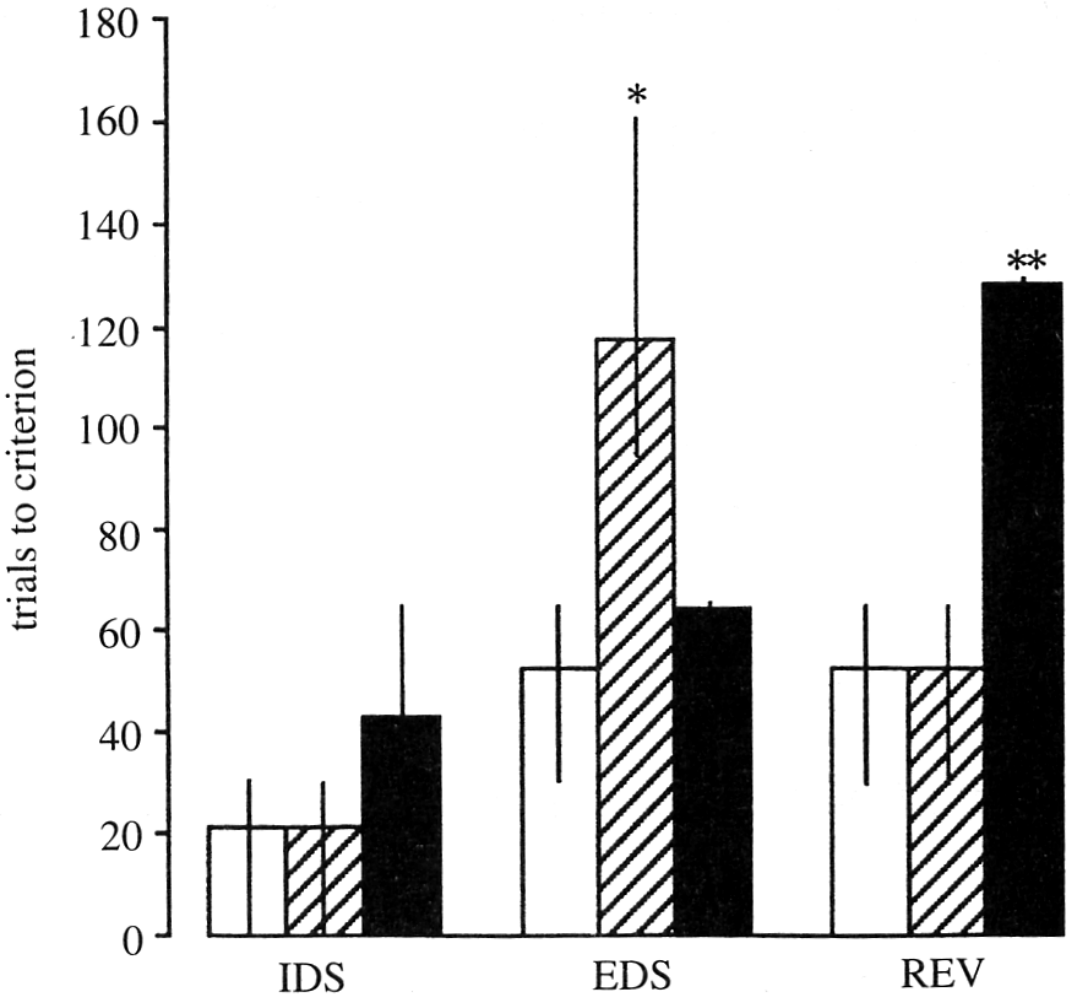
Rogers et al. (1999) Neuropsychopharm.

OFC neurons reverse rapidly during reversal-learning tasks



Rolls et al. (1996)

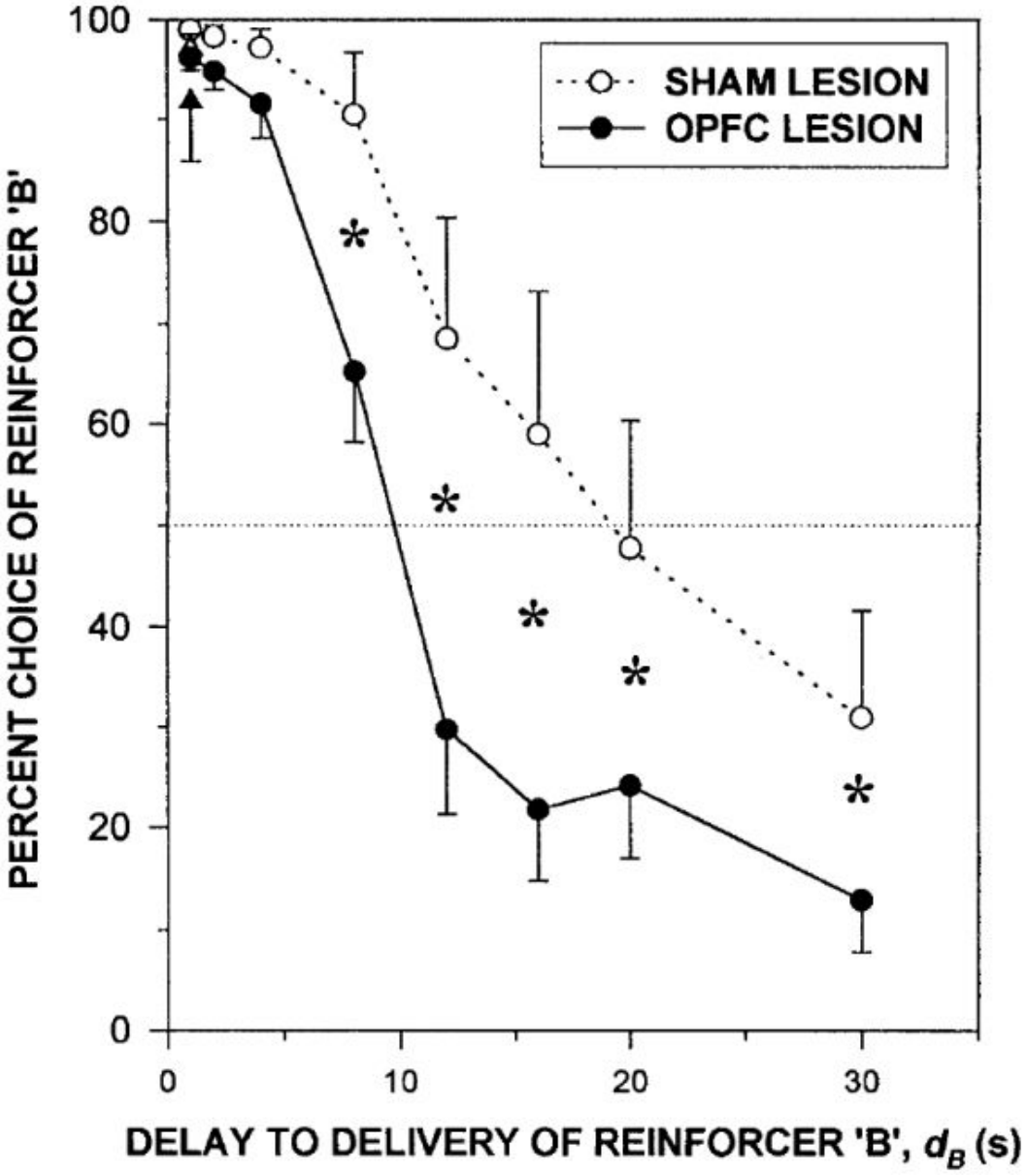
Reversal learning impaired by OFC lesions in marmosets

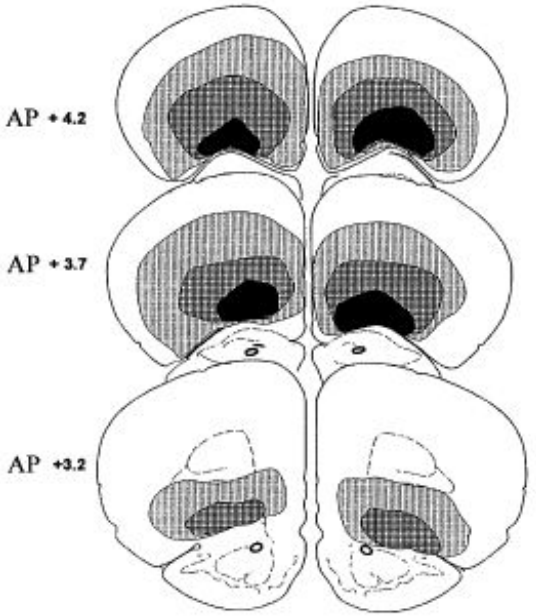


Open = sham-operated controls.
Hatched = DLPFC lesion (area 9).
Filled = OFC lesion.

Dias et al. (1996)

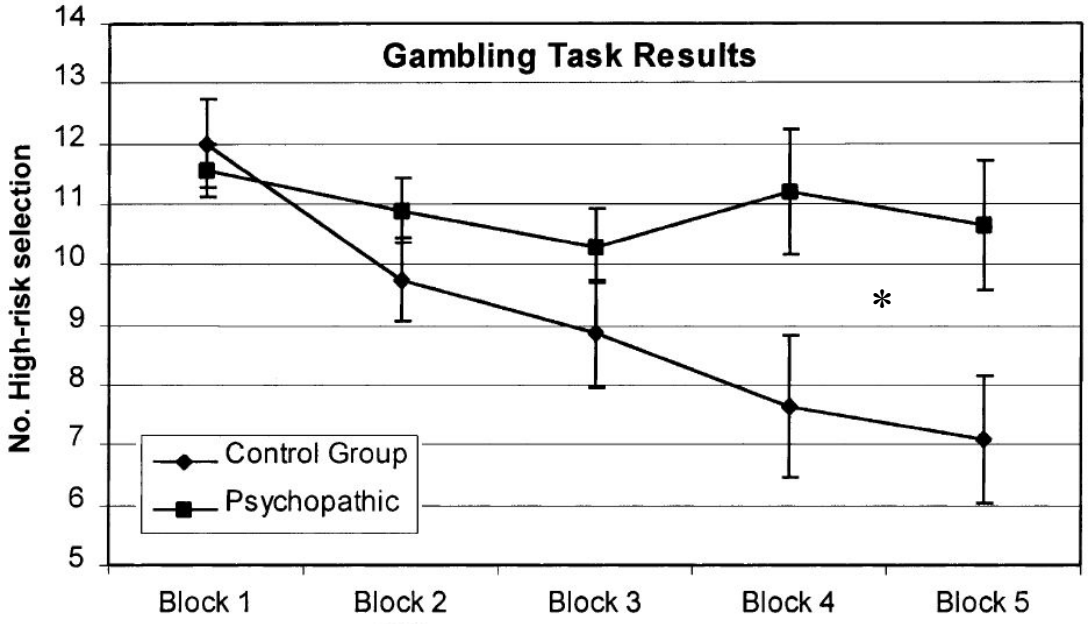
OFC lesions can induce impulsive choice in rats





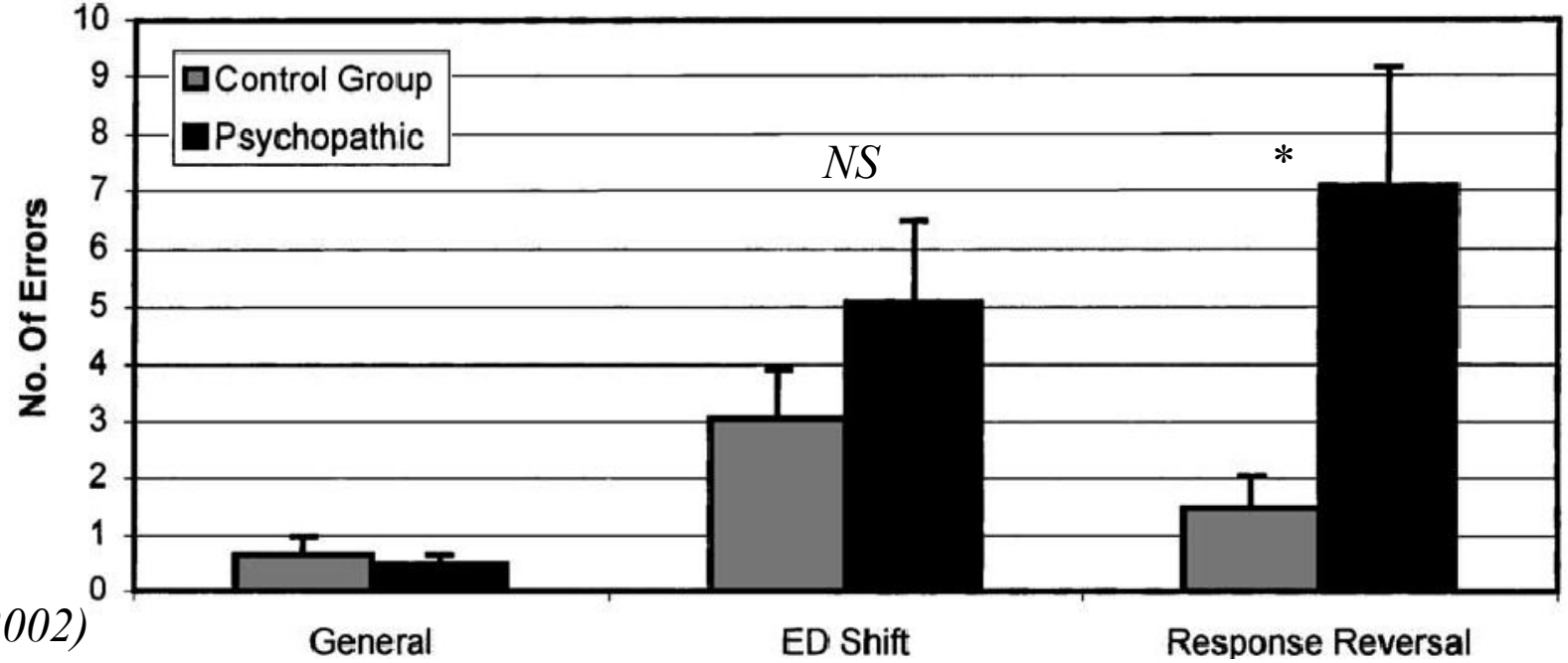
Mobini et al. (2002)

OFC dysfunction in criminal psychopathy?



psychopathic prisoners

control prisoners
(matched for age and performance on Raven's matrices)



Mitchell et al. (2002)