

NST II Psychology

NST II Neuroscience (Module 5)

Brain Mechanisms of Memory and Cognition – 6

The prefrontal cortex

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Department of Experimental Psychology

Monday 17, 24, 31 Jan; 7, 14, 28 Feb 2005; 10 am

Physiology Main Lecture Theatre

Slides will be at pobox.com/~rudolf/psychology

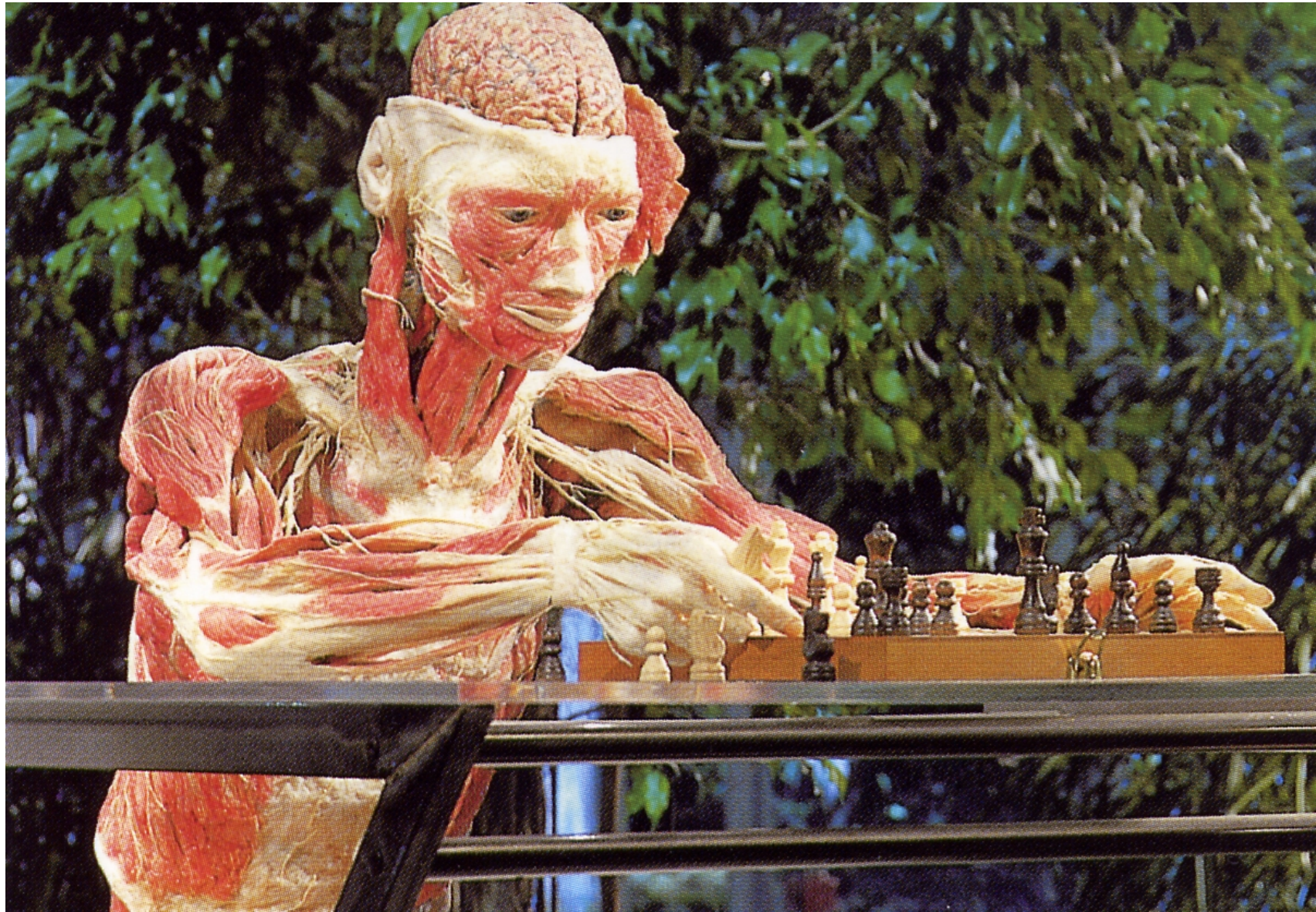


Chess and morality



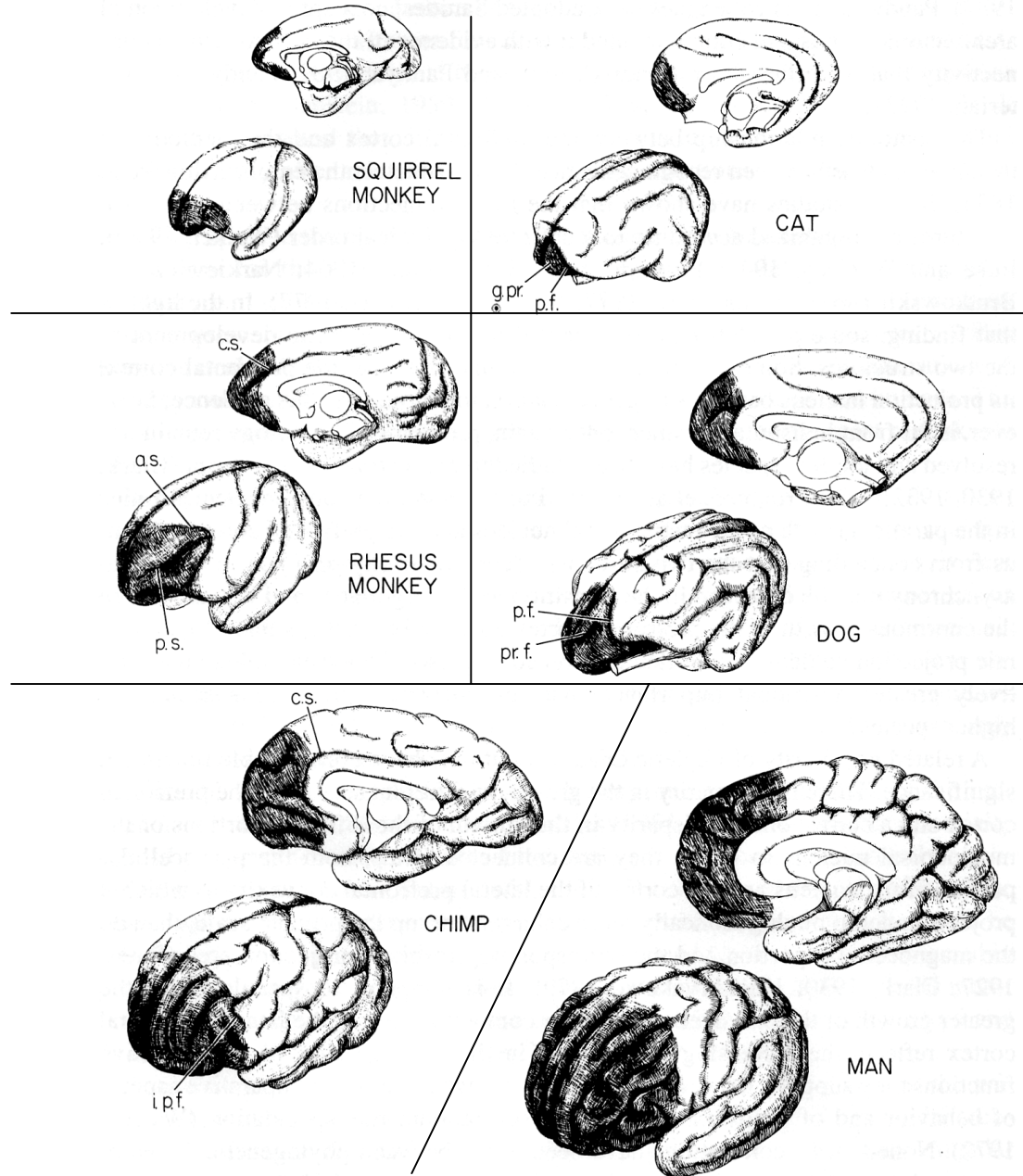
Bergman (1957): 'Det Sjunde Inseglet' (The Seventh Seal)

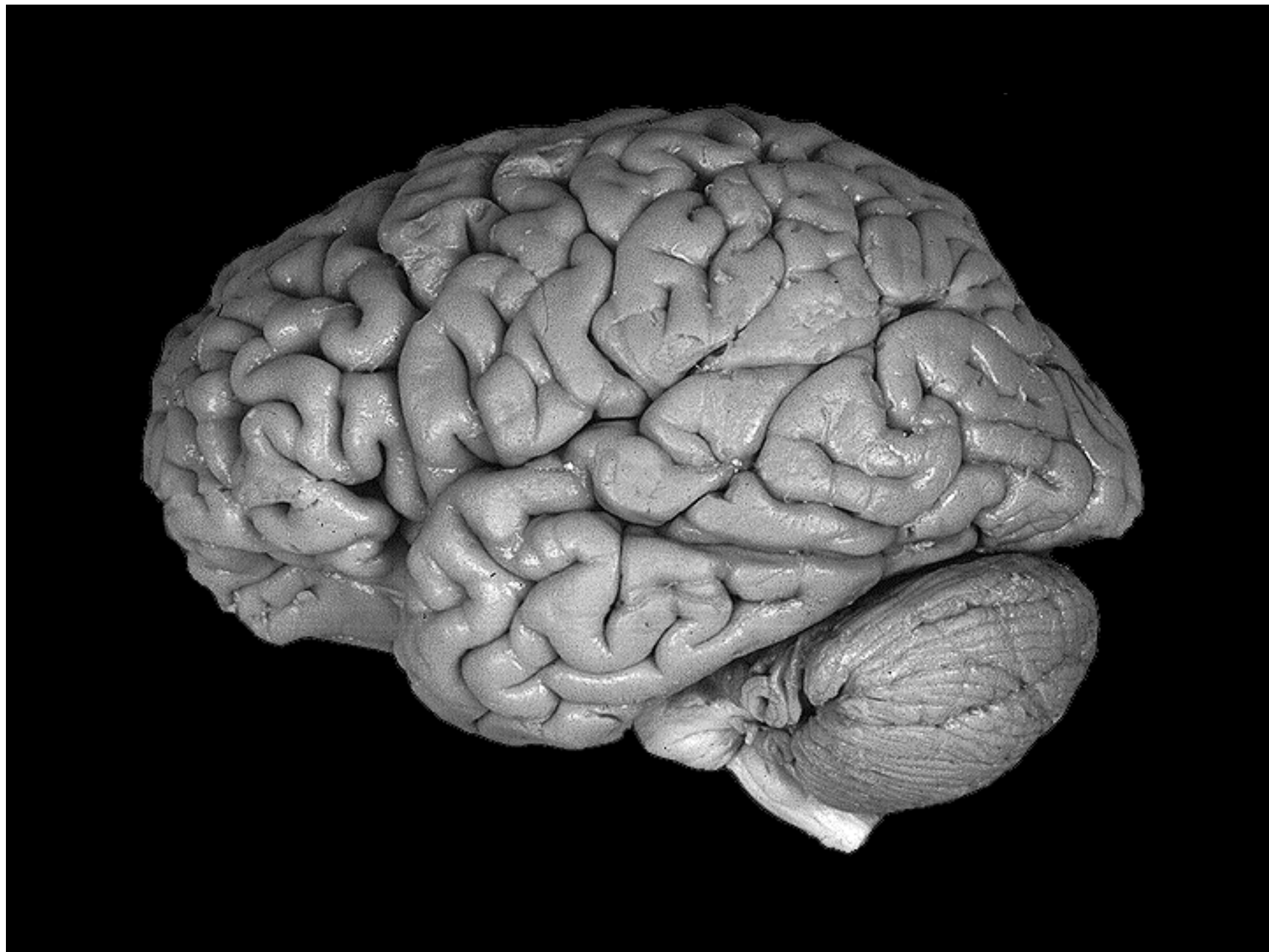
The prefrontal cortex



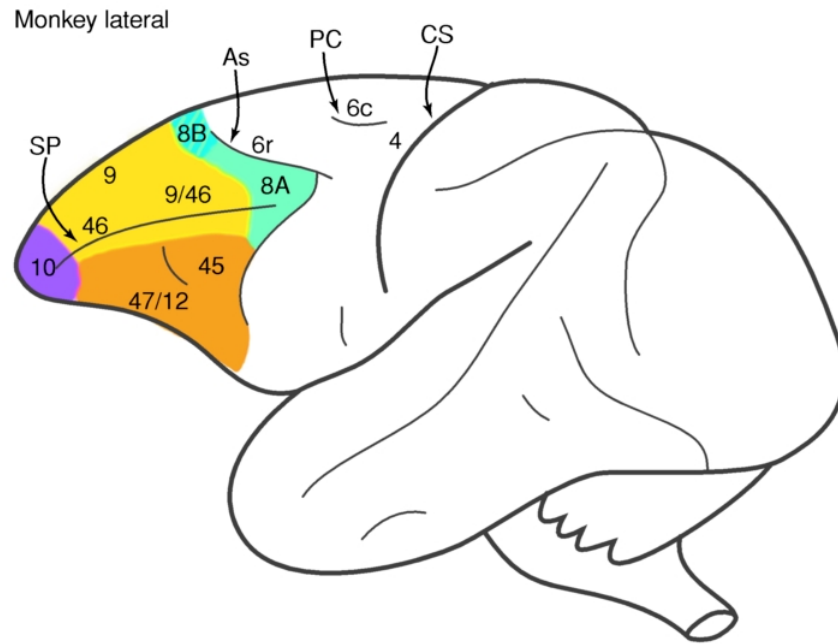
von Hagens (1996–): 'Bodyworlds'

The prefrontal cortex across species





Lateral PFC regions

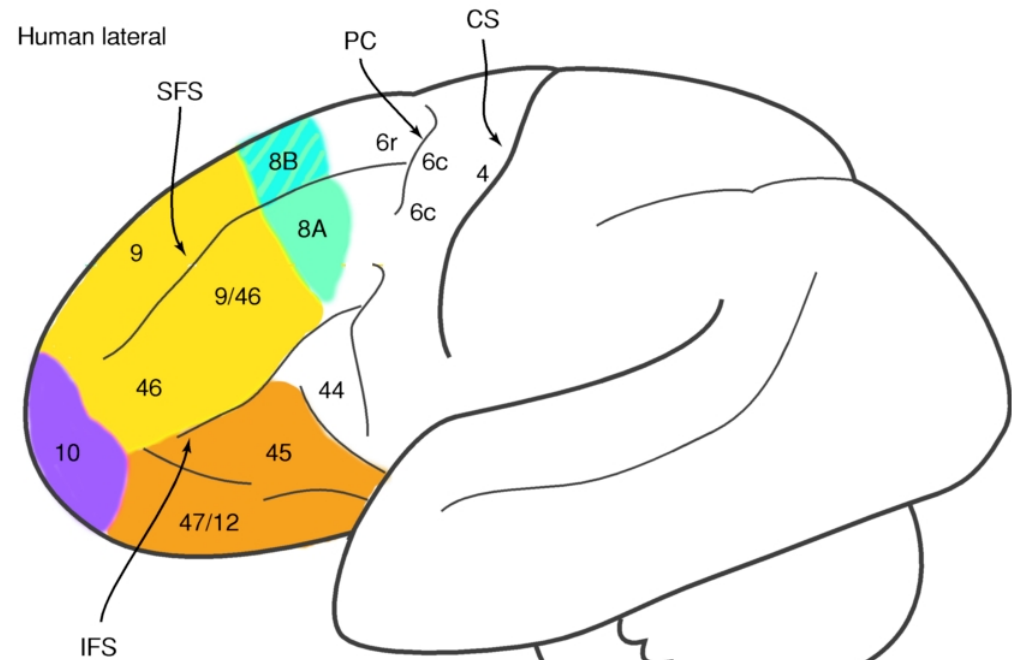


SP = sulcus principalis

As = arcuate sulcus

PC = precentral sulcus

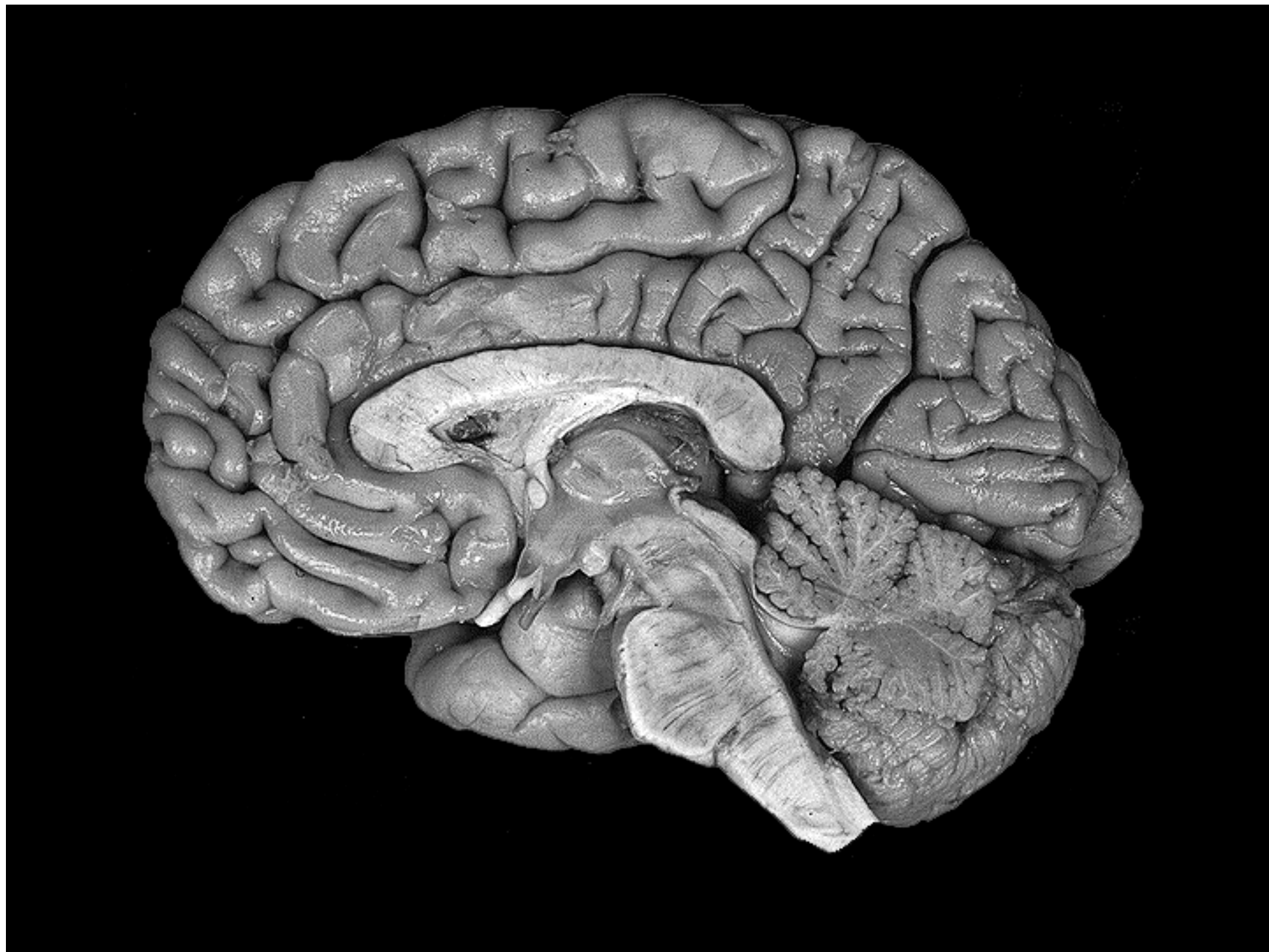
CS = central sulcus

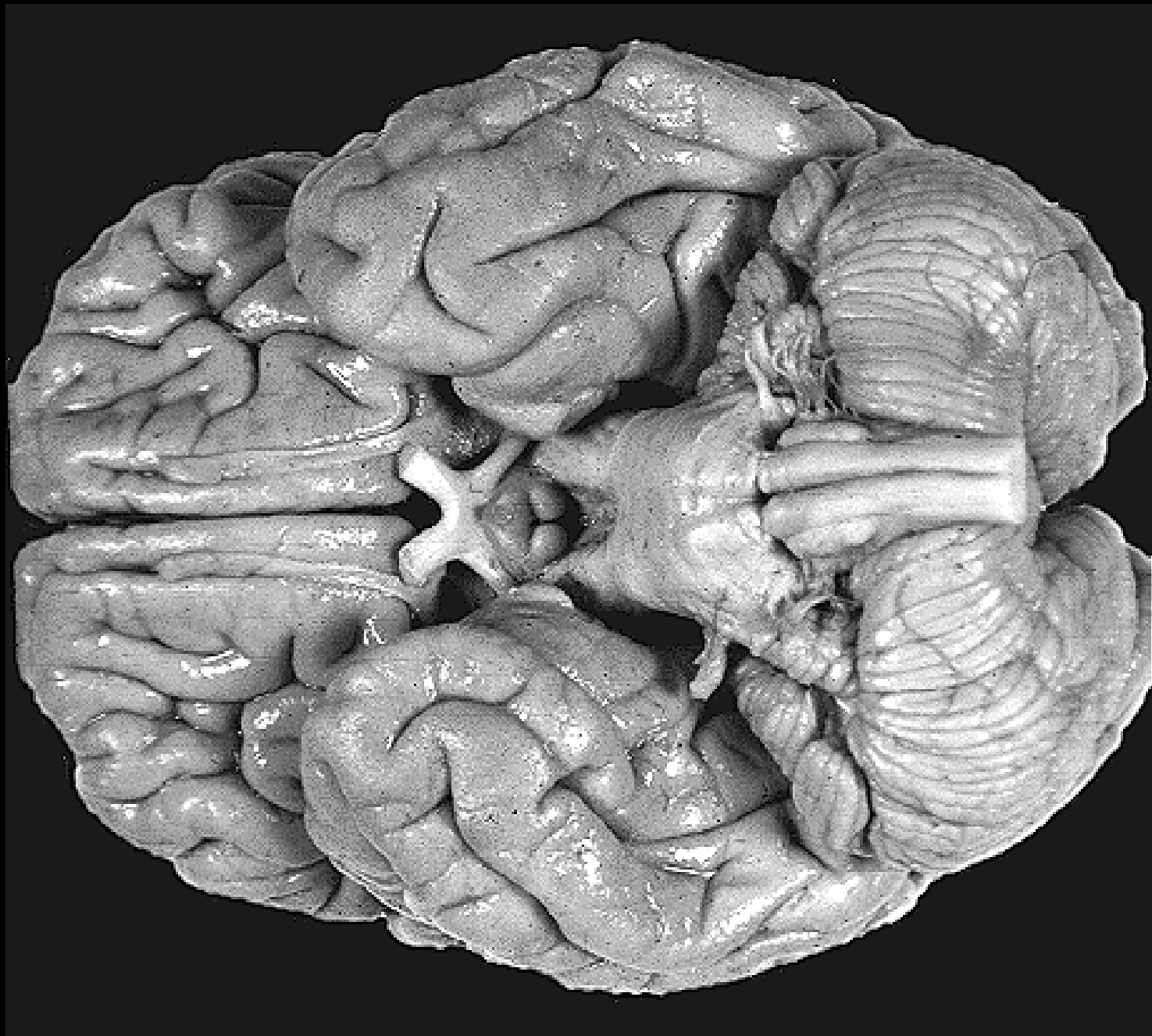


SFS = superior frontal sulcus

IFS = inferior frontal sulcus

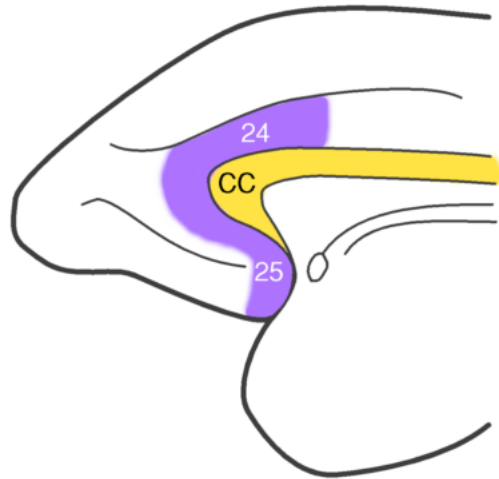
from Zigmond et al. (1999)



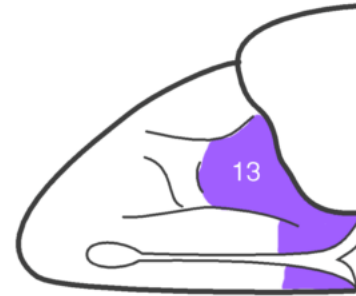


Medial and orbital PFC regions

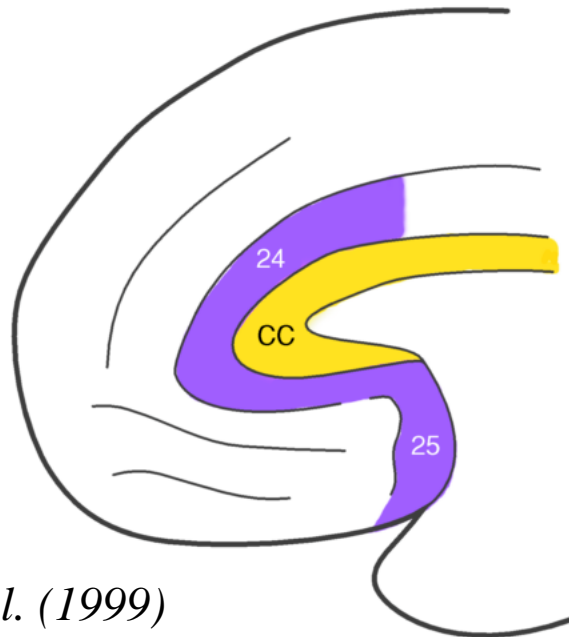
Monkey medial



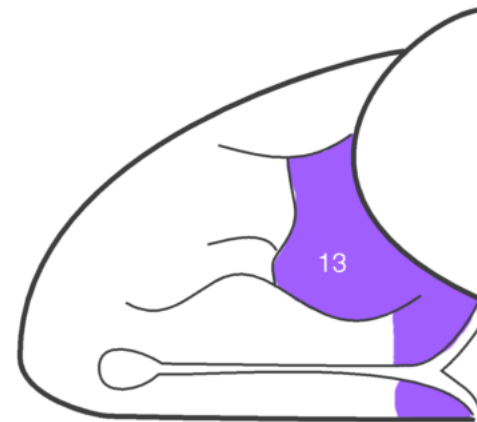
Monkey orbital



Human medial



Human orbital°



from Zigmond et al. (1999)



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)

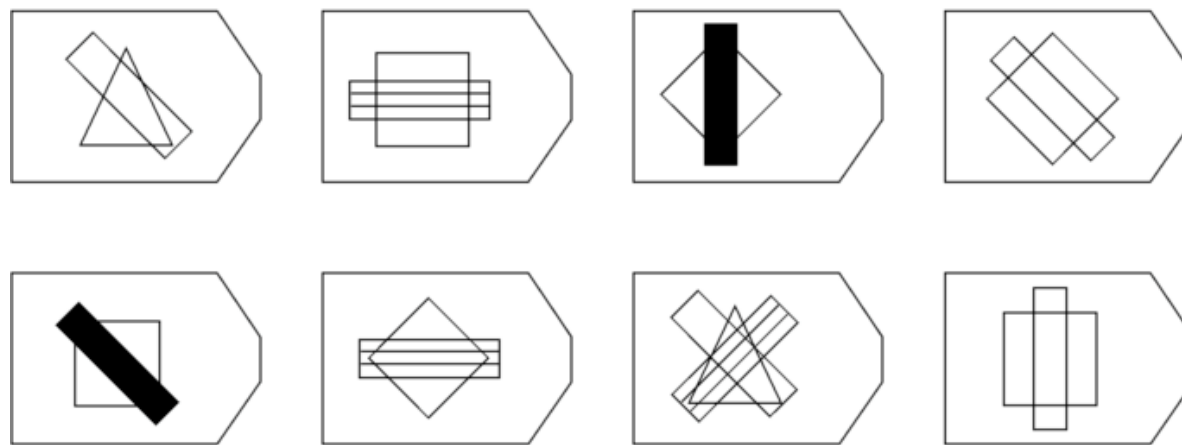
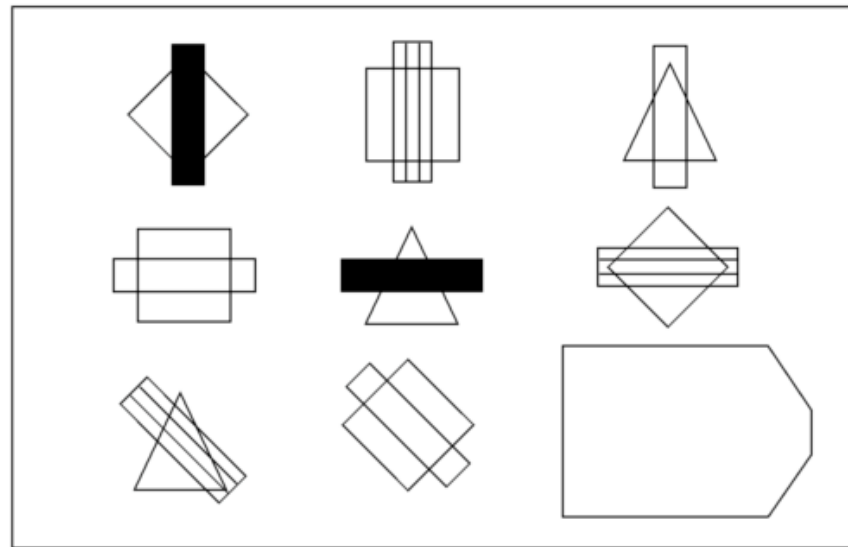
Release of primitive reflexes

Disordered 'executive function'

Impaired 'higher cognitive processing'

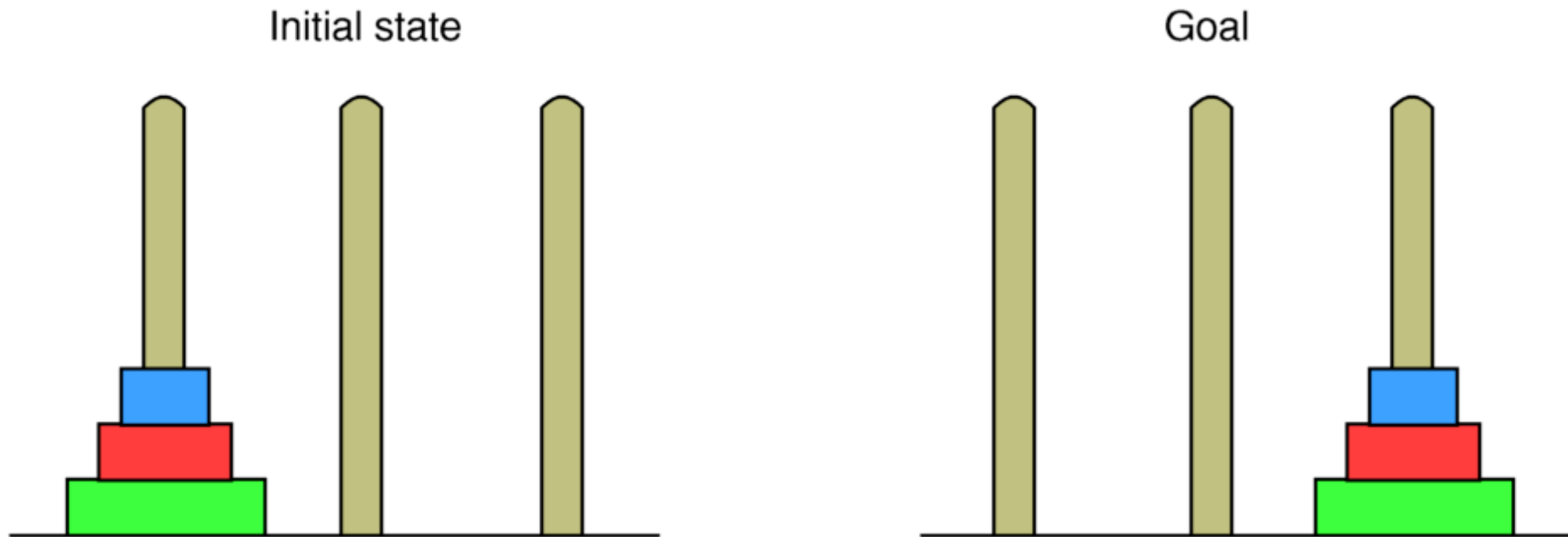
Dorsolateral prefrontal cortex

Raven's *Progressive Matrices* — geometric analogy



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

The Tower of Hanoi

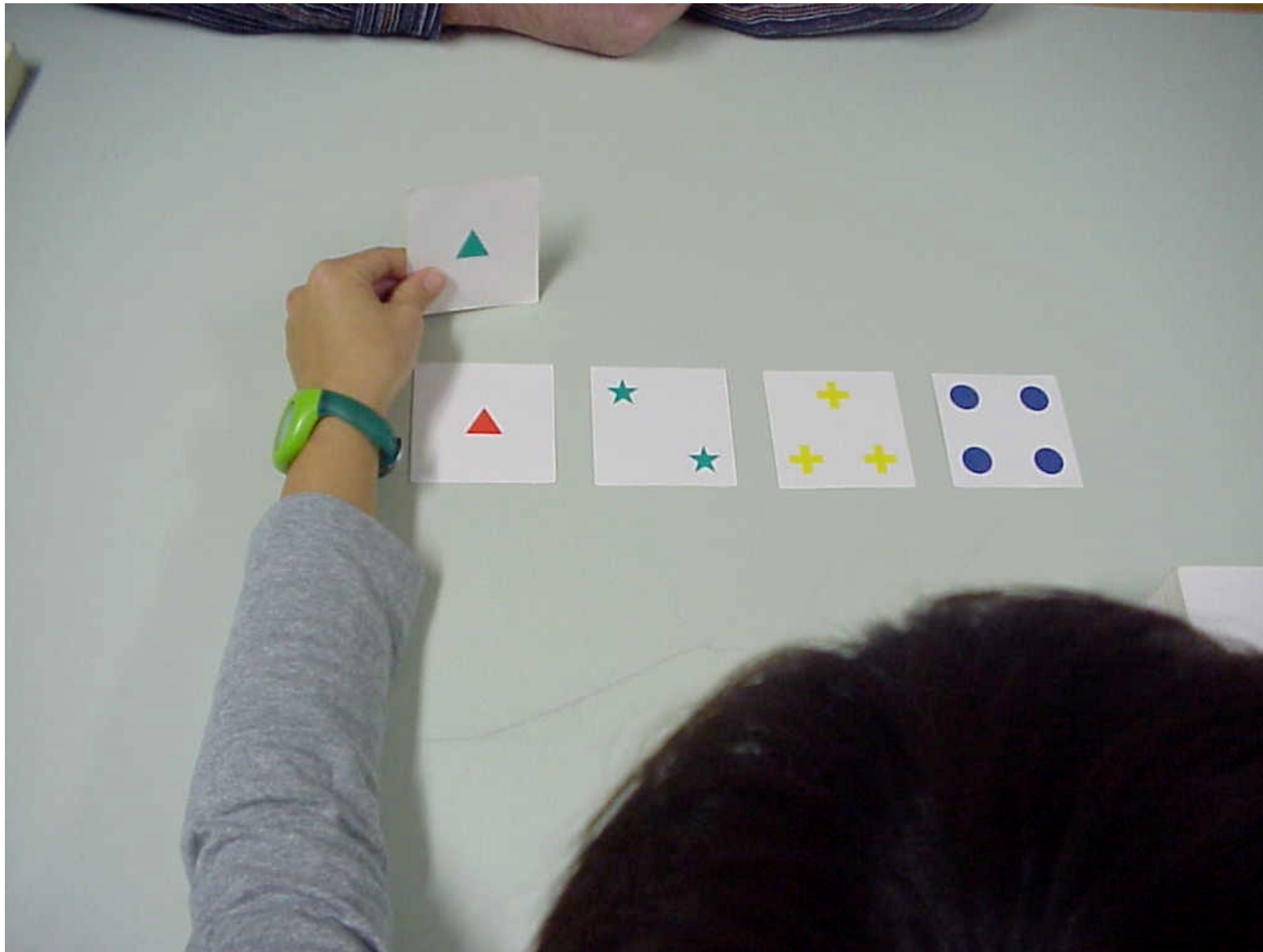


“Legend says that at the beginning of time the priests in a Hindu temple were given a stack of 64 gold disks, each one a little smaller than the one beneath it. Their assignment was to transfer the 64 disks from one of the three poles to another, with one important proviso — a large disk could never 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

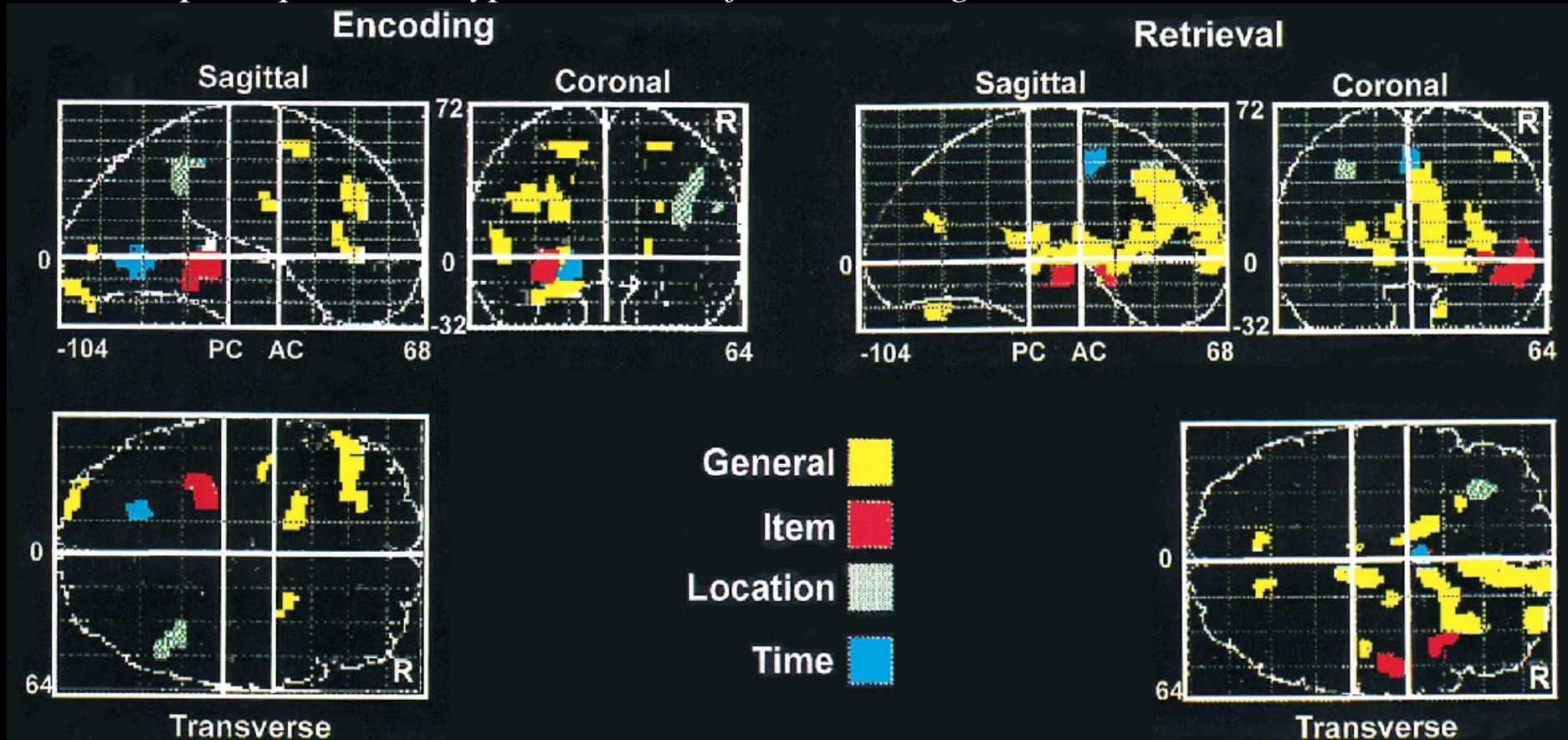


Grant & Berg (1948); impaired after DLPFC lesions (Milner, 1963)

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)

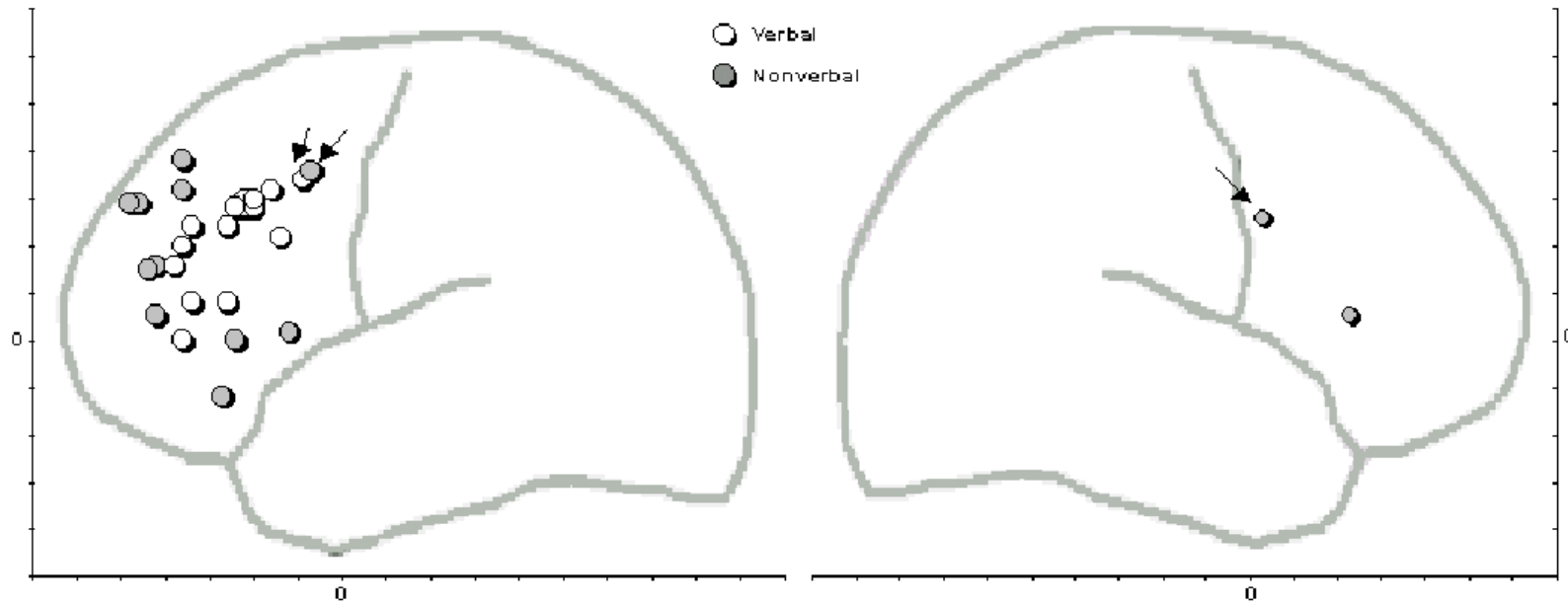
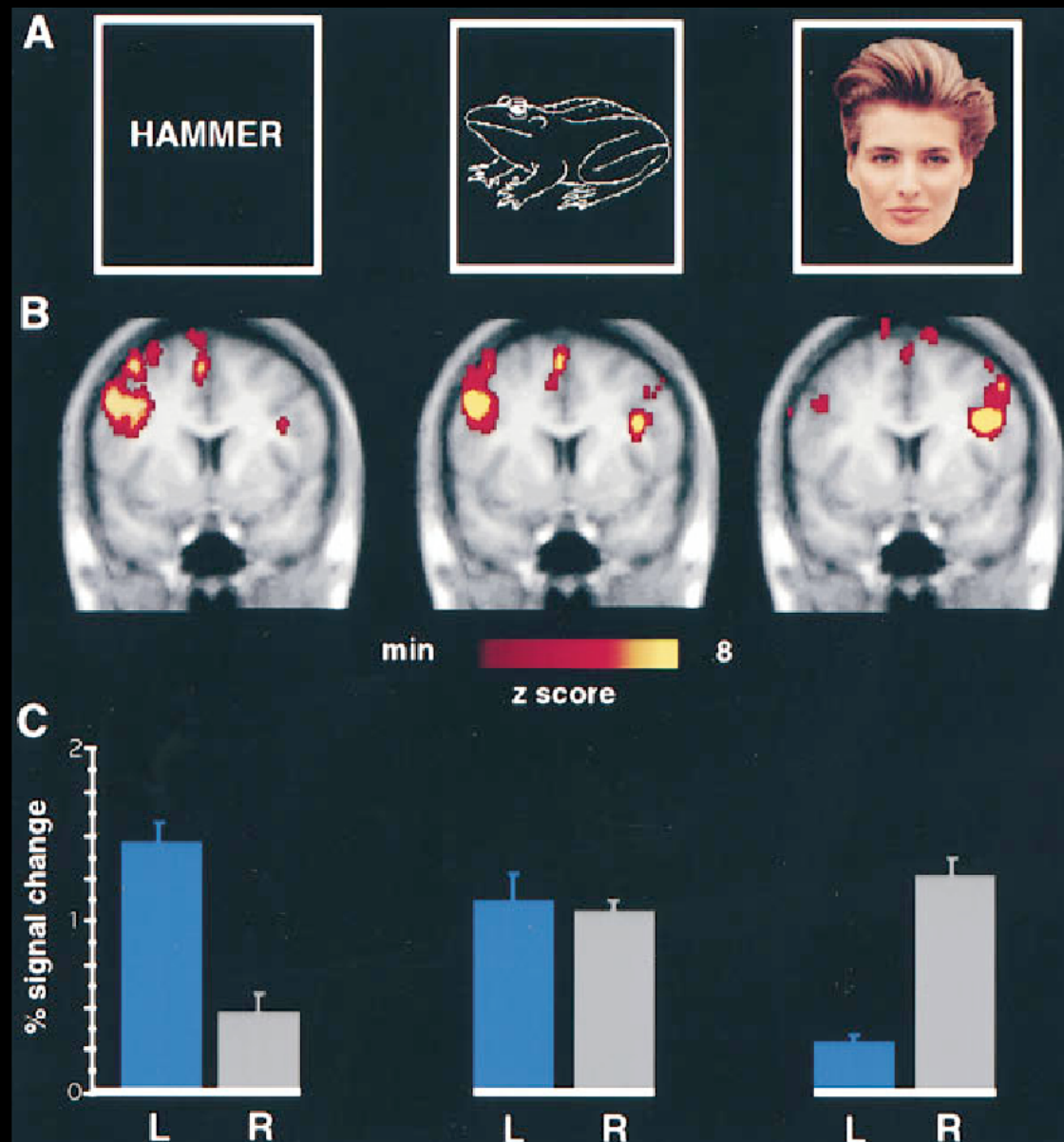


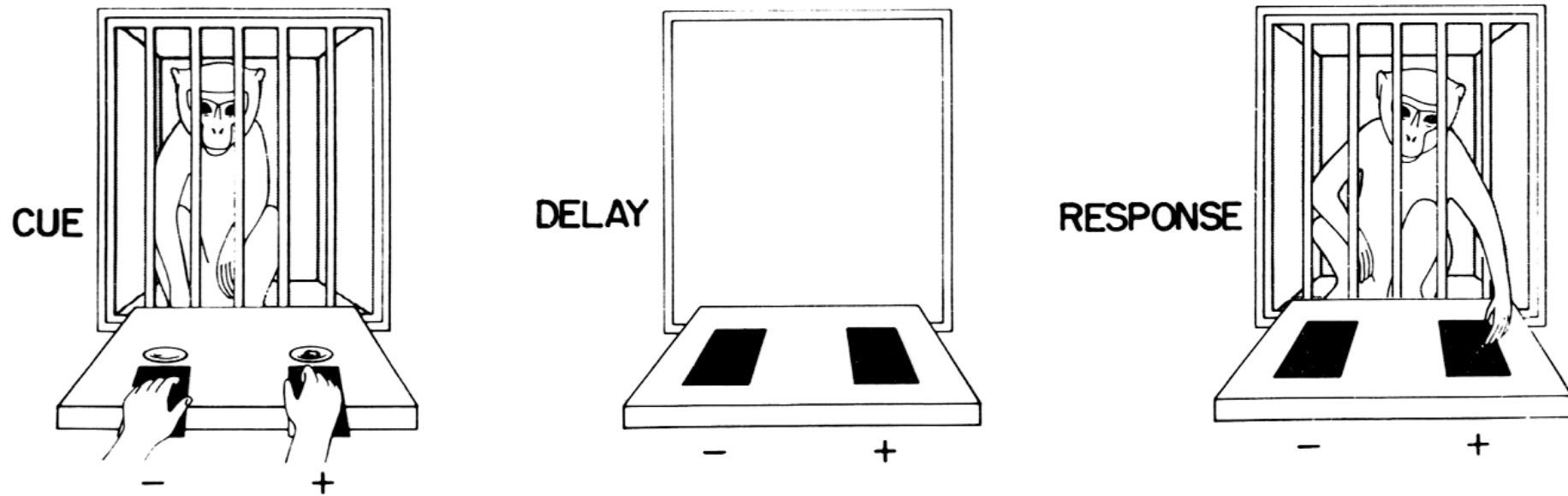
Fig. 1 Frontal cortical activation peaks from multiple neuroimaging studies of episodic memory encoding. Significant frontal activation peaks from studies involving intentional encoding of verbal^{7,15-17} and non-verbal^{6,14,18,19} information.

Memory encoding and retrieval (3)

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



Delayed response task (1)



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

Delayed response task (2)

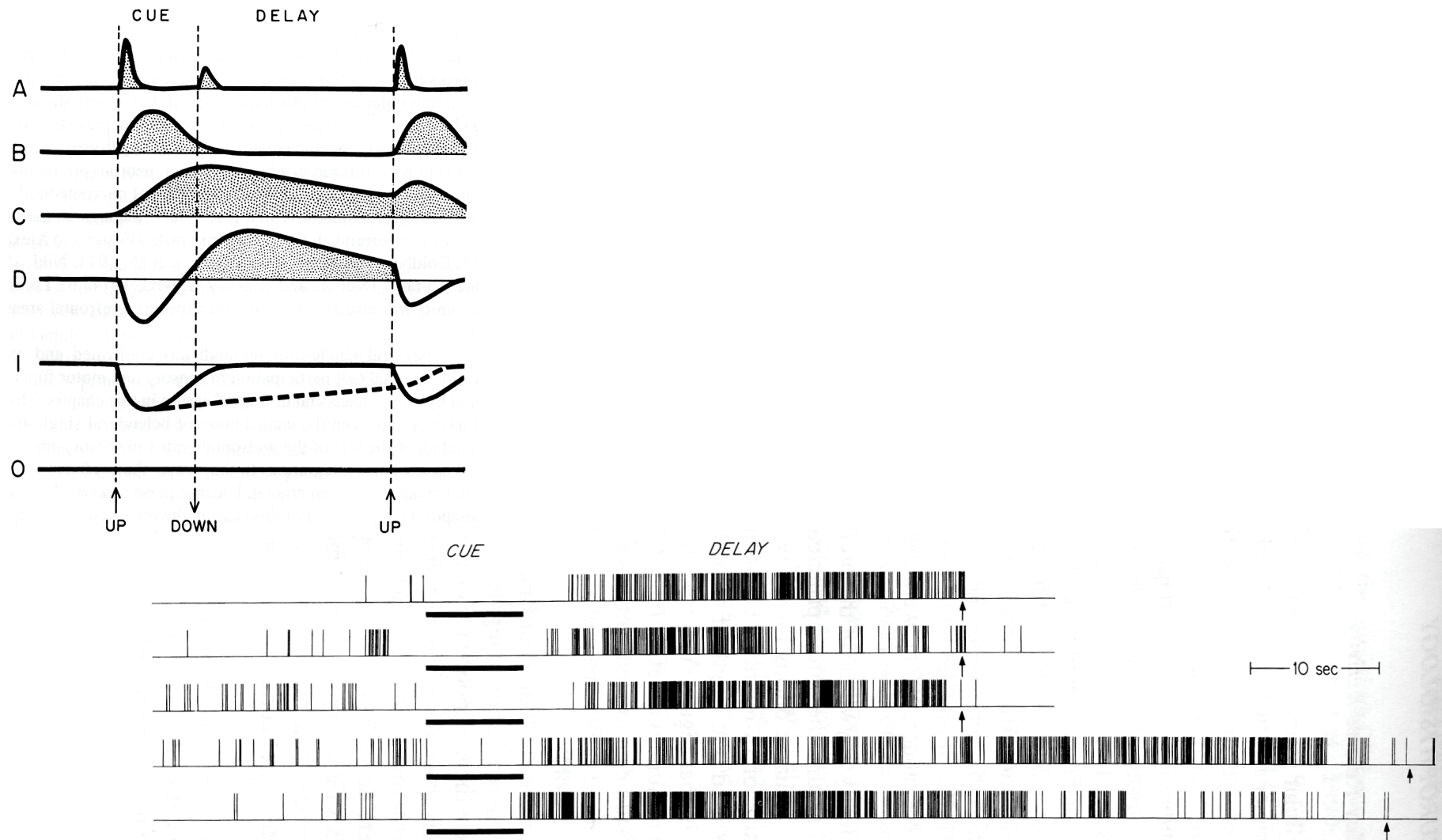


FIG. 5.9. Activity of a prefrontal unit during five delayed-response trials. In each trial, a horizontal bar marks the cue period and an arrow the end of the delay (i.e., the presentation of the choice stimuli). Note the activation of the cell during the delay: over 30 sec in the upper three trials,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

Fuster & Alexander (1971)

Chilled monkey brains



Speilberg (1984) Indiana Jones and the Temple of Doom

Delayed response task (3)

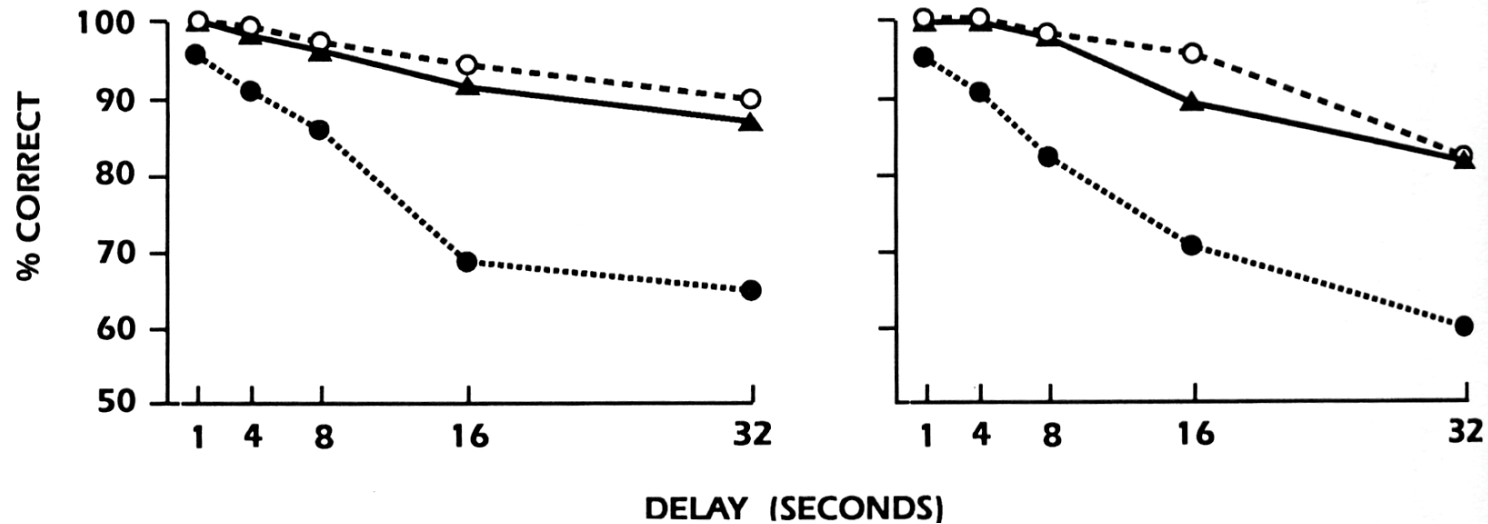
- ▲——▲ CONTROL, NORMAL TEMPERATURE
- - - -○ PARIETAL COOL 20°C
- ·····● PREFRONTAL COOL 20°C



DELAYED MATCH TO SAMPLE



DELAYED RESPONSE



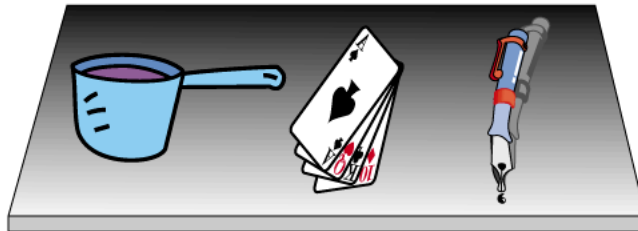
Fuster & Alexander (1970); Fuster (1995)

Self-ordered monitoring tasks

A *No effect of DLPFC lesion.*



Recognition

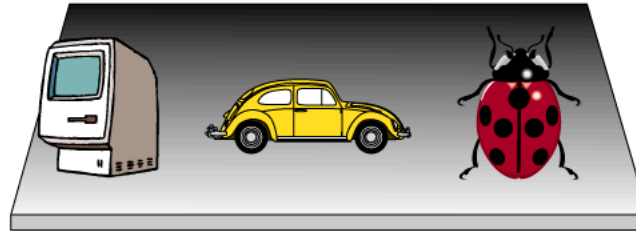


Choose novel object.

DLPFC lesions impair monkeys.

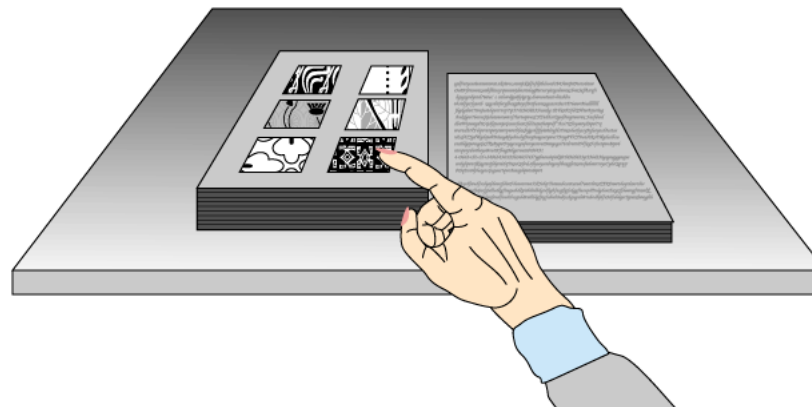


Monitoring



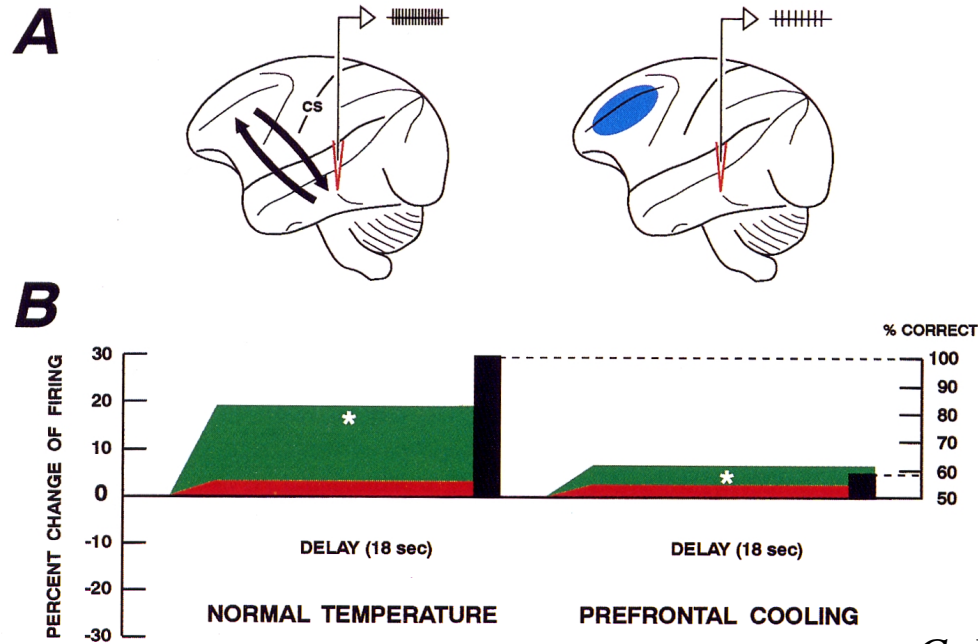
Choose object not previously chosen.

B



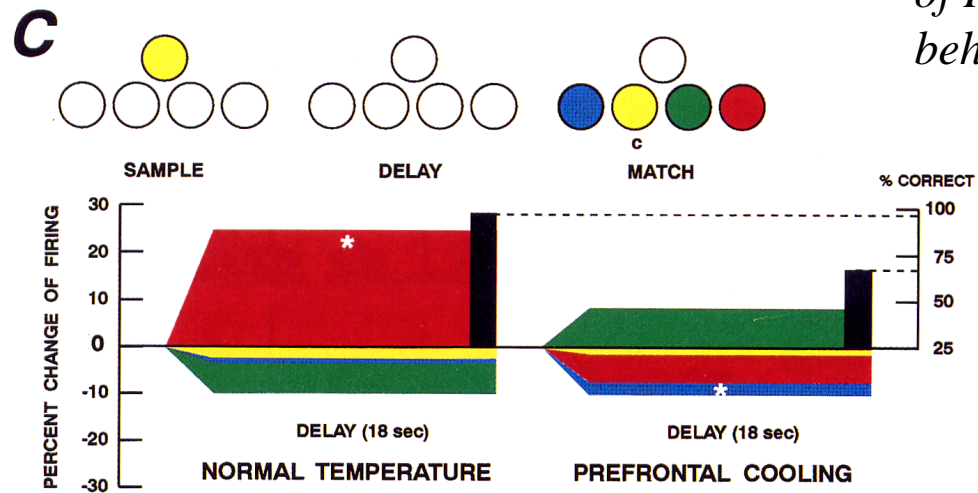
*Pick one of the six stimuli; turn to the next card; pick another stimulus (until all six have been selected). **DLPFC lesions impair humans.***

Working memory: PFC maintains posterior cortex activity?



Two-colour DMTS

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

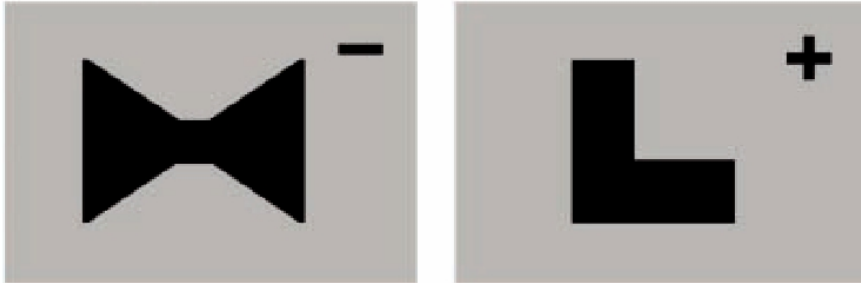


Four-colour DMTS

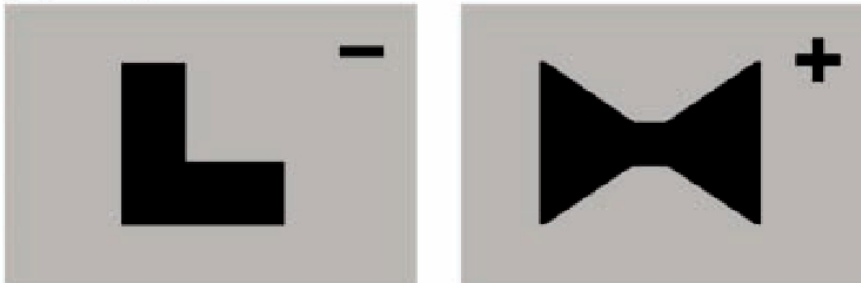
Fuster & Alexander (1970); Fuster (1995)

Attentional set and set-shifting

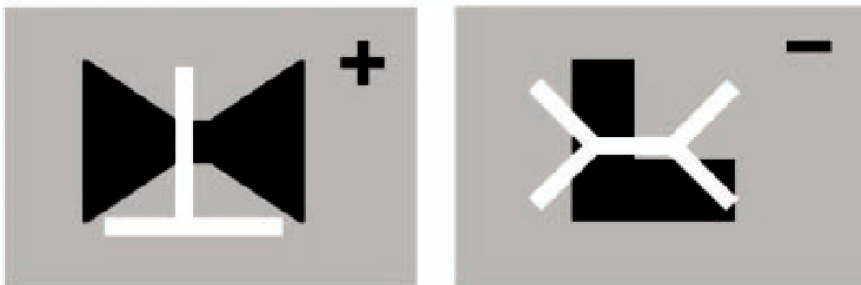
(b) Simple discrimination



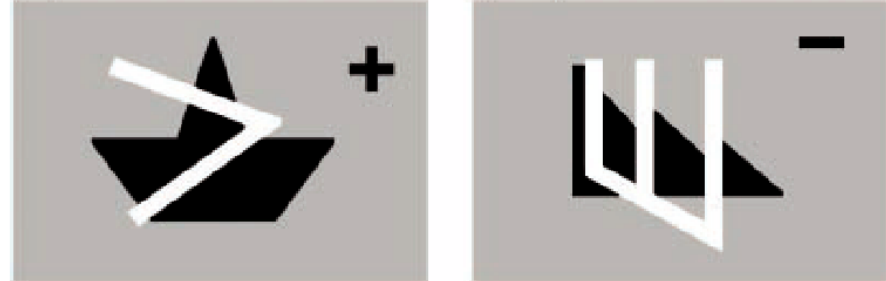
(c) Simple reversal



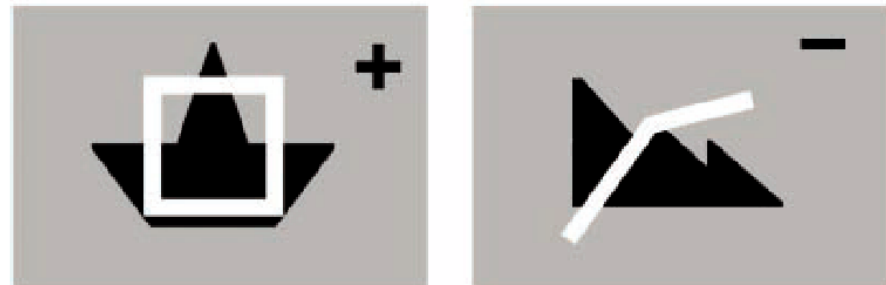
(d) Compound discrimination



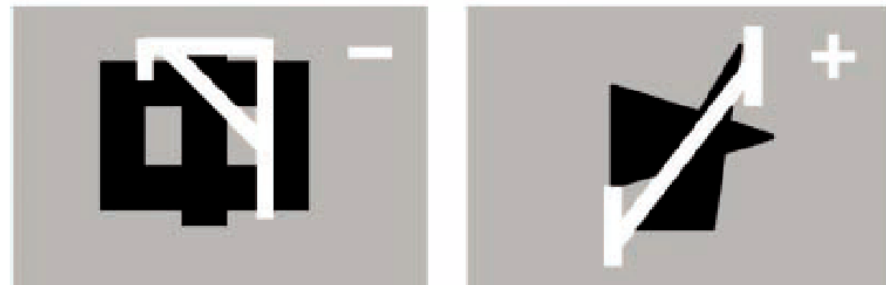
(e) Intra-dimensional shift (IDS)



(f) Distractor probe test

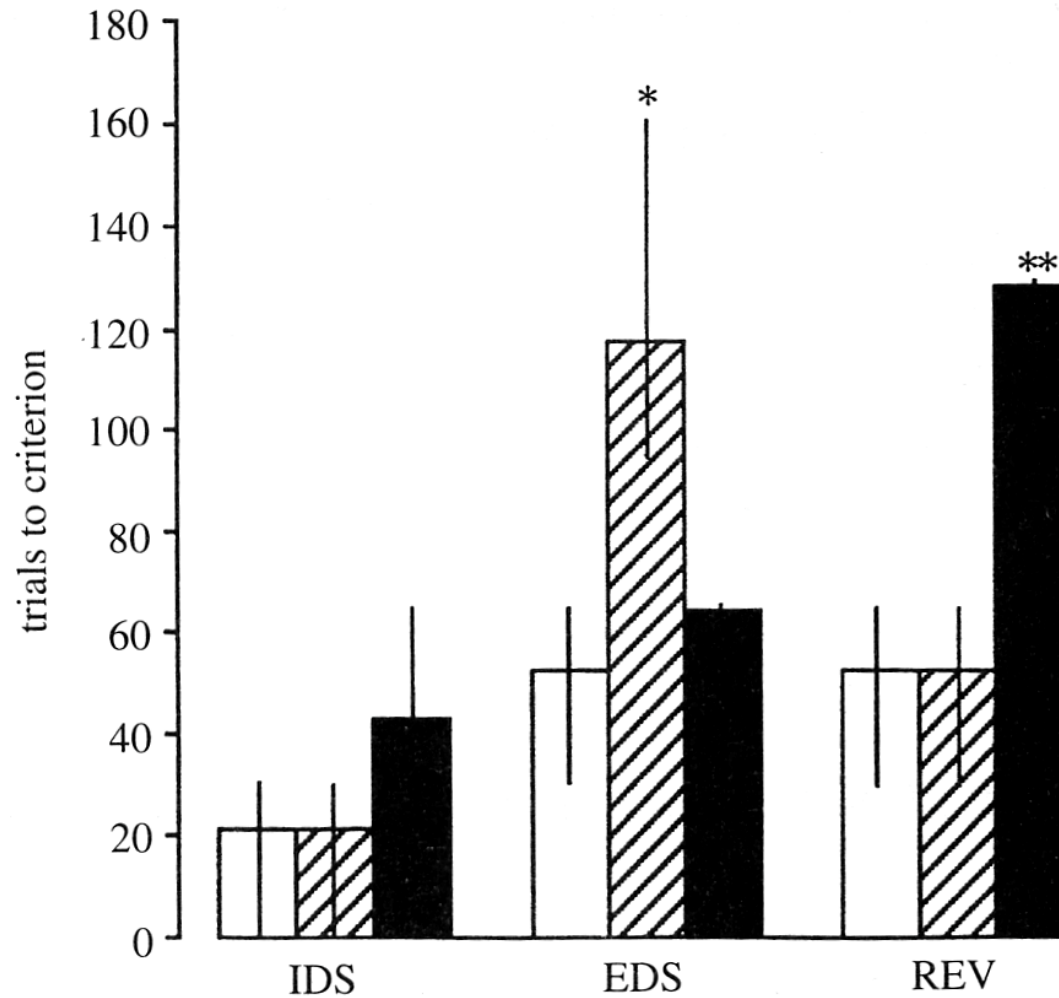


(g) Extra-dimensional shift (EDS)



from Crofts et al. (2001)

Extradimensional set shifts impaired by DLPFC lesions



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

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

Discrimination	Dimensions		Exemplar combinations	
	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

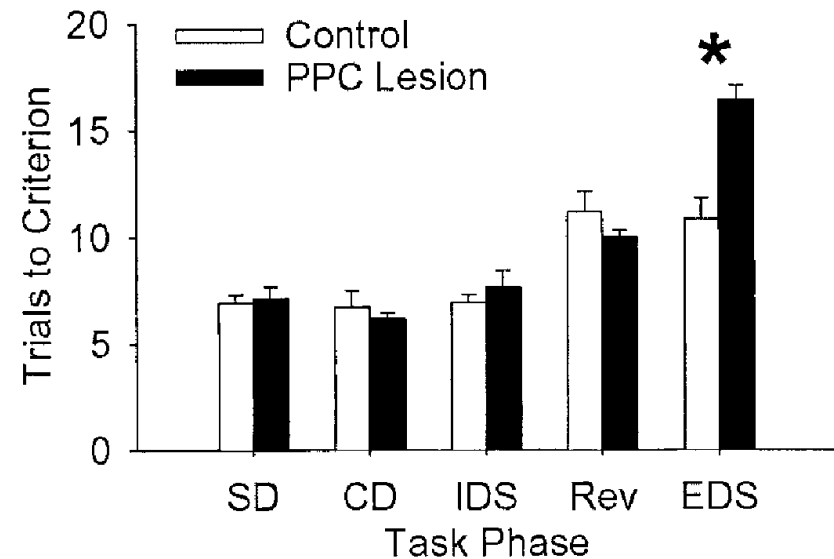
Half of the rats switched from medium to odor, and half switched from odor to medium. The correct exemplar is shown in bold and can be paired with either exemplar from the irrelevant dimension. In the IDS and EDS, the stimuli were novel exemplars of each dimension.

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)



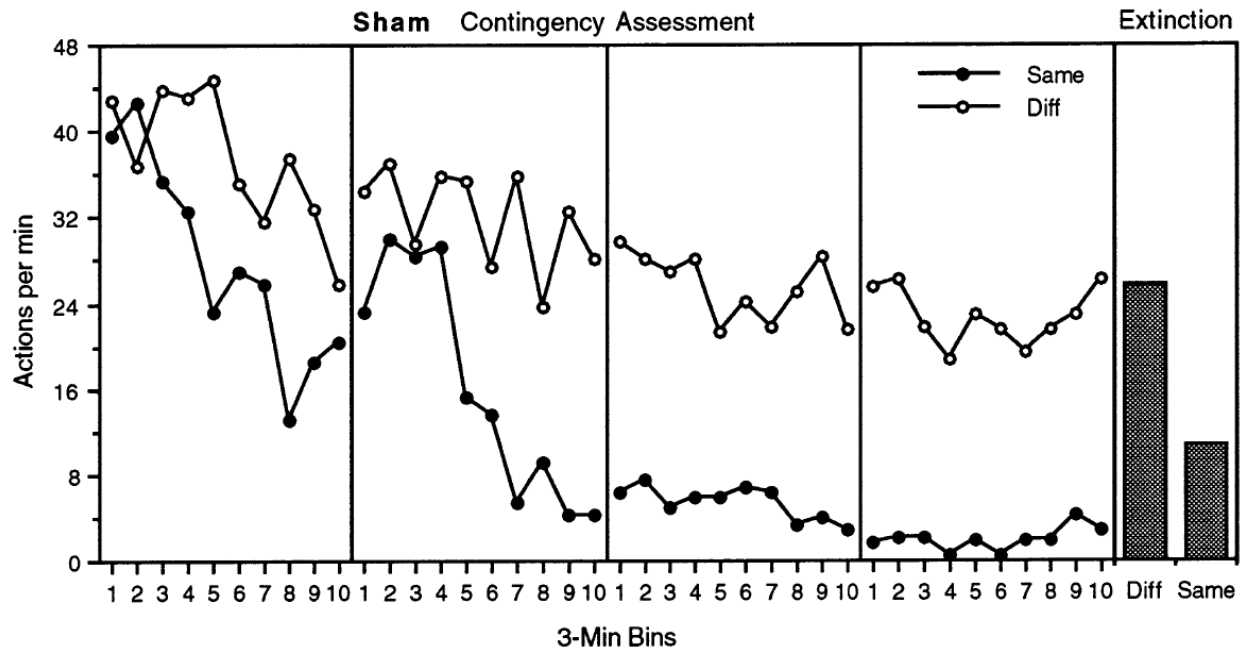
Neuropsychiatric links: schizophrenia? (1)

- *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)

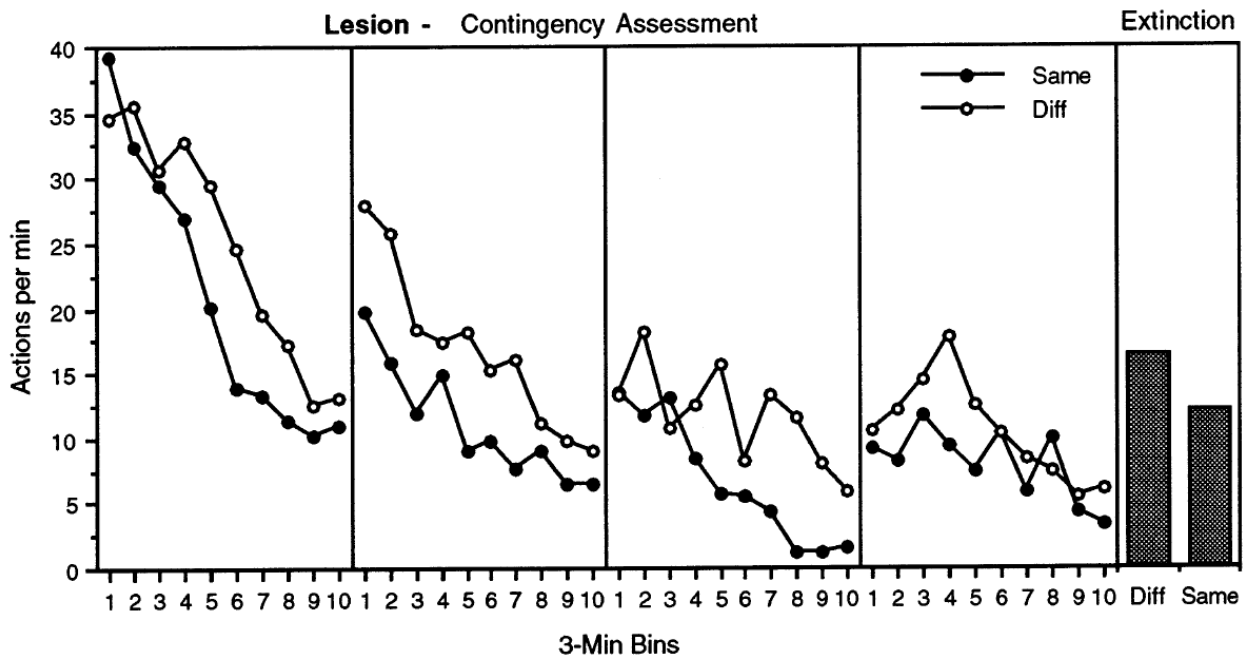
sham-operated rats

*Test of action–outcome
contingency knowledge*



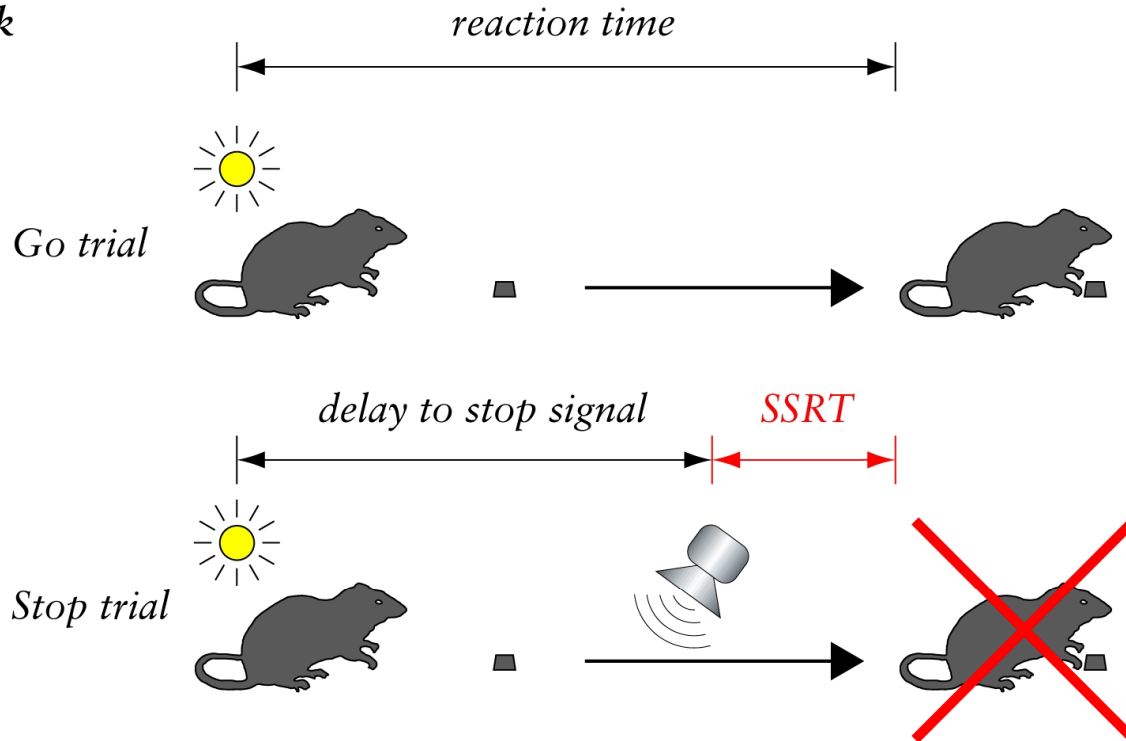
*prelimbic (~ DLPFC)-
lesioned rats*

Balleine & Dickinson (1998)



Inhibition: a central function of the PFC?

Stop task



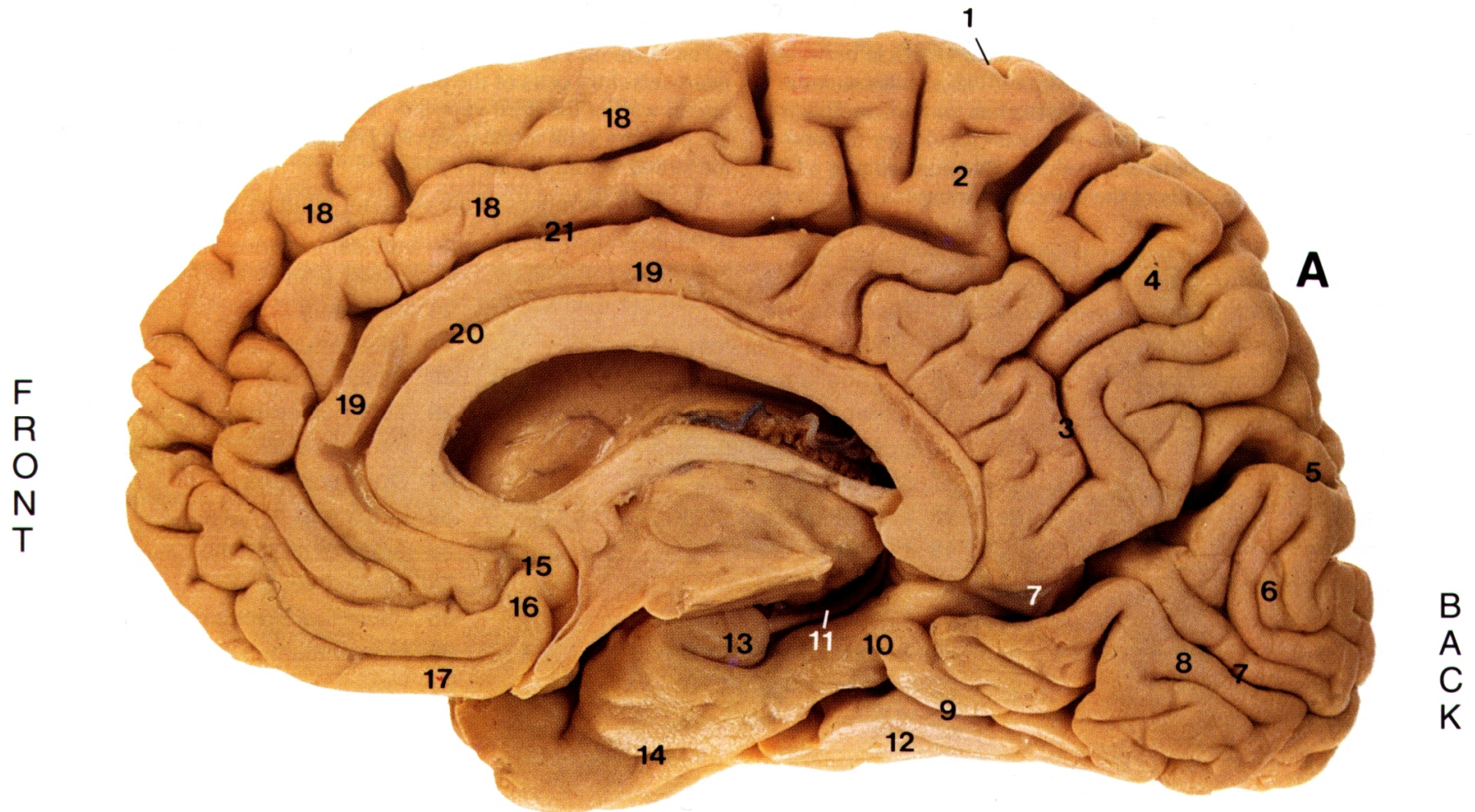
1. Go trials are more frequent than stop trials.
2. The median reaction time on go trials is calculated.
3. The time between the go and stop stimuli is adjusted until $p(\text{successful inhibition on stop trials}) = 0.5$. This means that the effects of the stop signal are fast enough to cancel 50% of 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

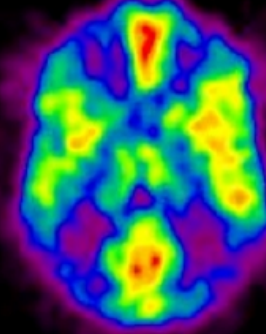
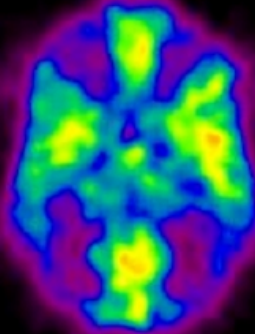
Cingulate cortex



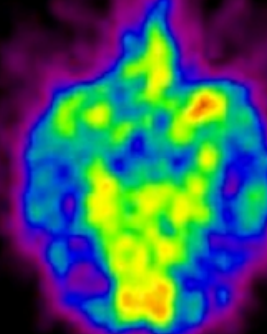
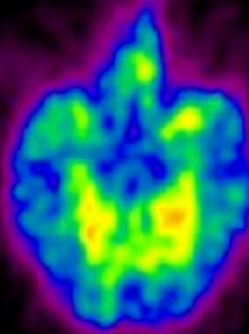
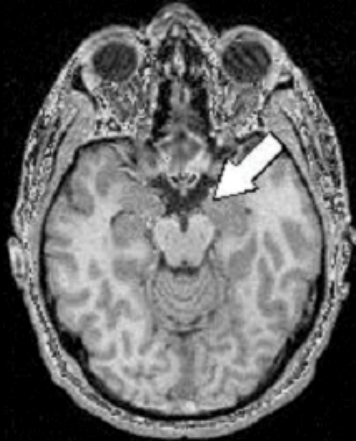
(The numbers don't mean anything!)

Sexual stimuli activate the ACC

Anterior Cingulate



Amygdala



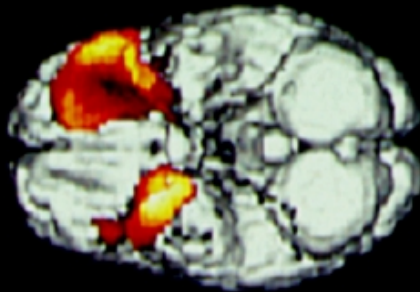
Nature Video

Sexual Video

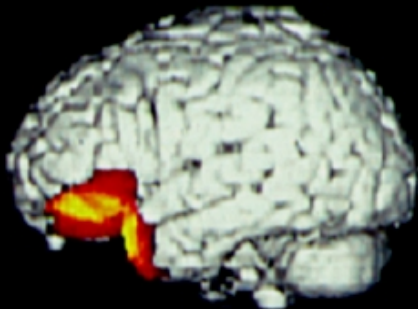
Childress et al. (1999→); see also Garavan et al. (2000)

Cue-induced cocaine craving activates the ACC and OFC

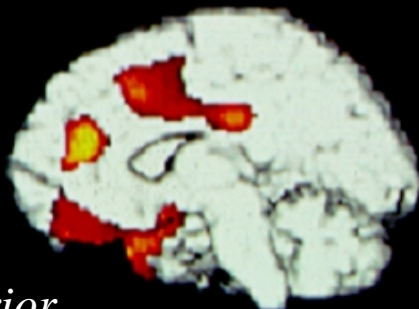
Cocaine addicts watching a cocaine video; activations correlated with subjective reports of craving



*medial temporal lobe
— amygdala*



OFC



ACC

anterior

posterior

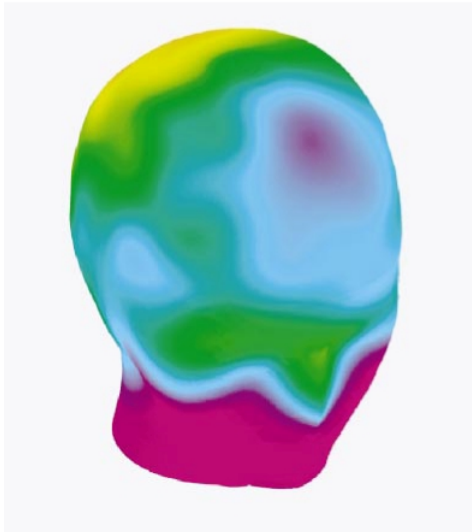


Above photos (and others in following articles) courtesy of Inspector Richard Groves, Community Involvement and Crime Prevention Branch, New Scotland Yard.

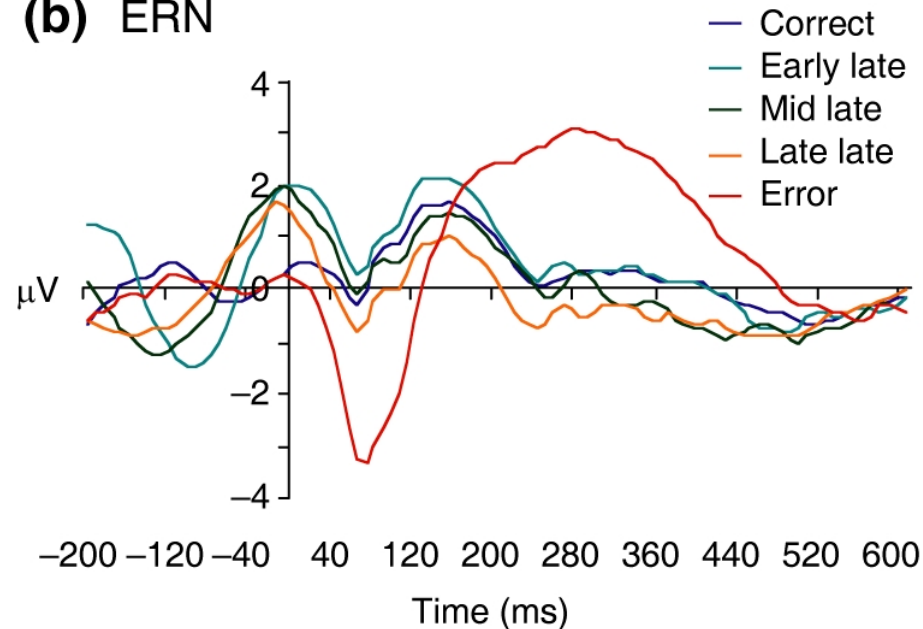
Childress et al. (2000)

Errors in responding produce an EEG signal localized to ACC

(a)



(b) ERN



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.

The Stroop test

congruent

blue
yellow
red
green
blue
green
yellow
blue
red
yellow

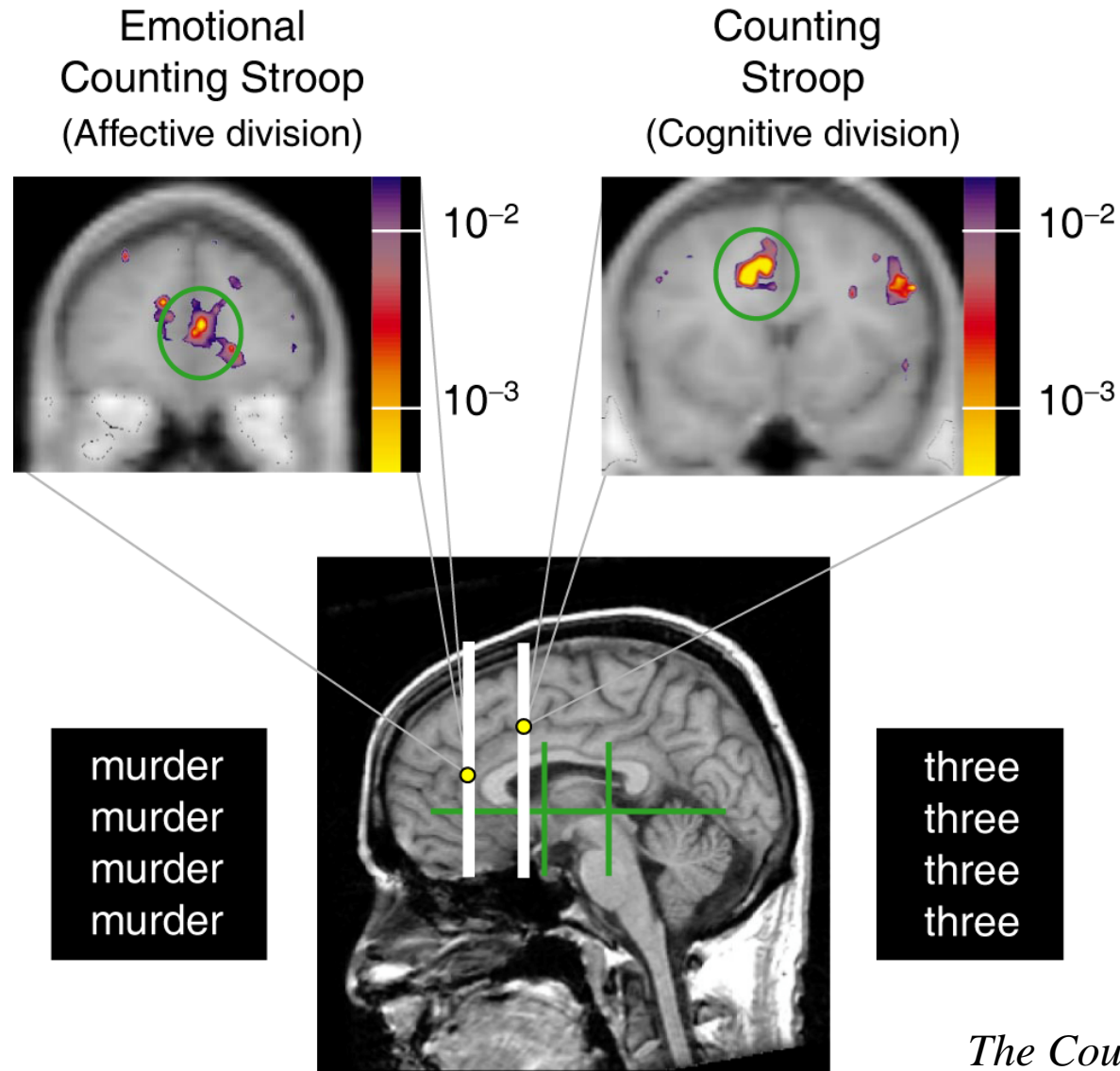
neutral

willow
trek
armchair
prefect
felicitous
destructive
milk
bore
selection
karyotype

incongruent

red
green
blue
yellow
blue
green
yellow
blue
red
green

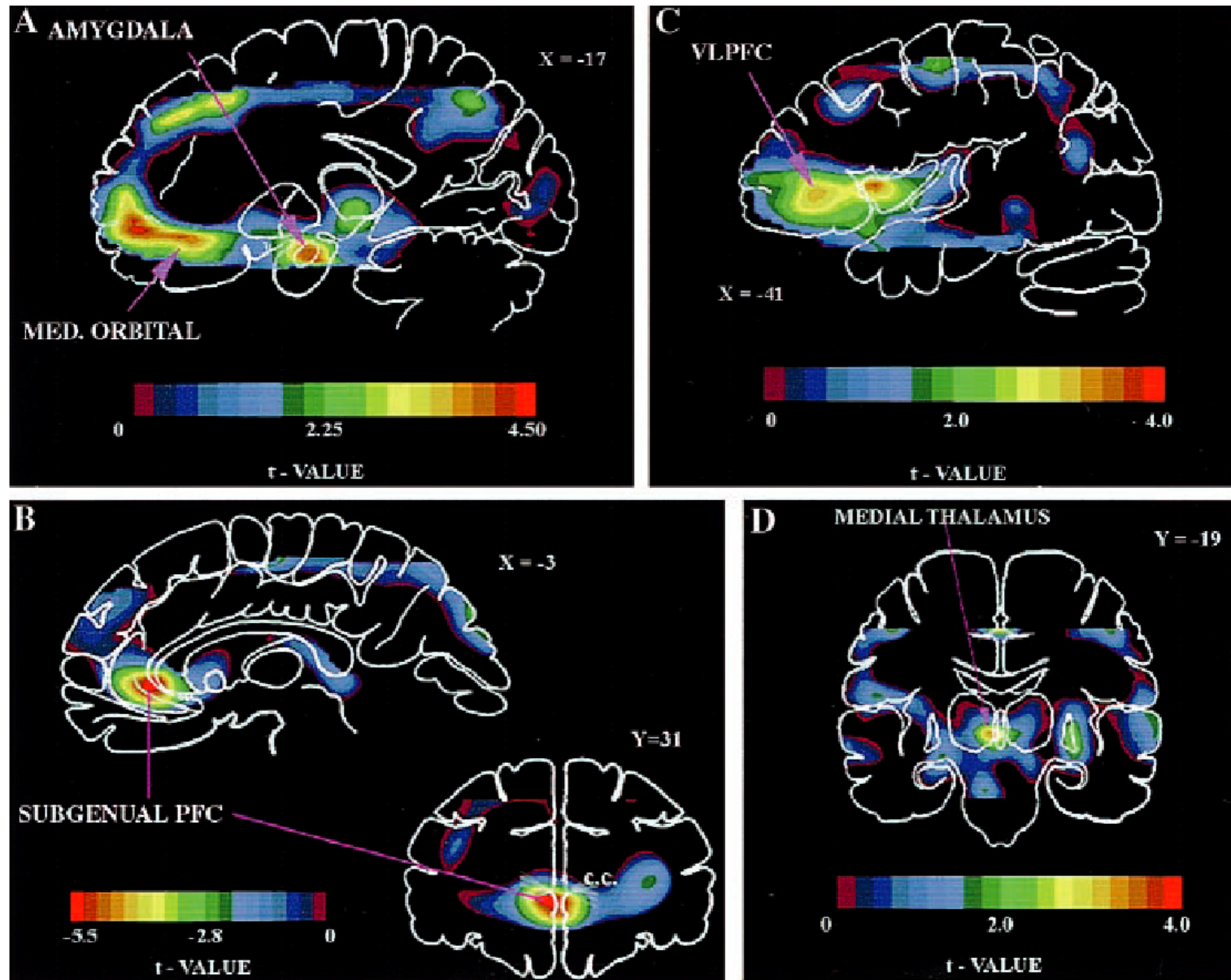
The Stroop test activates the ACC



*The Counting Stroop:
count the number of
words present.*

from Bush (2000)

ACC hyperactivity in depression

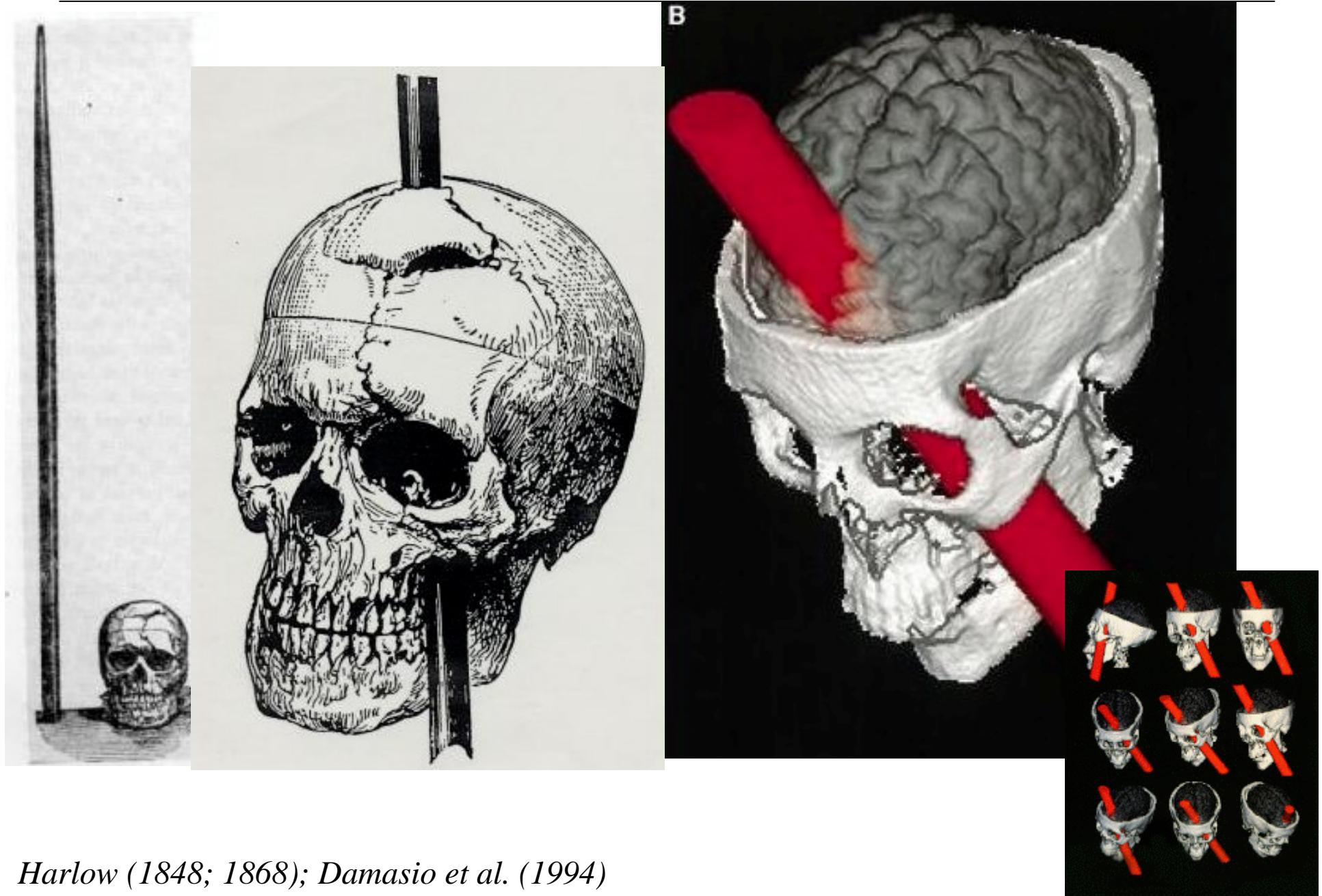


ACC

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

Rittmeister Baron Manfred Albrecht von Richthofen

- *Der rote Kampfflieger; the Red Baron.*
- *Highest-scoring flying ace of WW I (80 victories).*
- *Wrote the book on German aerial combat.*
- *2 July 1917: shot in the head by Woodbridge (gunner) and Cunnell (pilot) of the RFC. Momentarily paralysed and blinded.*
- *Personality change. Disinhibited.*
- *Flying skills intact: 23 subsequent kills! But poor judgement? Violated his own combat rules...*
- *Shot and killed on 21 April 1918 while pursuing a Sopwith Camel at low level and himself being chased by another fighter and shot at from the ground. Exhibited target fixation (perseveration).*



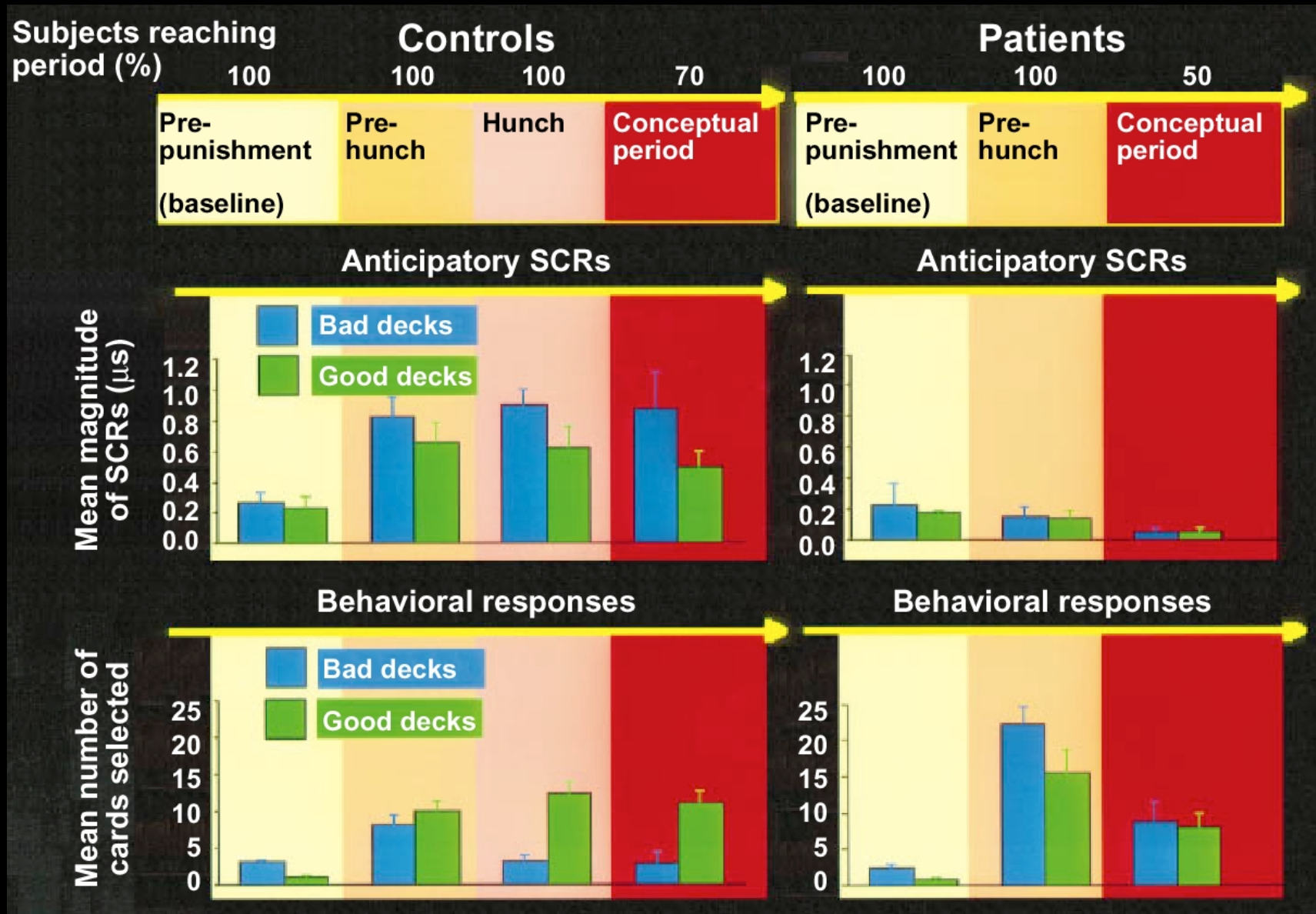
Orme & Hyatt (2004) *Human Factors & Aerospace Safety*

The Iowa gambling task

	"Bad" Decks		"Good" Decks	
	A	B	C	D
Payoff /Card	\$100	\$100	\$ 50	\$ 50
Loss /10 Cards	\$1250	\$1250	\$250	\$250
Profit/10 Cards	-\$250	-\$250	\$250	\$250

Bechara et al. (1994)

Anticipatory SCRs precedes knowledge



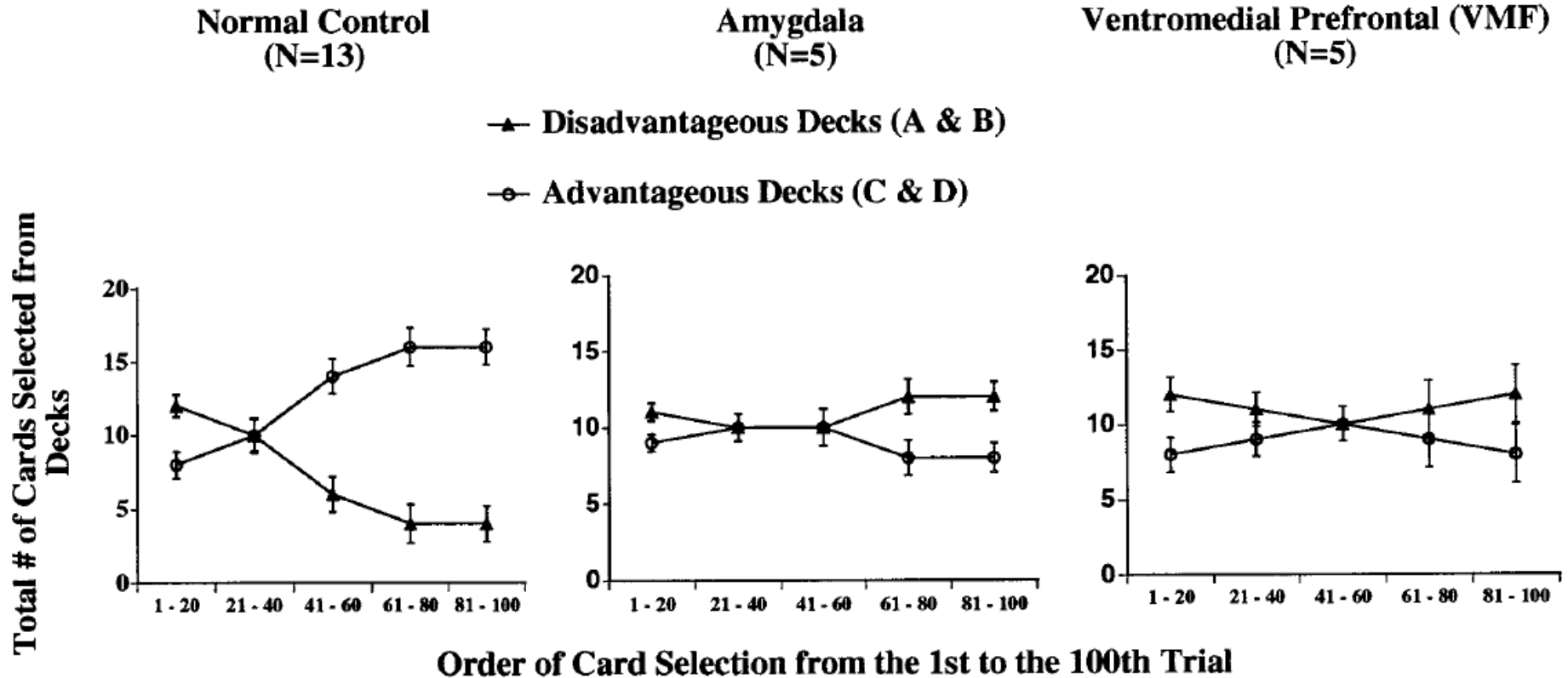
Bechara et al. (1997); normals and patients with ventromedial PFC (OFC) damage

“He chose poorly.”

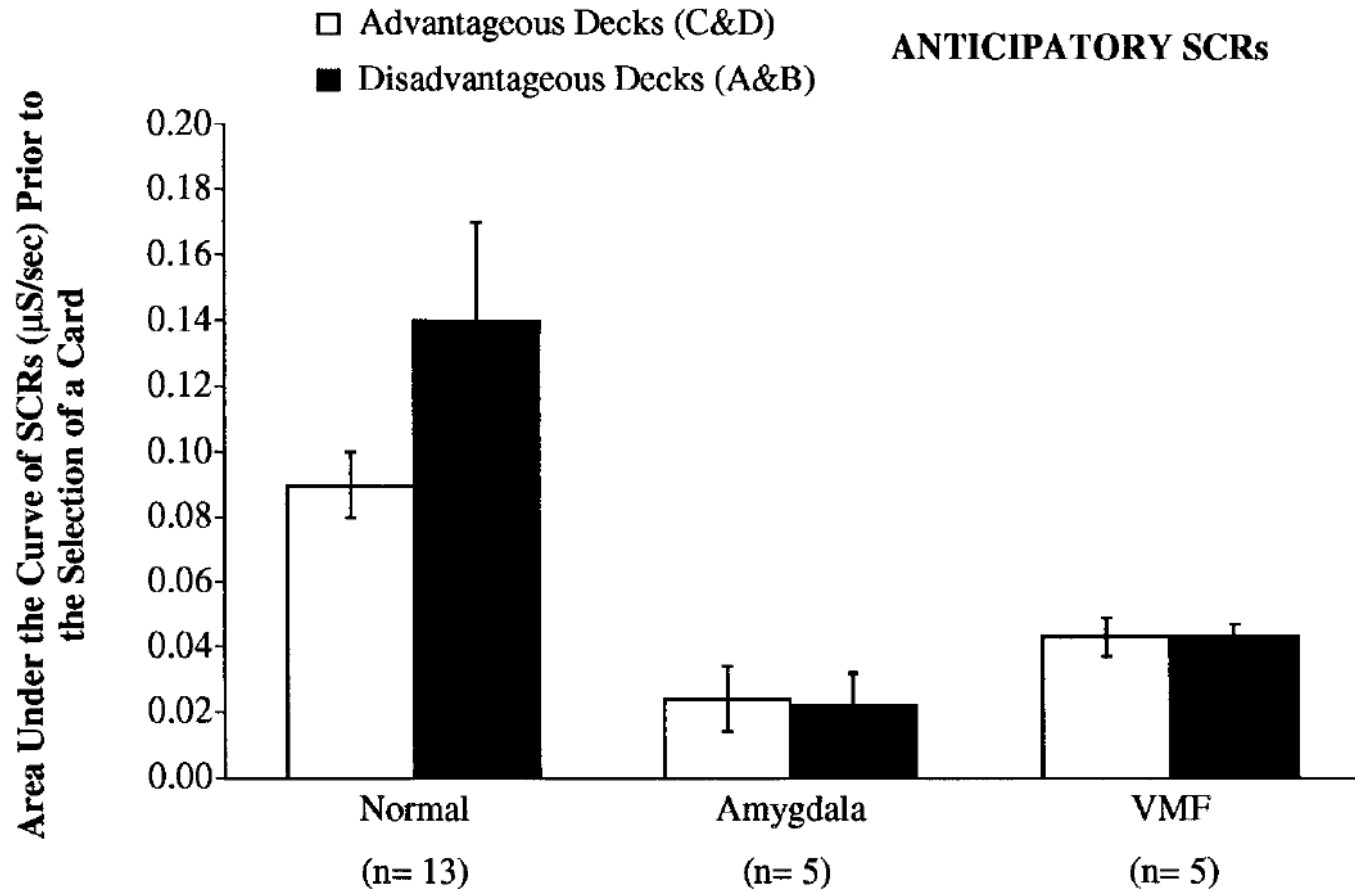


Spielberg (1989): 'Indiana Jones and the Last Crusade'

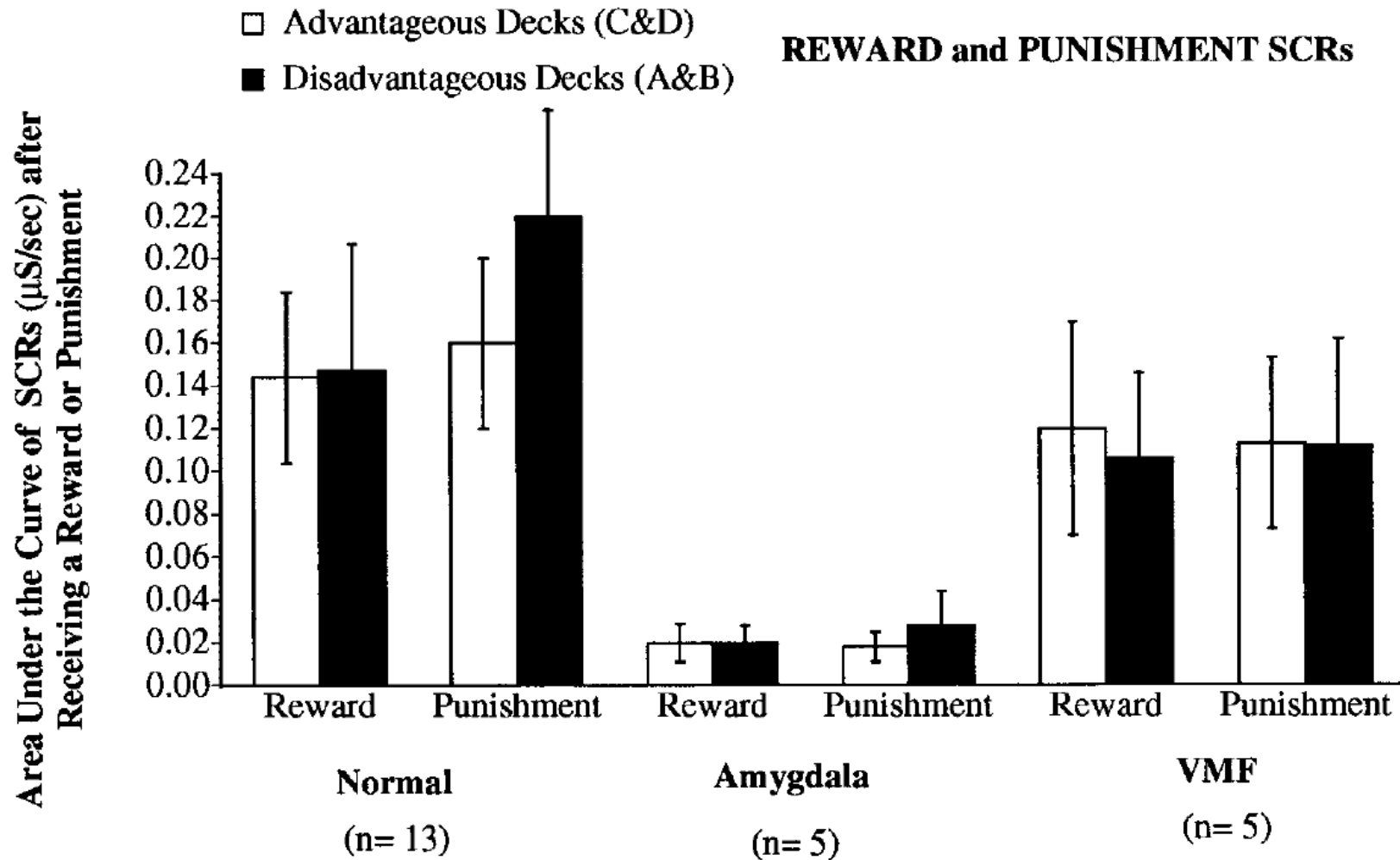
OFC and amygdala lesions on the Iowa gambling task (1)



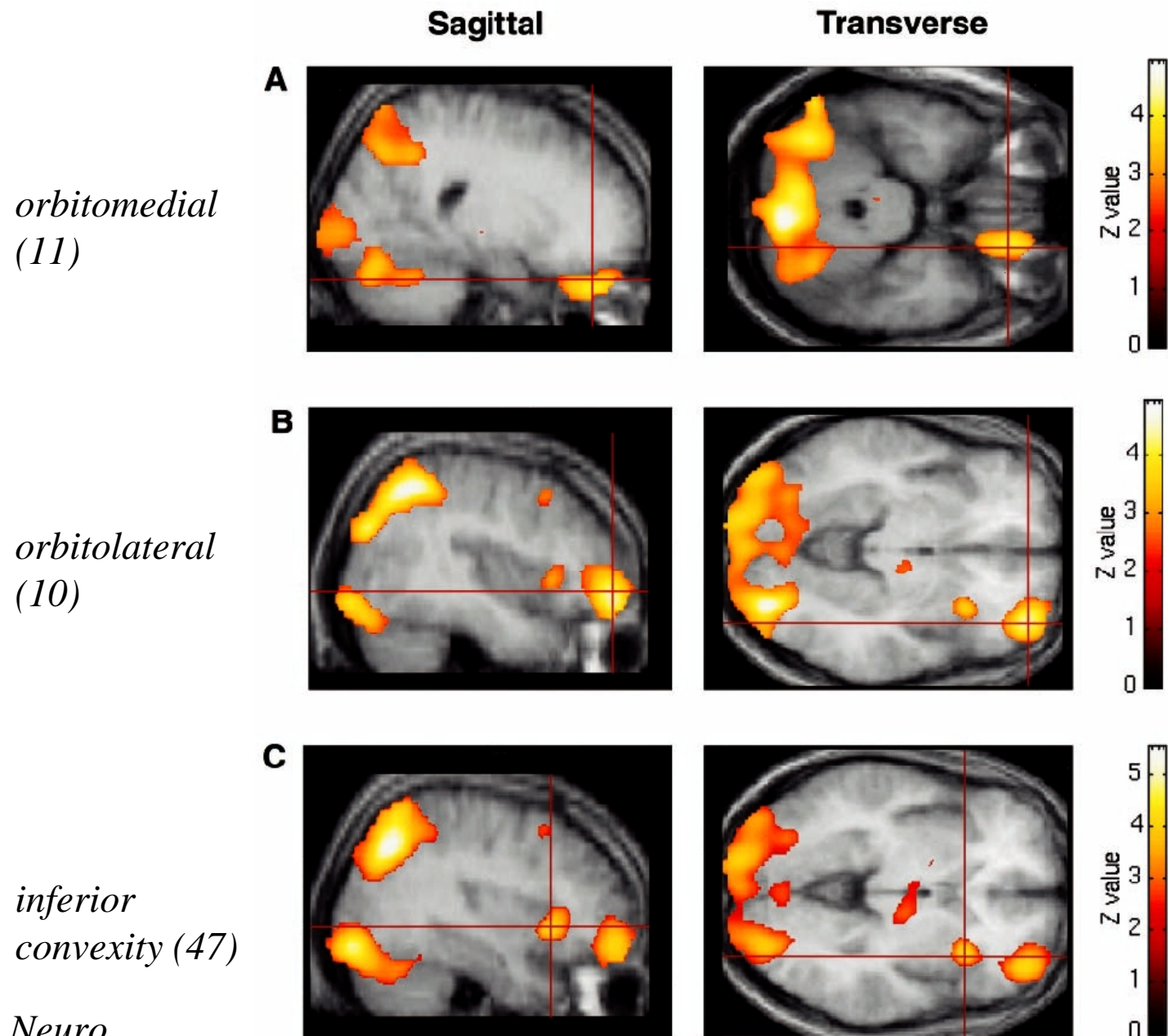
OFC and amygdala lesions on the Iowa gambling task (2)



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

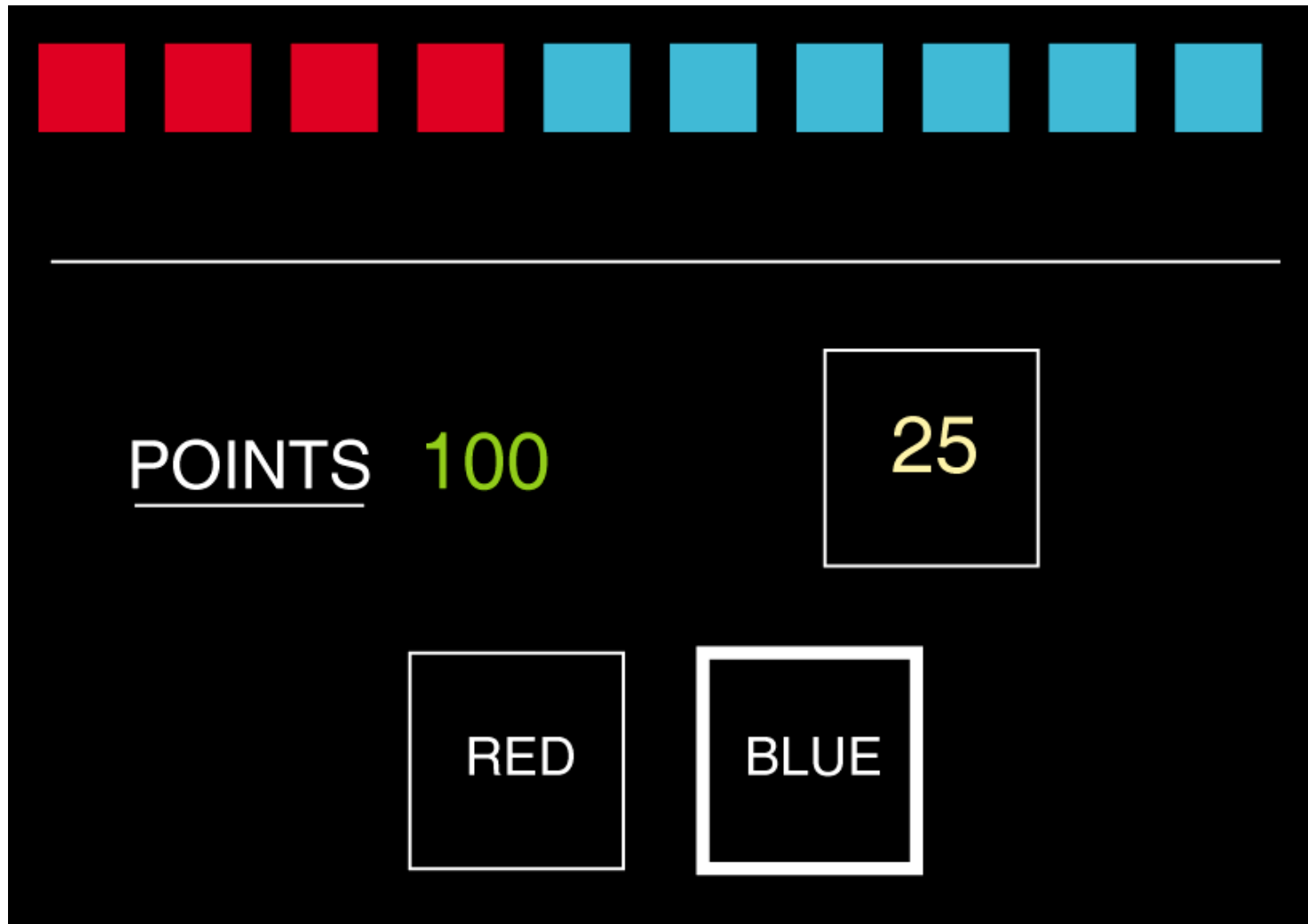


Choosing between small/likely and large/unlikely rewards



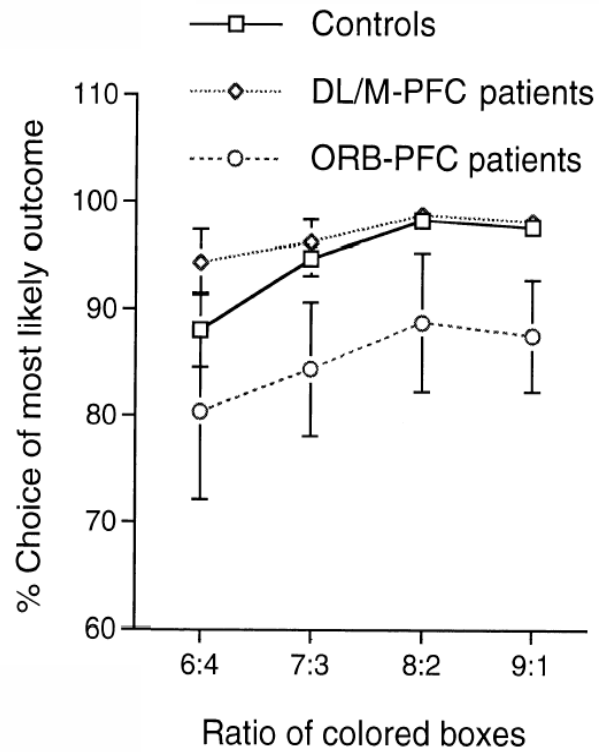
Rogers et al. (1999) *J. Neuro.*

Another gambling task...

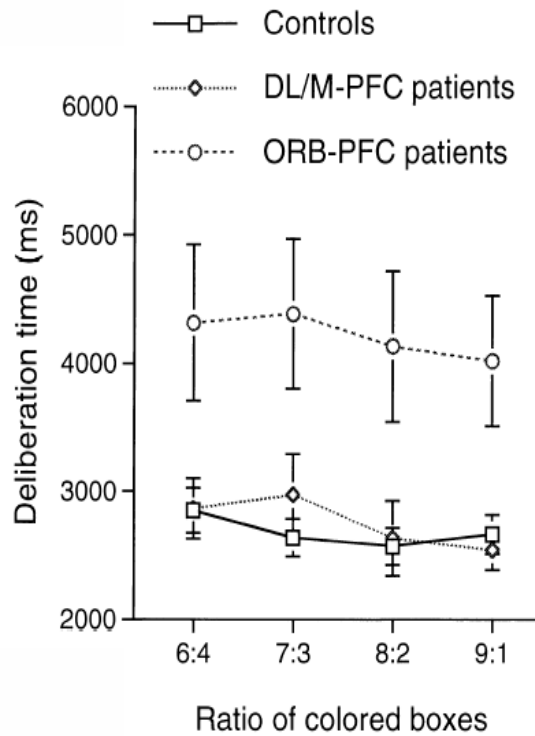


Rogers et al. (1999) Neuropsychopharm.

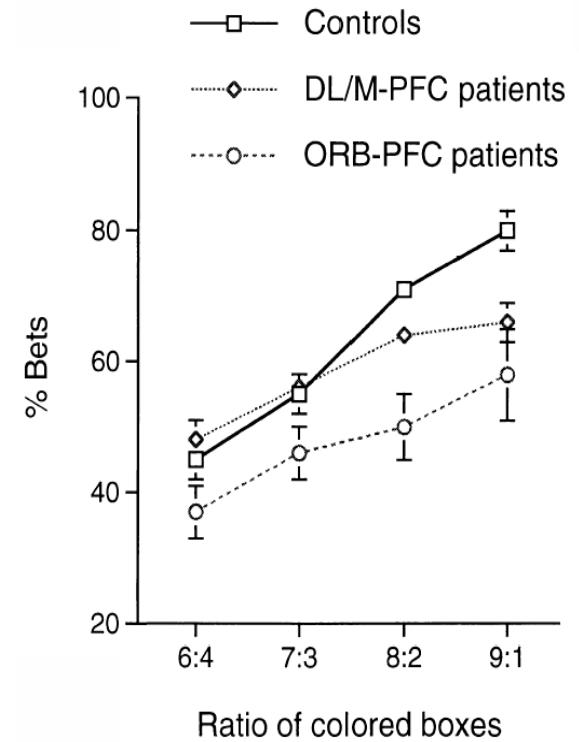
OFC lesions: wrong, slow, but not 'risk-taking'



% choice of most likely outcome

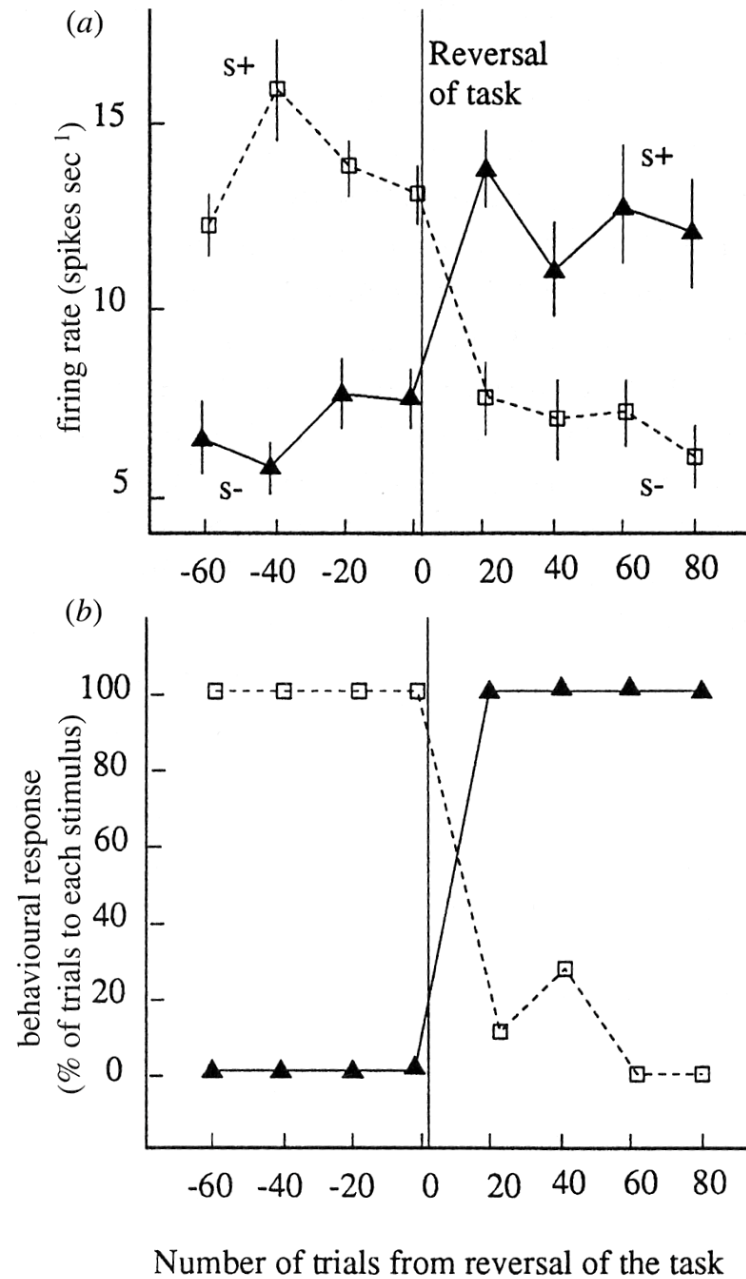


deliberation time



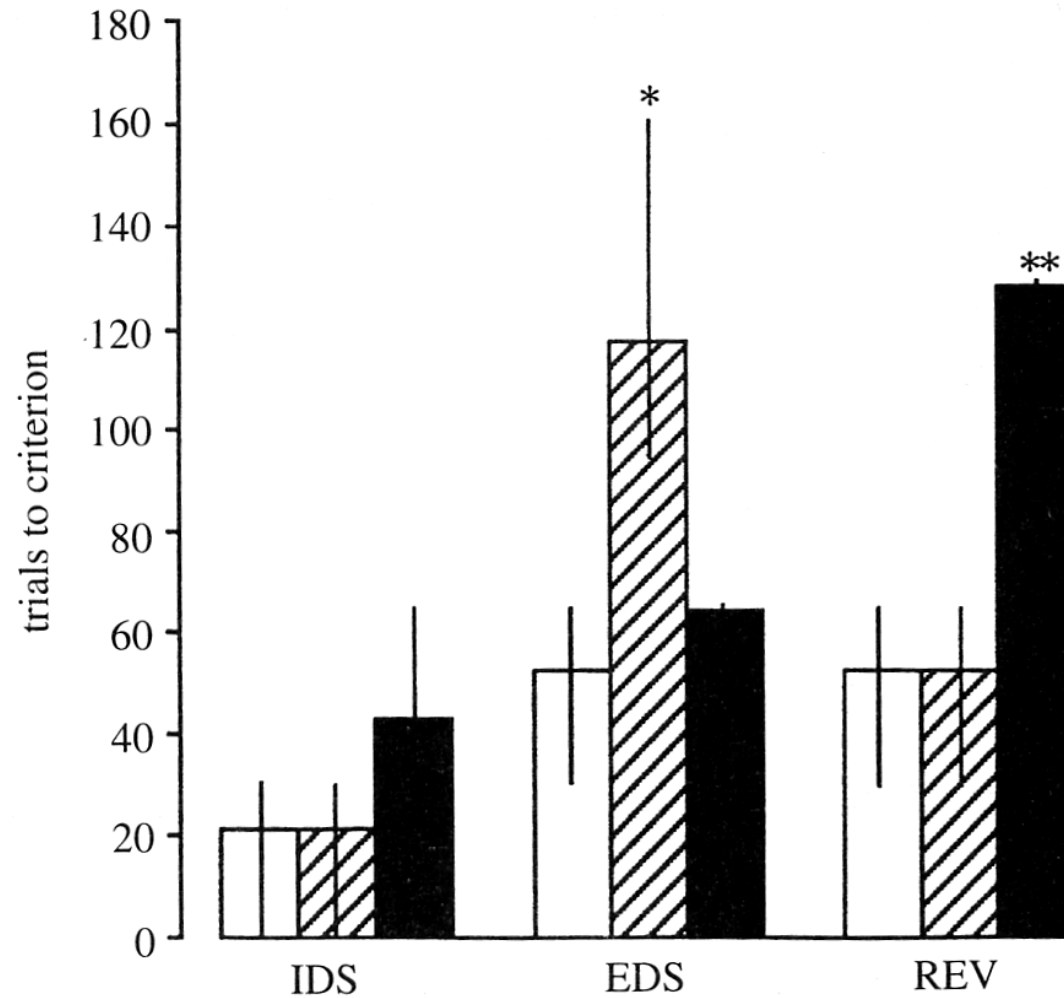
% of available points bet

OFC neurons reverse rapidly during reversal-learning tasks



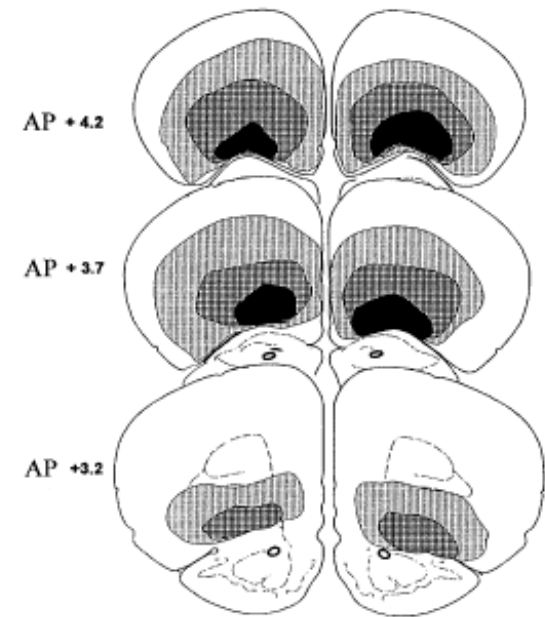
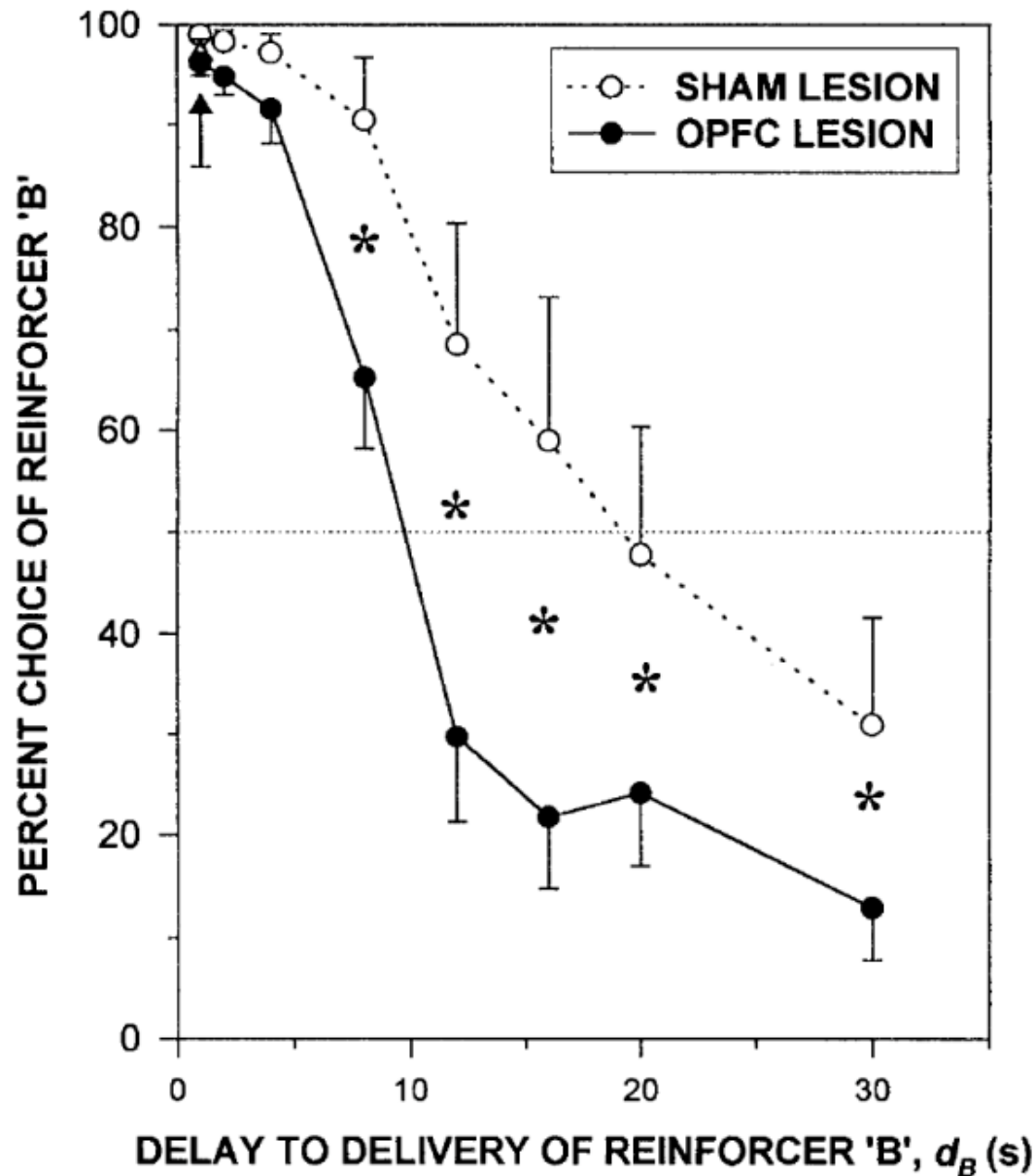
Rolls et al. (1996)

Reversal learning impaired by OFC lesions in marmosets



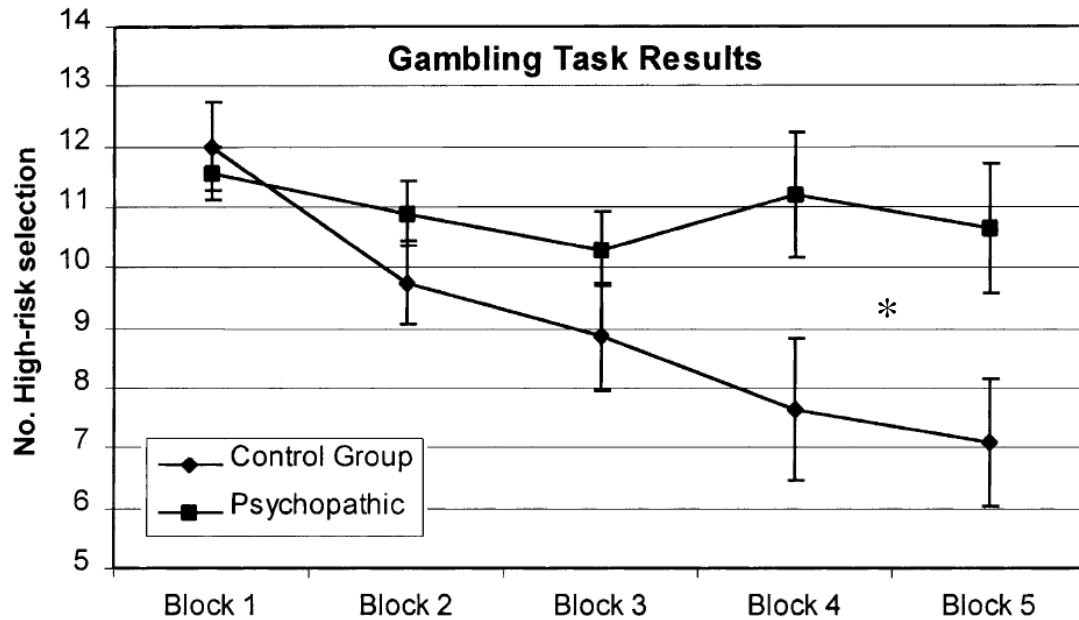
Open = sham-operated controls.
Hatched = DLPFC lesion (area 9).
Filled = OFC lesion.

OFC lesions can induce impulsive choice in rats



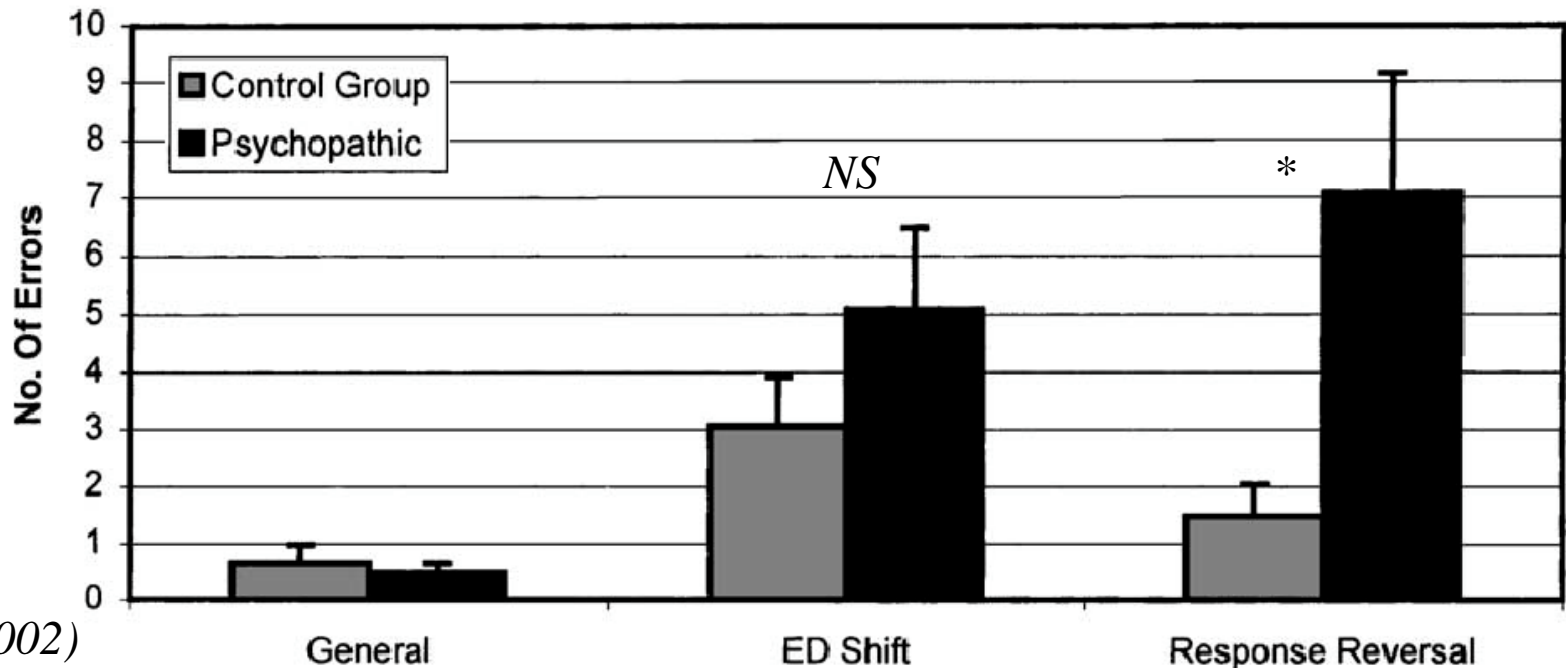
Mobini et al. (2002)

OFC dysfunction in criminal psychopathy?



psychopathic prisoners

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



Mitchell et al. (2002)

Chess and morality



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

