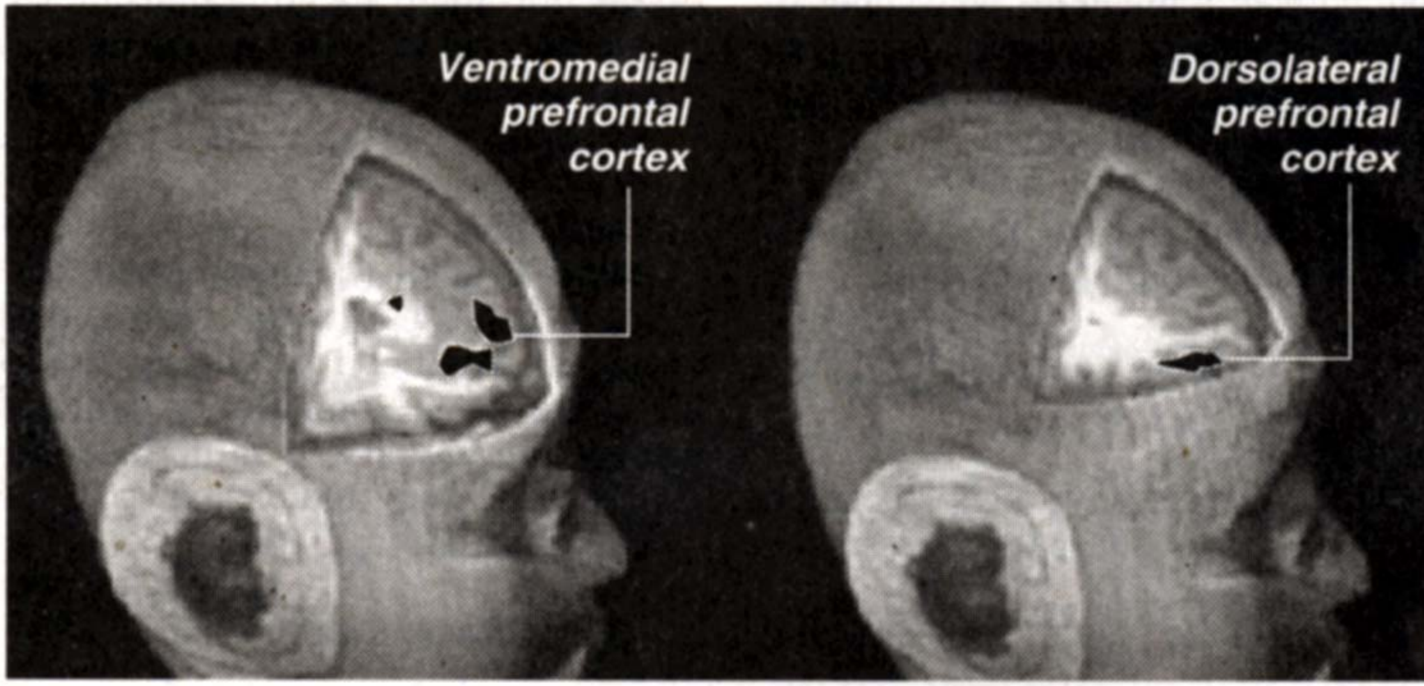
THE FRONTAL LOBE and Executive Functions

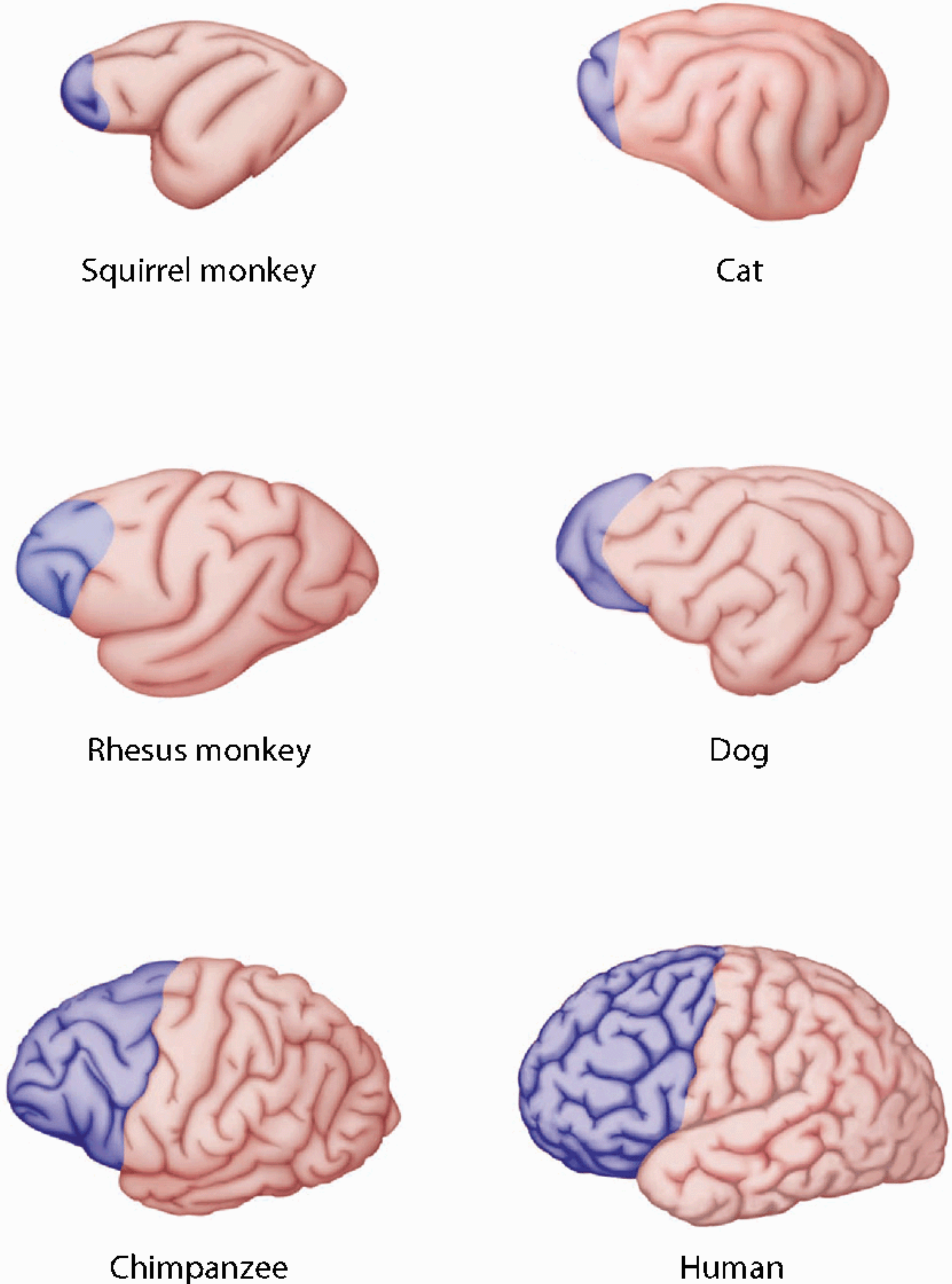
USING M.R.I. MACHINES TO SEE PARTIZANSHIP ON THE BRAIN



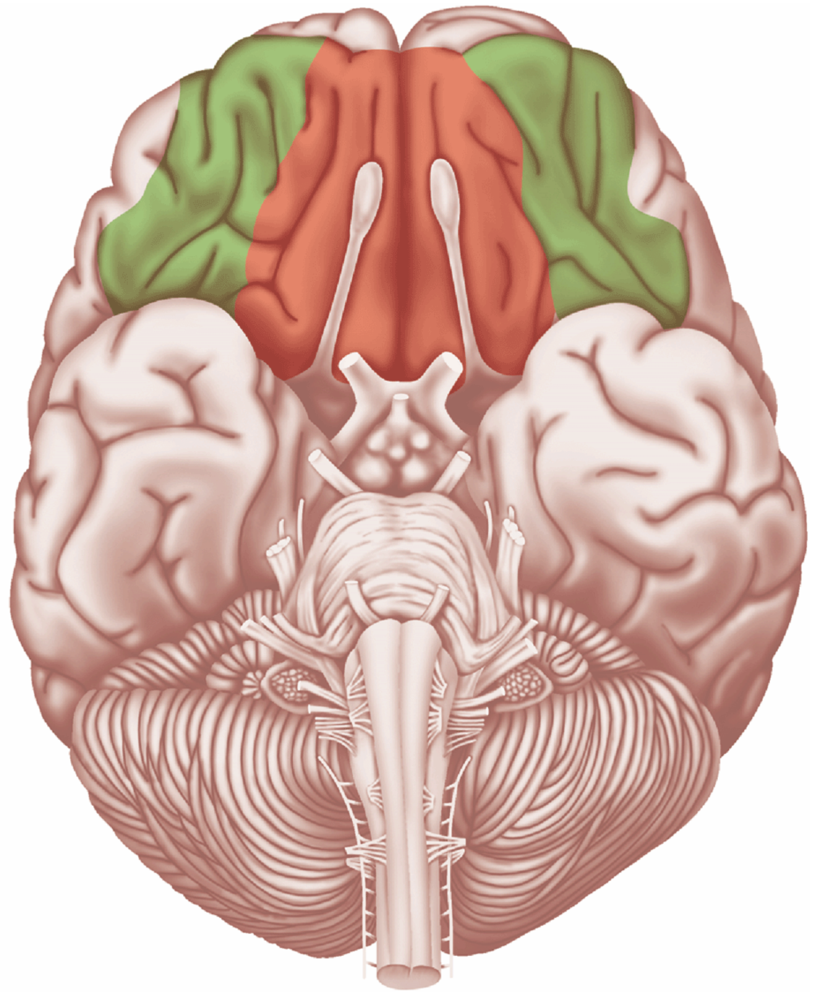
MY GUY The voter reacts to the candidate of his own party in the emotional, reflexive area of his brain, the ventromedial prefrontal cortex.

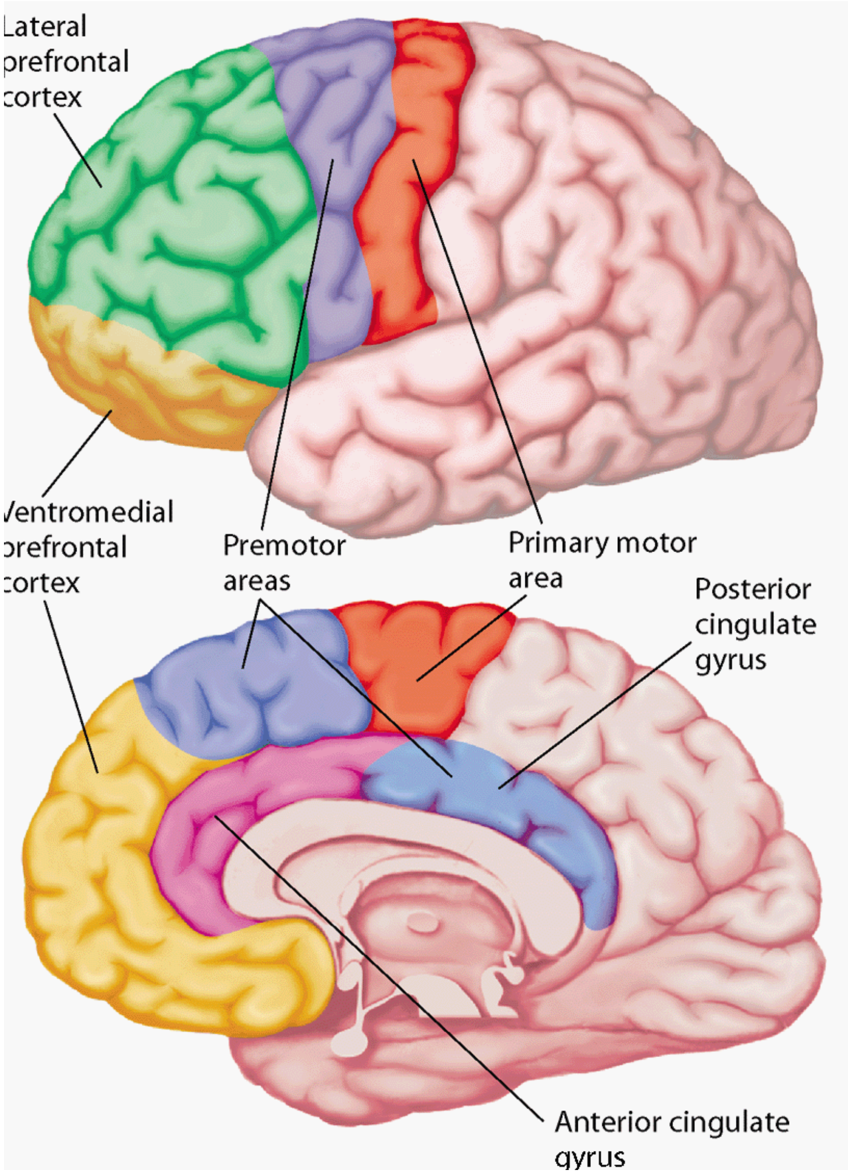
THE OTHER GUY Here, the voter reacts to the other party's candidate in the rational, cognitive area of his brain, the dorsolateral prefrontal cortex.

NEW YORK TIMES, Tuesday, April 20, 2004


Squirrel monkey
Cat
Rhesus monkey
Dog
Chimpanzee
Human

(a)





The orbitofrontal cortex is divided into **ventromedial** (reddish in the anterior view: above and yellow in the convex-lateral and median-sagittal view) and the **lateral** orbitofrontal cortex (green)

Clinical Effects of Frontal Lobe Lesions

These can be grouped under the following headings:

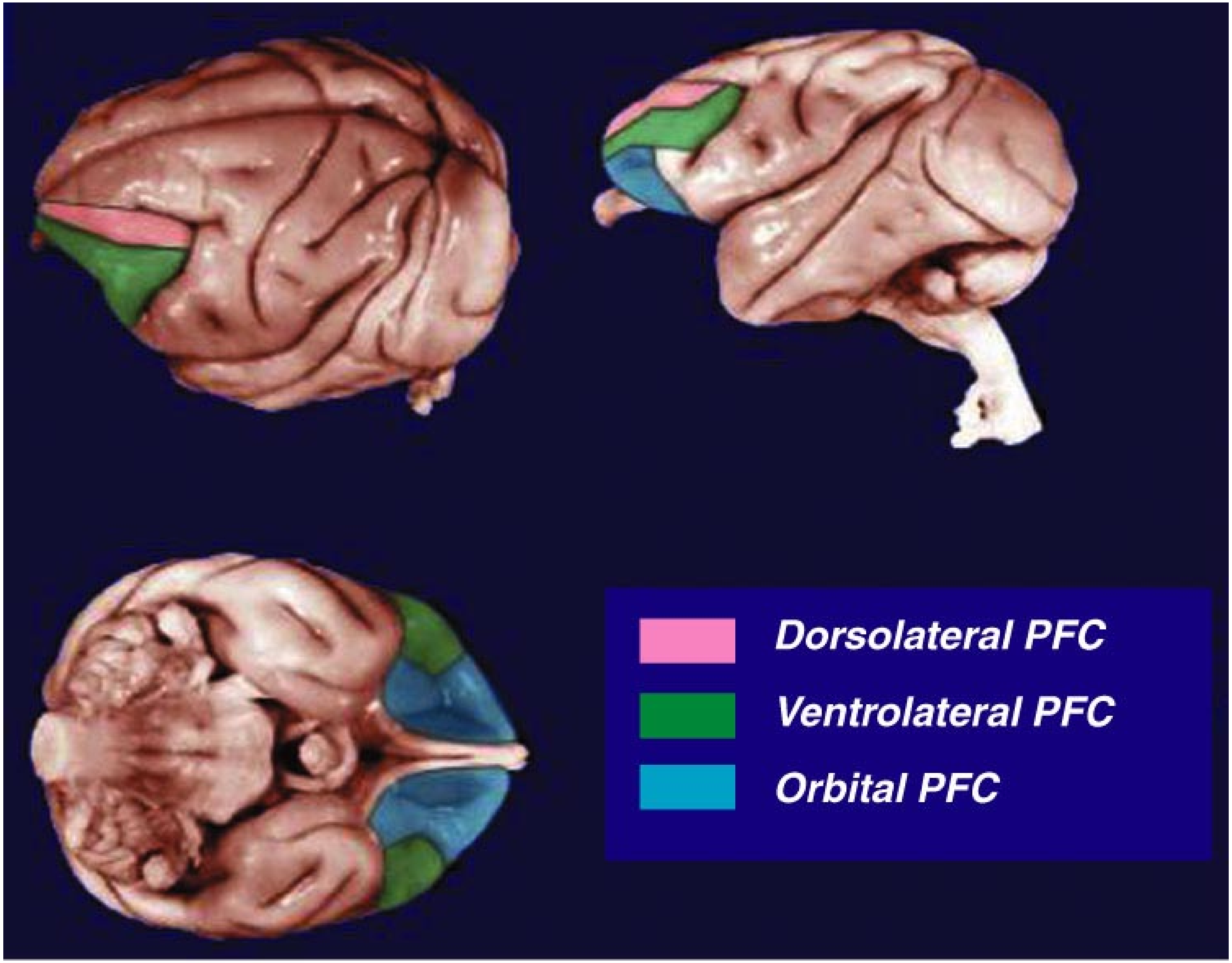
1. Motor abnormalities
2. Impairment of cognitive function, especially attention, concentration, and capacity for sustained action
3. Akinesia and lack of initiative and spontaneity (apathy and abulia)
4. Other changes in personality, particularly changes in mood and self-control (disinhibition of behavior)

I. Effects of unilateral frontal disease, either left or right
   - *A*. Contralateral spastic hemiplegia
   - *B*. Slight elevation of mood, increased talkativeness, tendency to joke, lack of tact, difficulty in adaptation, loss of initiative
   - *C*. If entirely prefrontal, no hemiplegia; grasp and suck reflexes may be released
   - *D*. Anosmia with involvement of orbital parts

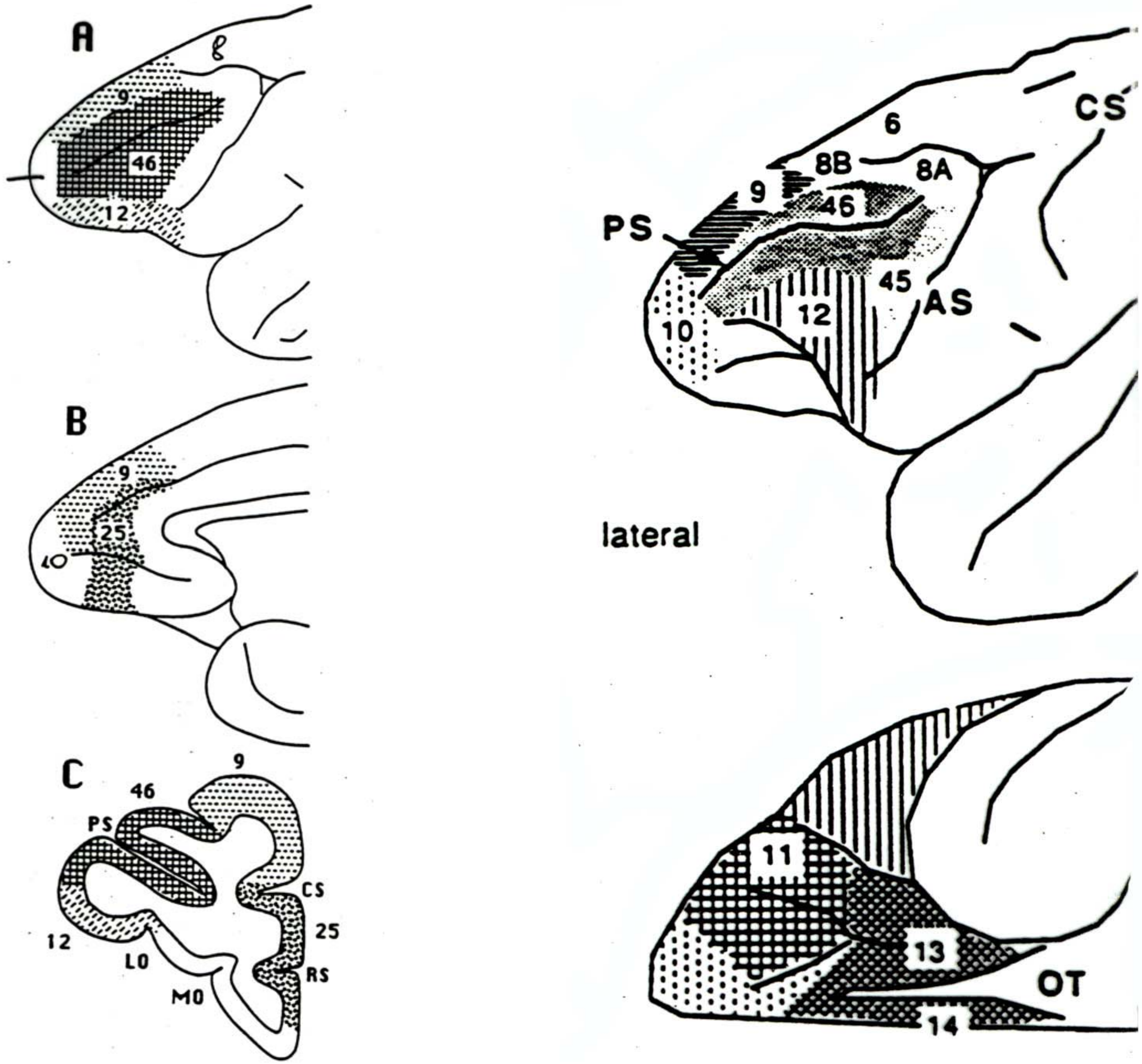
II. Effects of right frontal disease
   - *A*. Left hemiplegia
   - *B*. Changes as in I*B*, *C*, and *D*

III. Effects of left frontal disease
   - *A*. Right hemiplegia
   - *B*. Motor speech disorder with agraphia, with or without apraxia of the lips and tongue (see Chap. 23)
   - *C*. Loss of verbal associative fluency; perseveration
   - *D*. Sympathetic apraxia of left hand
   - *E*. Changes as in I*B*, *C*, and *D*

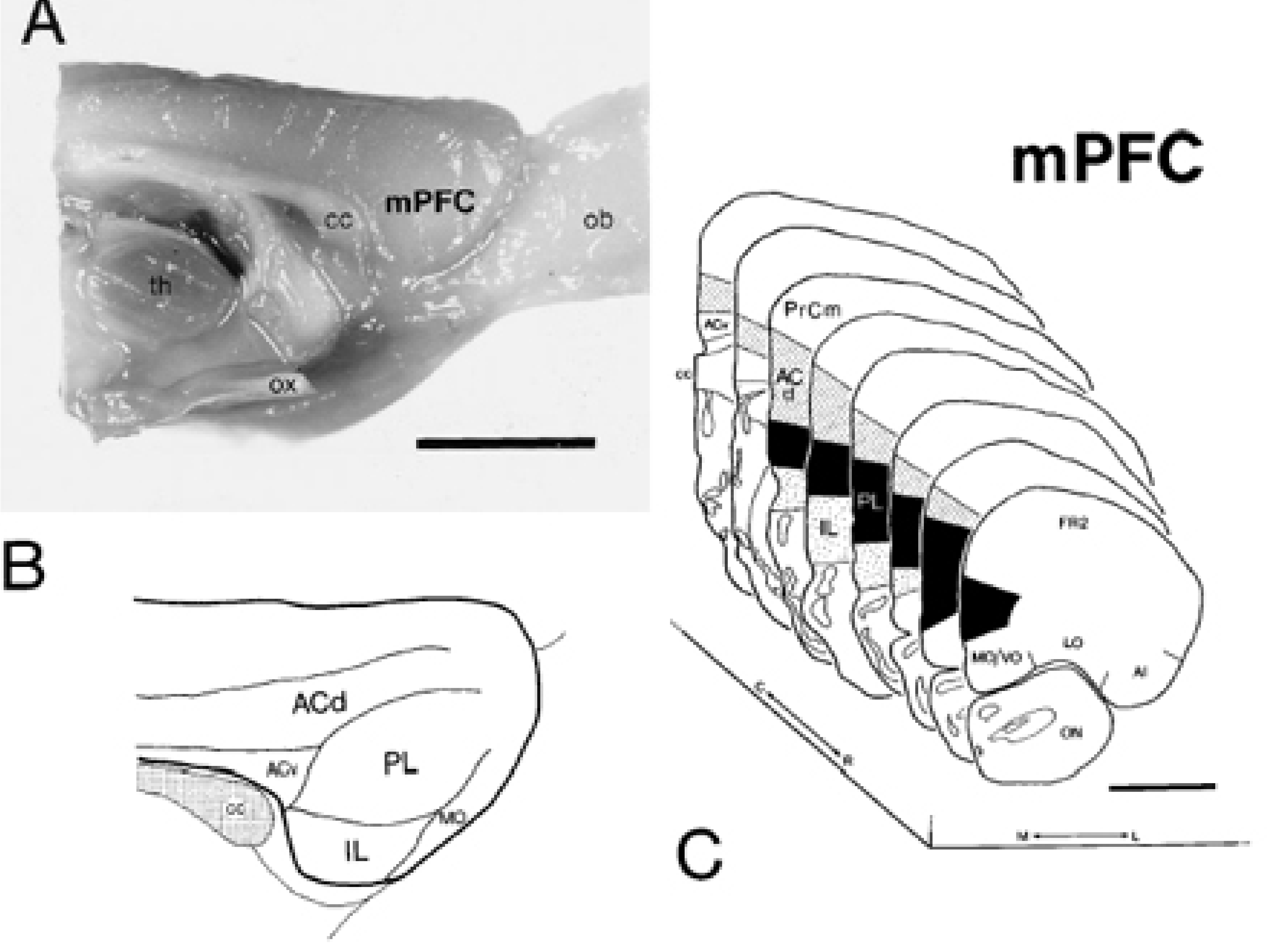
IV. Effects of bifrontal disease
   - *A*. Bilateral hemiplegia
   - *B*. Spastic bulbar (pseudobulbar) palsy
   - *C*. If prefrontal, abulia or akinetic mutism, lack of ability to sustain attention and solve complex problems, rigidity of thinking, bland affect and labile mood, and varying combinations of grasping, sucking, decomposition of gait, and sphincteric incontinence



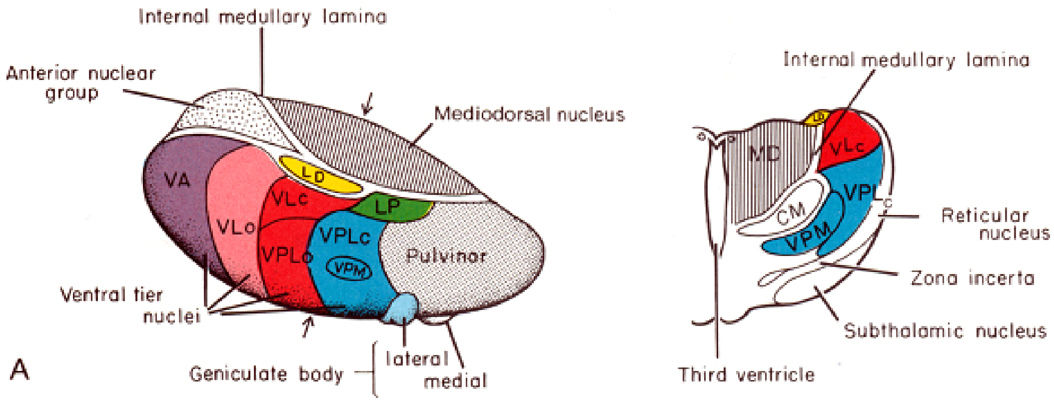
Brain of the macaque monkey with major subdivisions indicated.

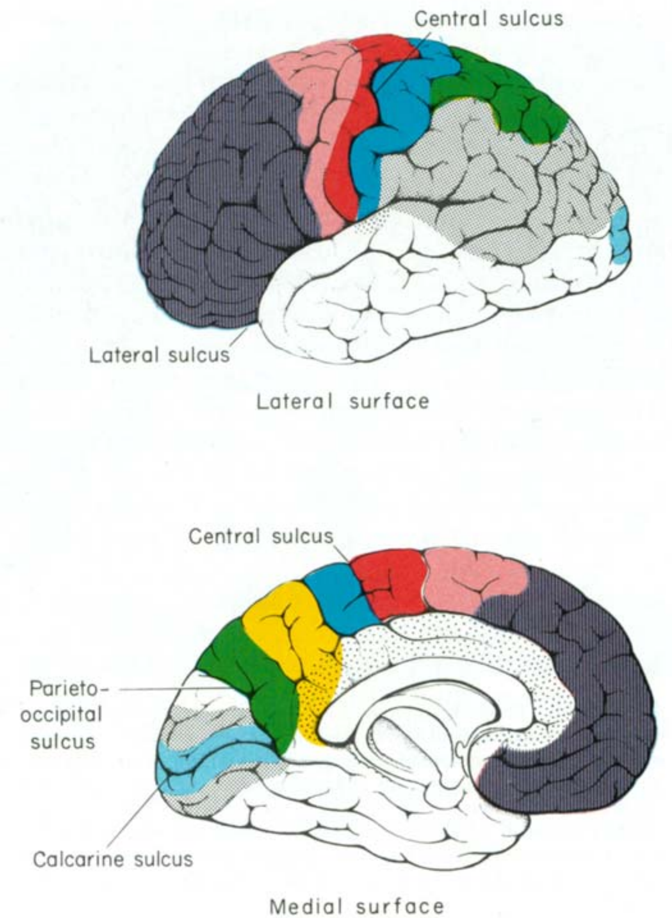


Walker’s cytoarchitectonic map of the monkey prefrontal cortex

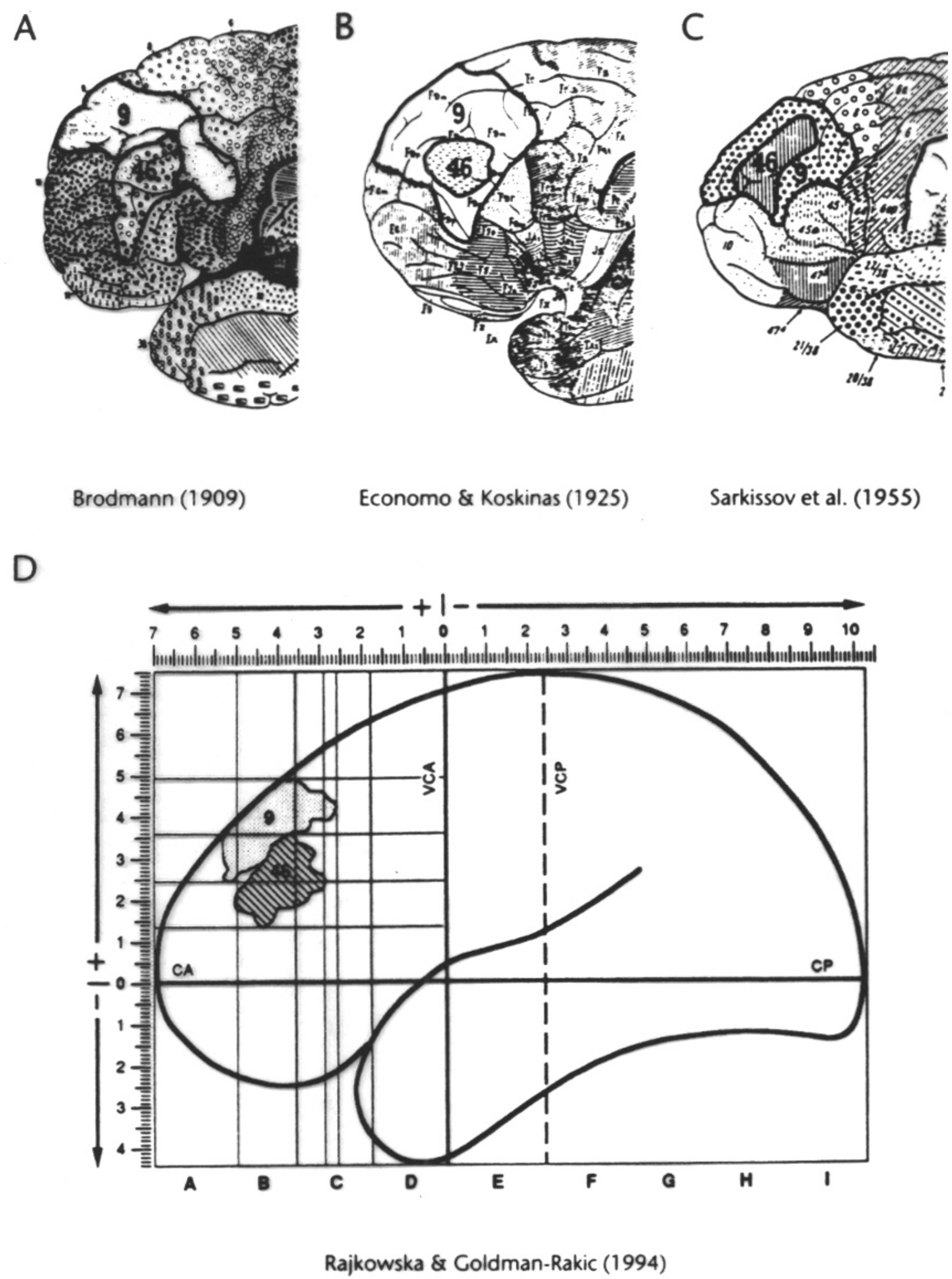

A
mPFC
cc
ob
th
ox
B
ACd
ACv
PL
cc
MO
IL
C
mPFC
PrCm
ACv
cc
AC
d
PL
IL
FR2
MO/VO
LO
AI
ON
M
L

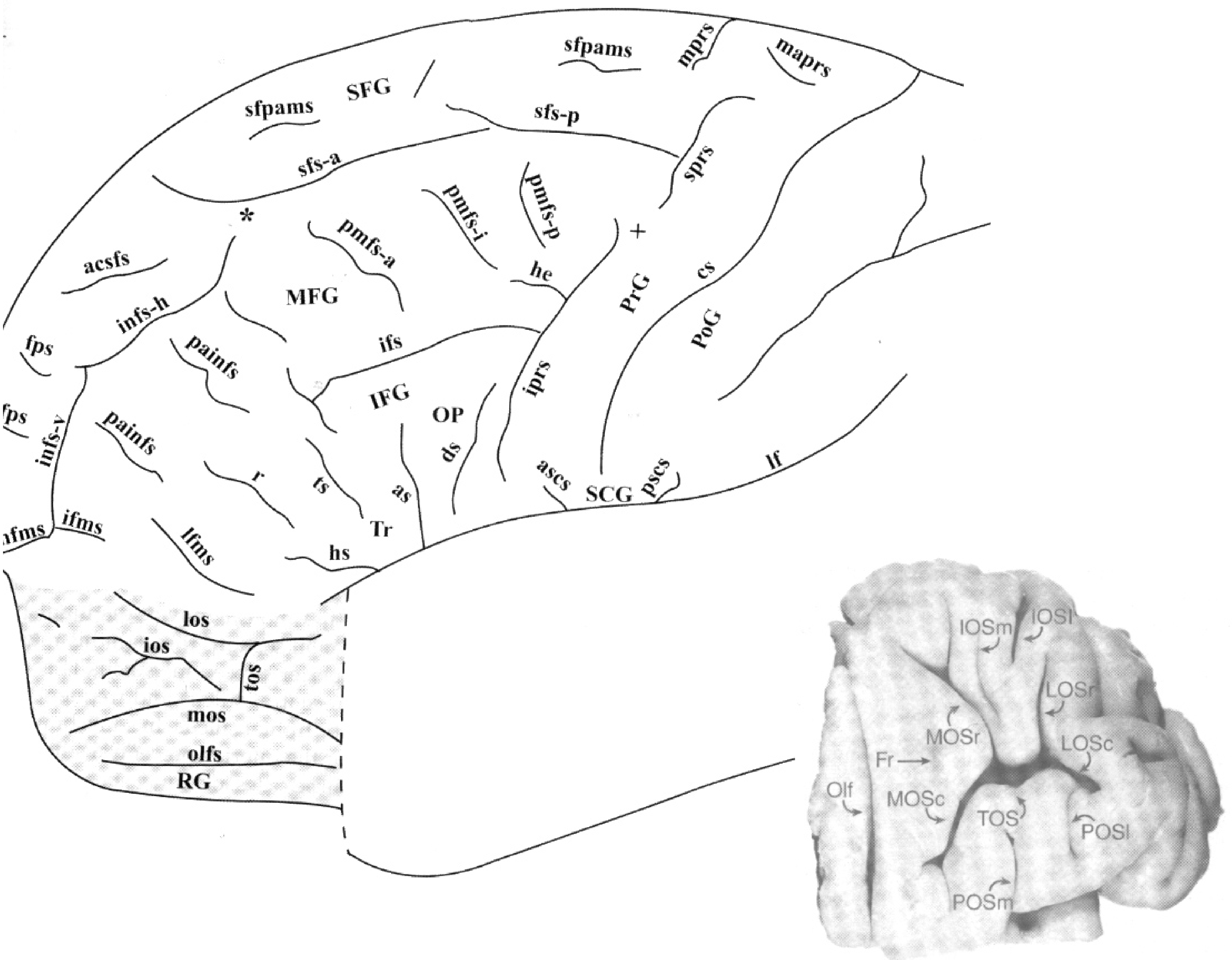
Mediodorsal nucleus projection to the PFC



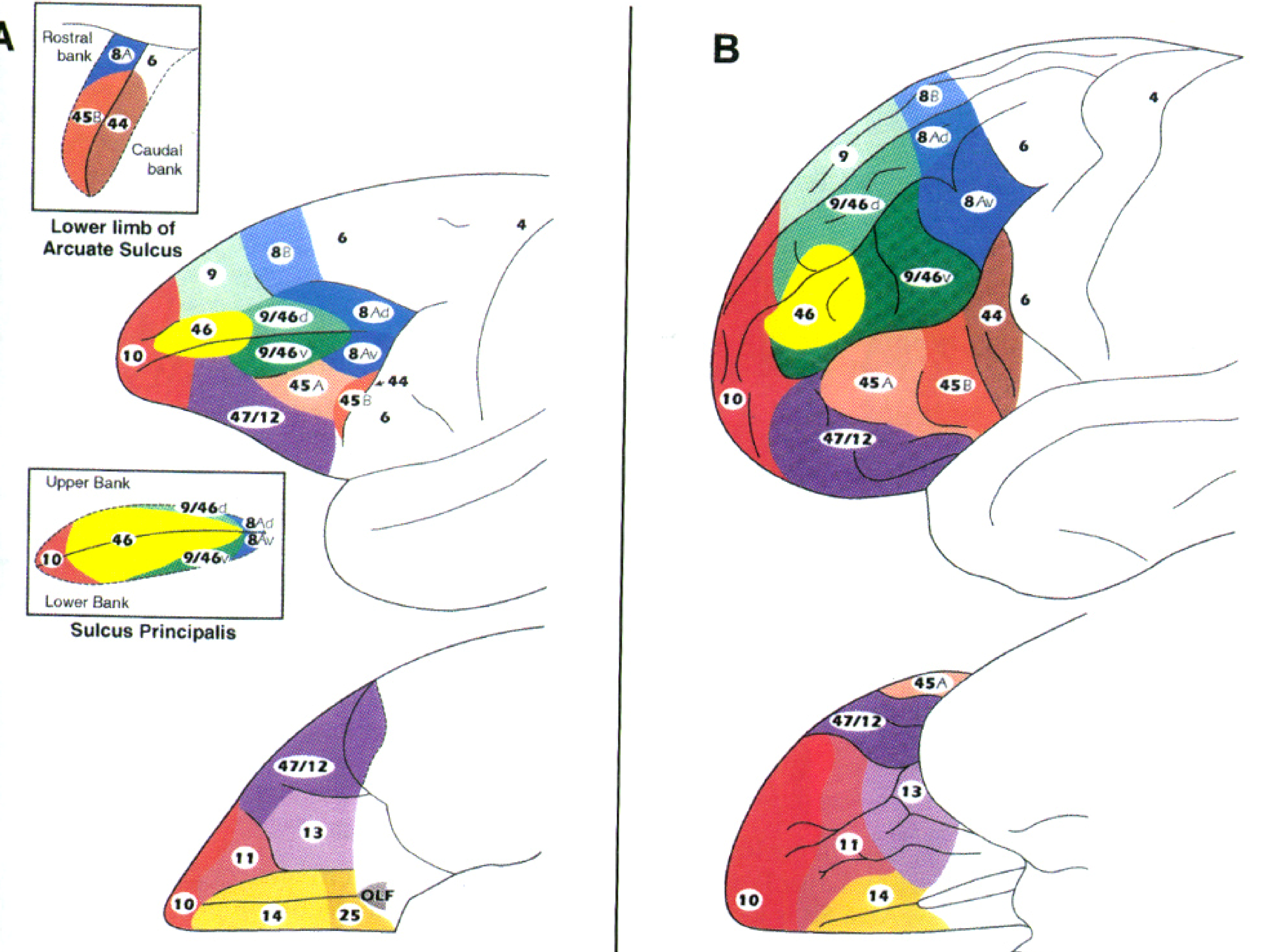


(Carpenter, 1991)

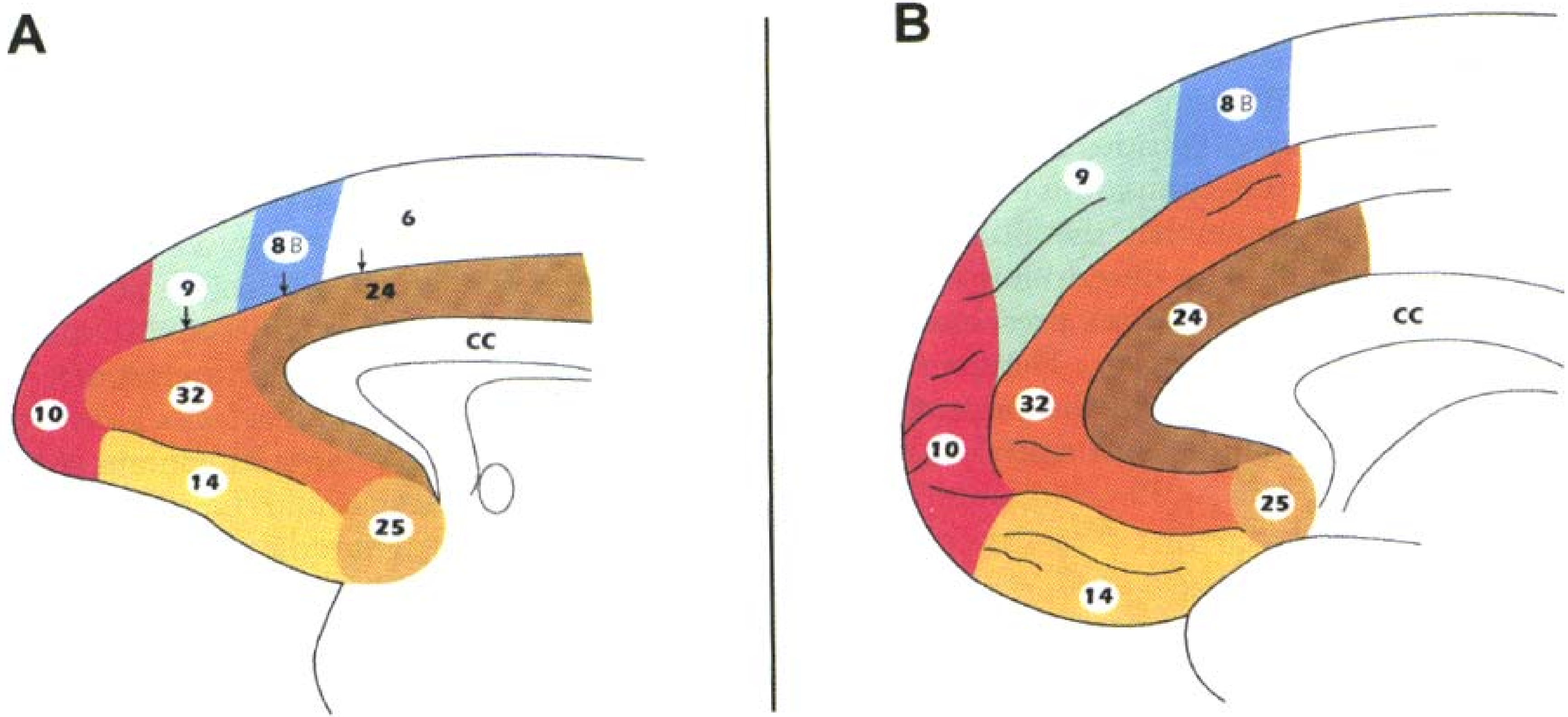

A
B
C
Brodmann (1909)
Economo & Koskinas (1925)
Sarkissov et al. (1955)
D
VCA
VCP
CA
CP
A
B
C
D
E
F
G
H
I
Rajkowska & Goldman-Rakic (1994)



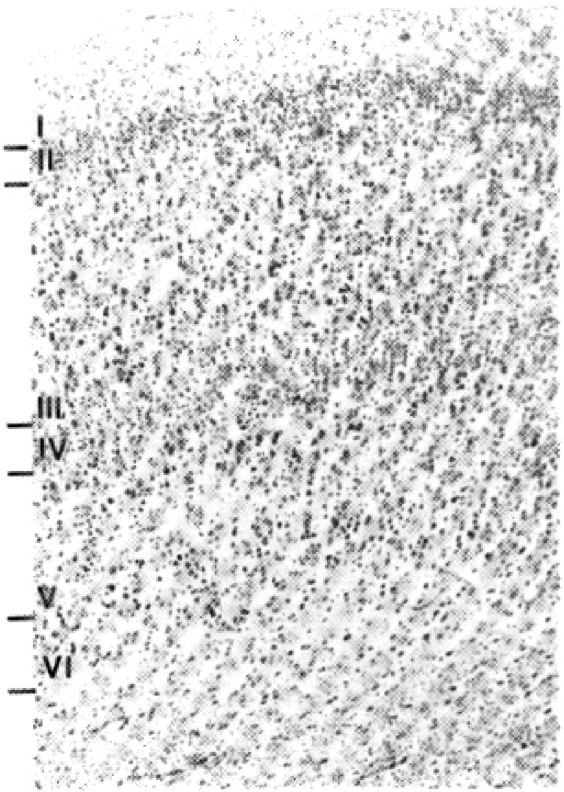
sfpams
mprs
maprs
SFG
sfpams
sfs-p
sfs-a
sprs
pmfs-i
pmfs-p
*
+
pmfs-a
acsfs
he
PrG
cs
MFG
infs-h
fps
ifs
painfs
PoG
IFG
iprs
fps
OP
painfs
infs-v
ds
r
ascs
pscs
lf
fs
as
SCG
ifms
Tr
nfms
lfms
hs
los
ios
tos
mos
olfs
RG
lOSm
lOSl
LOSr
MOSr
LOSc
Fr
Olf
MOSc
TOS
POSl
POSm



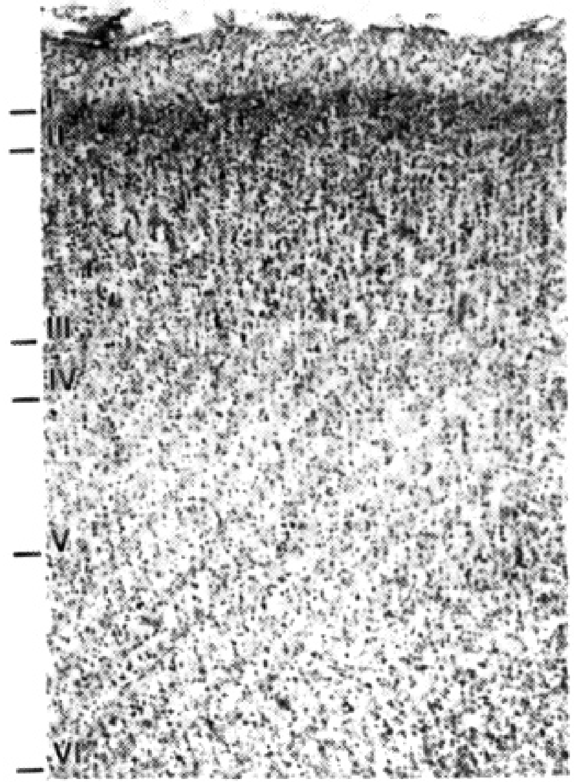
A
Rostral bank
8A
6
45B
44
Caudal bank
Lower limb of Arcuate Sulcus
8B
6
4
9
9/46d
8Ad
46
10
9/46v
8Av
45A
44
45B
6
47/12
Upper Bank
9/46d
8Ad
46
8Av
10
9/46v
Lower Bank
Sulcus Principalis
47/12
13
11
10
14
25
OLF
B
8B
4
8Ad
6
9
9/46d
8Av
9/46v
46
6
44
45A
45B
10
47/12
45A
47/12
13
11
10
14



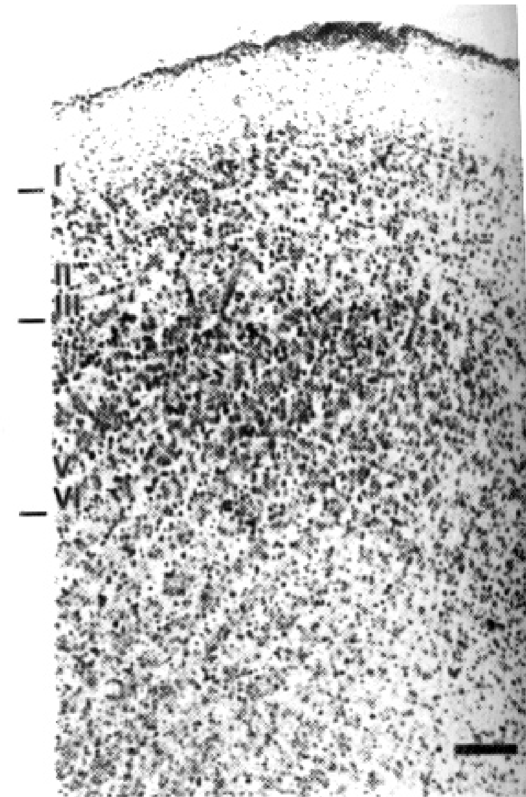
A
B
8B
9
6
24
CC
10
32
14
25



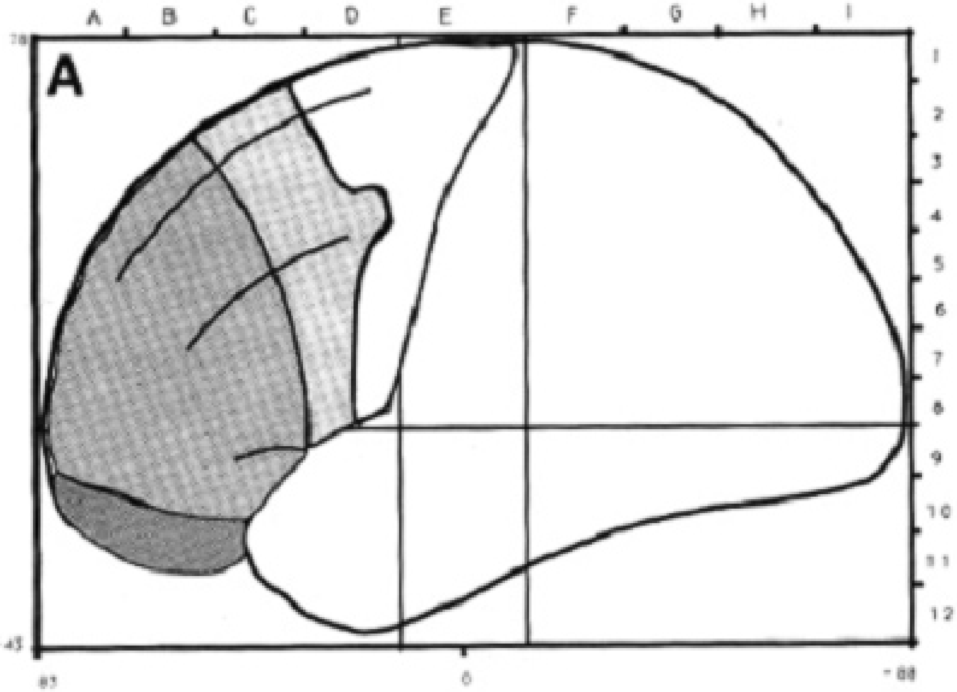
Area 10

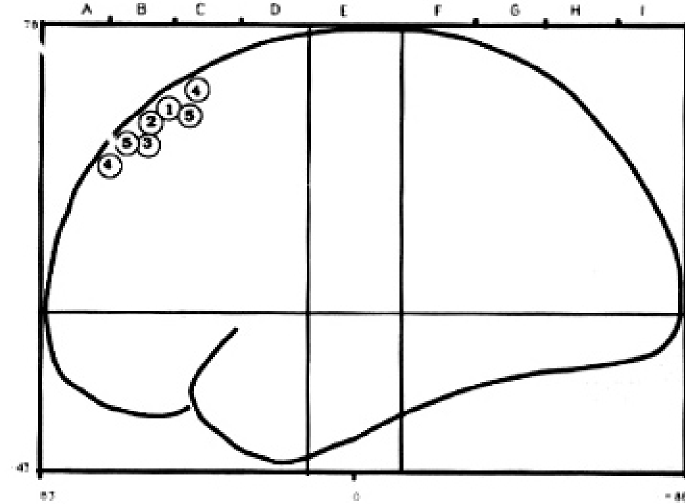


Area 9/46v

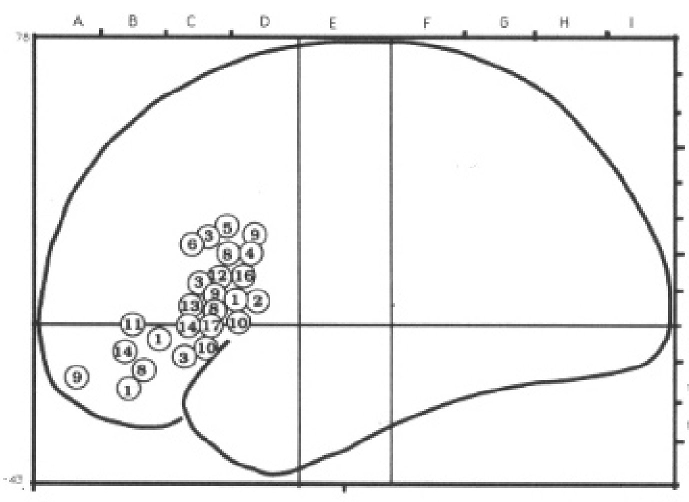


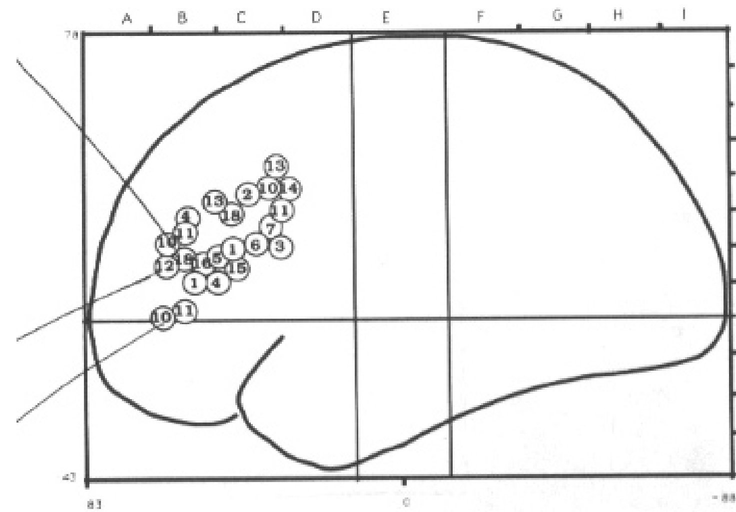
Area 25





1-2 speech;4 mental calculation; 5 route finding





8:vigilance somatosens;10 visual discr; 12: trimodal attention

1,2,3,4,5,6,8,9.11 speech; 7 vigilance SS; 14 visual discr of shape; 15 trimodal attention

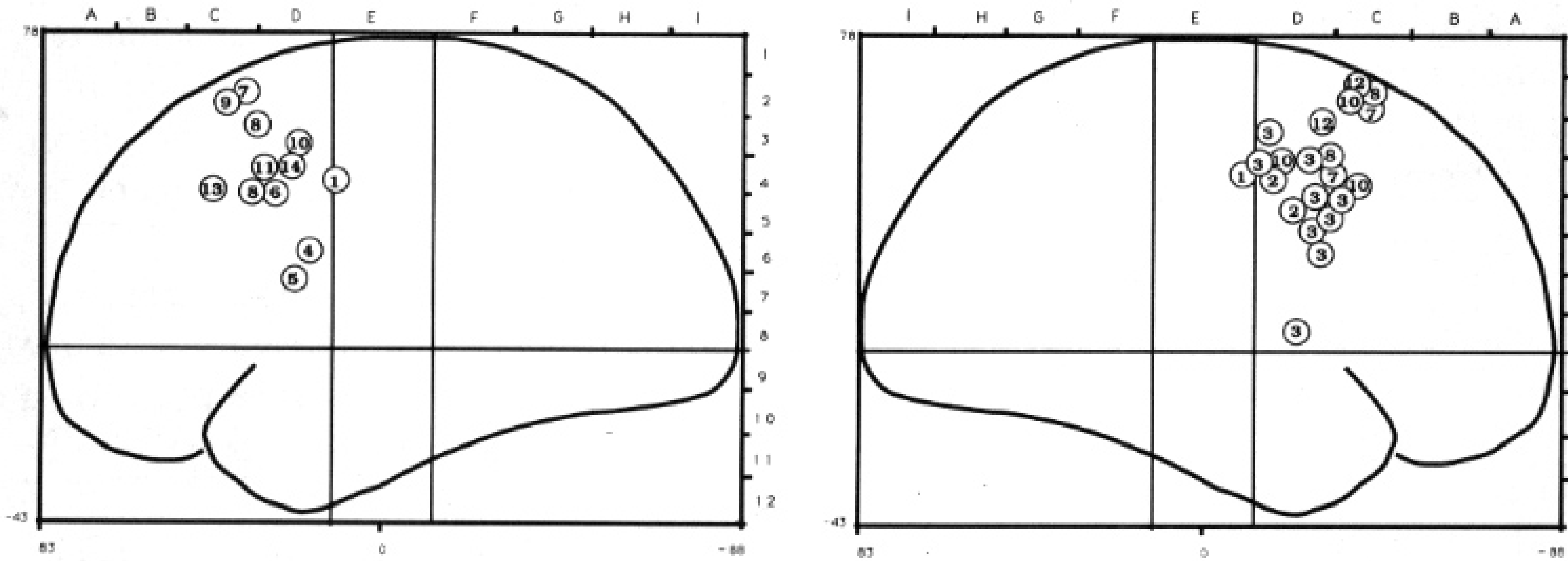
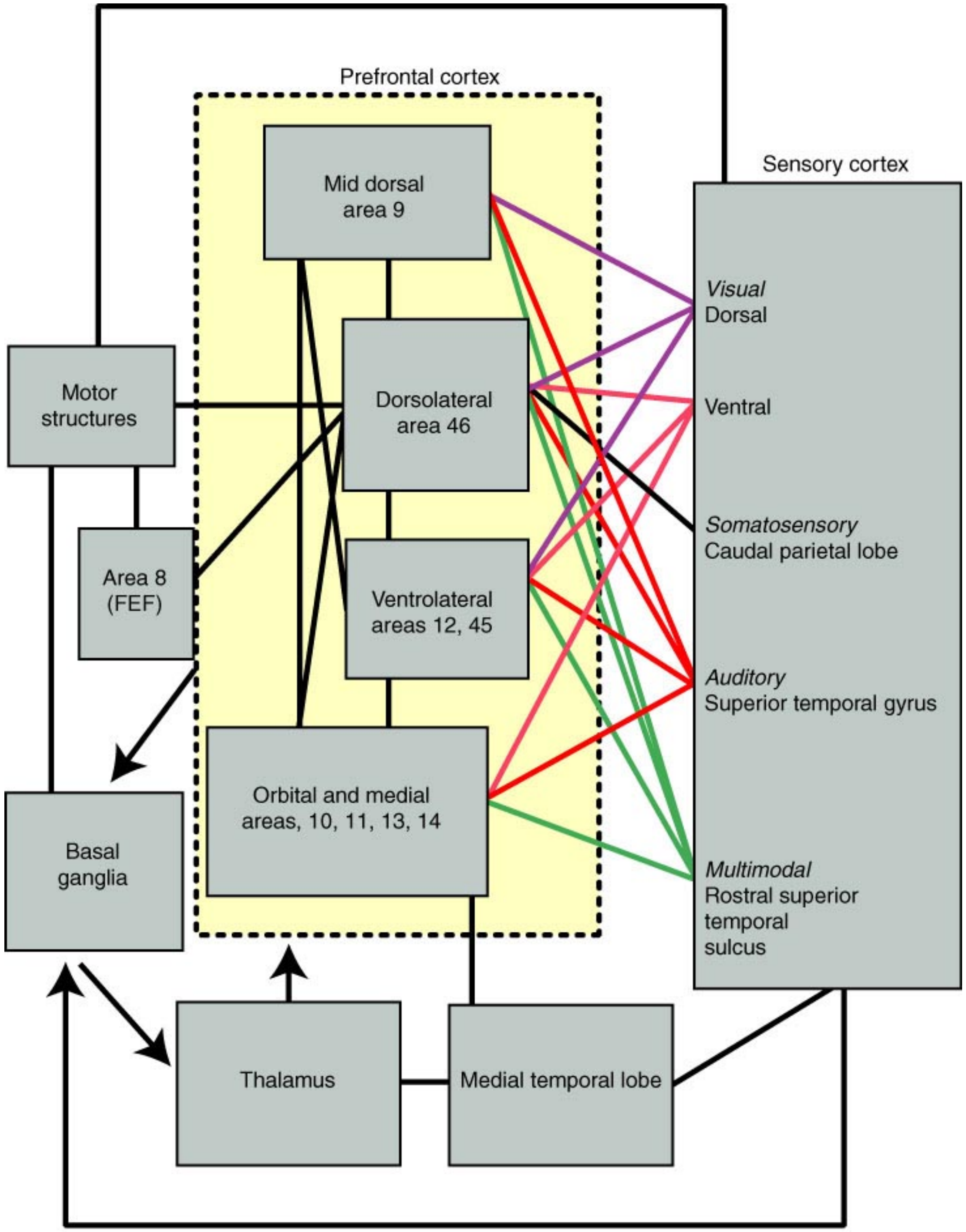
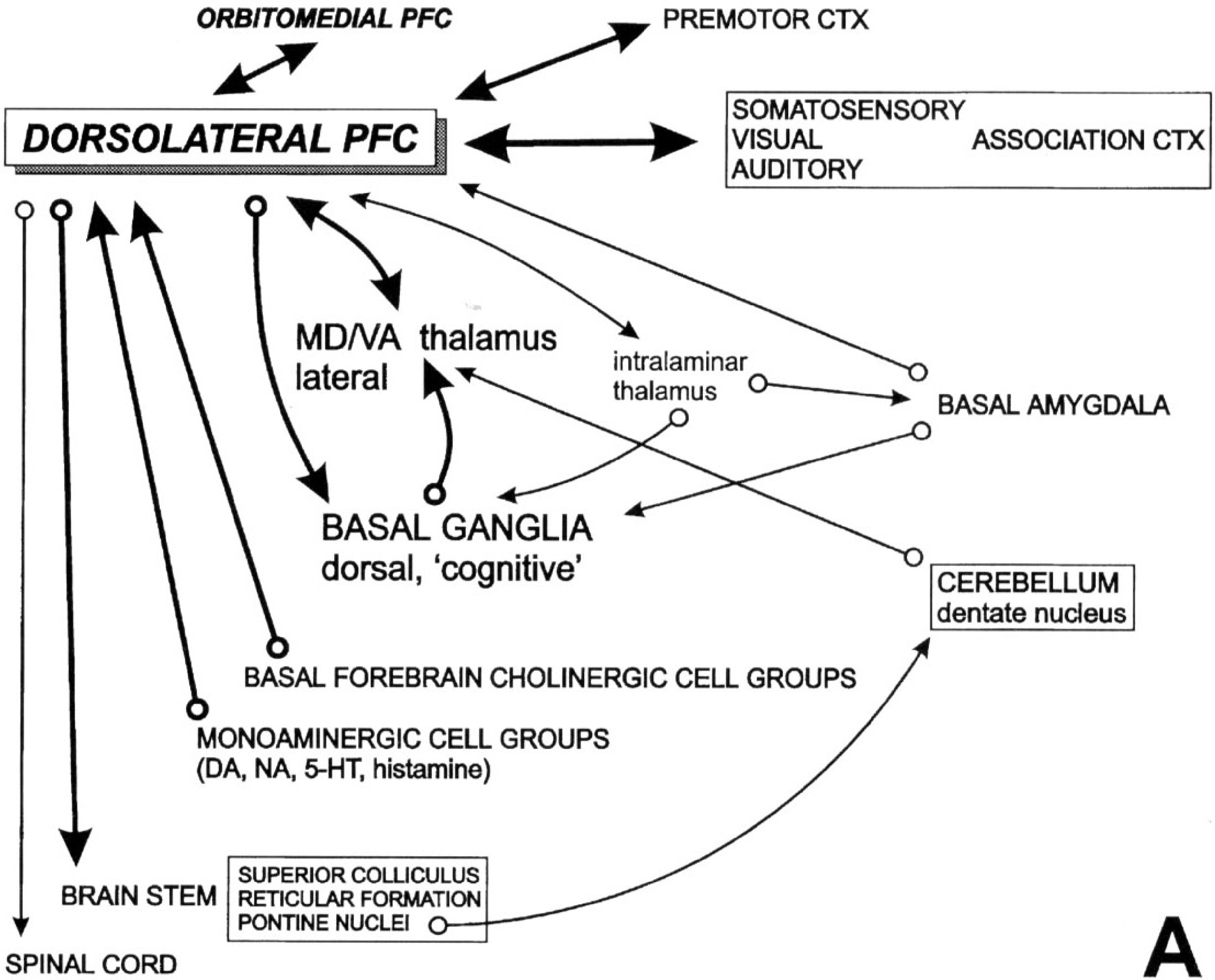
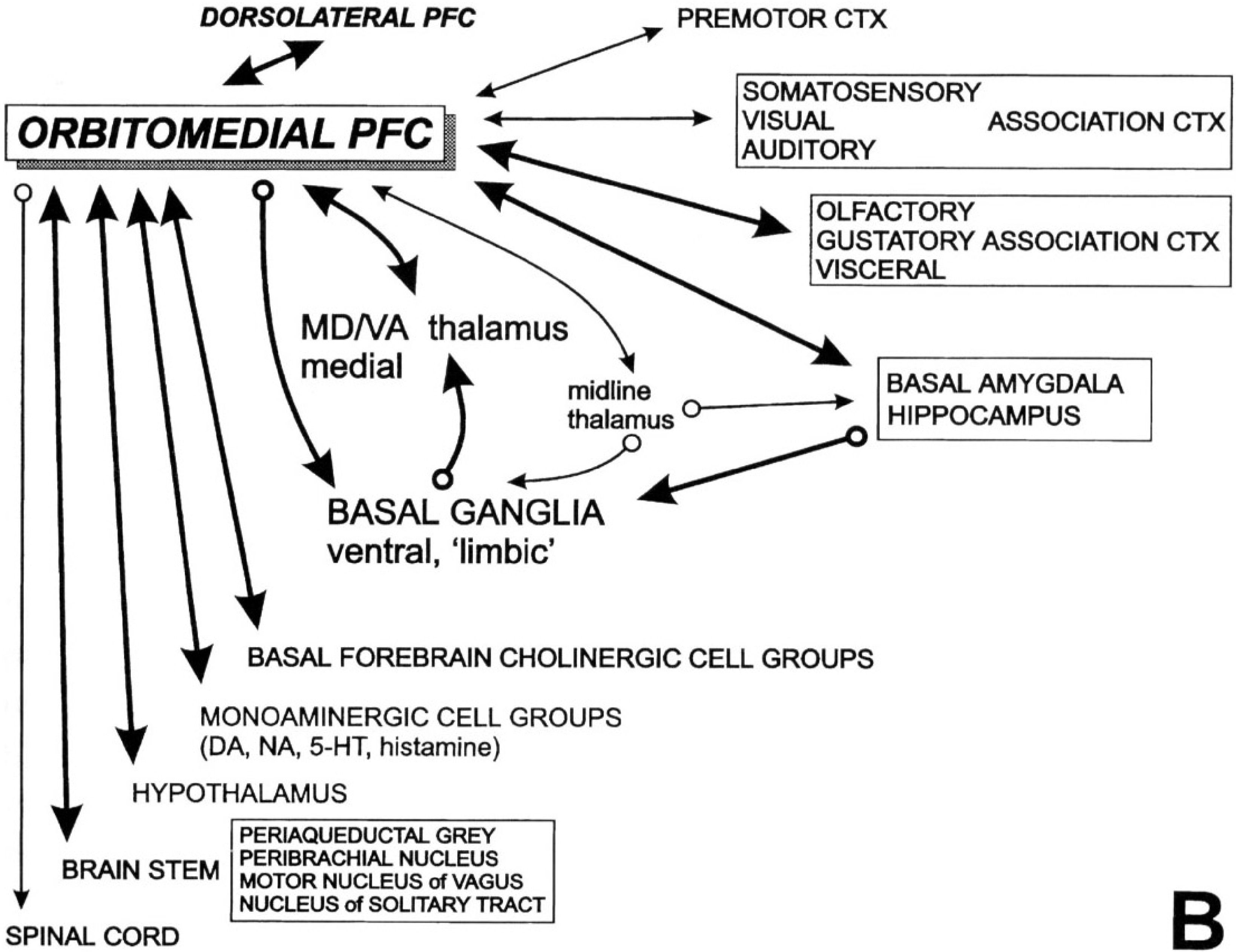


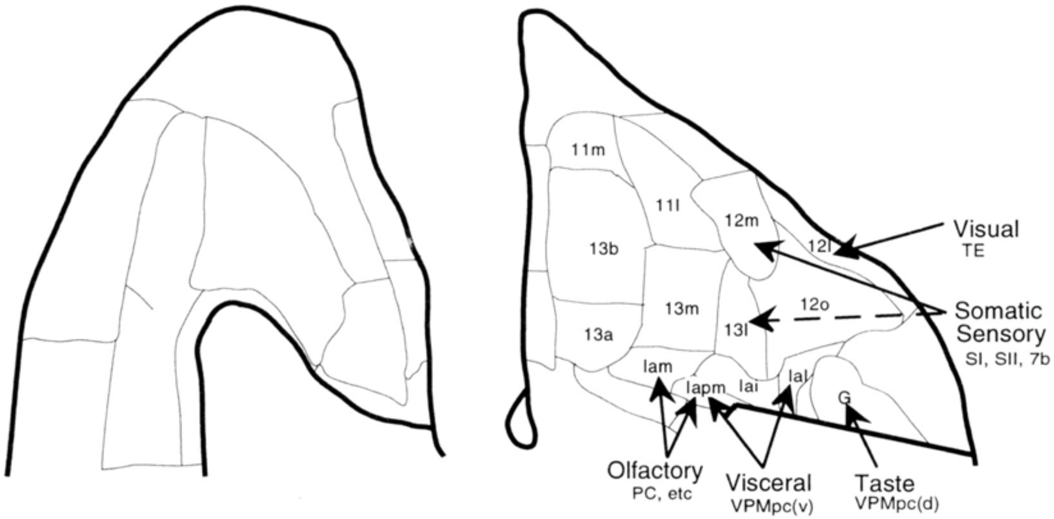
Figure 13.6. Talairach coordinates of activations of the dysgranular part of the prefrontal cortex. Codes: 1, Saccades (Fox et al., 1985b); 2, Visual vigilance (Pardo et al., 1991); 3, Somatosensory vigilance (Pardo et al., 1991); 4, Attention to speed (Corbetta et al., 1991a); 5, Selective attention-divided (Corbetta et al., 1991a); 6 verb generation (Wise et al., 1991); 7, Jingle thinking (Roland and Friberg, 1985); 8, Route finding (Roland and Friberg, 1985); 9, Mental calculation (Roland and Friberg, 1985); 10, Trimodal stimulation (Roland, 1982); 11, Visual discrimination (Roland and Skinhöj, 1981); 12, Tone rhythm discrimination (Roland et al., 1981); 13, Somatosensory tuning (Roland, 1981); 14, Letter sound- object categorization (Sergeant et al., 1992). On the medial side this sector was activated by random joystick movements (Deiber et al., 1991) and internal motor sequences (Roland et al., 1980a). The activations of the inferior frontal gyrus in language tasks are shown in Figure 13.4.

CONNECTIONS OF THE FRONTAL CORTEX

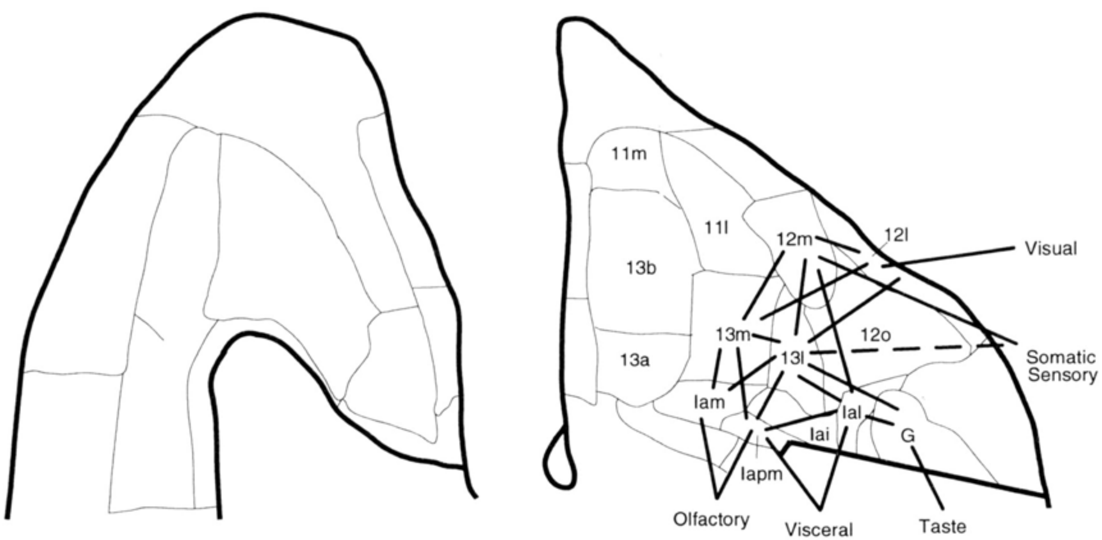



ORBITOMEDIAL PFC
PREMOTOR CTX
DORSOLATERAL PFC
SOMATOSENSORY
VISUAL
AUDITORY
ASSOCIATION CTX
MD/VA thalamus
lateral
intralaminar
thalamus
BASAL AMYGDALA
BASAL GANGLIA
dorsal, 'cognitive'
CEREBELLUM
dentate nucleus
BASAL FOREBRAIN CHOLINERGIC CELL GROUPS
MONOAMINERGIC CELL GROUPS
(DA, NA, 5-HT, histamine)
BRAIN STEM
SUPERIOR COLLICULUS
RETICULAR FORMATION
PONTINE NUCLEI
SPINAL CORD
A

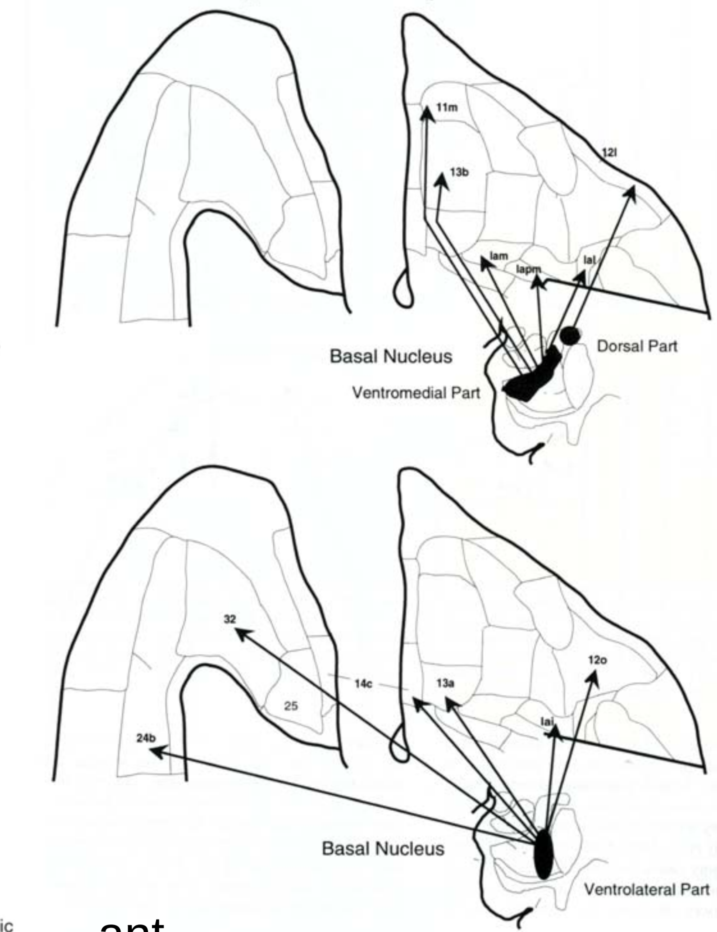

DORSOLATERAL PFC
PREMOTOR CTX
ORBITOMEDIAL PFC
SOMATOSENSORY
VISUAL
AUDITORY
ASSOCIATION CTX
OLFACTORY
GUSTATORY ASSOCIATION CTX
VISCERAL
MD/VA thalamus
medial
midline
thalamus
BASAL AMYGDALA
HIPPOCAMPUS
BASAL GANGLIA
ventral, 'limbic'
BASAL FOREBRAIN CHOLINERGIC CELL GROUPS
MONOAMINERGIC CELL GROUPS
(DA, NA, 5-HT, histamine)
HYPOTHALAMUS
BRAIN STEM
PERIAQUEDUCTAL GREY
PERIBRACHIAL NUCLEUS
MOTOR NUCLEUS of VAGUS
NUCLEUS of SOLITARY TRACT
SPINAL CORD
B



Sensory Inputs to Orbital Prefrontal Cortex



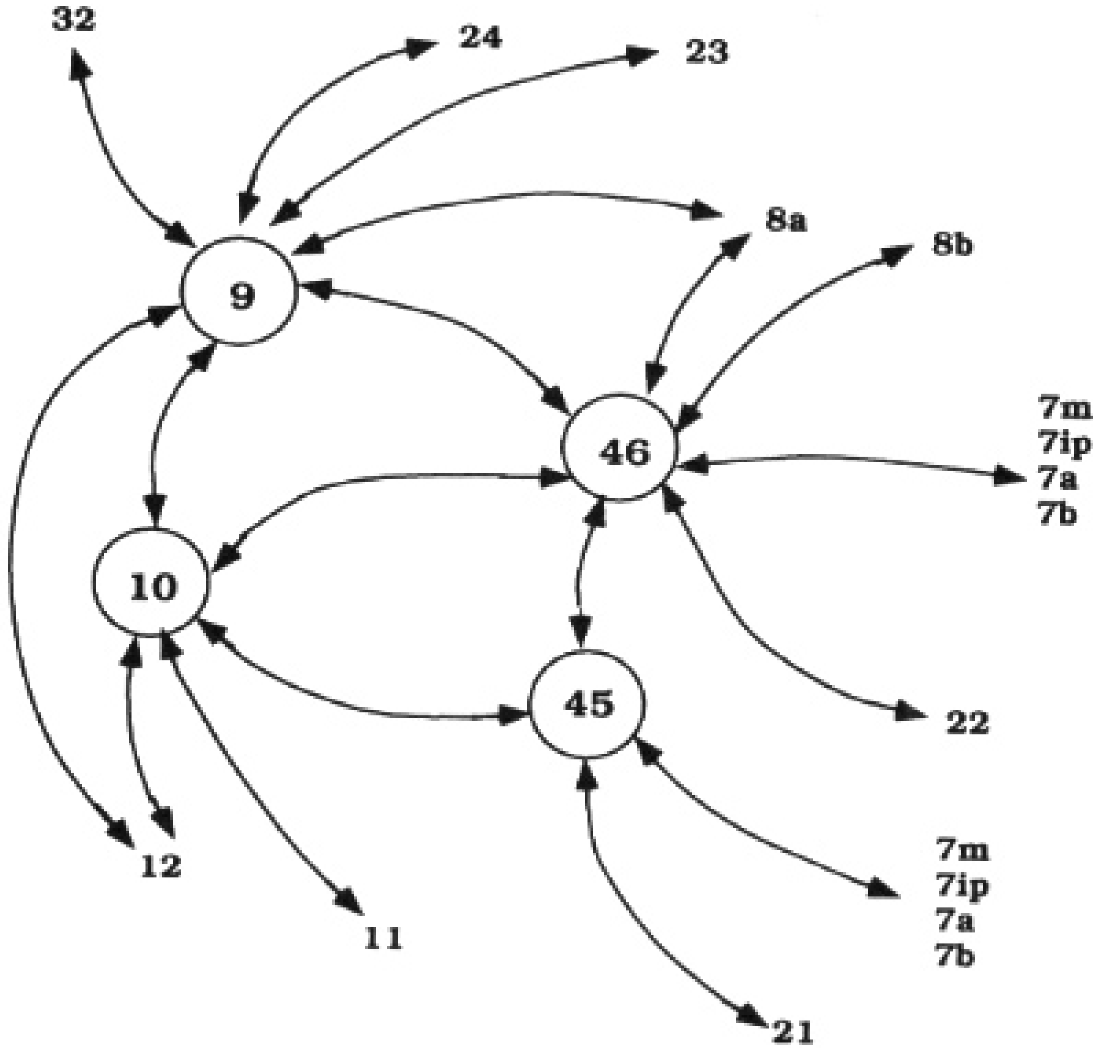
Amygdala-Prefrontal Projections



ant.
cingulate
cortex

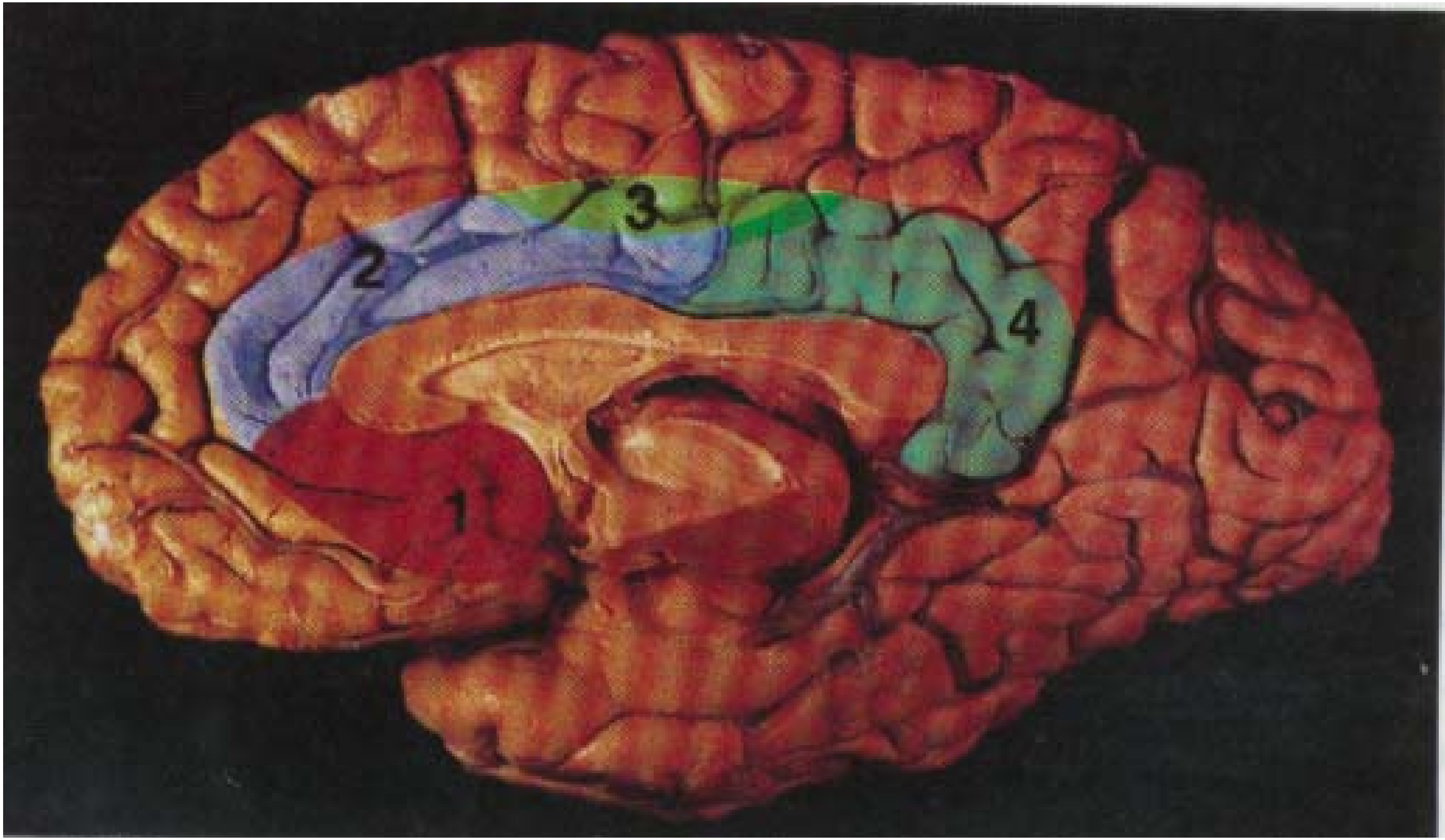
Median-sagittal

orbital

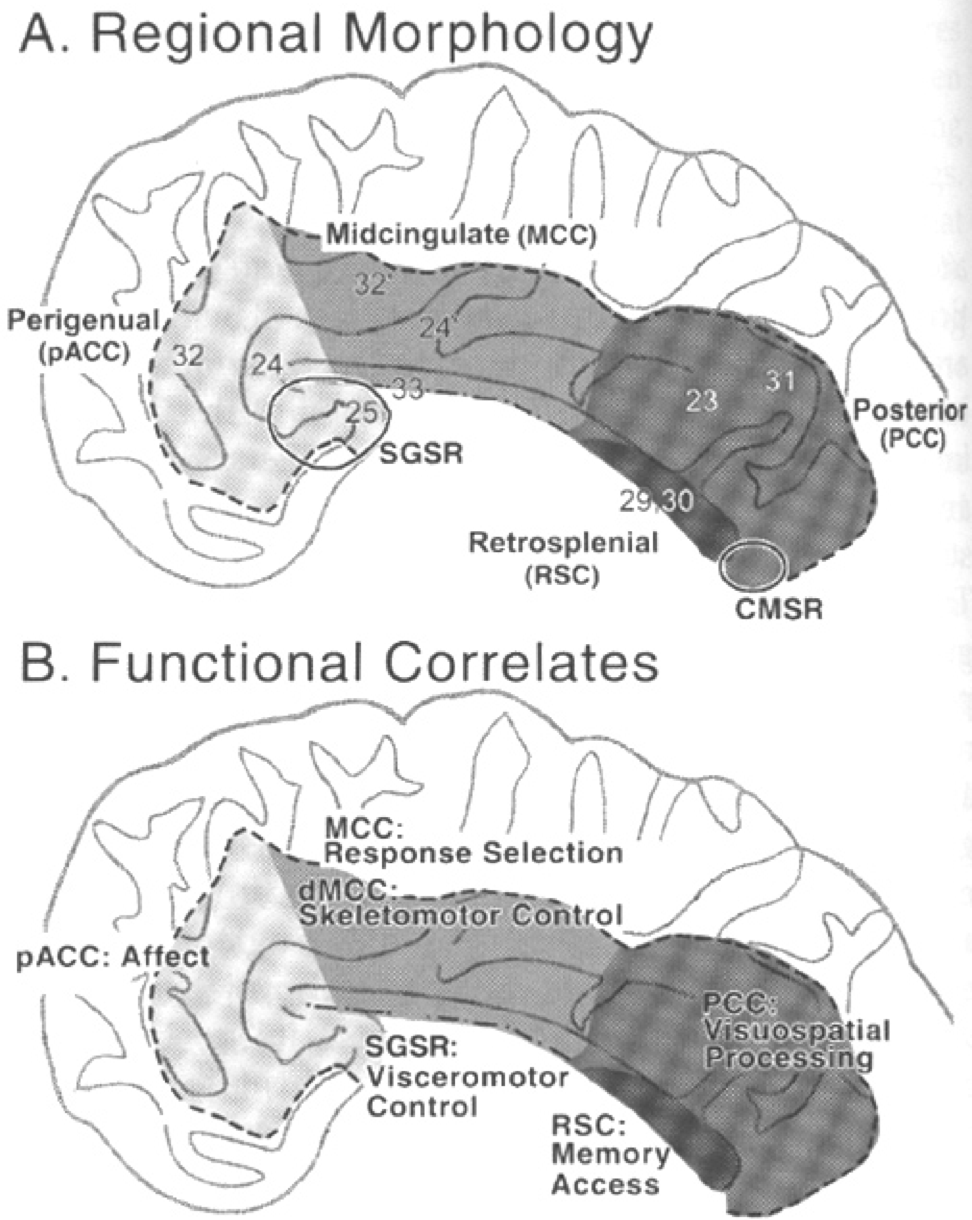


Connections of the prefrontal areas in the monkey. Based on Pandya et al. (1971); Jacobson and Trojanowsky (1977); Pandya and Yeterian (1985); Selemon and Goldman-Rakic (1988); Cavada and Goldman-Rakic (1989); Deacon (1992).

FUNCTIONAL DIVISIONS IN THE CINGULATE CORTEX

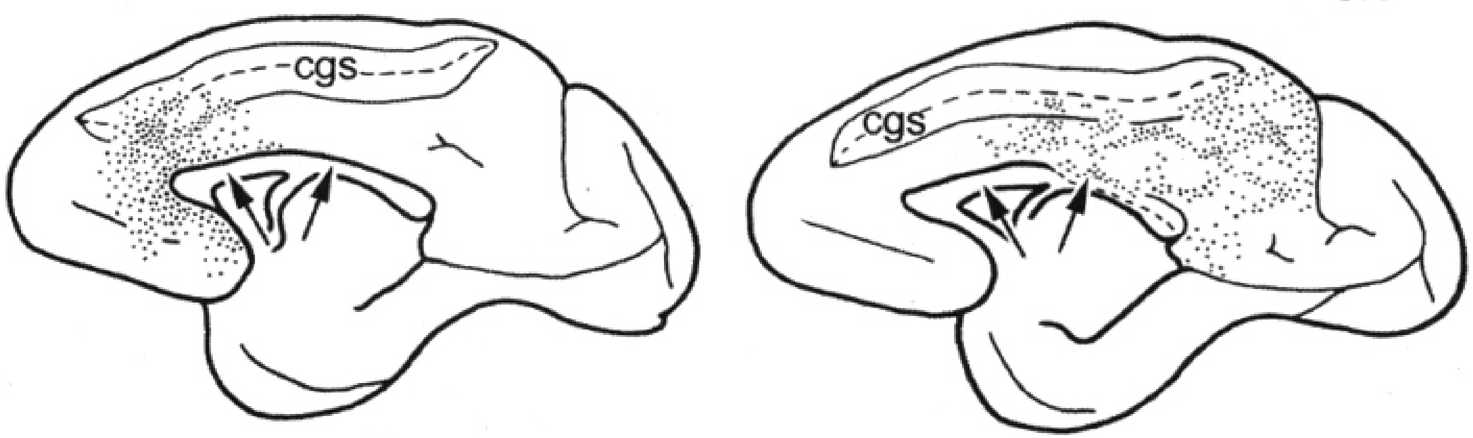


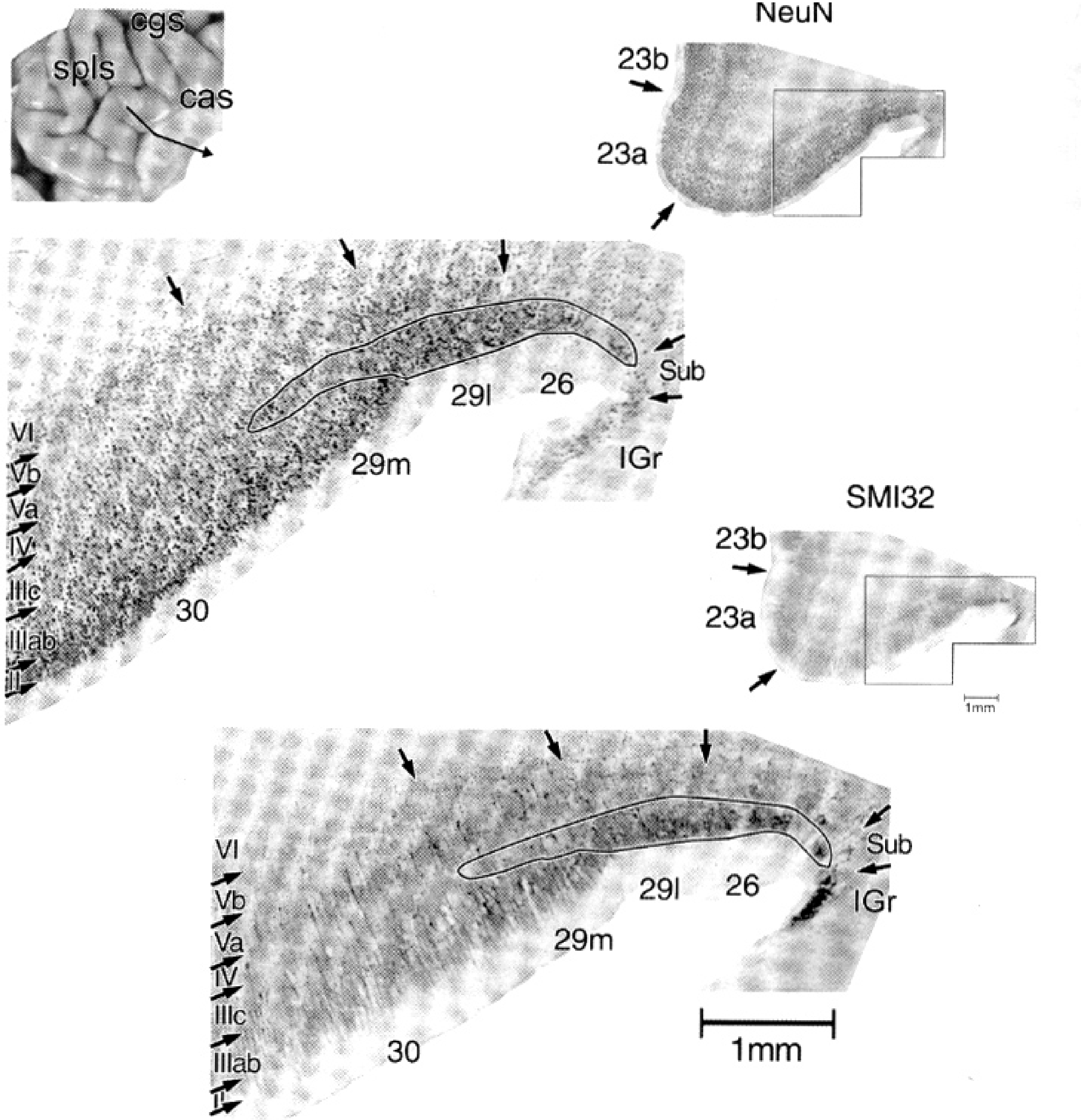
1: Visceral effector; 2: Cognitive effecor; 3: Skeletomotor effector; 4:Sensory processing region (Mega et al., 1997)


A. Regional Morphology
Midcingulate (MCC)
32'
24'
Perigenual
(pACC)
32
24
33
25
SGSR
23
31
Posterior
(PCC)
29,30
Retrosplenial
(RSC)
CMSR
B. Functional Correlates
MCC:
Response Selection
dMCC:
Skeletomotor Control
pACC: Affect
SGSR:
Visceromotor
Control
PCC:
Visuospatial
Processing
RSC:
Memory
Access

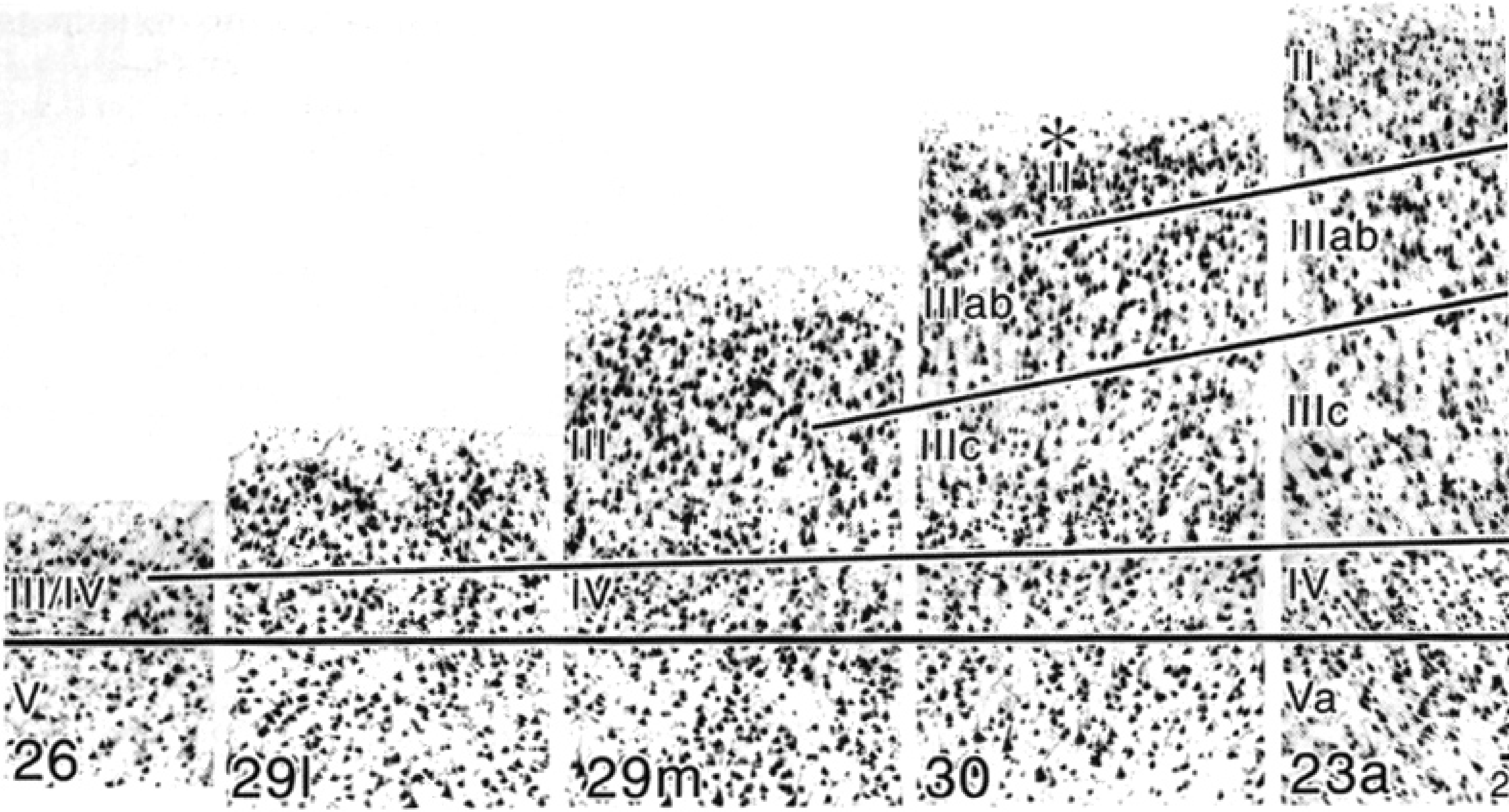
A. Amygdala

B. Inferior Parietal Cortex



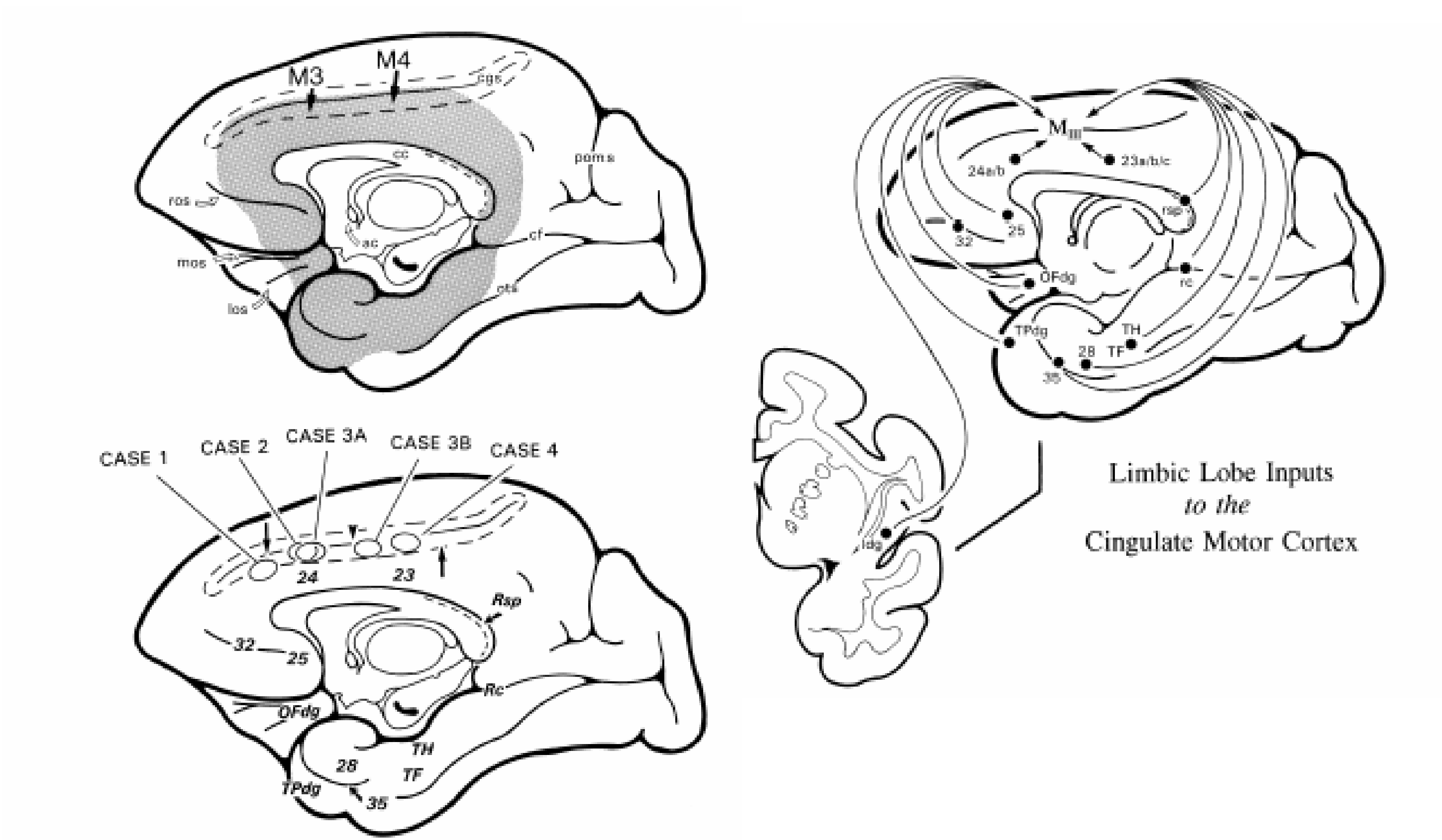


cgs
spls
cas
NeuN
23b
23a
Sub
29l
26
IGr
29m
30
VI
Vb
Va
IV
IIIc
IIIab
II
SMI32
23b
23a
1mm
Sub
29l
26
IGr
29m
30
VI
Vb
Va
IV
IIIc
IIIab
I
1mm

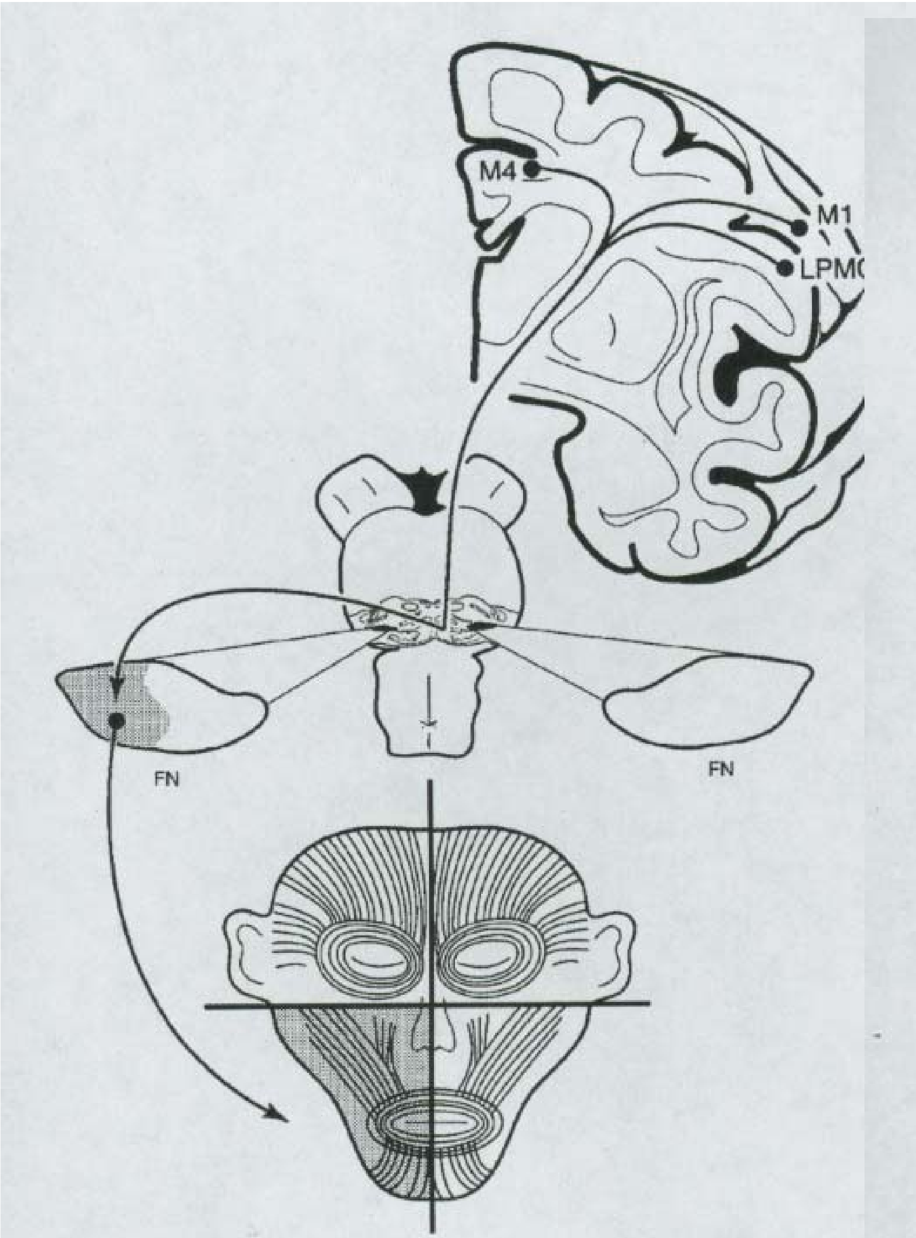


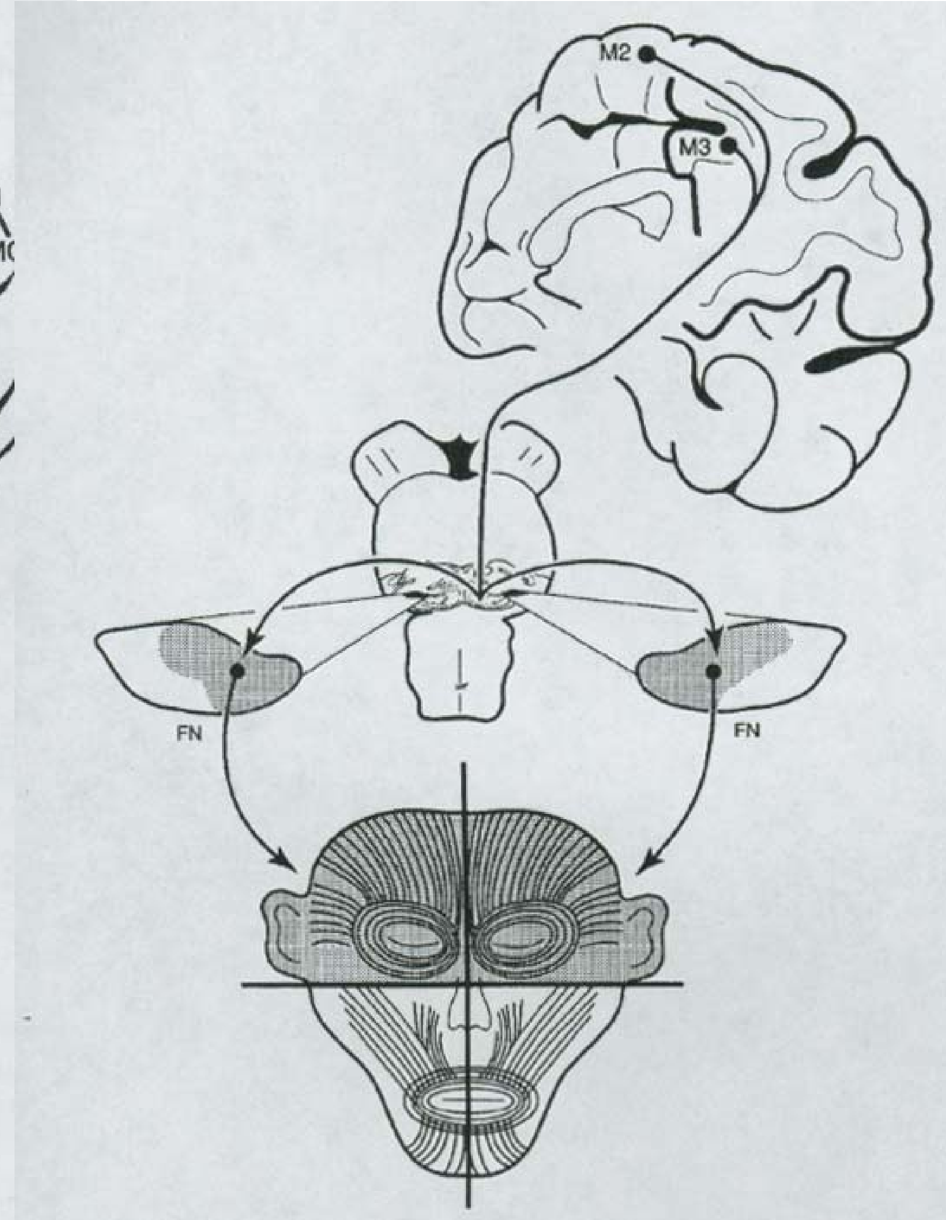
II
*
II
IIIab
IIIab
IIIc
IIIc
III
III/IV
IV
IV
V
Va
26
29l
29m
30
23a

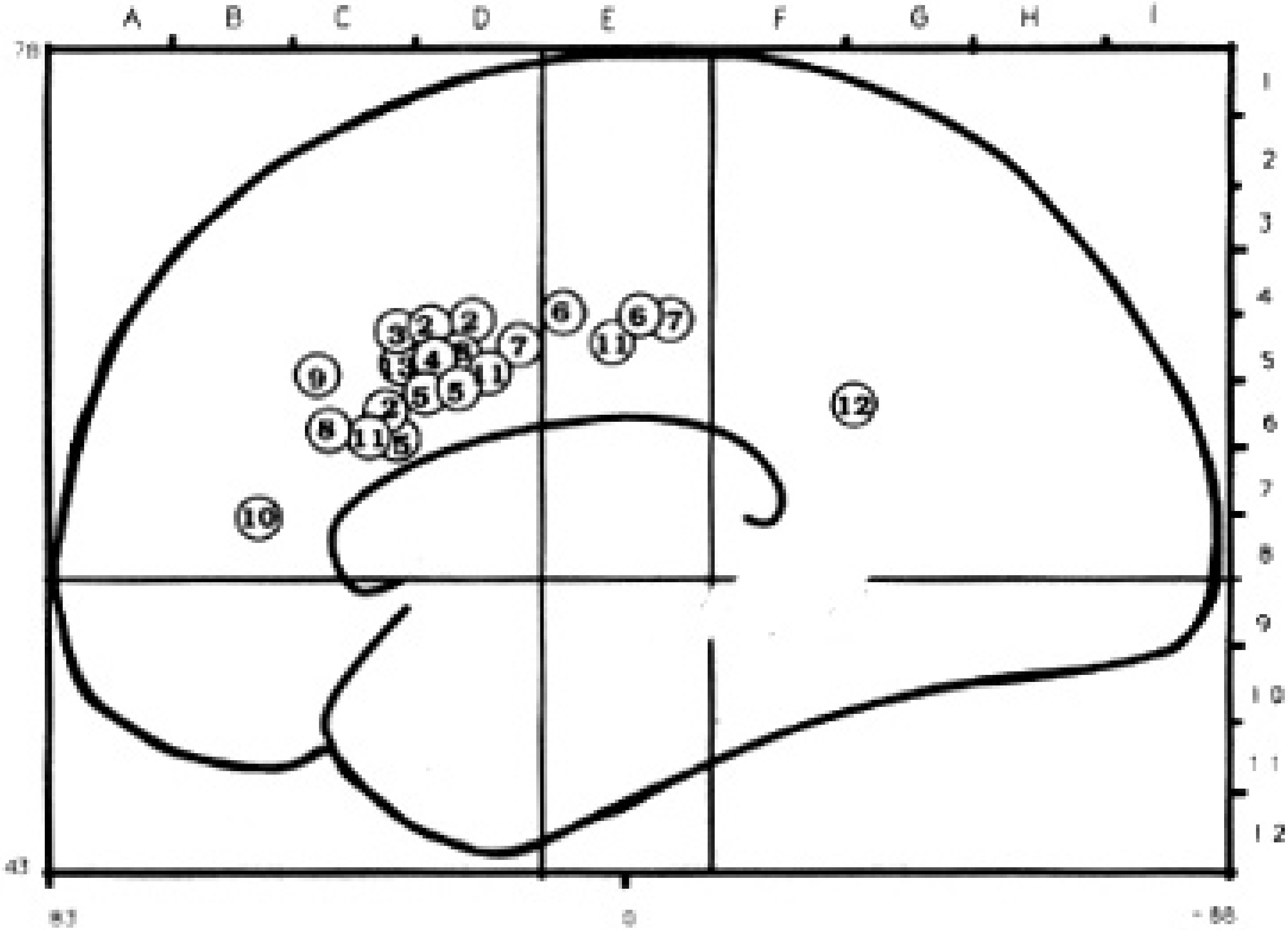
CINGULATE MOTOR AREA AND ITS LIMBIC CONNECTIONS



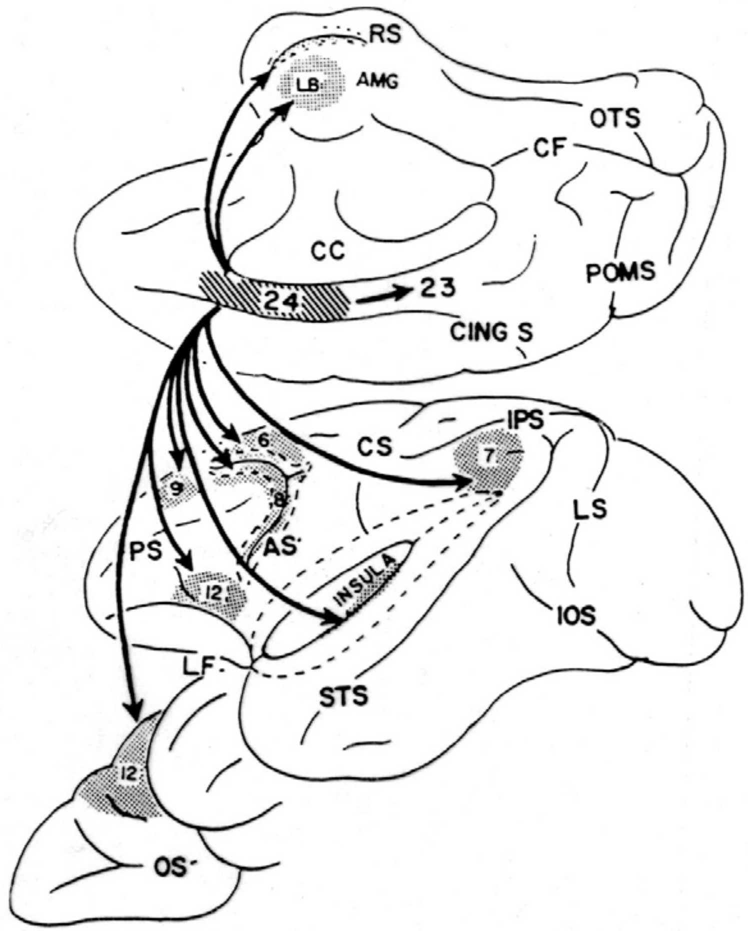
Morecraft and van Hoesen, 1998


M4
M1
LPMC
FN
FN

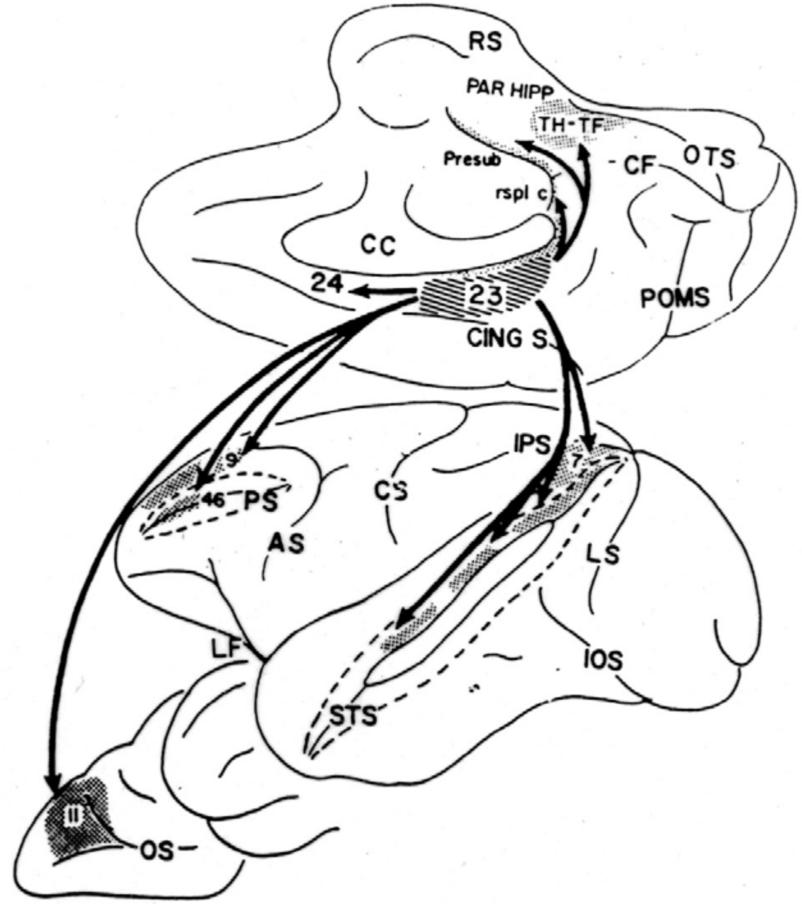

M2
M3
FN
FN



Functional activation in the cingulate cortex. 5 Stroop task; 6-7 thermal pain; 8 divided attention; 10 anticipatory fear; 11 panick attack (From Roland, 1994)



RS
LB
AMG
OTS
CF
CC
24
23
POMS
CING S
6
IPS
CS
7
9
8
LS
PS
AS
INSULA
12
IOS
LF
STS
12
OS



RS
PAR HIPP
TH-TF
Presub
CF
OTS
rspl c
CC
24
23
POMS
CING S
IPS
9
7
46
PS
CS
AS
LS
LF
IOS
STS
11
OS

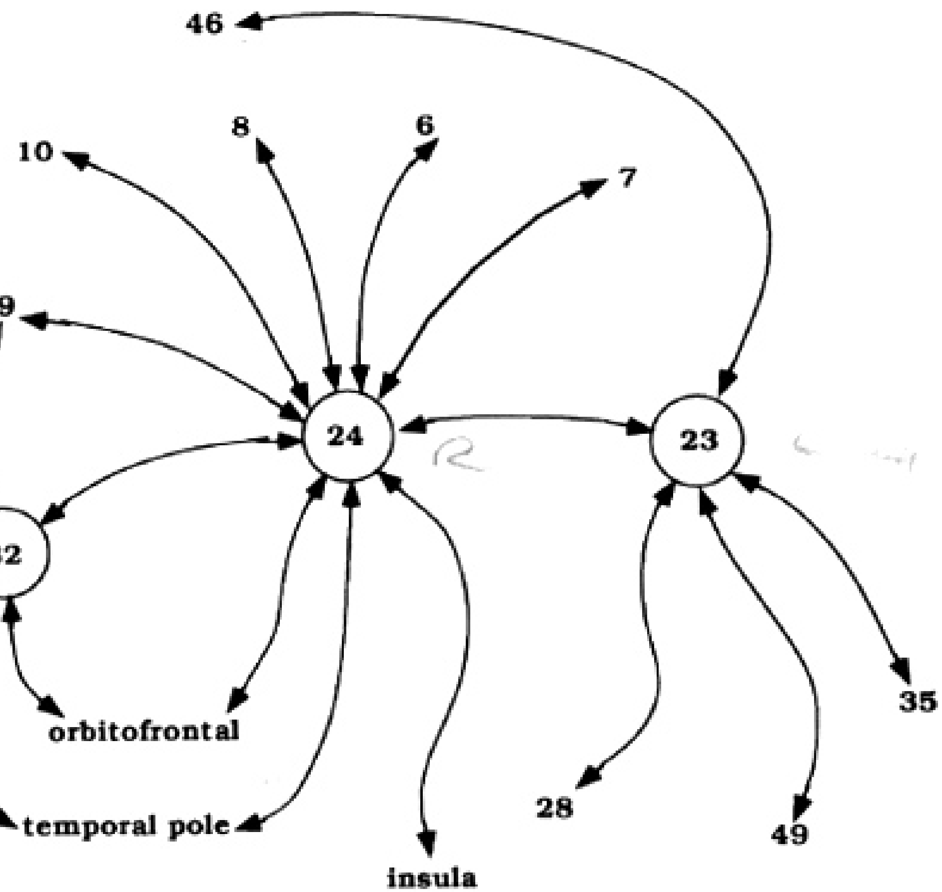
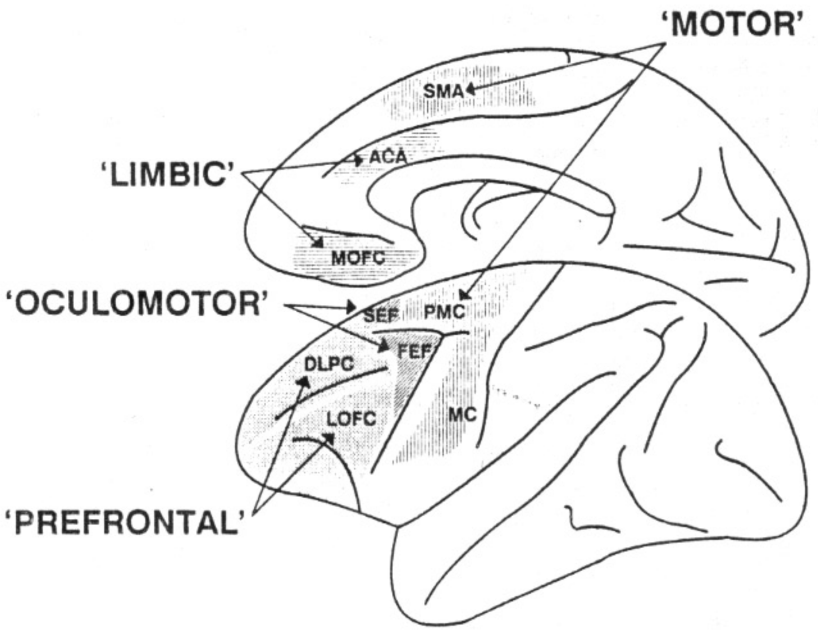
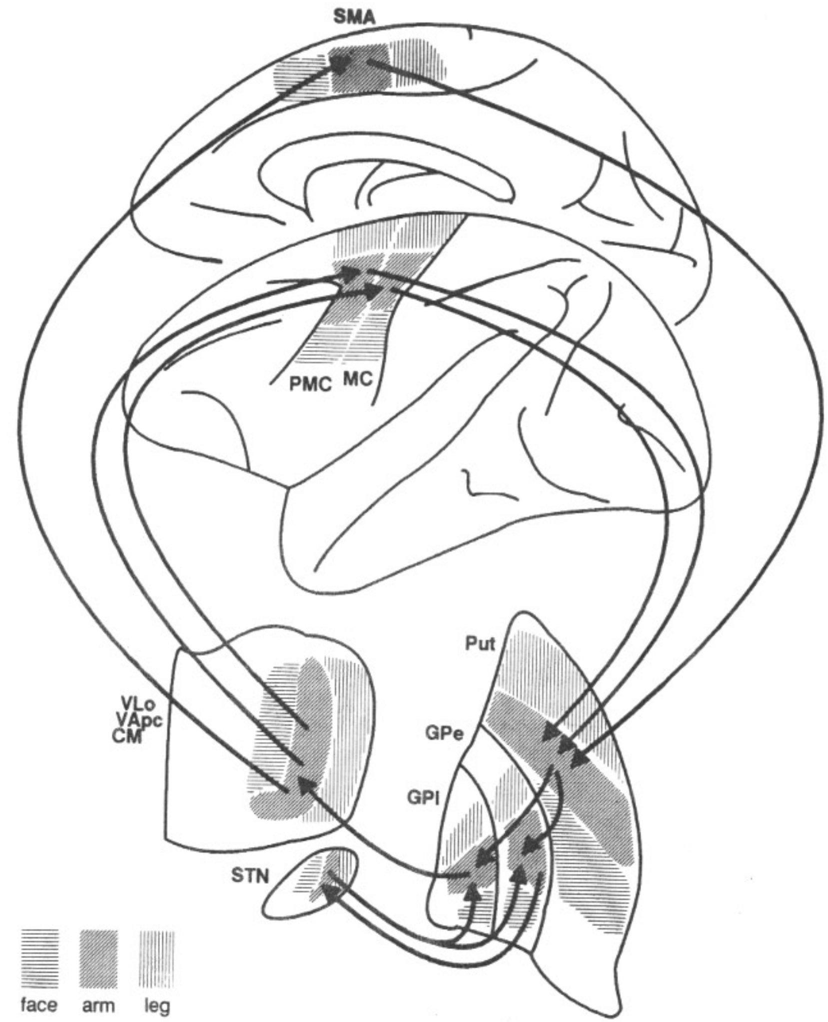


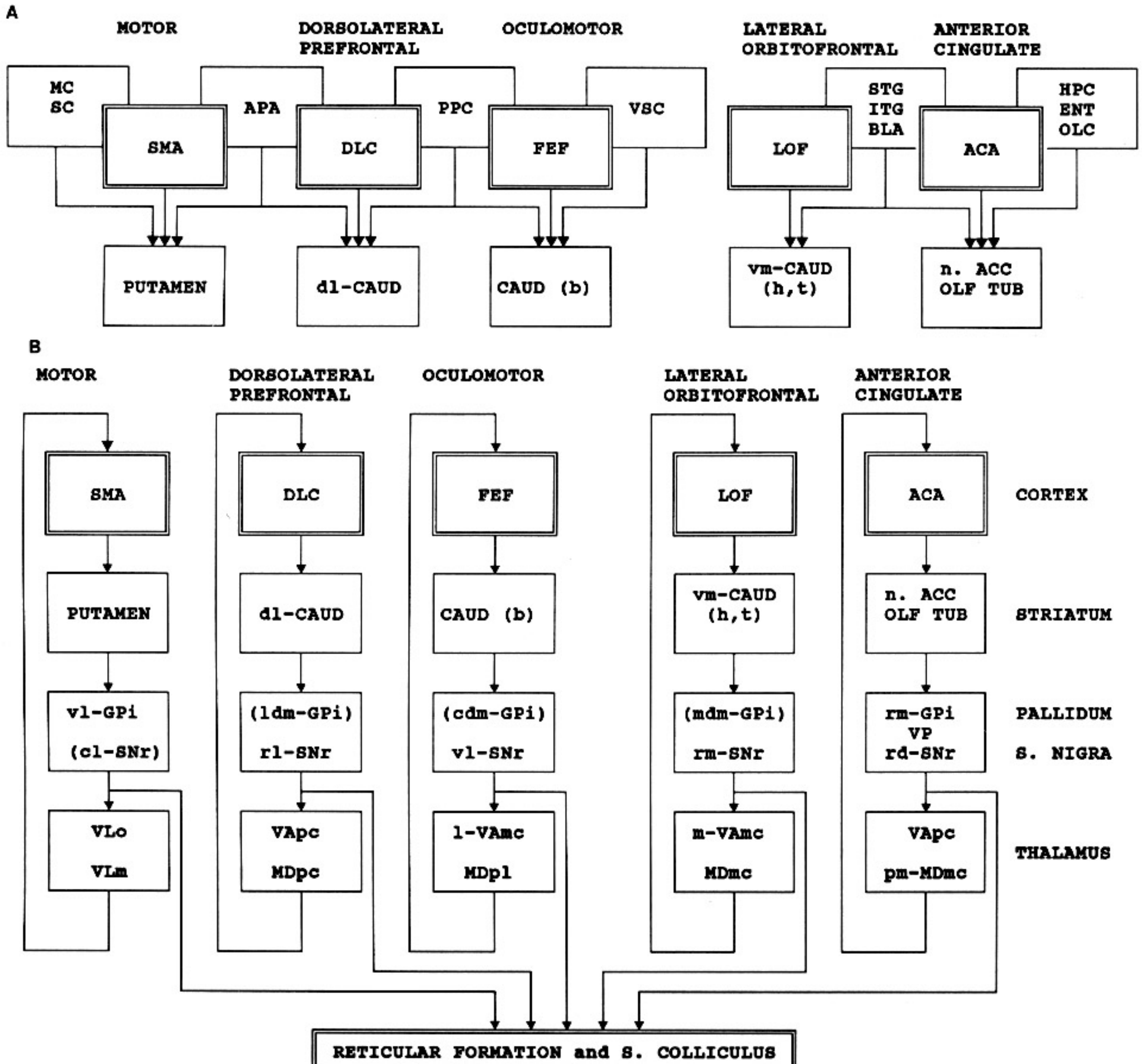
Figure 13.11. Cortical connections of cingulate gyrus. Based on connections in the monkey (Pandya et al., 1981; Baleydier and Mauguière, 1980; Pandya and Yeterian, 1985).

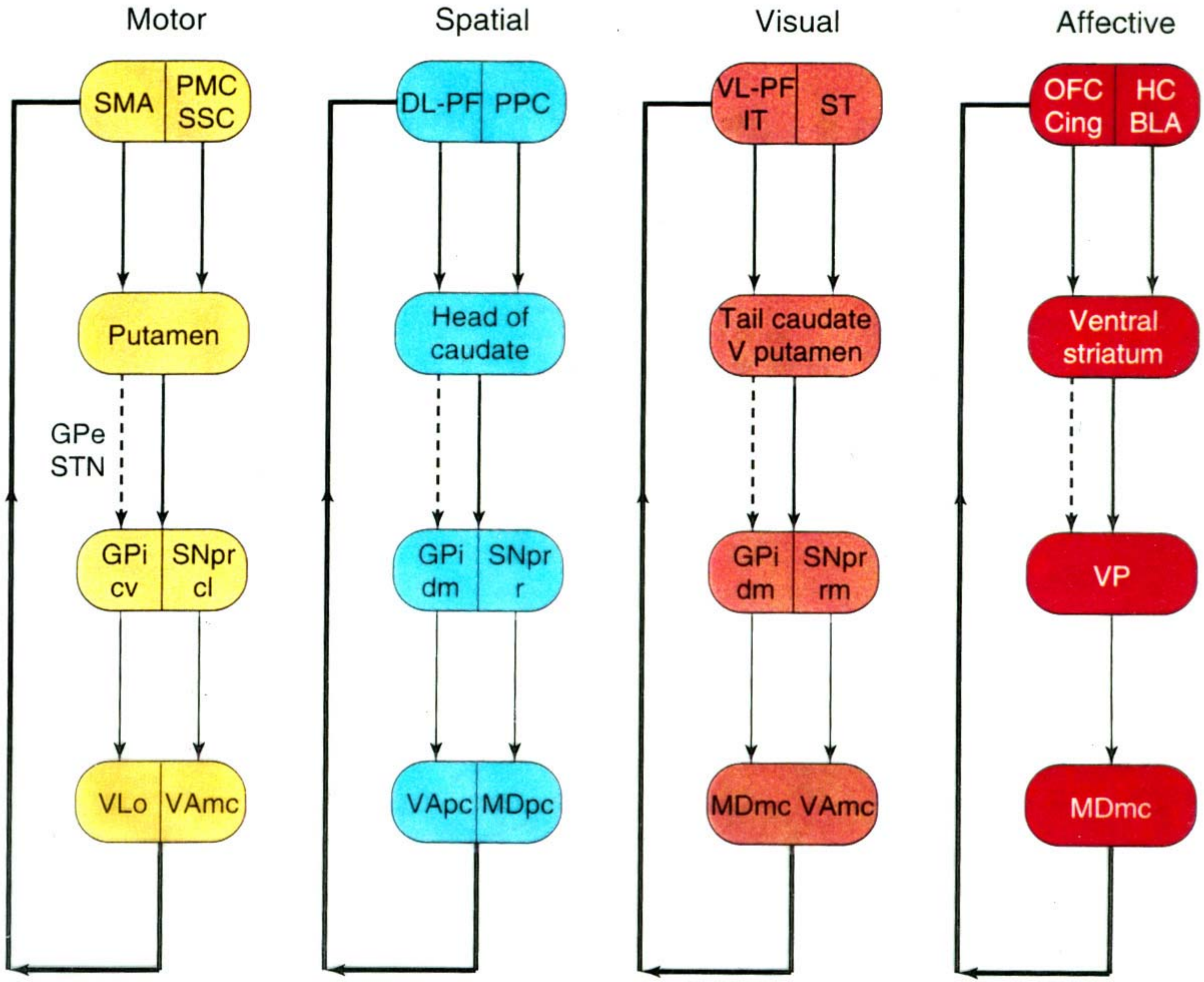


'MOTOR'
SMA
'LIMBIC'
ACA
MOFC
'OCULOMOTOR'
SEF
PMC
FEF
DLPC
LOFC
MC
'PREFRONTAL'



SMA
PMC
MC
Put
VLo
VApc
CM
GPe
GPi
STN
face
arm
leg


A
MOTOR
DORSOLATERAL PREFRONTAL
OCULOMOTOR
LATERAL ORBITOFRONTAL
ANTERIOR CINGULATE
MC
SC
SMA
APA
DLC
PPC
FEF
VSC
LOF
STG
ITG
BLA
ACA
HPC
ENT
OLC
PUTAMEN
dl-CAUD
CAUD (b)
vm-CAUD (h,t)
n. ACC
OLF TUB
B
MOTOR
DORSOLATERAL PREFRONTAL
OCULOMOTOR
LATERAL ORBITOFRONTAL
ANTERIOR CINGULATE
SMA
DLC
FEF
LOF
ACA
CORTEX
PUTAMEN
dl-CAUD
CAUD (b)
vm-CAUD (h,t)
n. ACC
OLF TUB
STRIATUM
vl-GPi
(cl-SNr)
(ldm-GPi)
rl-SNr
(cdm-GPi)
vl-SNr
(mdm-GPi)
rm-SNr
rm-GPi
VP
rd-SNr
PALLIDUM
S. NIGRA
VLo
VLm
VApc
MDpc
l-VAmc
MDpl
m-VAmc
MDmc
VApc
pm-MDmc
THALAMUS
RETICULAR FORMATION and S. COLLICULUS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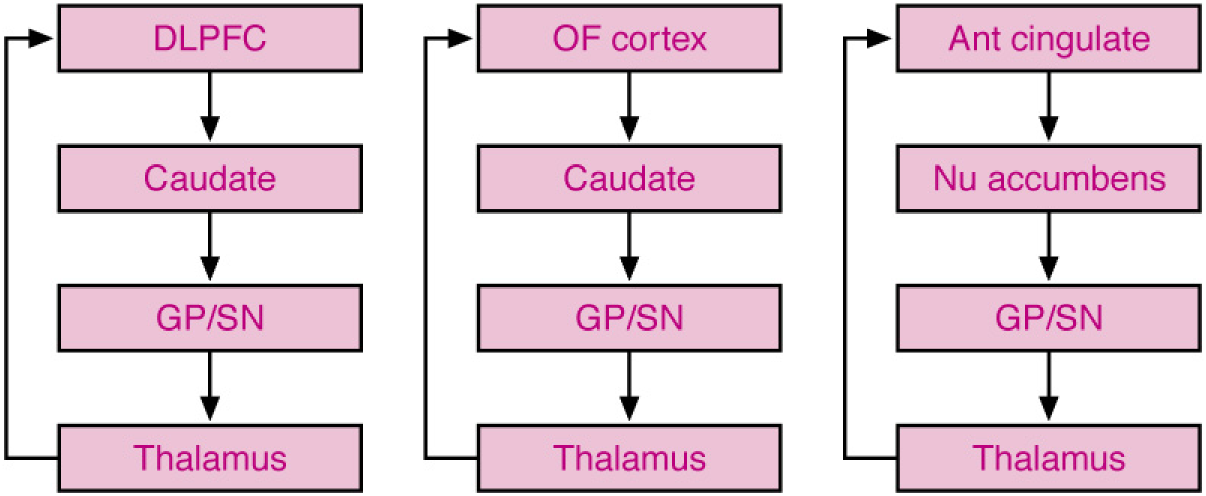
executive social behavior motivation

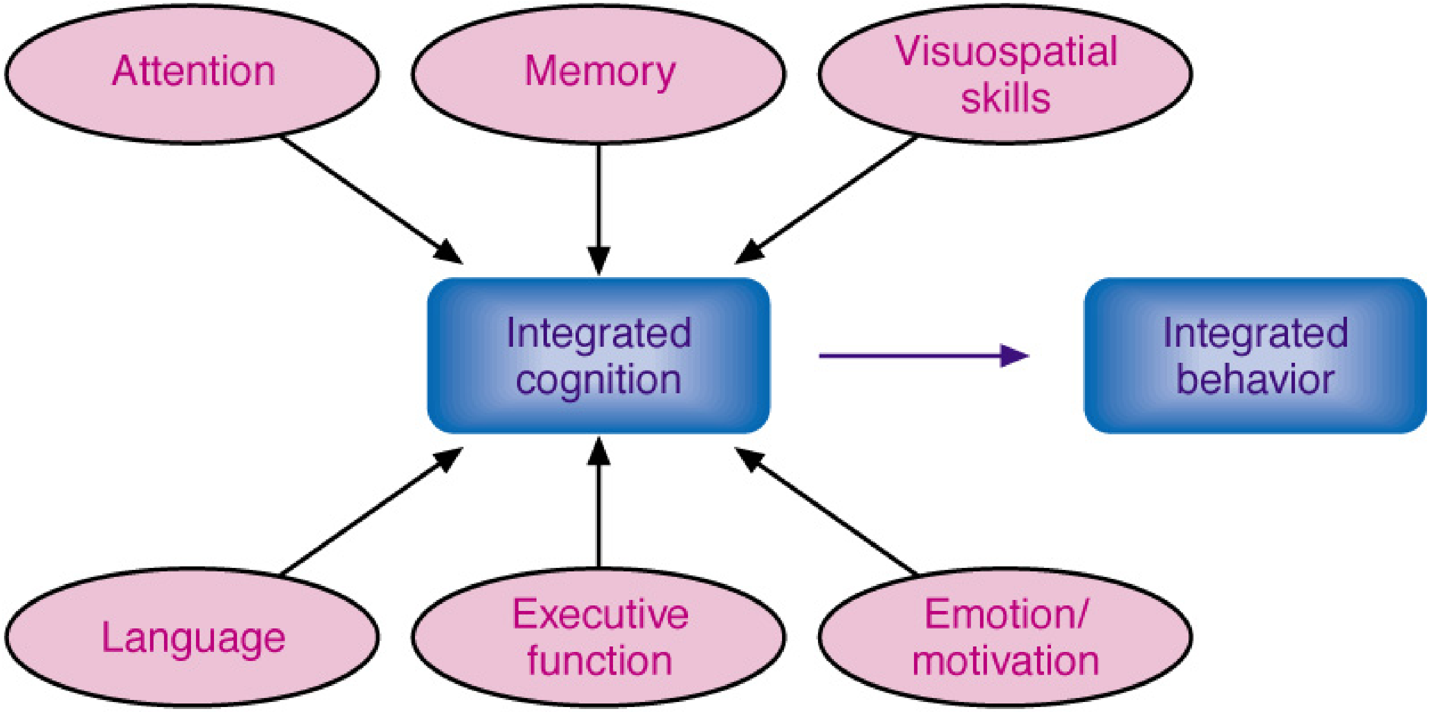


Three behaviorally relevant frontal-subcortical circuits.. DLPFC, dorsolateral prefrontal cortex; GP, globus pallidus; SN, substantia nigra; Nu accumbens, nucleus accumbens; Ant cingulate, anterior cingulate; OF, orbitofrontal.

inability to focus and direct cognitive processes and to resist distraction, unable to focus and sustain attention over a period of time

retrieval deficit with poor recall (frontal variant of AD); recognition (amnestic) for recently learned info (both semantic and episodic) [parietal-temp lesion]

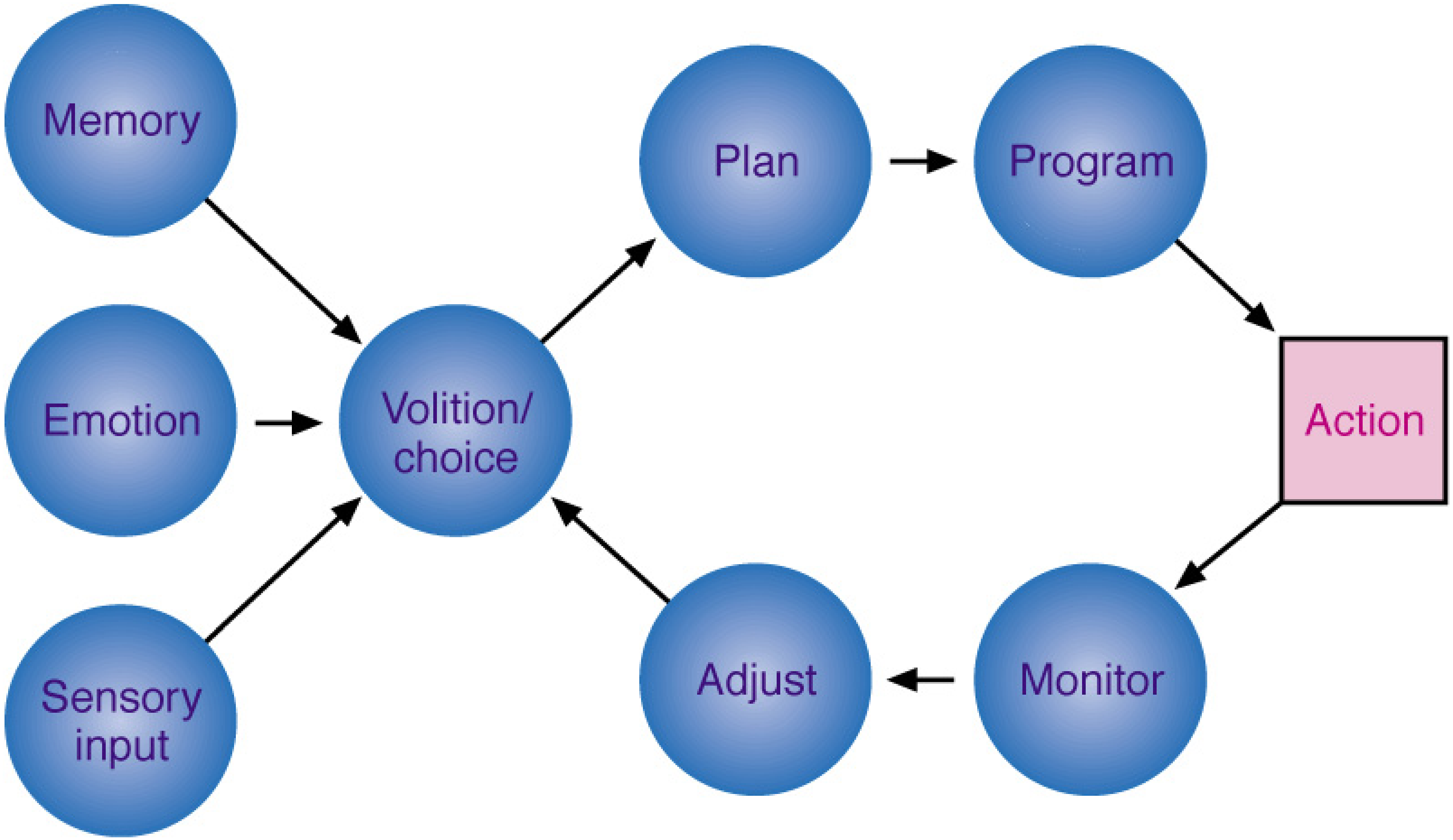
difficulty copying complex figures, problems with route finding and dressing



anomia progressing to TCS aphasia; echolalia and palilalia late in course.
TCS: Disturbance of single word comprehension with relatively intact repetition

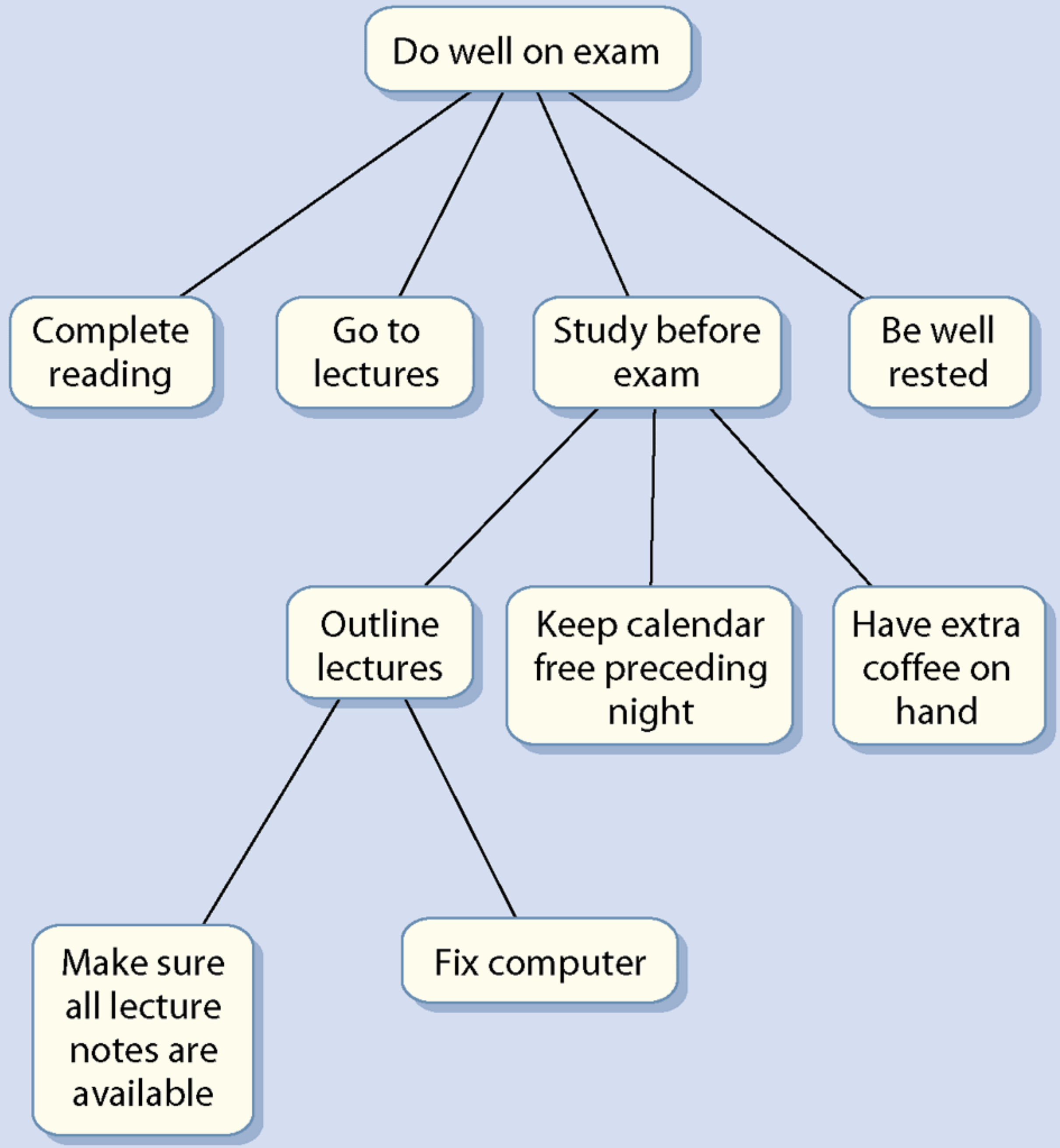
poor judgment, impaired insight, poor strategy, abstraction, planning inability to adjust to novelty, impaired motor programming, difficulties with set shifting, behavioral inhibition, reduced initiation, imitation, inability to withhold responses, distractibility, intrusions, perseveration, reduced responses to feedback

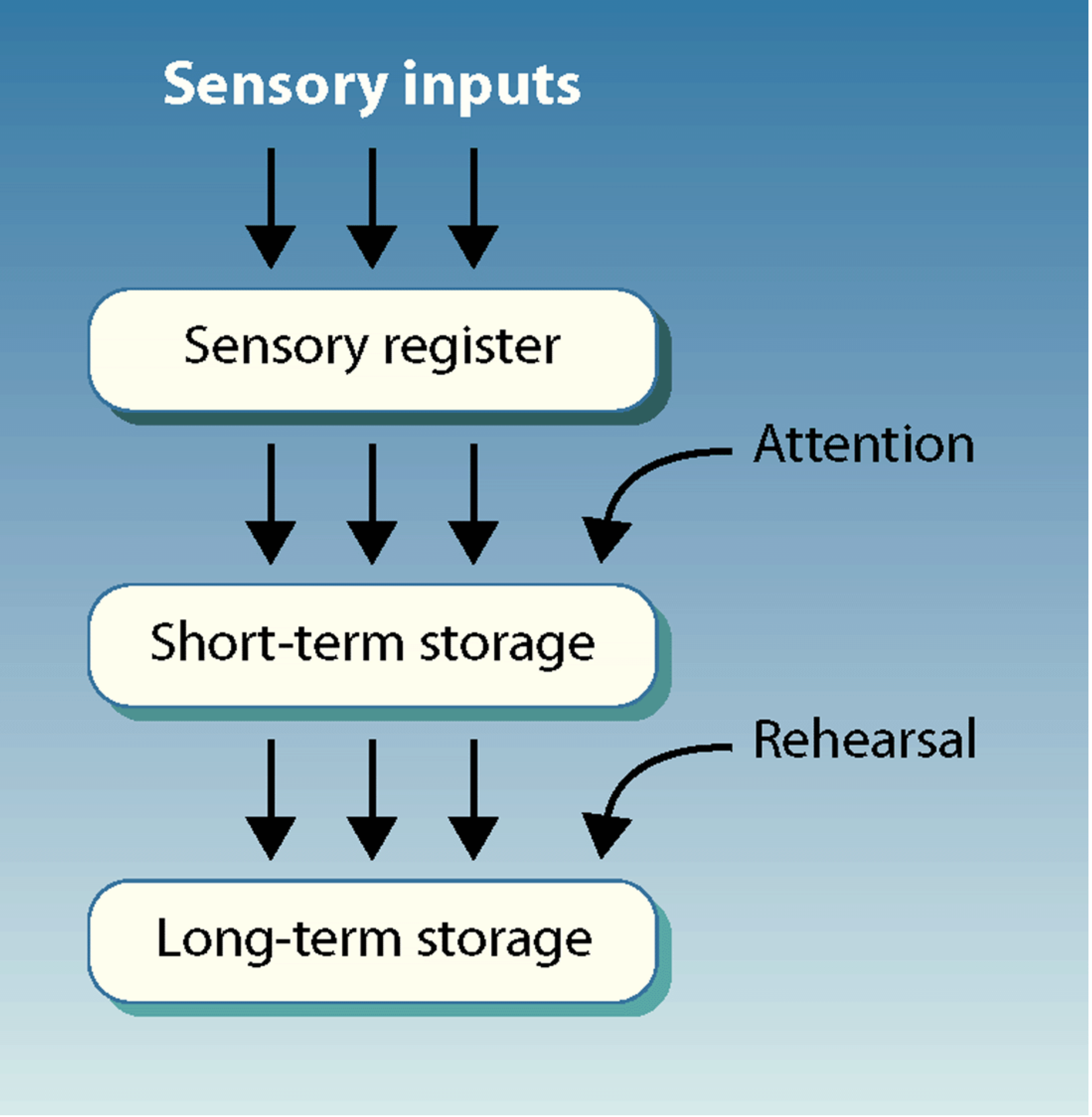
apathy, depression, agitation, anxiety, obsessive symptoms, sexual changes, euphoria, Psychosis (delusion, hallucinations) component mechanisms involved in executive functions



GOAL DIRECTED BEHAVIOR

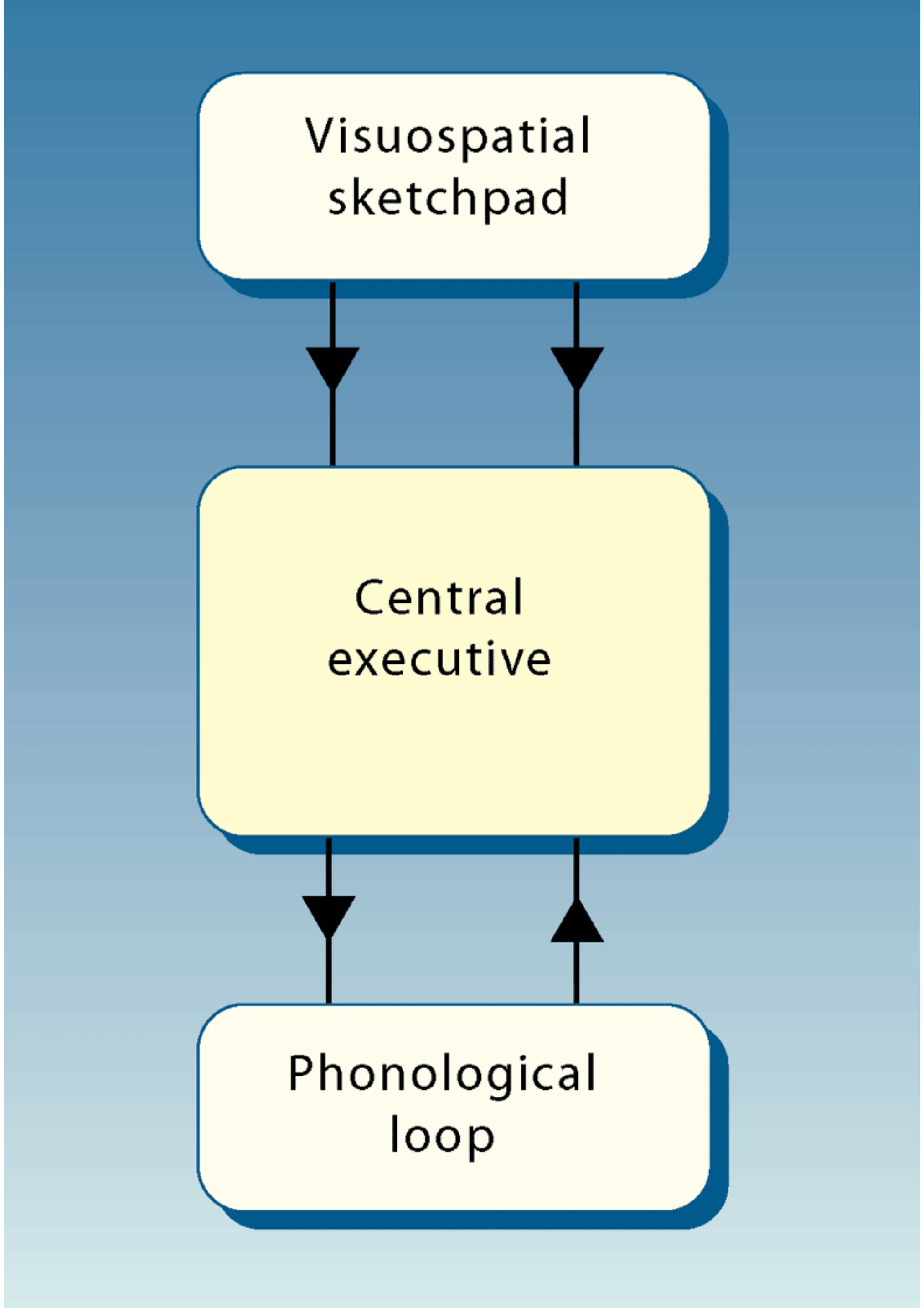
1. Planning: identify goals, develop subgoals.
2. Receive information about goals and means. Rule learning. Reward
3. Selection of task relevant information- selection of responses (focusing, attention)
4. Determine what temporal order is required to achieve the subgoals
5. Switching tasks, when necessary
6. Monitoring progress





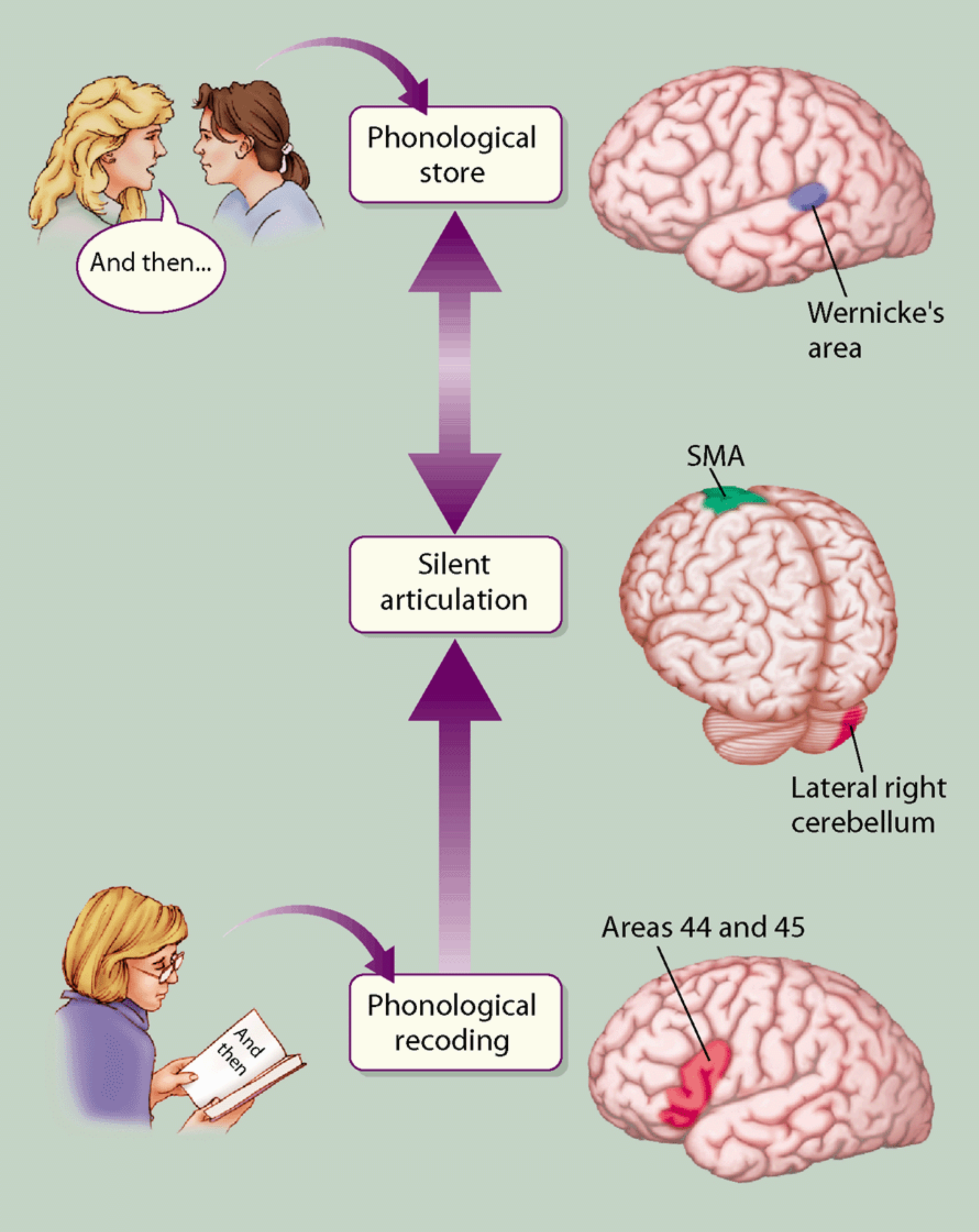
SHORT-TERM MEMORY-LONG-TERM MEMORY

Atkinson-Shiffrin model. Sensory information enters the information-processing system and is first stored in a sensory register. Items that are **selected via the attentional process** are then moved into short-term storage. With rehearsal, the item can be moved from short term to long- term storage. The shortcomings of this model led to the working memory models



Baddeley's model of working memory (Baddeley and Hitch, 1974). Working memory entails 3 components: a central executive (**attentional**) and two (independent) subsystems: one for sustaining (rehearsing) **visuospatial** representations and the other for sustaining verbal representations in a **phonological** (acoustical coding) format (covert articulatory rehearsal).

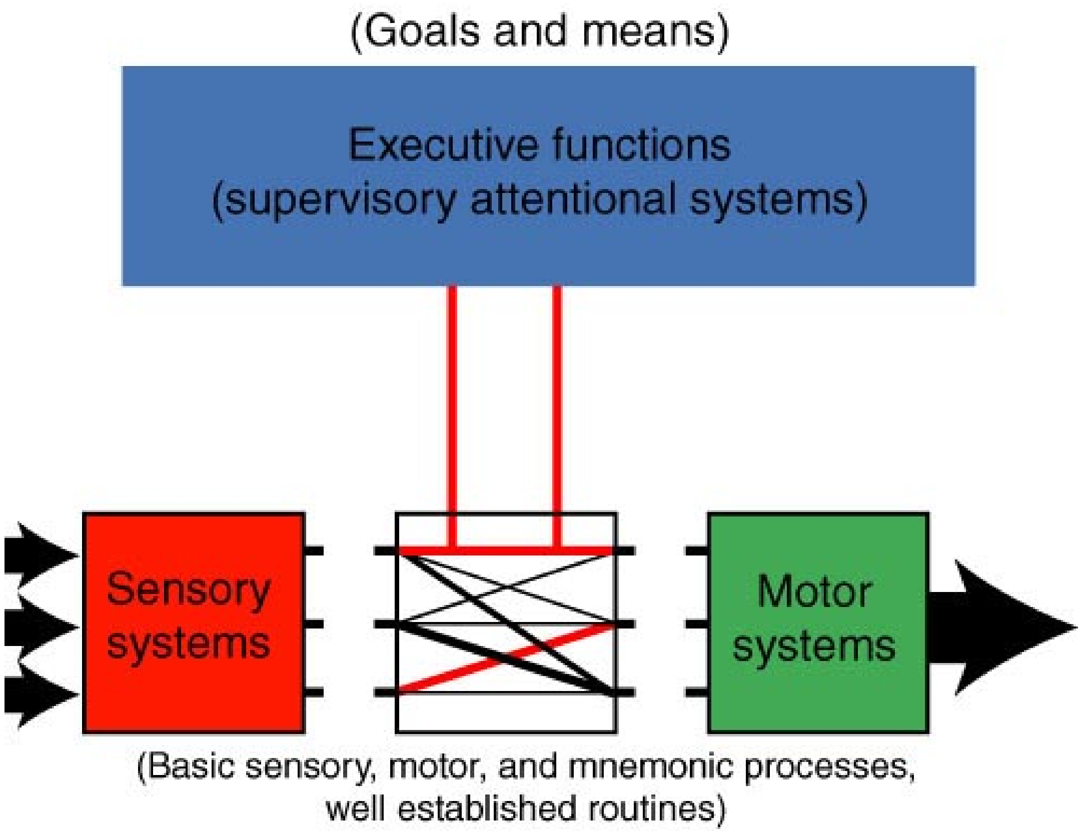
Evidence about the distinct nature of these subsystems comes from studies of patients with specific brain lesions.



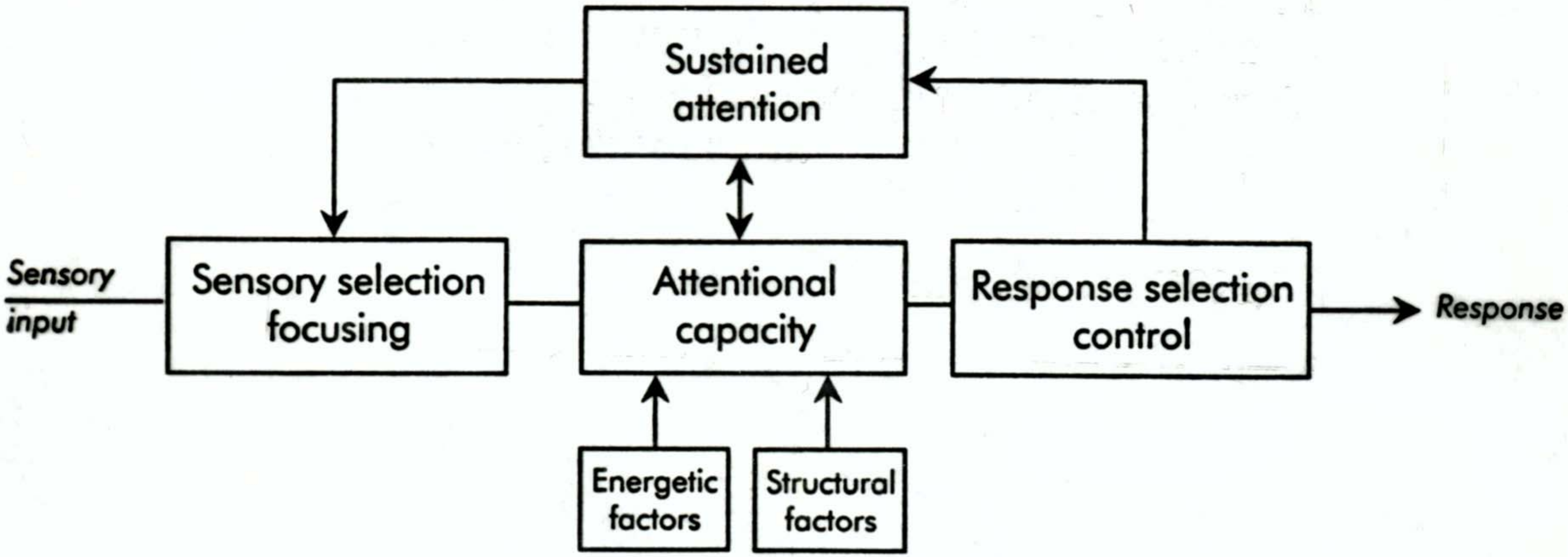
COMPONENTS OF THE PHONOLOGICAL LOOP

For task remembering a list of read words, the phonological loop is hypothesized to be composed of 3 components: areas **left** 44-45, **left** SMA, lateral **right** cerebellum and **left** Wernicke' area-supramarginal gyrus (Gazzaniga, 2002).

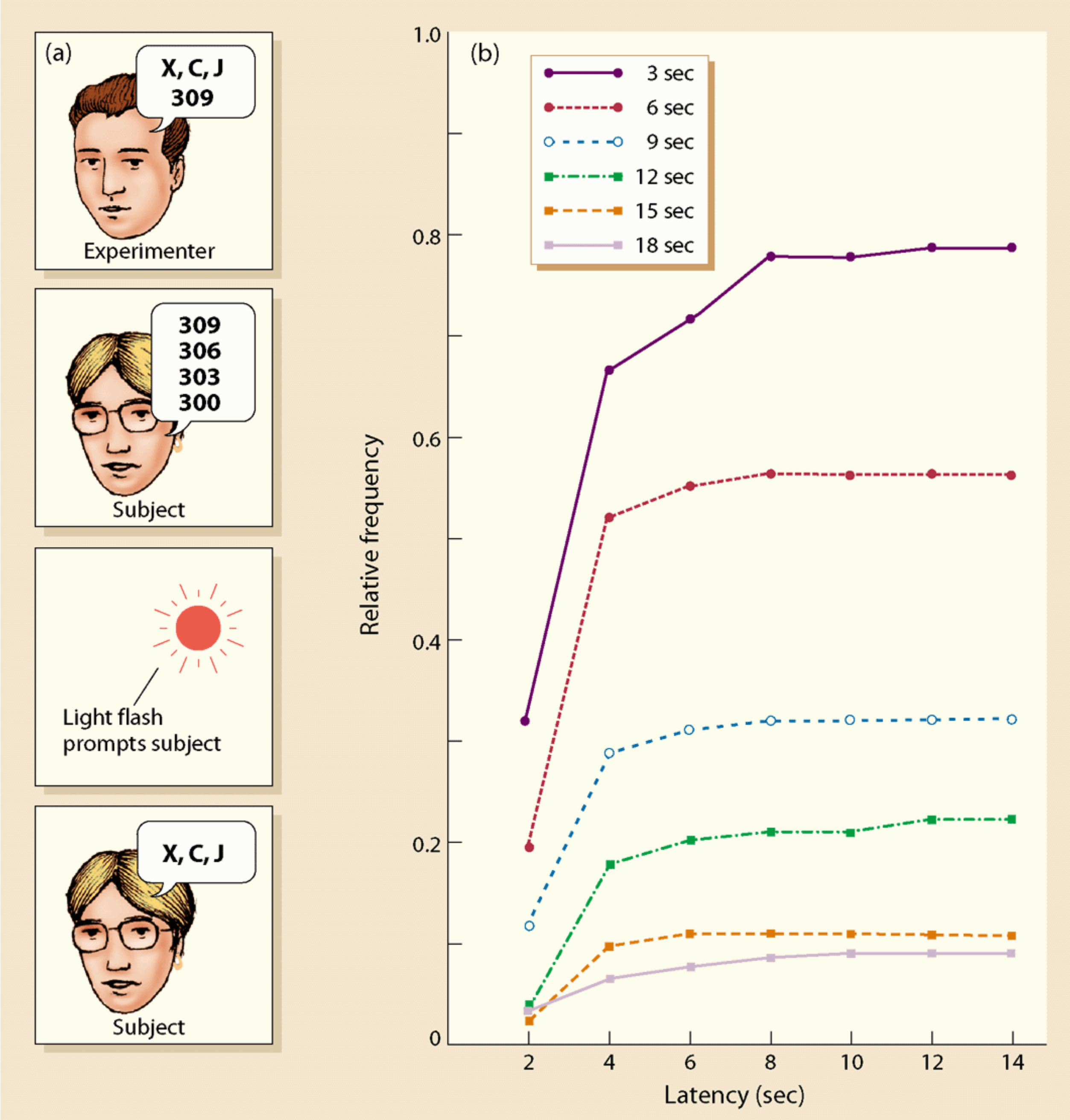
The **visuospatial sketchpad** is compromised by damage to the **parieto-occipita**l region of both hemispheres, but damage to the **right** hemisphere produces more severe deficits in visuo-spatial short-term memory.



Two levels of cognitive processes proposed by Norman and Shallice. Represented here is the notion that specialized functions that acquire information about goals and means select and coordinate among innate and well-established routines. Active processing lines are indicated by red

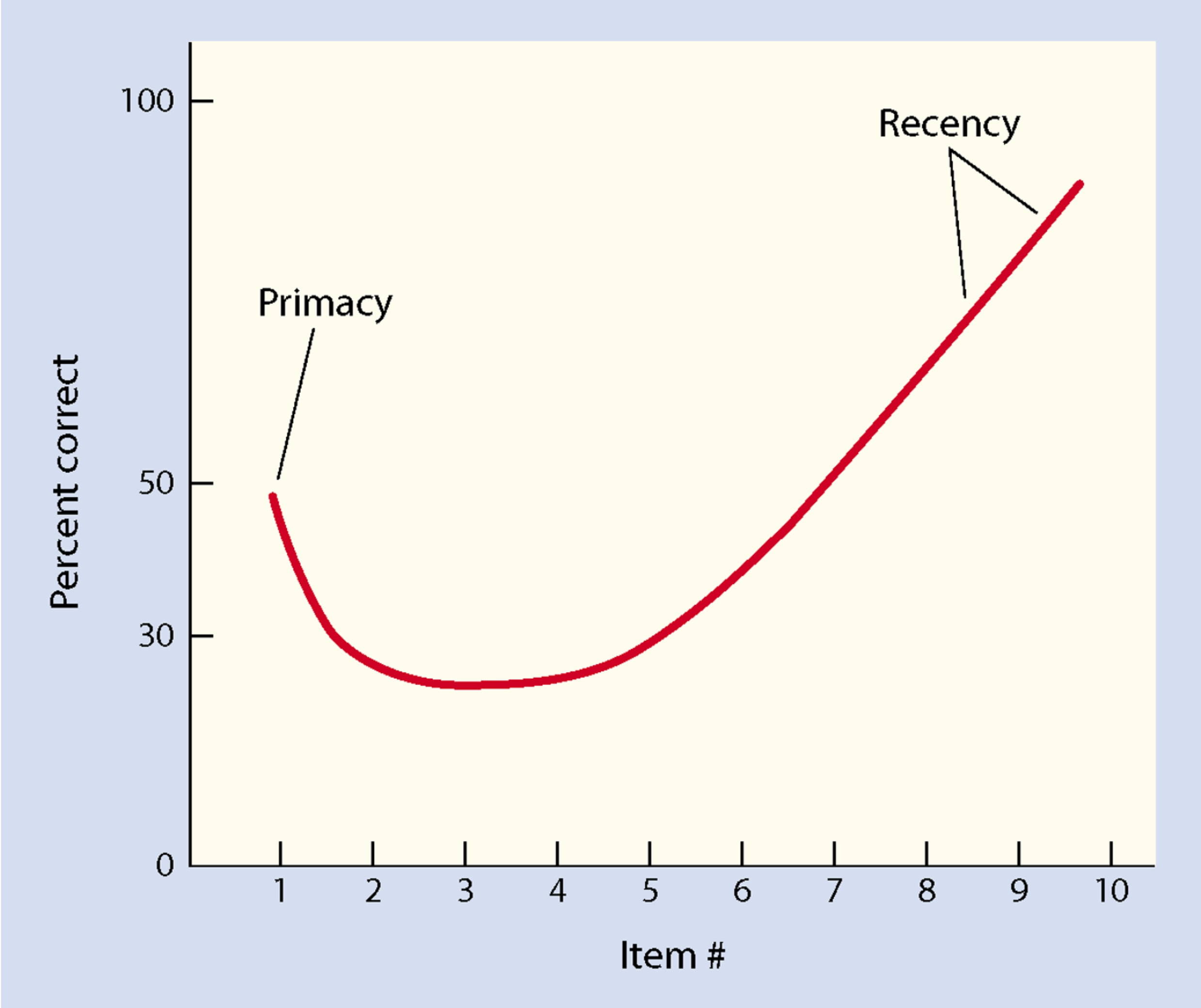


Primary factors underlying attention. This model depicts the flow of information through the four major components of attention: 1) sensory selection, 2) response selection control, 3) capacity, and 4) sustained attention. Attentional capacity is influenced by energetic and structural components. Sustained attention is the product of the information flow through the system and the resulting feedback, which affects each factor.

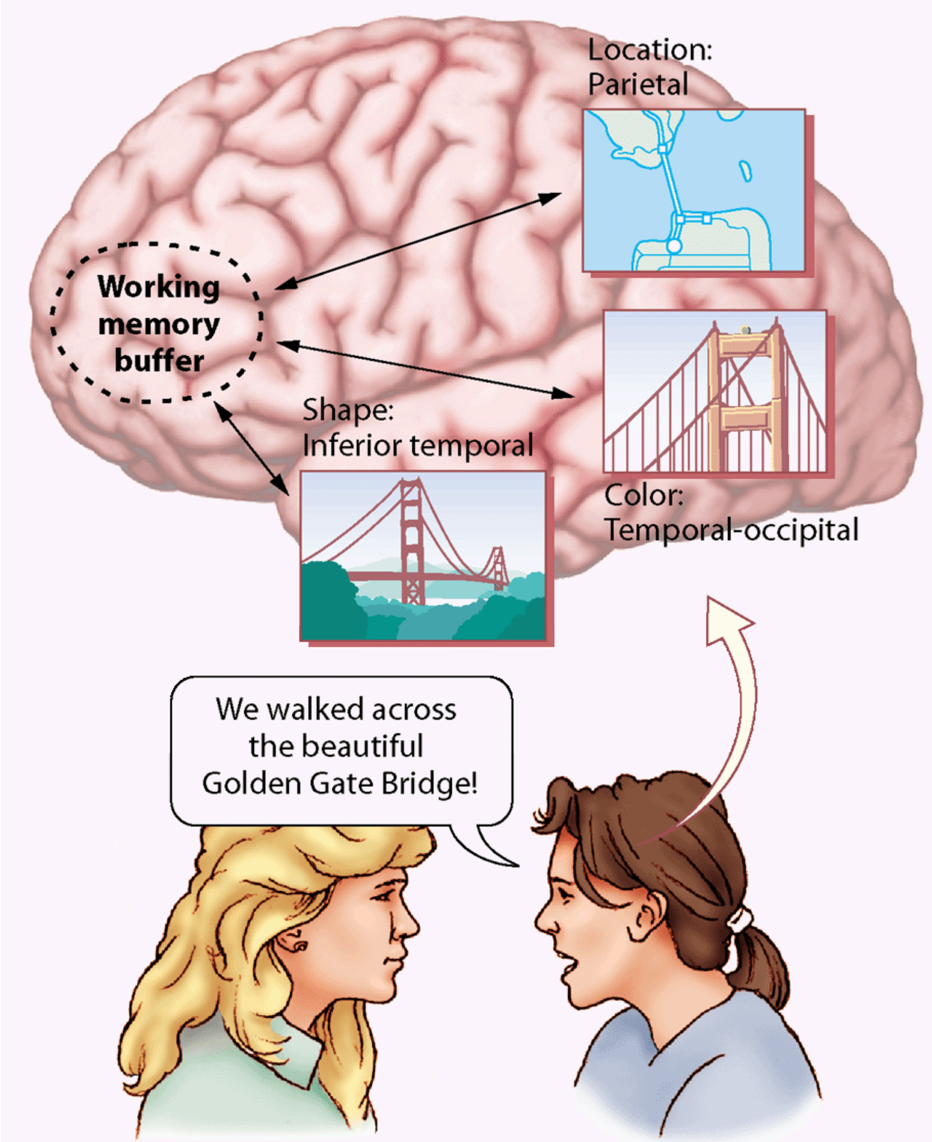


SHORT-TERM MEMORY

Volunteers are presented with three letter consonants. Even after 30 sc subjects remember the consonant strings when they were permitted to rehearse (silently). However, if between the presentation of the letter and the cue (3-18 sec), the subjects were distracted from rehearsing the letters by asked to perform mental arithmetic such as backward subtraction, by 18 sec the percentage of correct responses dropped below 10%



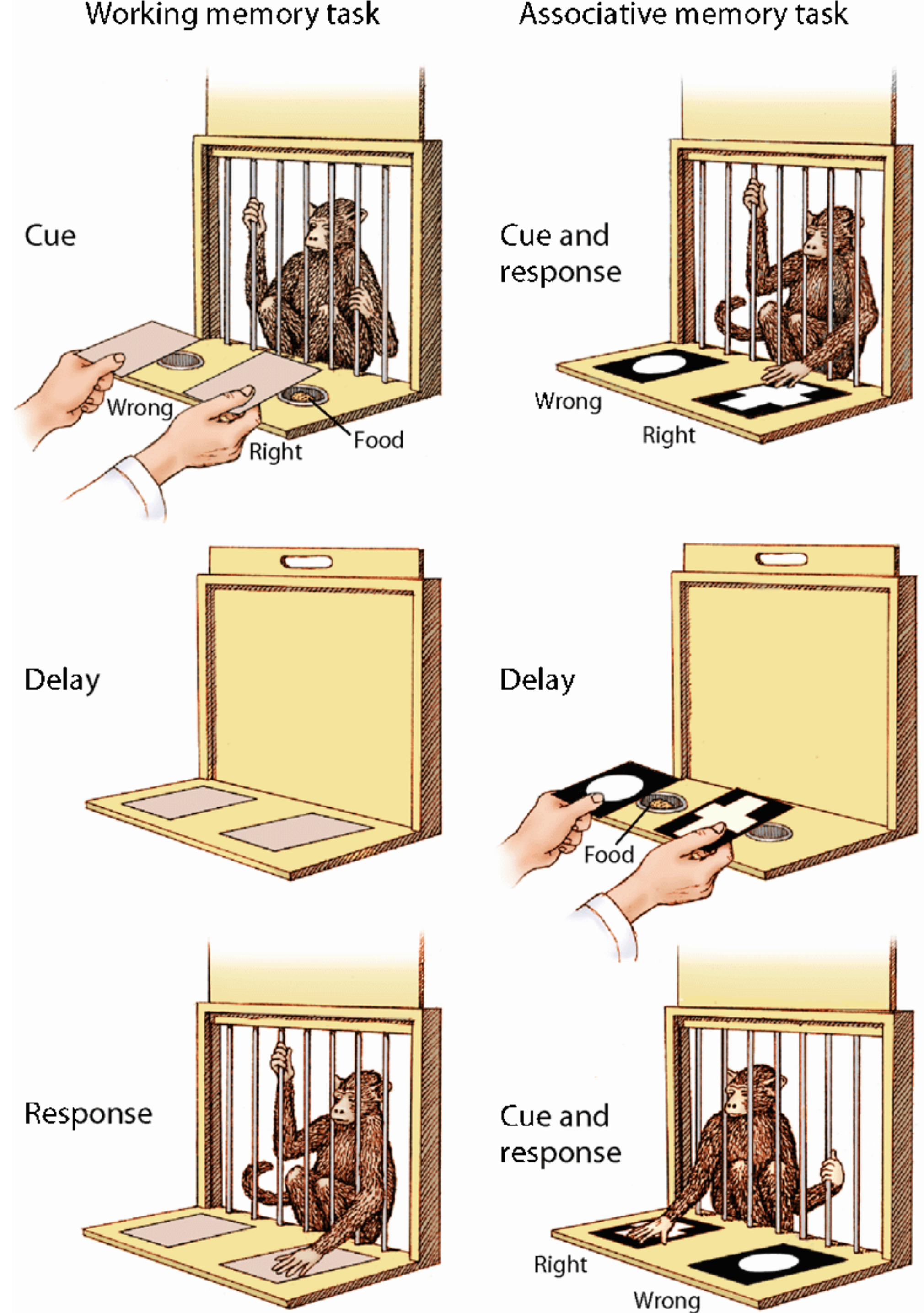
Serial position effect. The percentage of items recalled is plotted as a function of the item's position in the list. Primacy and recency effects are represented by the better recall of items at the beginning and at the end of the list. It is suggested that the primacy effect is related to quick transfer of information from short to long term memory. Primacy effect can be eliminated if the list items were presented more quicly, a manipulation that did not effect recency. On the other hand, the recency effect reflects retention in short term memory. Introducing distractors that interfere with rehearsal eliminate the recency effect.(Gazzaniga, 2002)



WORKING MEMORY

Representing, maintaining and manipulating information that is not immediately present in the environment. It allows for the interaction of current goals with perceptual information and knowledge accumulated from past experience. Its time course from seconds to minutes and is readily available to conscious awarness. The content of working memory might originate from sensory inputs by way of sensory memory but also might be retrieved from long-term memory. In any case working memory contains information that can be acted on and processed, not merely maintained by rehearsal, although this is one aspect of working memory.

Lateral PFC may provide a transient buffer for sustaining information in other cortical regions. In this example the person is telling a friend about her walk across the Golden-Gate bridge. Long term knowledge is reactivated and temporarily maintained through the reciprocal connections between the PFC and more posterior regions. Note that the long-term memories of the GGB are stored in dimension-specific cortical regions (Gazzaniga, 2002).



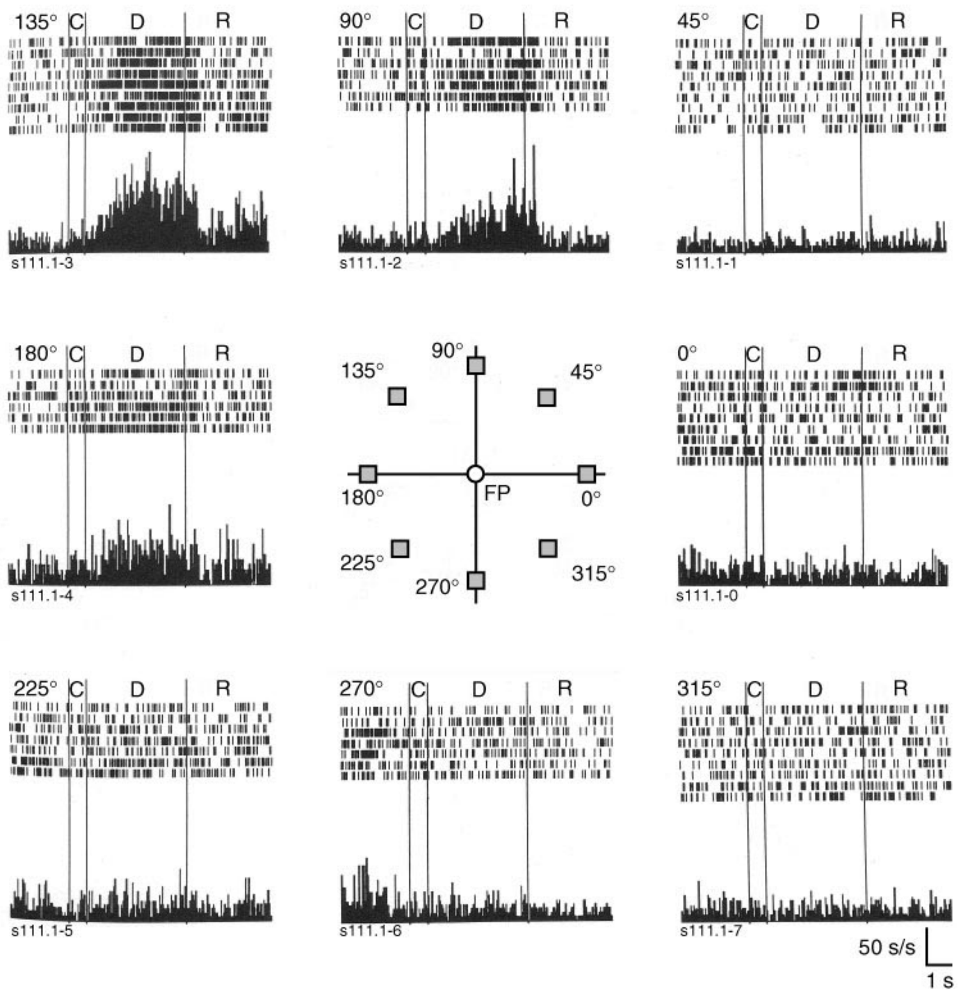
WORKING MEMORY DEFICIT: DELAYED RESPONSE TASK

Monkeys with prefrontal lesions demonstrate selective impairment on the working memory delayed-response task (L). In the working memory task, the monkey sees one well baited with food. After a delay period, the animal retrieves the food. The location of the food is determined randomly. In the associative memory task, the food reward is always associated with one of the visual cues. The location of the cues (and food) is determined randomly. Working memory is required in the first task because, at the time the animal responds, there are no external cues indicating the location of the food. Long-term memory is required in the second task since the animal must remember which visual cue is associated with reward (Goldman-Rakic, 1992; Gazzaniga, 2002).

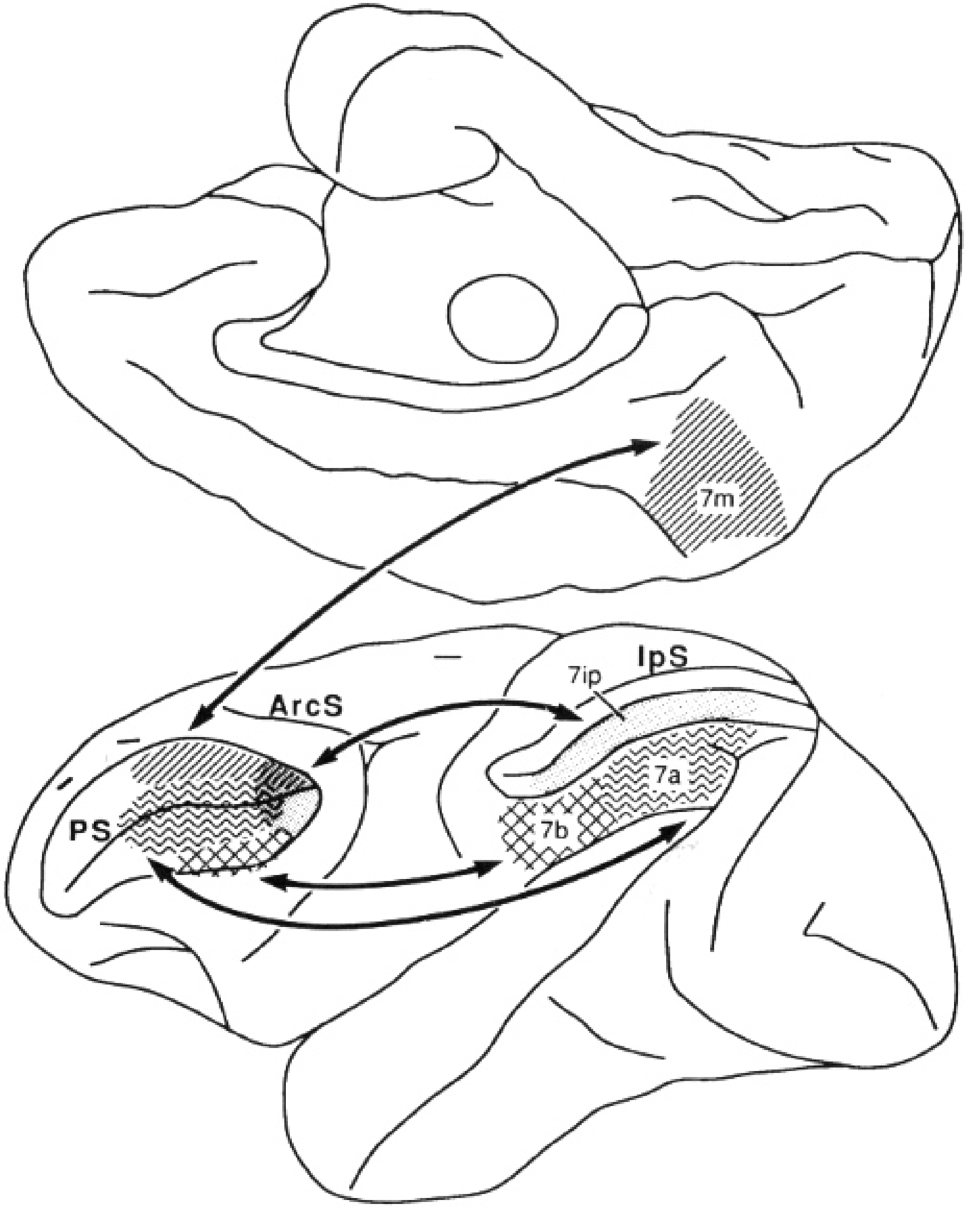
CELLULAR BASIS OF WORKING MEMORY

PFC delay activity. The activity of a single PFC neuron during five trials of a spatial delayed response task is shown. The arrow indicates the monkey's behavioral response at the end of the memory delay. Each small vertical line indicates an action potential from the neuron. Note the increased activity in the delay relative to other epochs. From Fuster (1973).

SPATIAL-DELAYED RESPONSE TASK



Activity of a single PFC neuron during performance of an oculomotor spatial delayed response task. Each trial starts with the monkey fixating the central fixation point (FP) indicated in the central diagram. Then, a cue light (C) was flashed briefly on in one of the eight locations indicated in the central diagram. After a delay (D), the monkey was allowed to respond (R) by moving its eyes to the remembered location of the cue. Neural activity from cuing each location is shown by the corresponding histogram. This neuron exhibited delay period activity when the cue to be remembered was presented in the upper left quadrant of the visual field. Scale bars in the lower right indicate 1 s of time (1 S) and 50 spikes per second of neural activity (50 S/S). From Funahashi *et al*. (1989).



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7ip
ArcS
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PS
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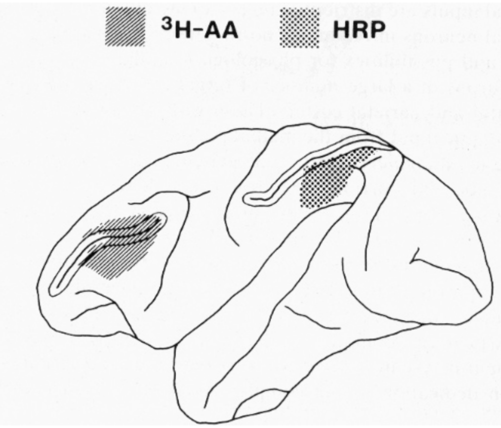
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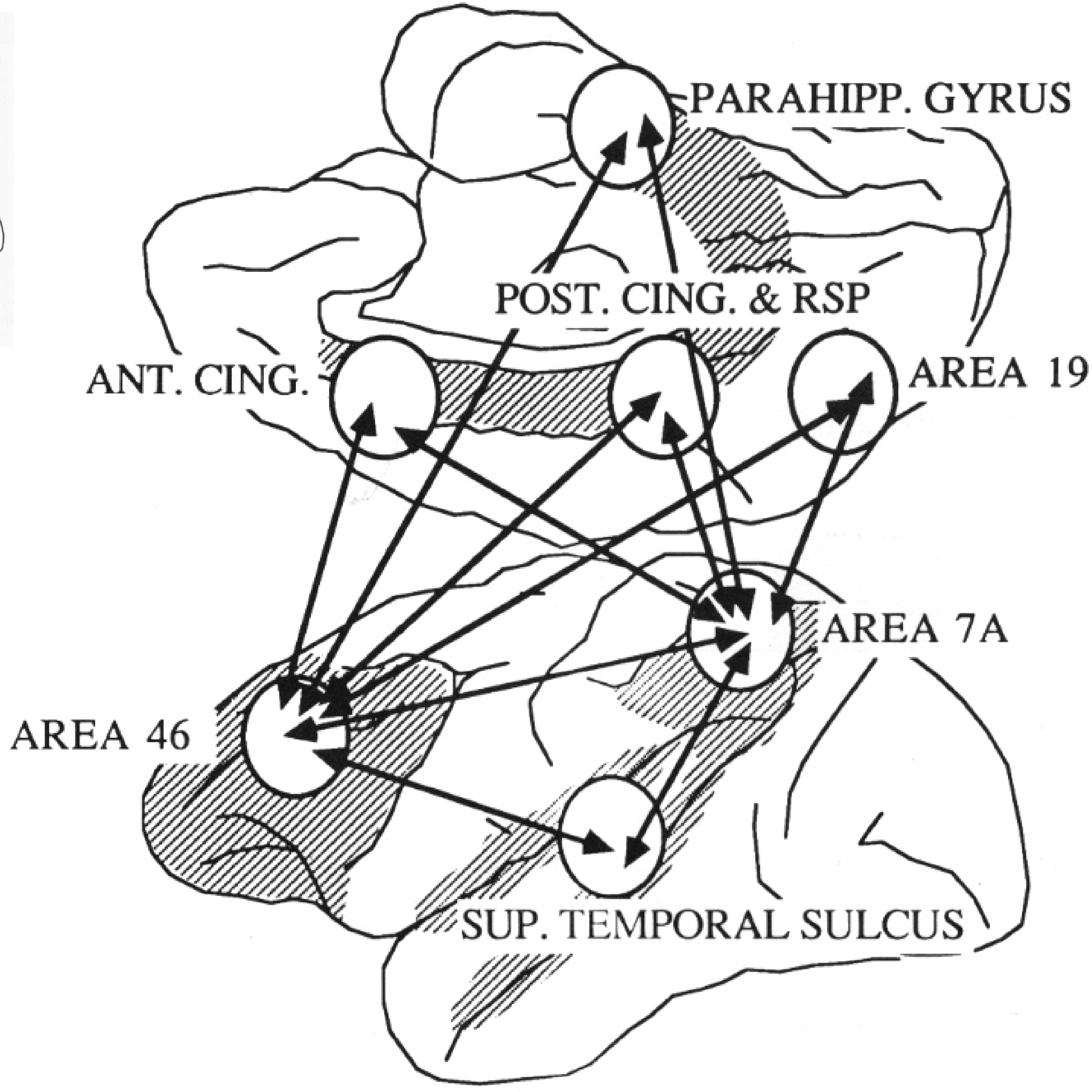
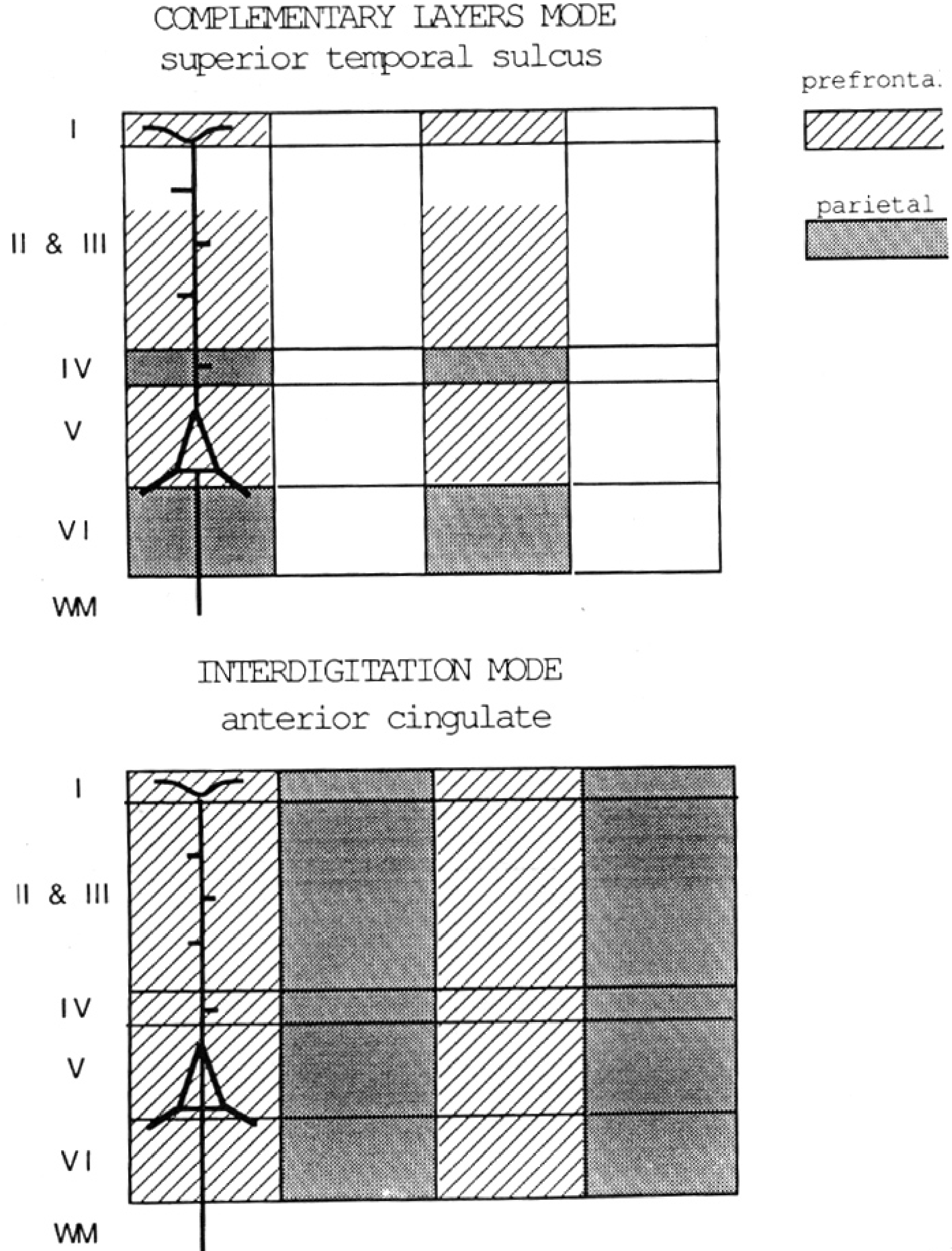

PARAHIPP. GYRUS
POST. CING. & RSP
ANT. CING.
AREA 19
AREA 7A
AREA 46
SUP. TEMPORAL SULCUS


COMPLEMENTARY LAYERS MODE
superior temporal sulcus
prefrontal
parietal
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WM
INTERDIGITATION MODE
anterior cingulate
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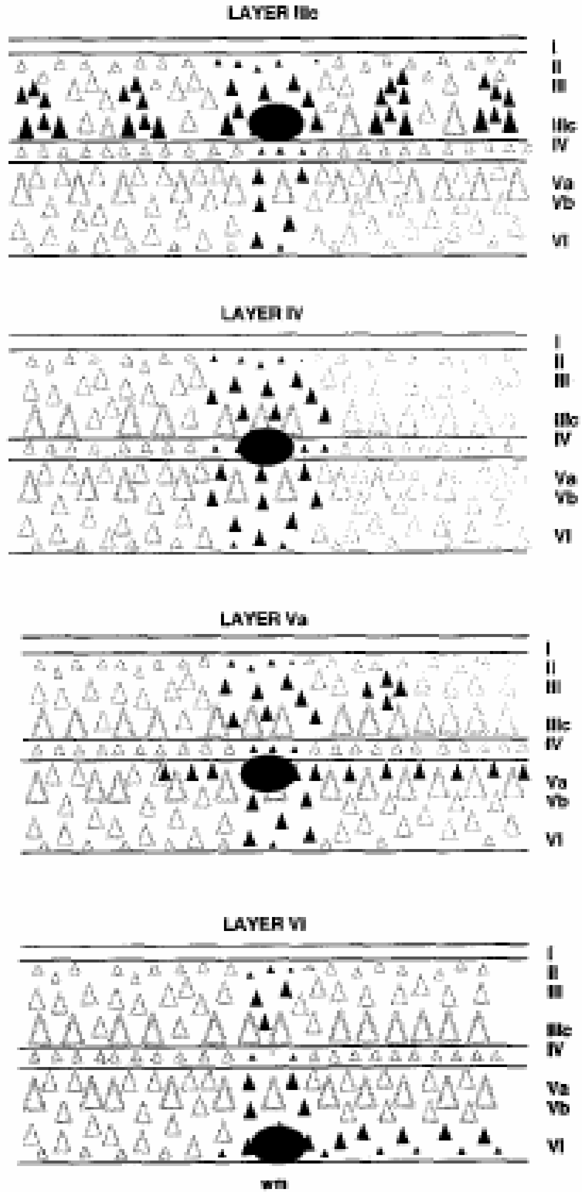


Figure 3. Layer-Specific Patterns of Intrinsic Connections in Prefrontal Cortex (Walker's areas 46 and 9) as Retrogradely Labeled with Cholera Toxin-B Subunit

In this summary diagram, labeled neurons in layer III and, to a lesser extent, layer V form spaced clusters of pyramidal cells with presumed similar "best directions" (from Kritzer and Goldman-Rakic, 1995).

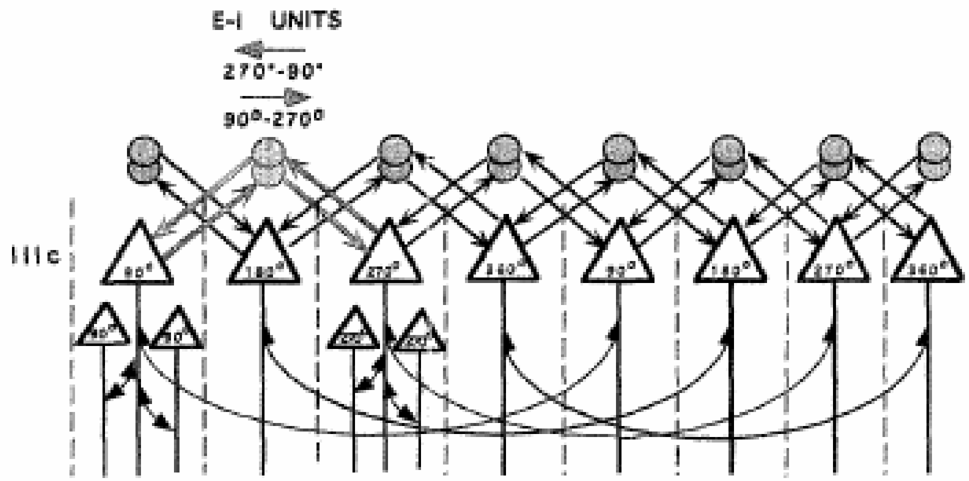


Figure 5. Hypothetical Model of Working Memory Modules in Prefrontal Cortex

Model of working memory modules consisting of clusters of tuned pyramidal neurons (red and black triangles) arrayed by target location and directly interconnected with each other by their local excitatory axon collaterals (long, thin, curved red and black arrows). Clusters of pyramidal neurons with like best directions are interconnected in a manner similar to iso-orientation columns in visual cortex. Two inhibitory interneurons (gray circles; presumed basket cells in the diagram) provide the reciprocal interconnections (blue arrows) between pyramidal cells with opposite best directions that could explain the opponent memory fields observed by Funahashi et al. (1989). For simplicity, only the 90°–270° and 270°–90° ensemble is illustrated. For now, the organization of the pyramidal cells with particular memory fields is hypothetical, as is the reciprocity of the excitatory–inhibitory units. Further analysis of these local circuits is essential for analyzing the neural substrates of working memory.

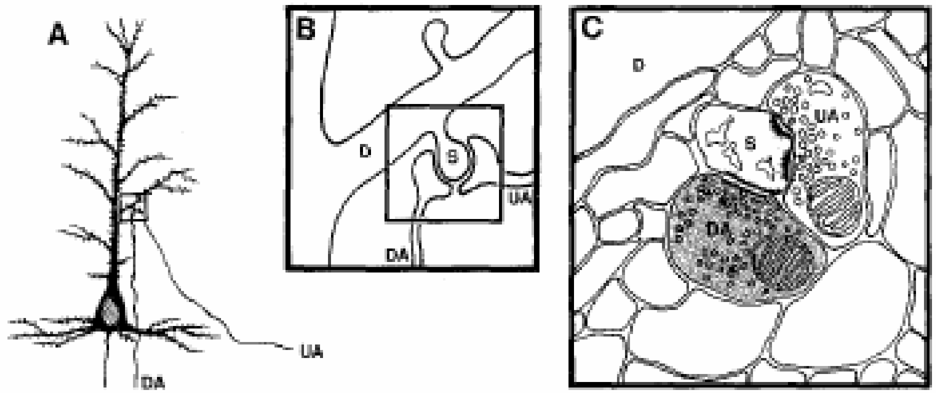
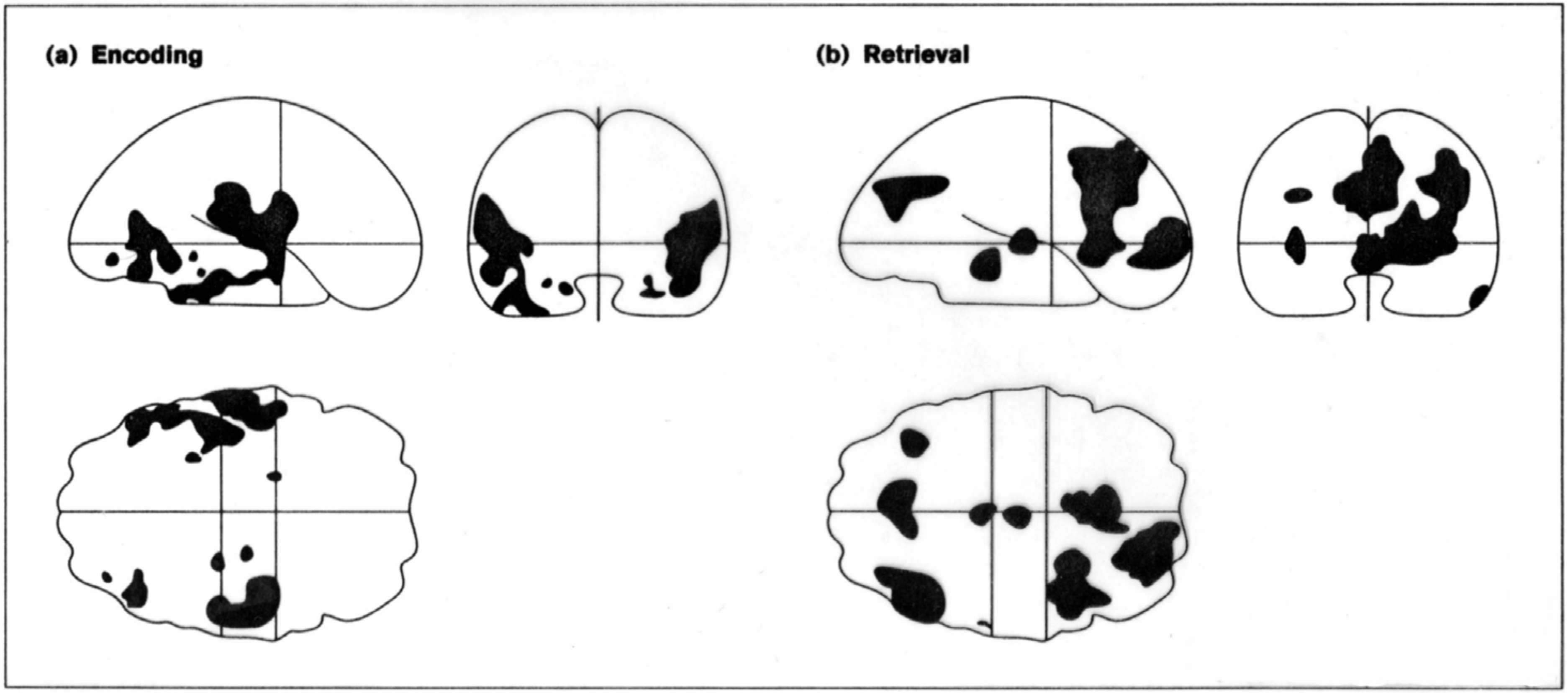


Figure 6. Diagram of Synaptic Arrangements Involving the Dopamine Input to the Cortex

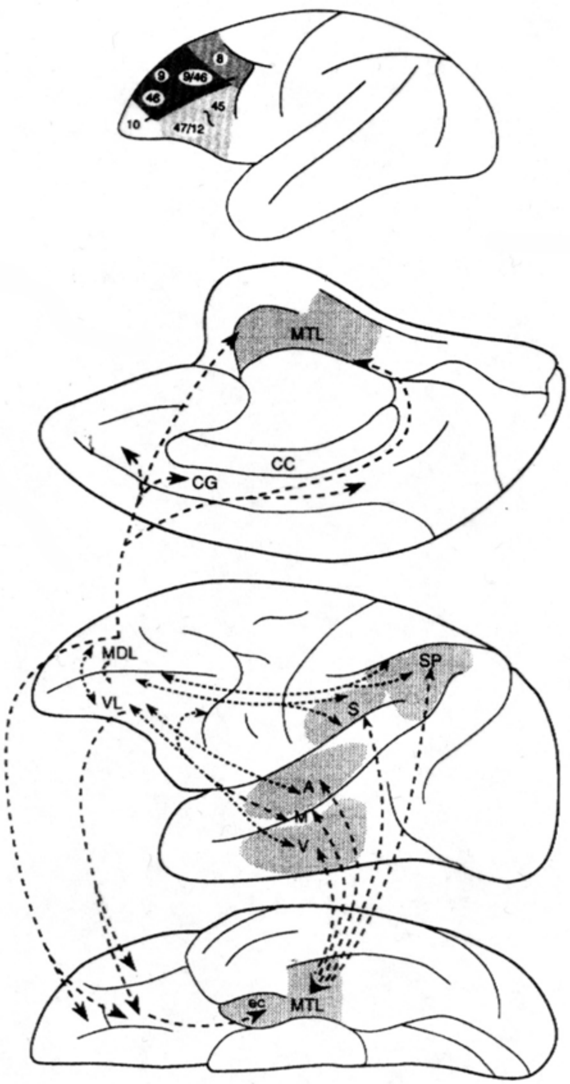
(A) Afferents labeled with a dopamine (DA)–specific antibody terminate on the spine of a pyramidal cell in the prefrontal cortex, together with an unidentified axon (UA). (B) Enlargement of axospinous synapses illustrated in (A) showing apposition of the DA input and a presumed excitatory input (UA) that makes an asymmetrical synapse on the same dendritic (D) spine

(C) Diagram of ultrastructural features of the axospinous synapses illustrated in (B); the dopamine terminal (darkened profile representing DA immunoreactivity) forms a symmetrical synapse; the unidentified profile forms an asymmetrical synapse with the postsynaptic membrane (diagram modified from data presented in Goldman-Rakic et al., 1989).

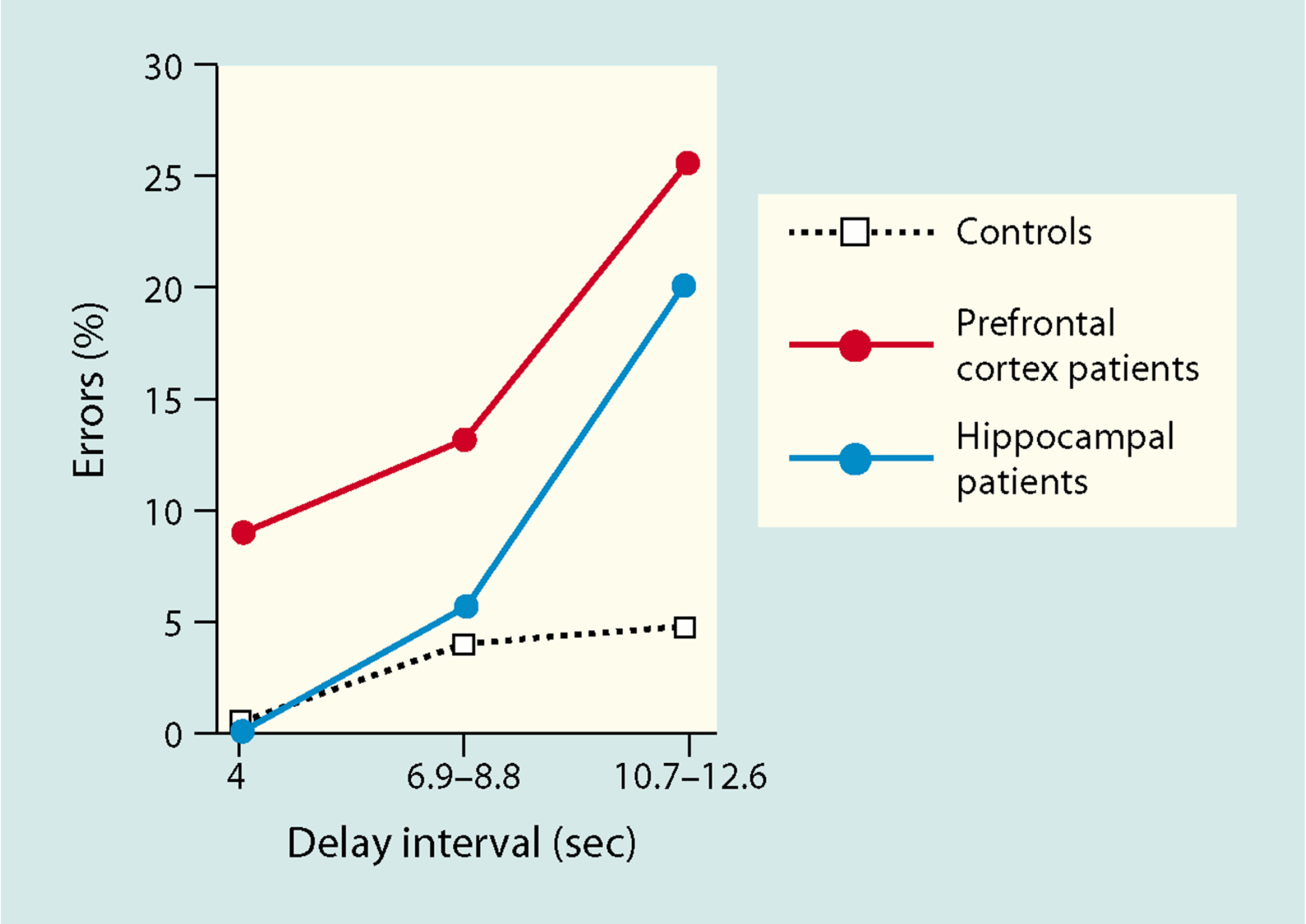


Brain regions are differentially active during encoding and retrieval, as indicated by differences in regional cerebral blood flow in a direct within-subjects comparison. (a) Brain regions more active during encoding than retrieval, including bilateral temporal lobes, left fusiform extending to the perirhinal cortex, right parahippocampal gyrus and bilateral entorhinal cortex. (b) Brain regions more active during retrieval than during encoding, incl. right frontal lobe, ant. cingulate, thalamus, brainstem, and cuneus/precuneus. The displays are sagittal views from the right, coronal views from back, and transverse views from the top of the brain. The data were pooled from four different PET studies involving a total of 48 healthy subjects (from Tulving and Markowitsch, 1997)

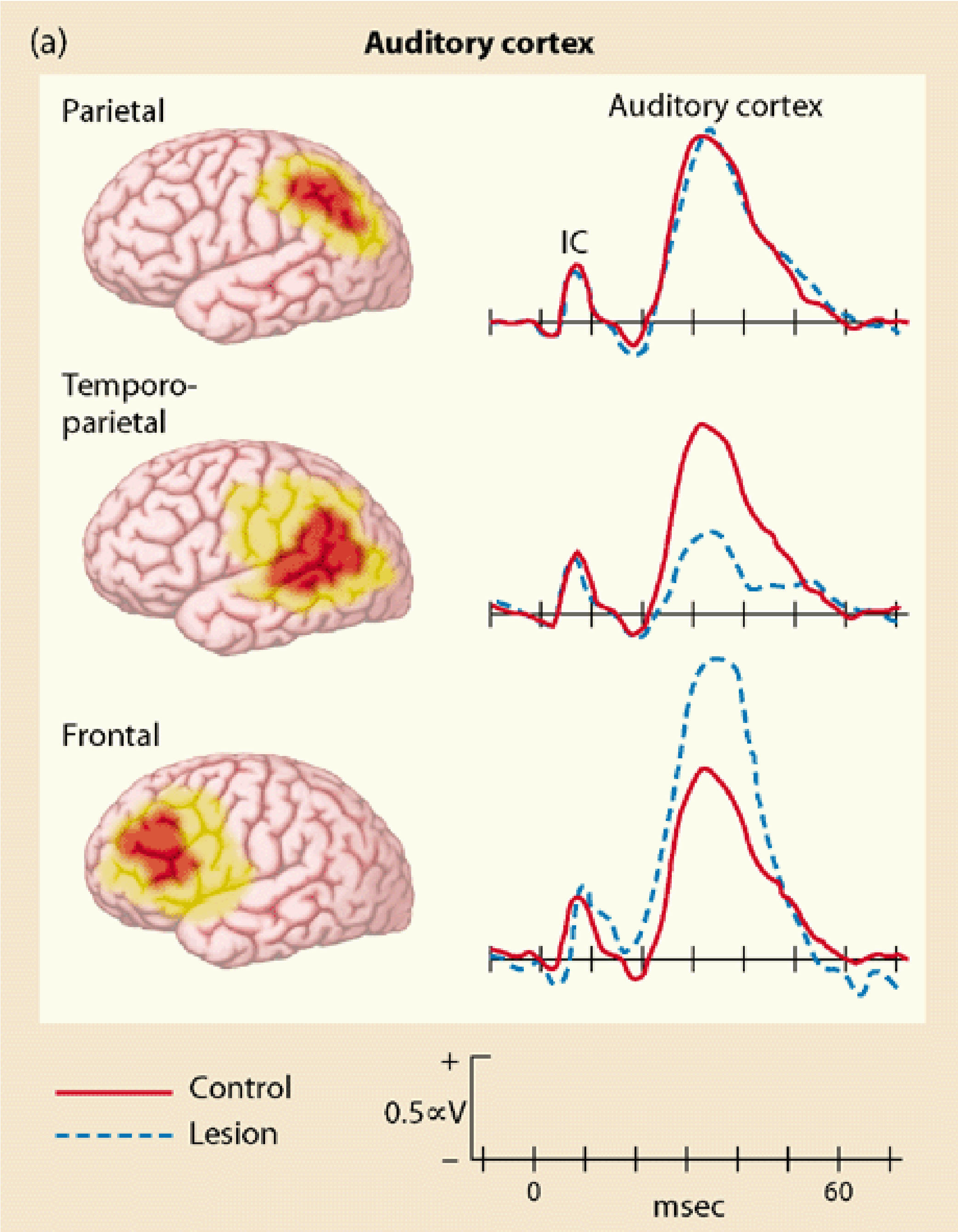
MULTIPLE PROCESSING LEVELS



Somatosensory (S), spatial (SP), auditory (A), visual (V) and some aspect of multimodal (M) information are processed in posterior temporal and parietal association areas. In the human brain, linquistic information is processed, primarily in the left parieto-temporal junction. **Processing in these posterior associational cortical areas is assumed to underlie not only perception and long-term storage, but also transient maintenance of information for further processing.** These areas interact with ventrolateral (VL) frontal cortical areas when **executive processing**, such as decision making, comparison, or active retrieval of information held in memory, is involved. The mid-dorsolateral (MDL) frontal cortex, which is connected with the VL and with the memory system of the medial temporal lobe (MTL), exercise a higher-order control of mnmonic processing when **monitoring and manipulation of information in worrking memory** is required (Petrides, 1998).

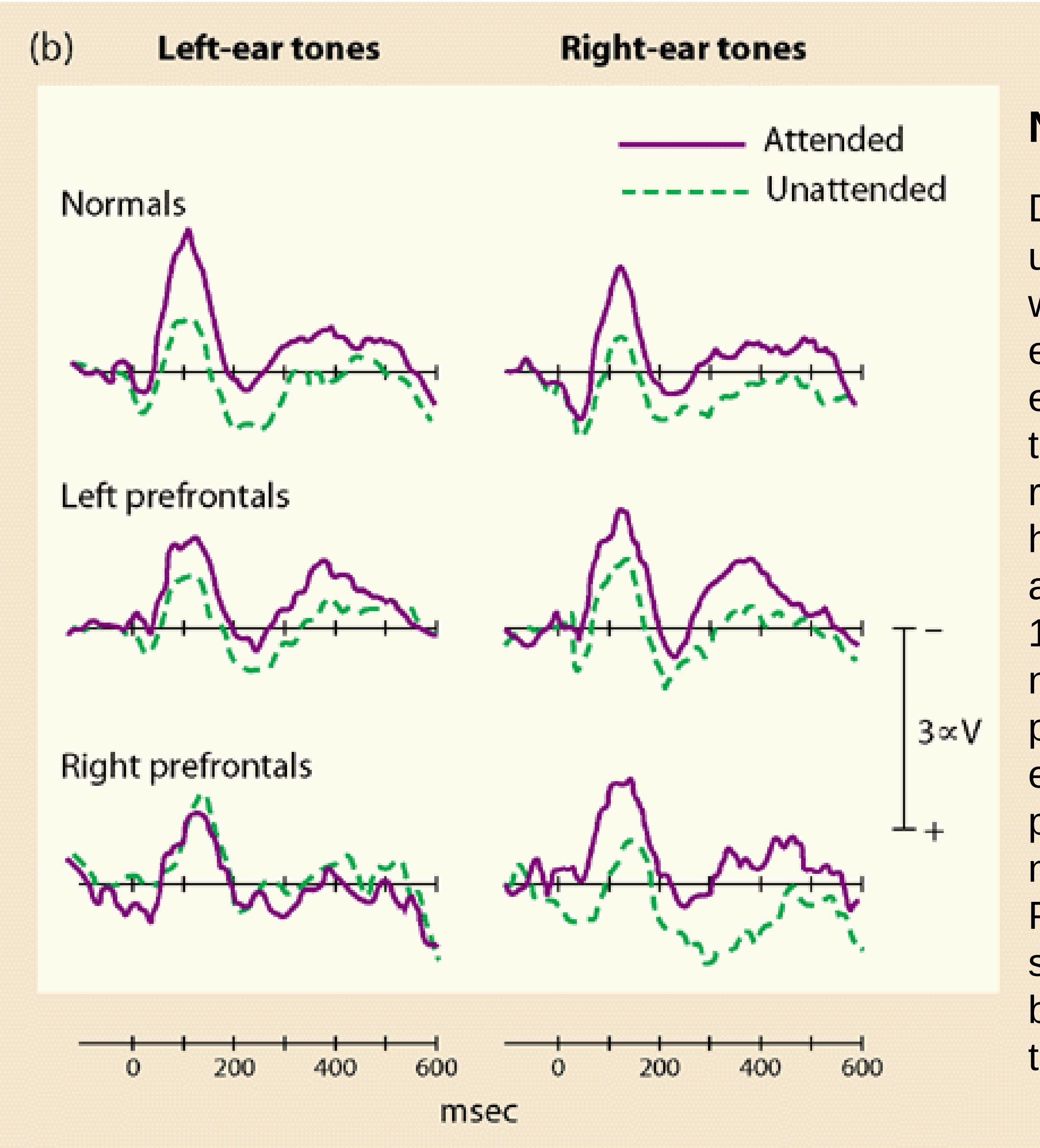


Subjects performed a **delayed auditory matching-to-sample** task. Unrelated distractors tones were presented during the delay period. Patients with prefrontal lesions made more errors for all delay conditions and the deficits became greater as the number of distractors increased. Patients with hippocampal lesions were impaired only at the longest delay (Chao and Knight, 1995).



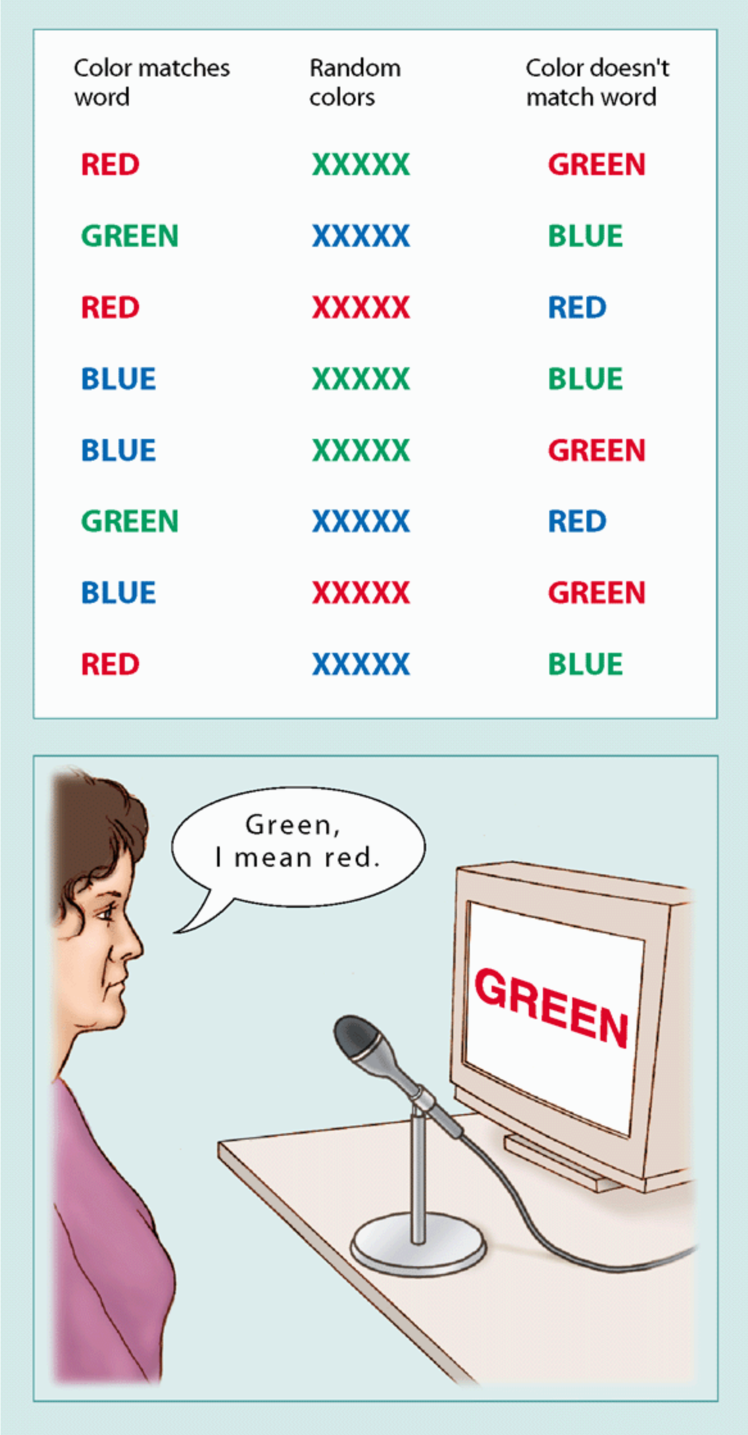
P30: FILTERING DEFICIT

Evoked potentials reveal filtering deficits in patients with lesions in the lateral prefrontal cortex. Evoked responses to auditory clicks in 3 groups of neurological patients. The first positive peak occurs at about **8 msec** and reflects neural activity in the inferior colliculus. The second positive peak occurs around **30 msec, the P30**, reflecting neural responses in the primary auditory cortex. Both responses are normal in patients with parietal lesion. The second peak is reduced in patients with temporo-parietal lesion, reflecting loss of neurons in the auditory cortex. The auditory cortex response is amplified in patients with frontal damage, suggesting loss of inhibition from frontal to temporal lobe.



N100 ATTENTION DEFICIT

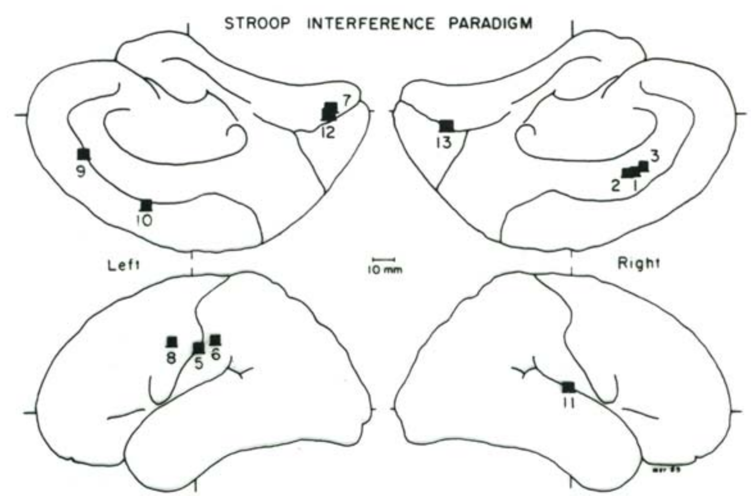
Difference waves for attended and unattended auditory signals. Subjects were instructed to monitor tones in either the left or the right ear. The evoked response to the unattended tones is subtracted from the evoked response to the attended tones. In healthy individuals, the effects of attention are seen at approximately 100msec, marked by a larger negativity (N100). Patients with right prefrontal lesions show no attention effect for contralesional tones presented in the left ear but show normal effect for ipsilesional tones. Patients with left prefrontal lesions show reduced attentional effects for both contralesional and ipsilateral tones (Knight and Grabowecky, 1995).

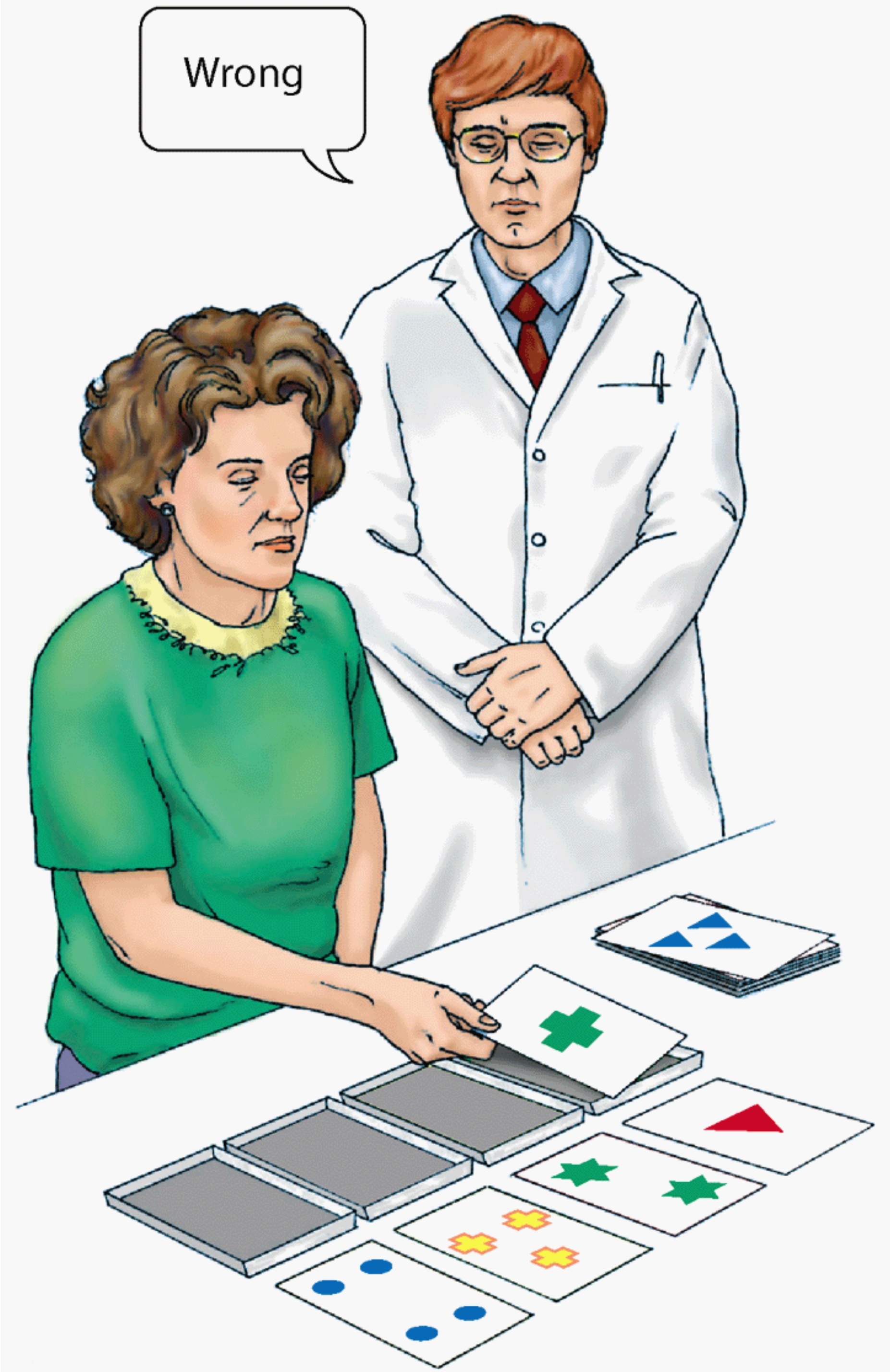


STROOP TASK: DEFICIT in cognitive control/attention. Ability to acquire conditional if-then rules. The PFC contain modules dedicated to represent task rules and contingencies.

The subject is required to scan down each column, naming the actual color of the world while ignoring the world itself. In the third column each stimulus contains a mismatch between word and color, which creates distraction and demands for attentional focus (Stroop, 1935).

Cortical activation foci during the Stroop task (Pardo et al., 1990). Frontal lobe patients display heightened interference on the Stroop task.

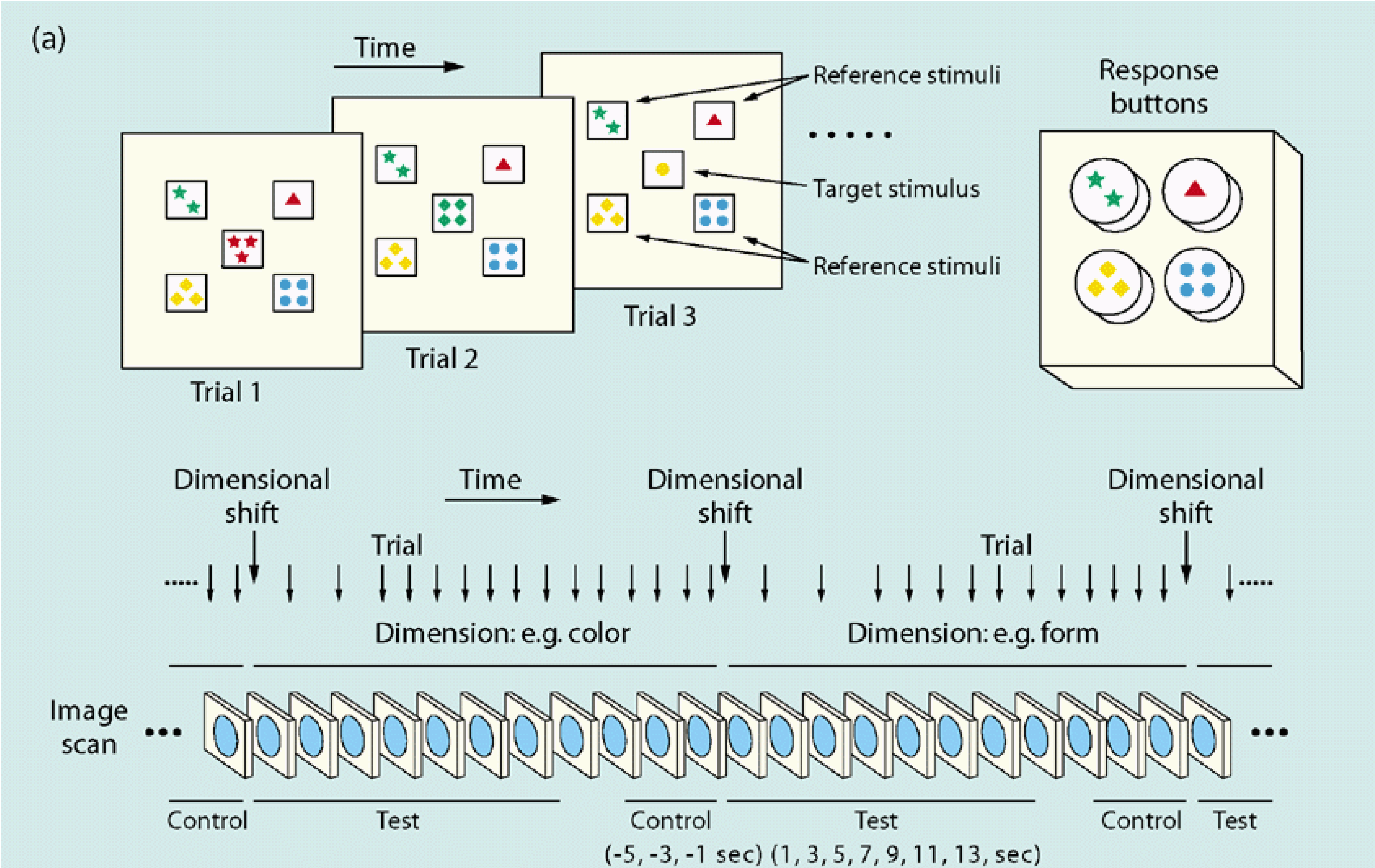




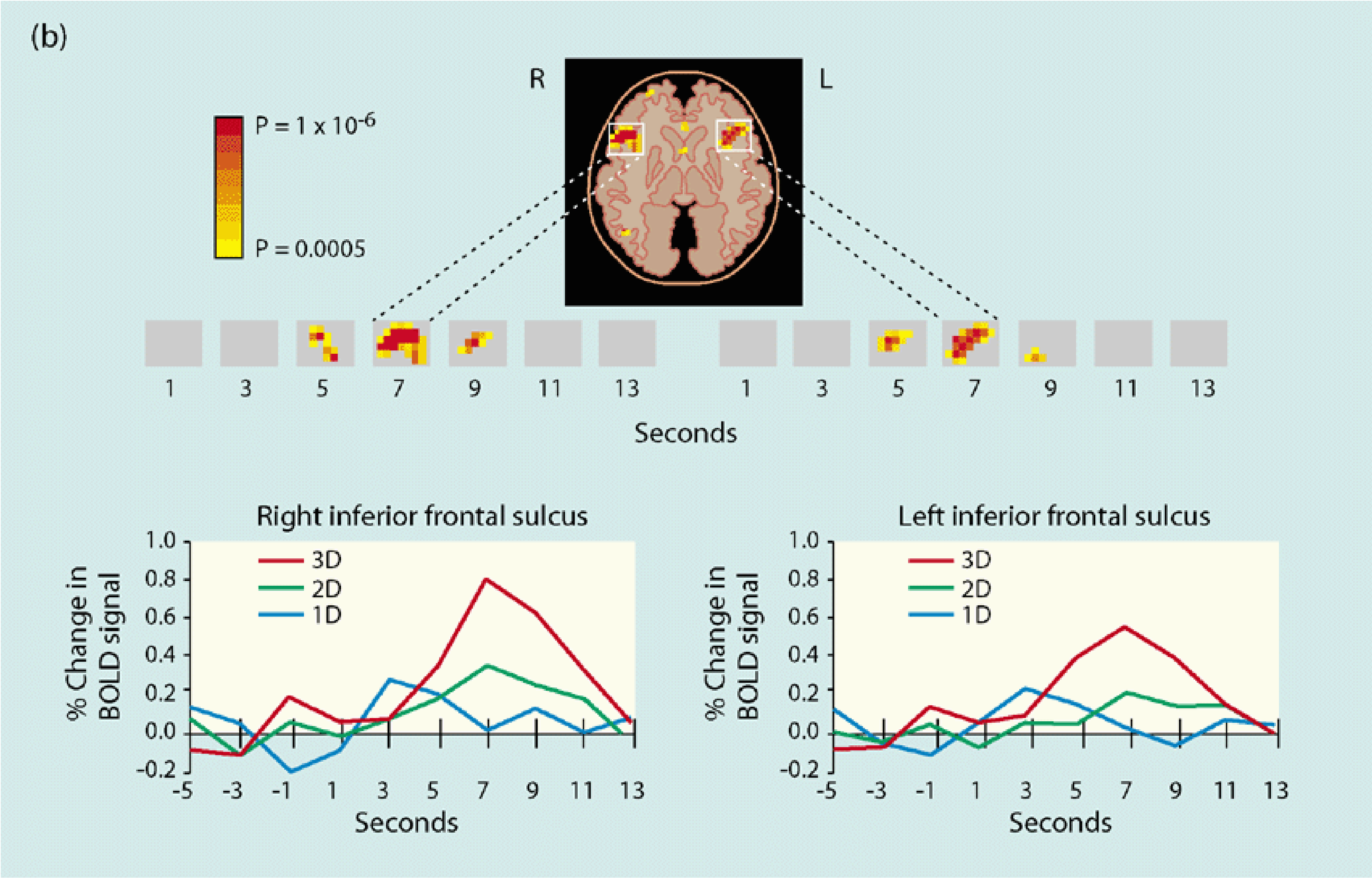
Wisconsin Card Sorting Task: SET SHIFT

Patients with damage in the lateral prefrontal cortex has difficulty on the WCST. On each trial, the subjects place the top card on the deck under one of the four target cards. The experimenter indicates whether the response is correct or incorrect, allowing the subject to learn the sorting rule by trial and error. The sorting rule changes whenever the subject makes ten consecutive correct responses (Gazzaniga, 2002).

MODIFIED WCST for fMRI

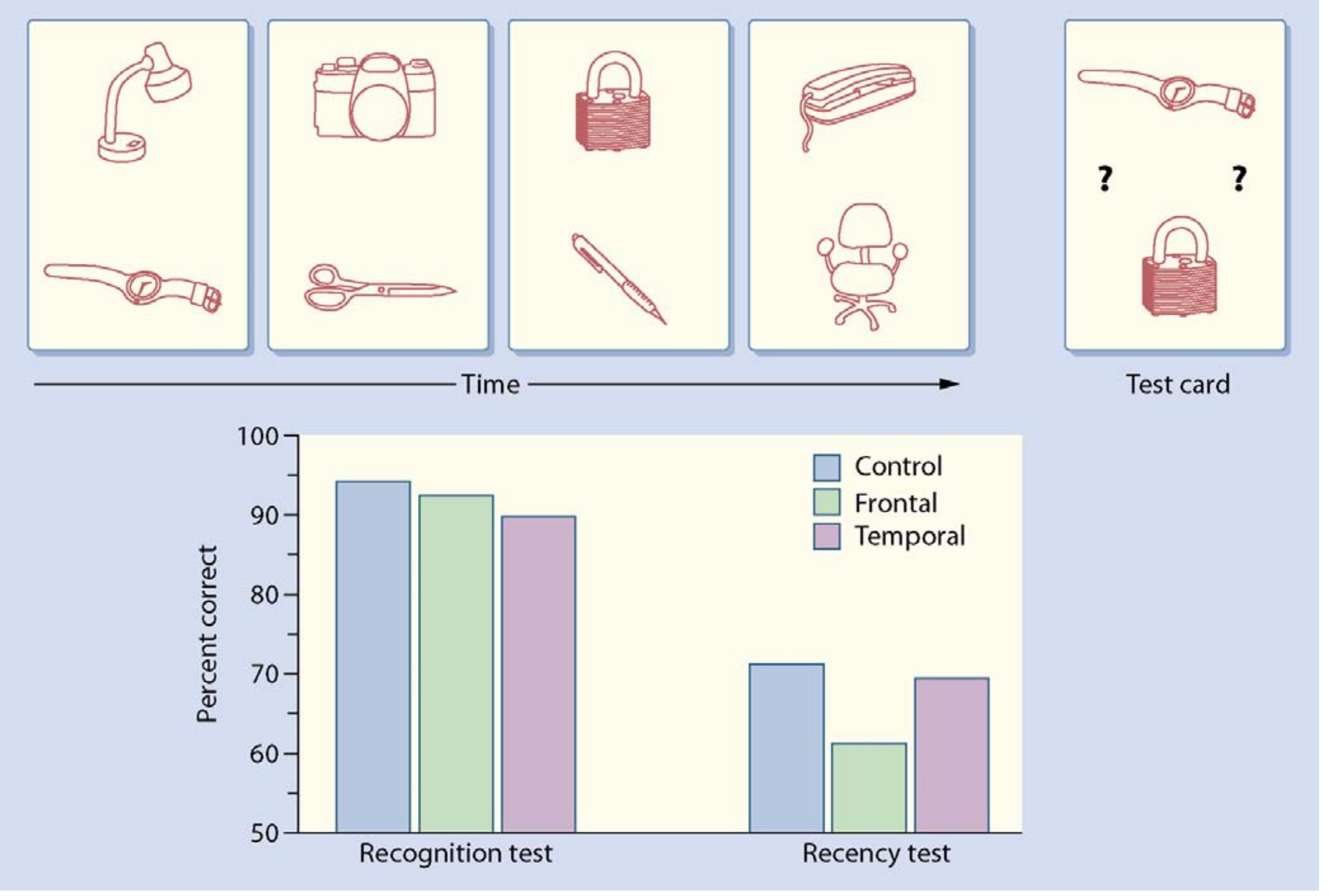


(a) Stimulus displays and response board. Subjects matched the center objects (target) to one of four objects in the corner (reference), using the response board. The match could be made on the basis of color, form or number. After 10 correct response the matching rule would change, indicating a dimension shift.

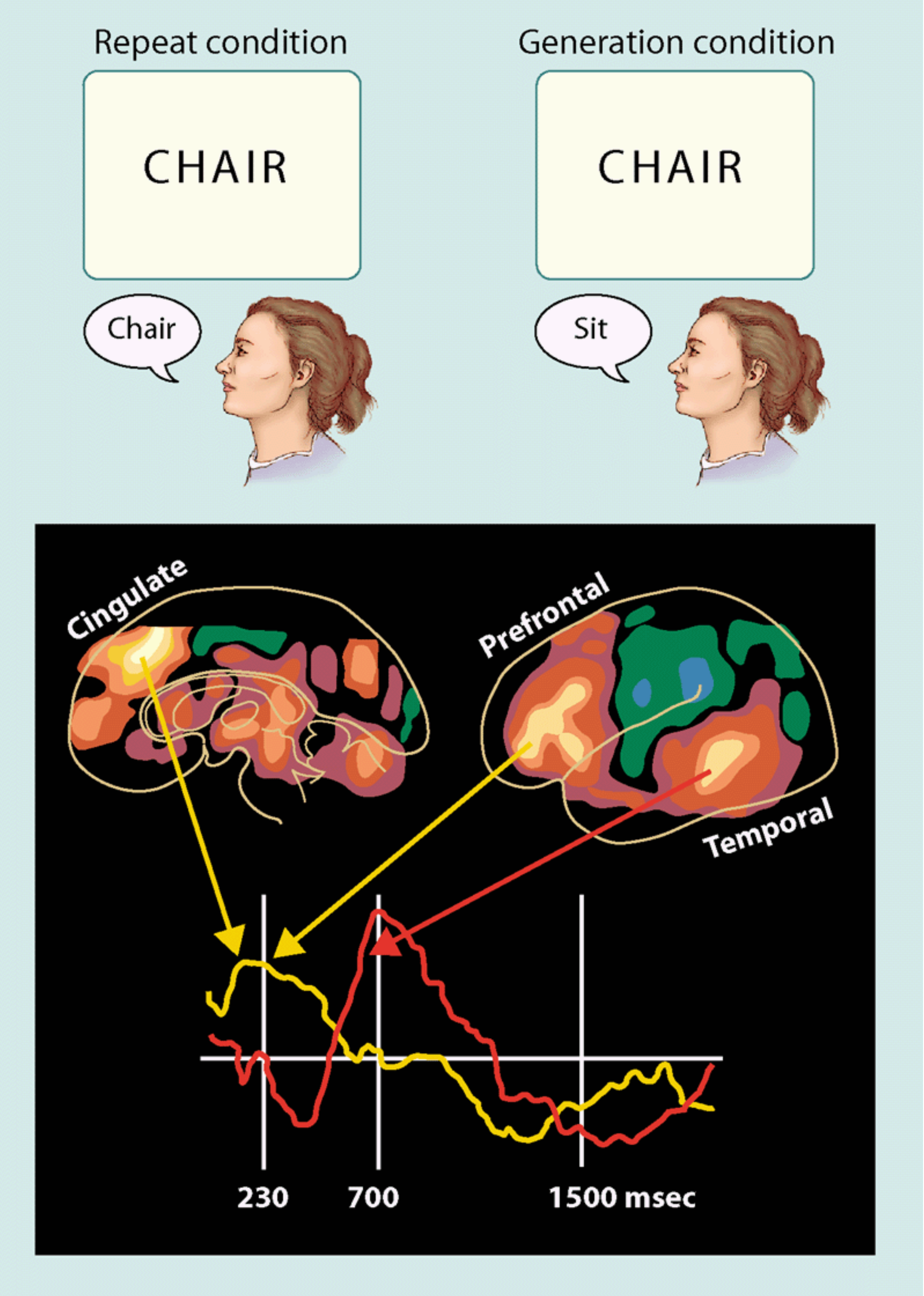


(b) Increased activation was observed bilaterally in the IFG following the signal to shift dimensions. The hemodynamic response peaks about 7 sec after the shift (Konishi et al., 1998)

RECENCY MEMORY: TEMPORAL ORDER OF EVENTS

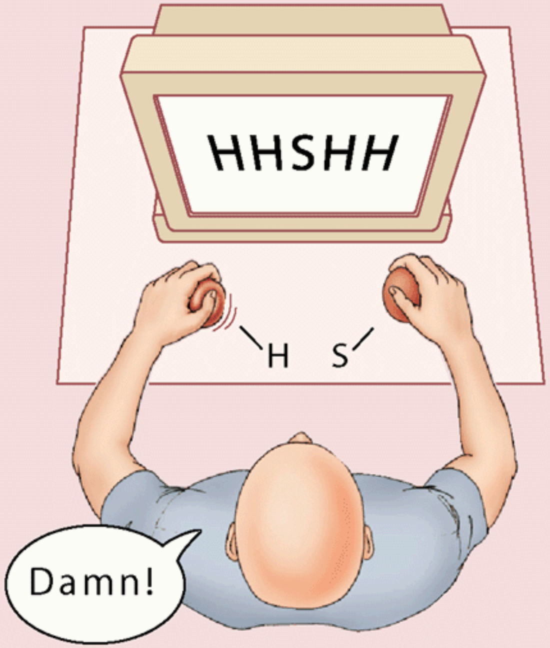


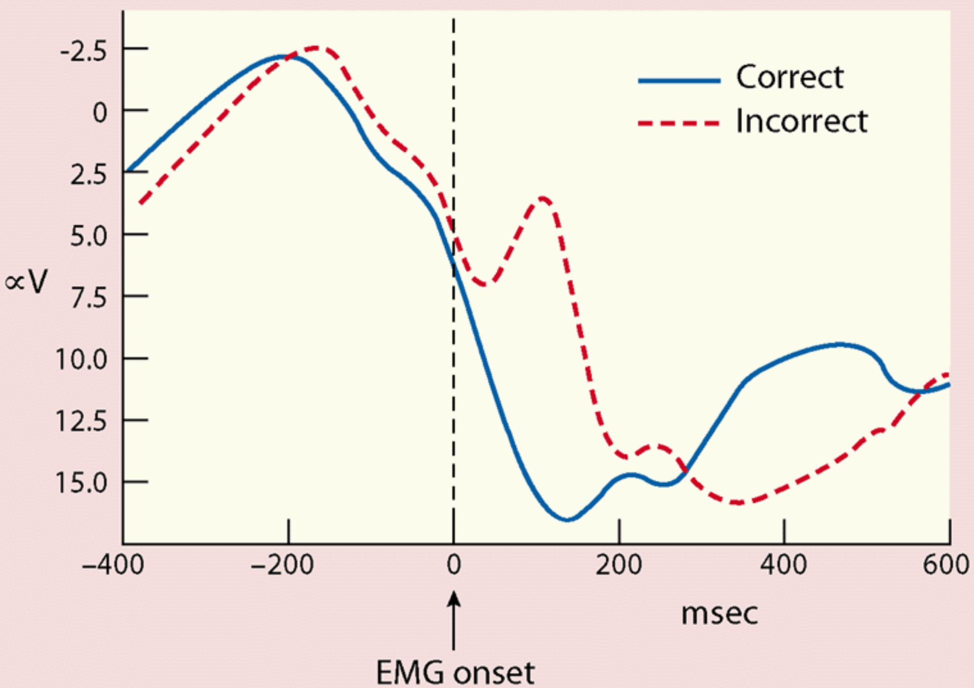
Recency memory is impaired in patients with prefrontal lesions. Subjects are presented with a series of cards each one showing a pair of objects. On test cards, the objects are flanked by question marks, and the subject must indicate which object was seen most recently. In the recency test, both objects on the test cards had been seen previously. In the item recognition test, only one object had appeared previously. The results revelead a single dissociation. Patients who had a frontal lobectomy performed more poorly on the recency task compared to both control subjects and patients with temporal lobectomy (Milner, 1991; Gazzaniga, 2002).



THE ANT. CINGULATE CTX. AS MONITORING SYSTEM

Subjects hear a noun. In the repeat condition, they simple repeat the word; in the generation condition, they name a word that is a verb associate. To avoid including motor activity in the evoked potentials, subject were instructed to withold their responses until a ‘go’ signal appeared, abot 1500 msec after the stimulus. The difference waveform is obtained by subtracting the evoked potential in the repeat condition from the EP in the generation condition. Dipole modeling was used to identify the neural region associated with each peak. The first difference waveform was observed **180 msec** after the onset of the target noun and was attributed activation in the **ACG**. About **30 msec** later, a second generator was required to model the data. This generator was localized in the **lateral PFC** in the left hemisphere. Finally, around **620 msec** after stimulus onset, a third generator was linked to the **posterior cortex** in the left hemisphere (Snyder et al., 1995).





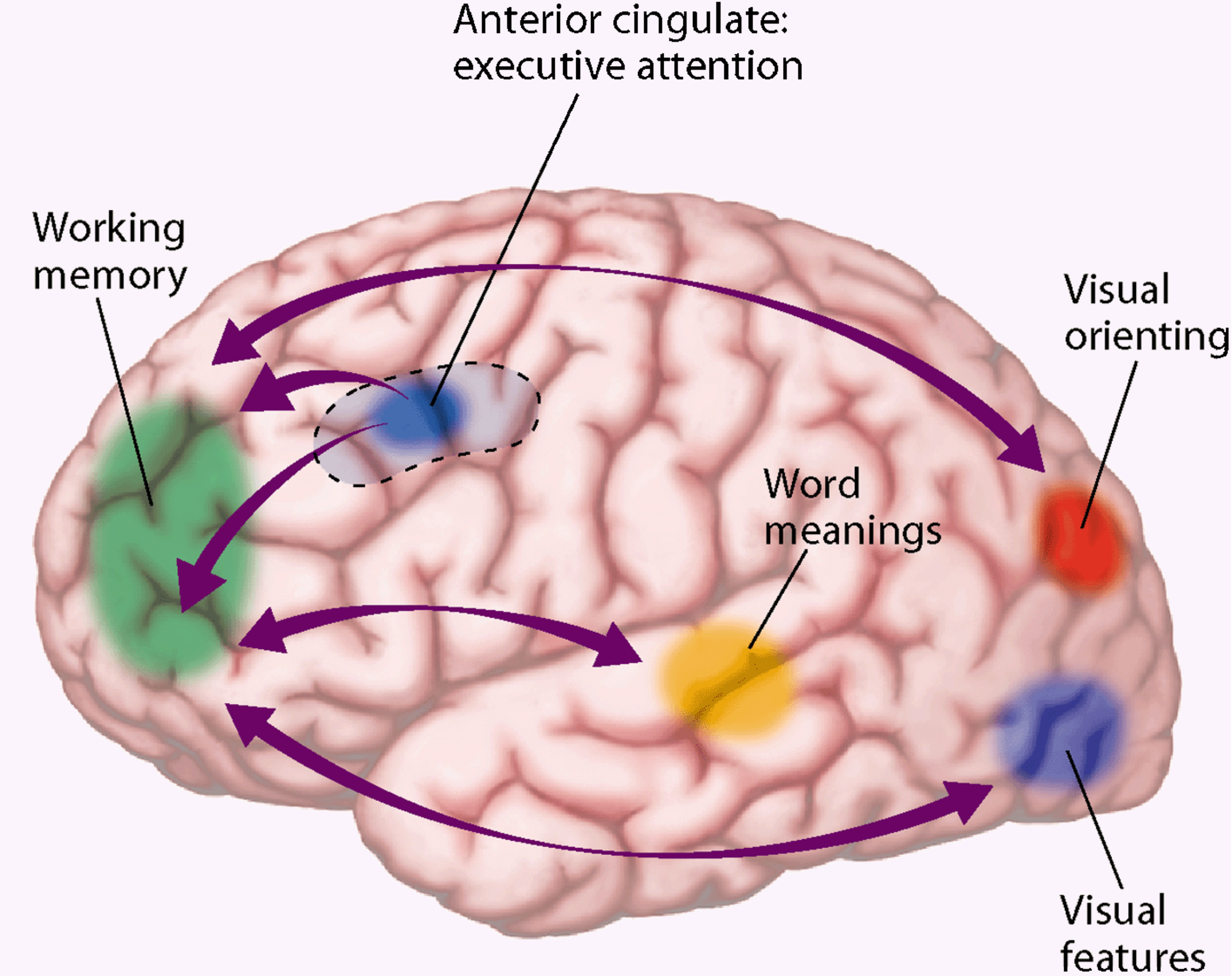
ERROR-RELATED NEGATIVITY

Subjects were tested on a two-choice letter discrimination task in which they made speeded responses with either the right or the left hand. Errors were obtained by emphasizing speed and by flanking the targets with irrelevant distractors. Evoked potentials for incorrect responses deviated from those obtained on trials with correct responses just after the onset of peripheral motor activity (EMG onset). This error detection signal is maximal over a central electrode positioned over the anterior cingulate (Gehring et al., 1993).

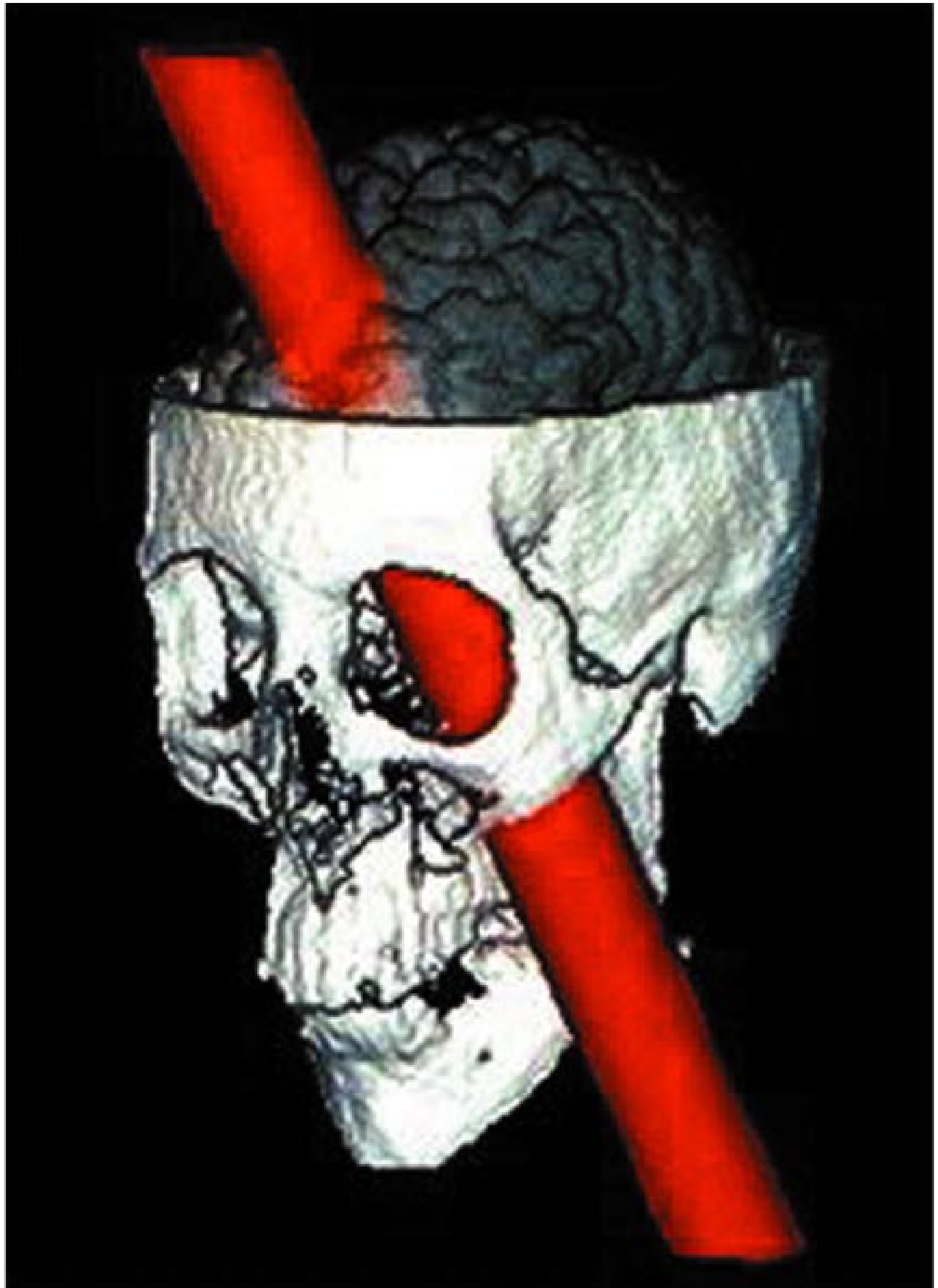
Adapted from Gehring, W.J., Goss, B., Coles, M.G.H., Meyer, D.E., and Donchin, E., A neural system for error detection and compensation, Psychological Science 43 (1993): 385–390.

Four ways in which a supervisory attentional system (SAS) would be involved in monitoring functions. Evidence for a role of the cingulate cortex in each function listed on the right.

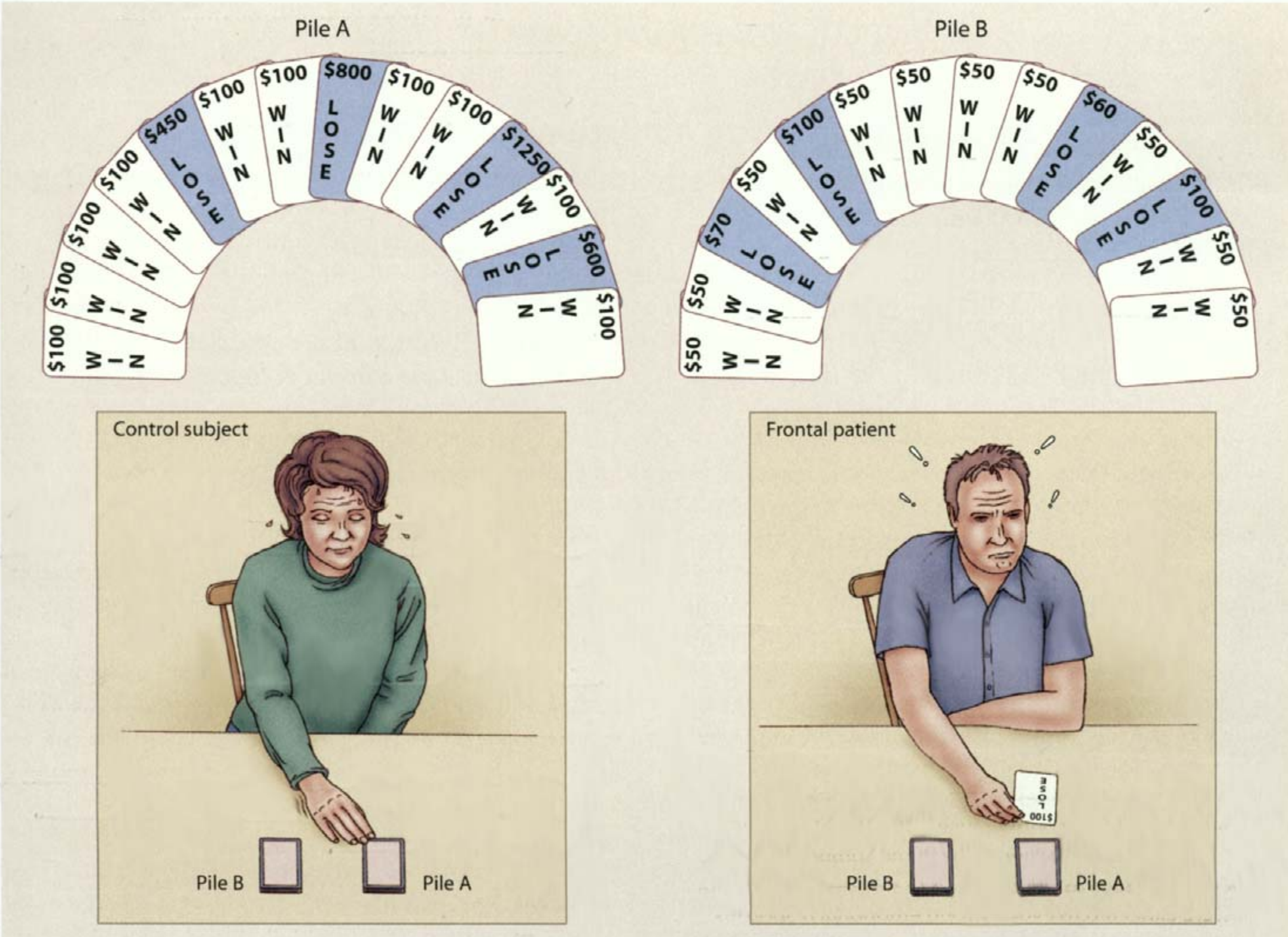
Required function of the SAS	Evidence indicating function related to anterior cingulate
Difficult situations	Blood flow increases during divided attention studies in comparison to focused attention studies
Novel situations	Blood flow increases during word generation task in comparison to word repeat task
Error correction	Evoked potential studies
Overcoming habitual responses	Blood flow increases during incongruent Stroop trial in comparison to congruent Stroop trials



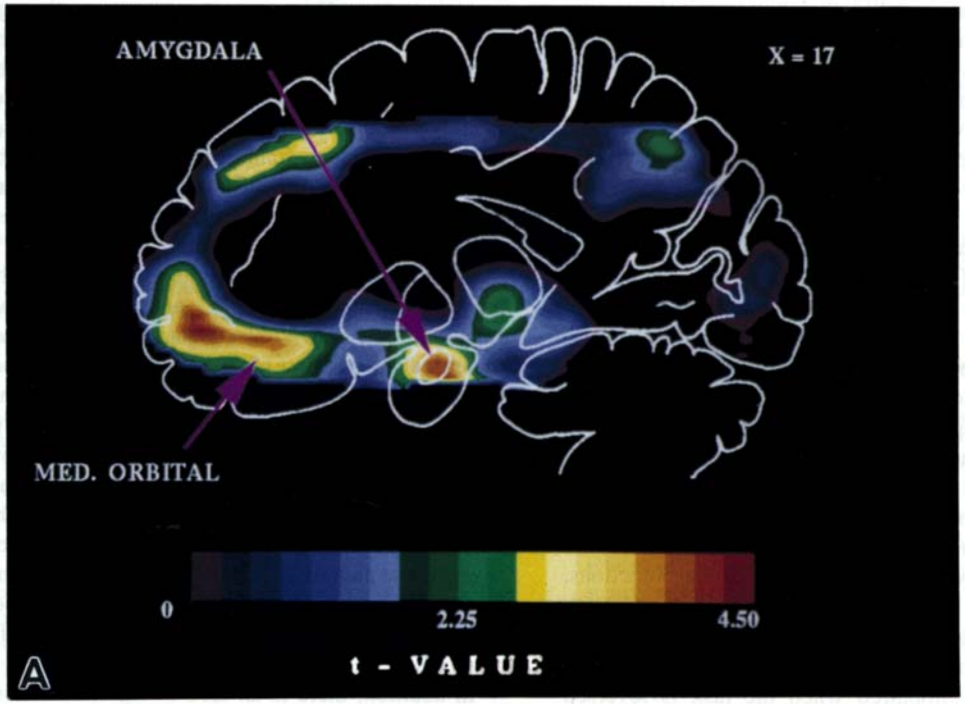
The anterior cingulate cortex has been hypothesized to operate as an executive attention system. This system serves to ensure that processing in other brain regions is most efficient given the current task demands. Interactions with the PFC may select working memory buffers; interactions with the posterior cortex can serve to amplify activity in one perceptual module over others (Posner and Raichle, 1994; Gazaniga, 2002).



EMOTIONAL DECISION. The somatic marker hypothesis



Subjects were required to choose cards from one pile or the other, with each card specifying an amount won or lost. Through trial and error, the subjects can learn that pile A was riskier than pile B. Control subjects not only tended to avoid the high-risk pile but also showed large skin conductance response (SCR) when considering choosing from this pile. The patients with prefrontal lesions failed to show this anticipatory SCRs. However, they show a large SCR upon turning a card and discovering they had lost $1000 (of play money) (Gazzaniga, 2002).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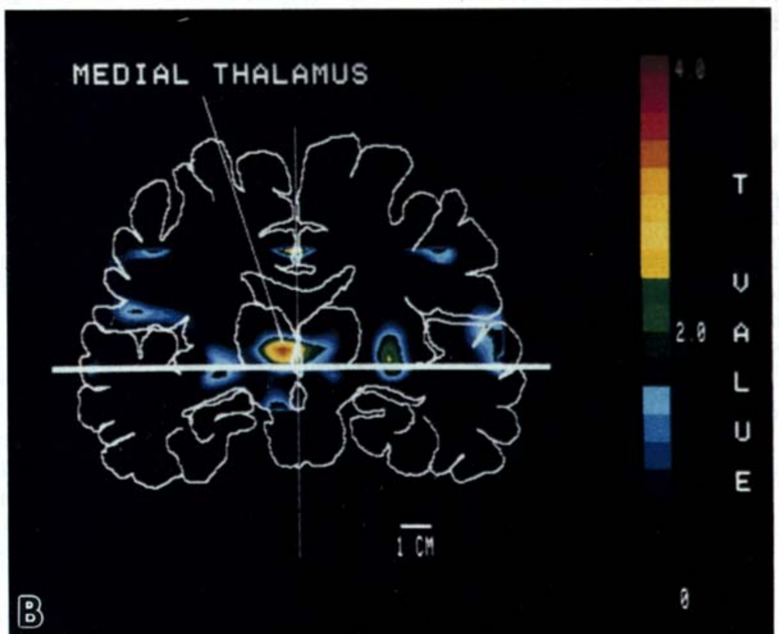
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