LES AIRES CORTICALES HUMAINES IMPLIQUEES DANS LE TRAITEMENT VISUEL : LES QUESTIONS D´HOMOLOGIES

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Cours 4

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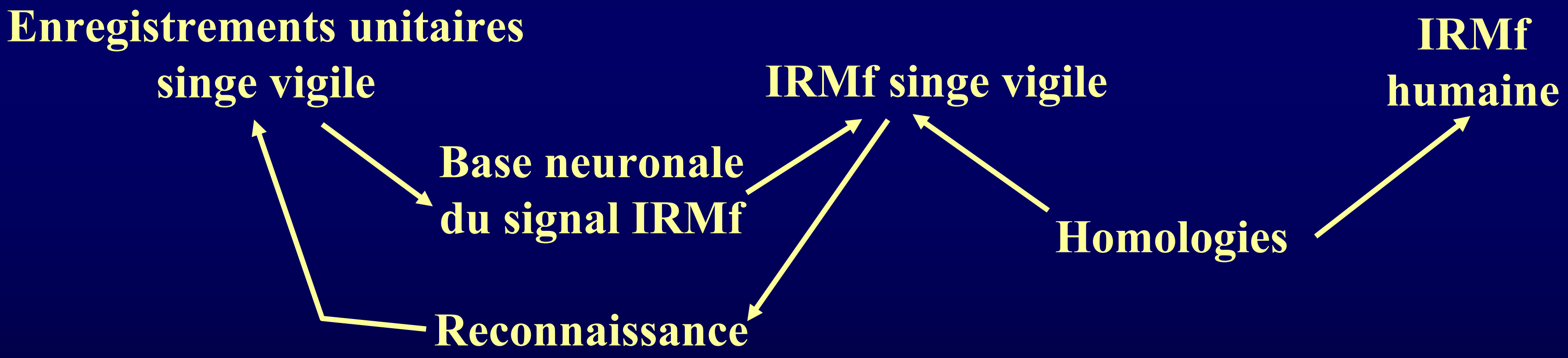
La triade des neurosciences cognitives



Enregistrements unitaires
singe vigile

Base neuronale
du signal IRMf

Reconnaissance

IRMf singe vigile

Homologies

IRMf
humaine

Homologie Cérébrale

- Des aires corticales sont homologues lorsqu’elles dérivent d’un ancêtre commun
- Cette propriété peut seulement être déduite de l’étude d’espèces existantes
- la certitude de cette déduction dépend du nombre d’espèces étudiées et du nombre de critères utilisés pour caractériser une aire

Homologies Cérébrales

(certitude décroissante)

1. Aires homologues parmi les mammifères

2. Aires homologues parmi les primates

3. Aires homologues entre Homo et Maccaca

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Aires homologues parmi les mammifères

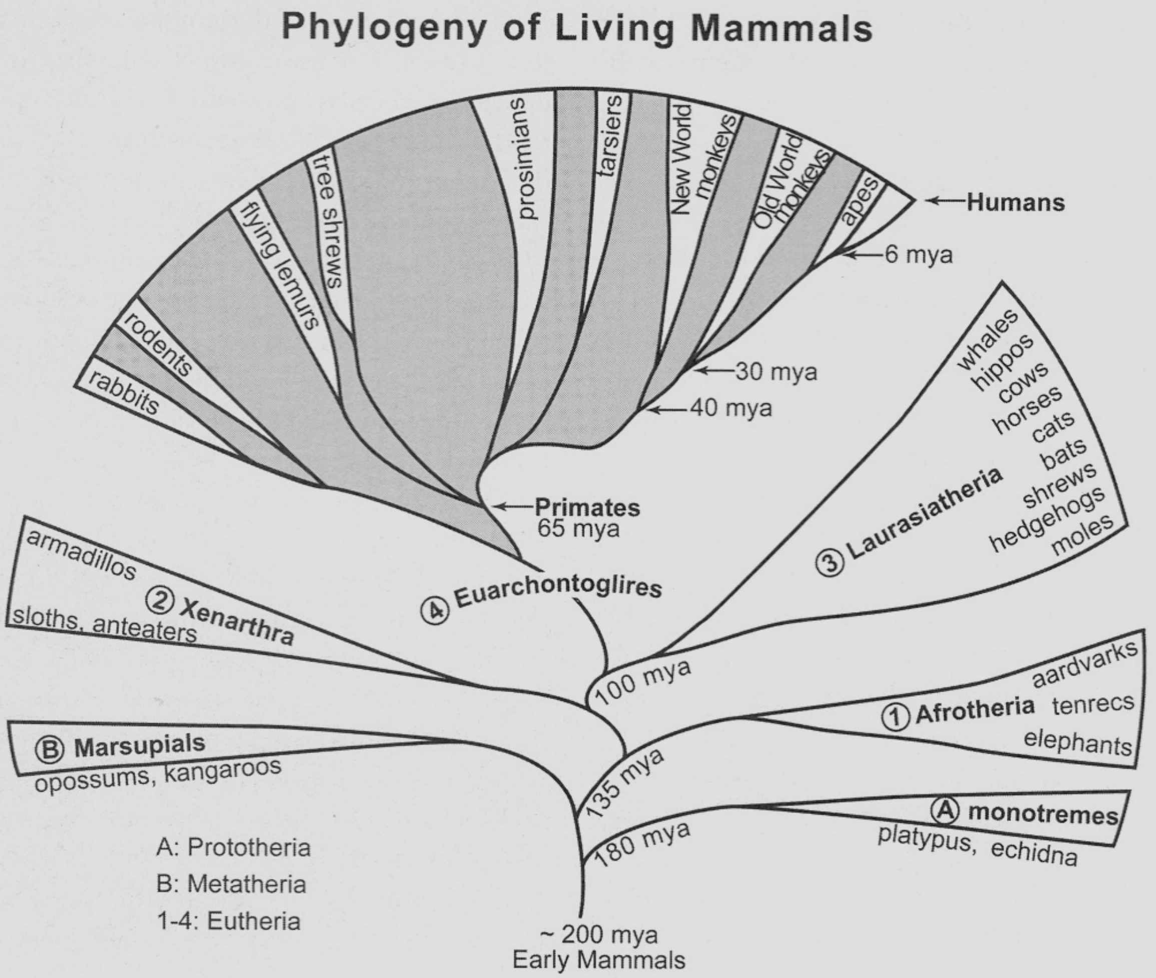
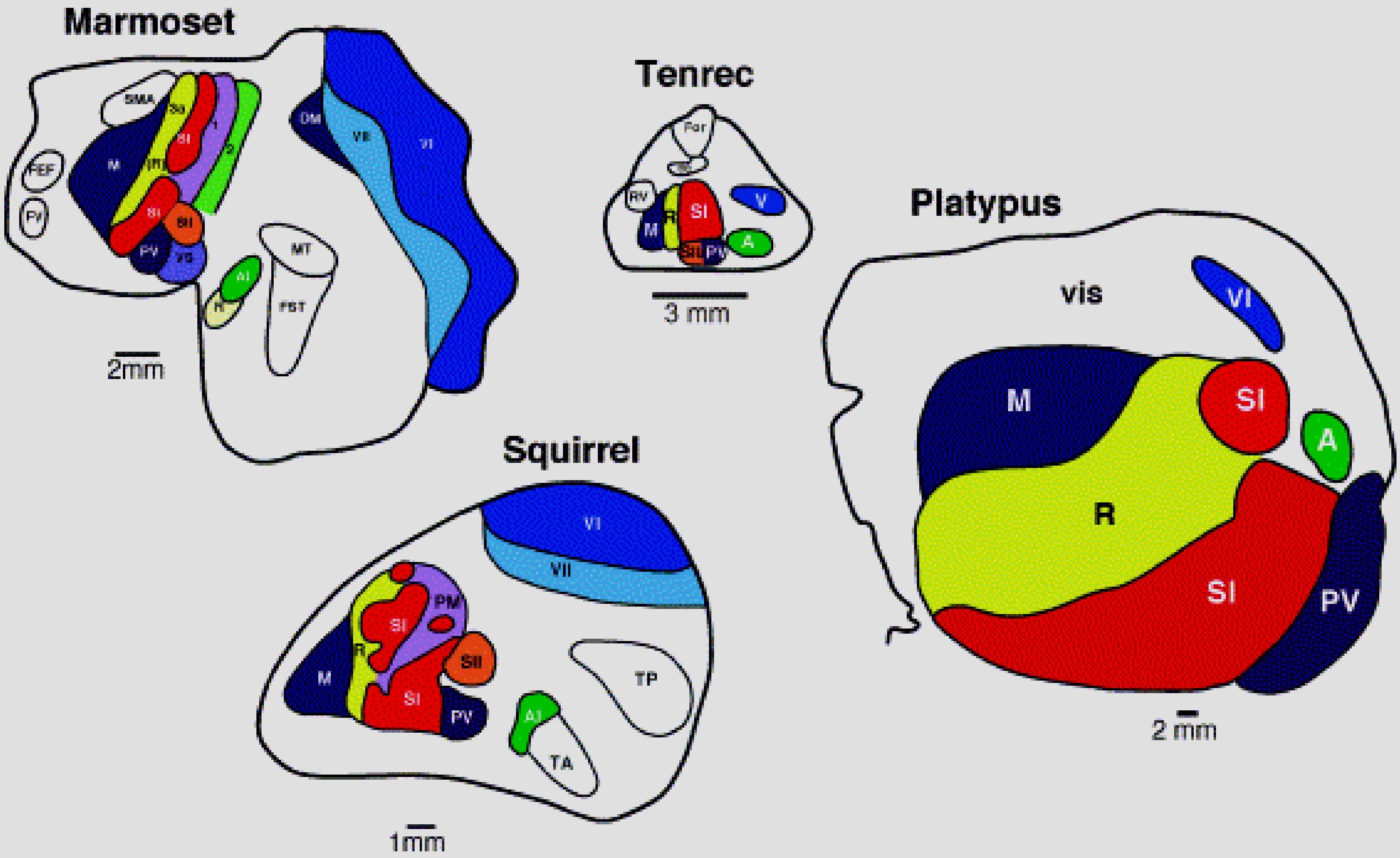


Figure 105.1. The evolutionary history of mammals. Recent molecular studies of mammalian phylogeny (e.g., Murphy et al., 2001) have reorganized the phylogenetic tree into four superordinal groups or superorders (1–4) of Eutherian (placental) mammals. Prototherian (A: Monotremes) and Metatherian (B: Marsupials) mammals diverged even earlier from the ancestors of placental mammals. Recent evidence is also pushing back the times of divergences, so the values indicated here, in millions of years ago (mya), are approximate and controversial. Humans are placed with other primates in the superorder Euarchontoglires, with our closest relatives being tree shrews (Scandentia) and flying lemurs (Dermoptera). Rodents and lagomorphs (rabbits) are somewhat more distant.

J.H. Kaas ´04

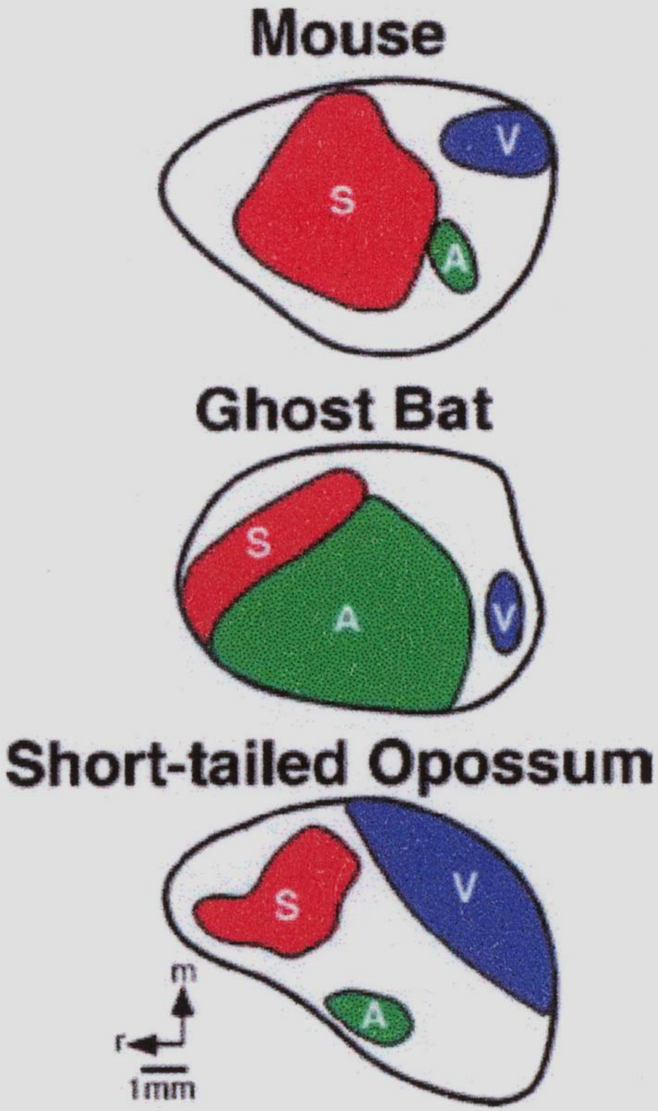
Aires homologues parmi les mammifères



Variations in cortical field organization of different mammals with vastly different lifestyles. In all mammals observed, there are cortical fields that are common (e.g. SI, VI, AI, SII, PV, and M), and patterns of callosal and subcortical connections are fairly constant across different lineages, despite differences in size, shape and geographic location of different fields. However, there are large shifts in the geographic location of homologous fields as well as changes in their size and shape.
Rostral is to the left, medial is up.

L. Krubitzer and D.M. Kahn ´03

Aires homologues parmi les mammifères



Primary cortical areas in three species of mammals that have approximately the same size cortical sheet, but different amounts of cortex allotted to different sensory systems, related to specialized sensory receptor arrays and use of particular sensory receptor arrays. For example, in the mouse, which relies heavily on tactile inputs from the whiskers for survival, the primary somatosensory cortex (red) and the rest of somatosensory cortex is enlarged, and the portion of cortex representing the whiskers is magnified, compared with the ghost bat and short-tailed opossum. Similarly, the primary auditory cortex and surrounding fields in the cortex of the echolocating ghost bat (green) is expanded, while the primary visual area (blue) and somatosensory area is relatively small. Finally, the cortex of the highly visual short-tailed opossum is dominated by V1 (blue) and other visual areas. Although the size, shape, and the details of internal organization of particular cortical fields vary depending on use (activation from peripheral receptors), certain aspects of organization are conserved in these brains, even in the absence of apparent use. The similarity in relative location of cortical domains and fields therein suggests that the geographic organization and overall pattern of thalamocortical projections of the brain is constrained by developmental mechanisms. On the other hand, the differences in size, shape, and detailed organization of primary cortical fields indicate that input from the periphery is a crucial factor in guiding many of the details of organization of the neocortex. Medial is up and rostral is to the left, scale bar=1 mm.

L. Krubitzer and D.M. Kahn ´03

Aires homologues parmi les mammifères

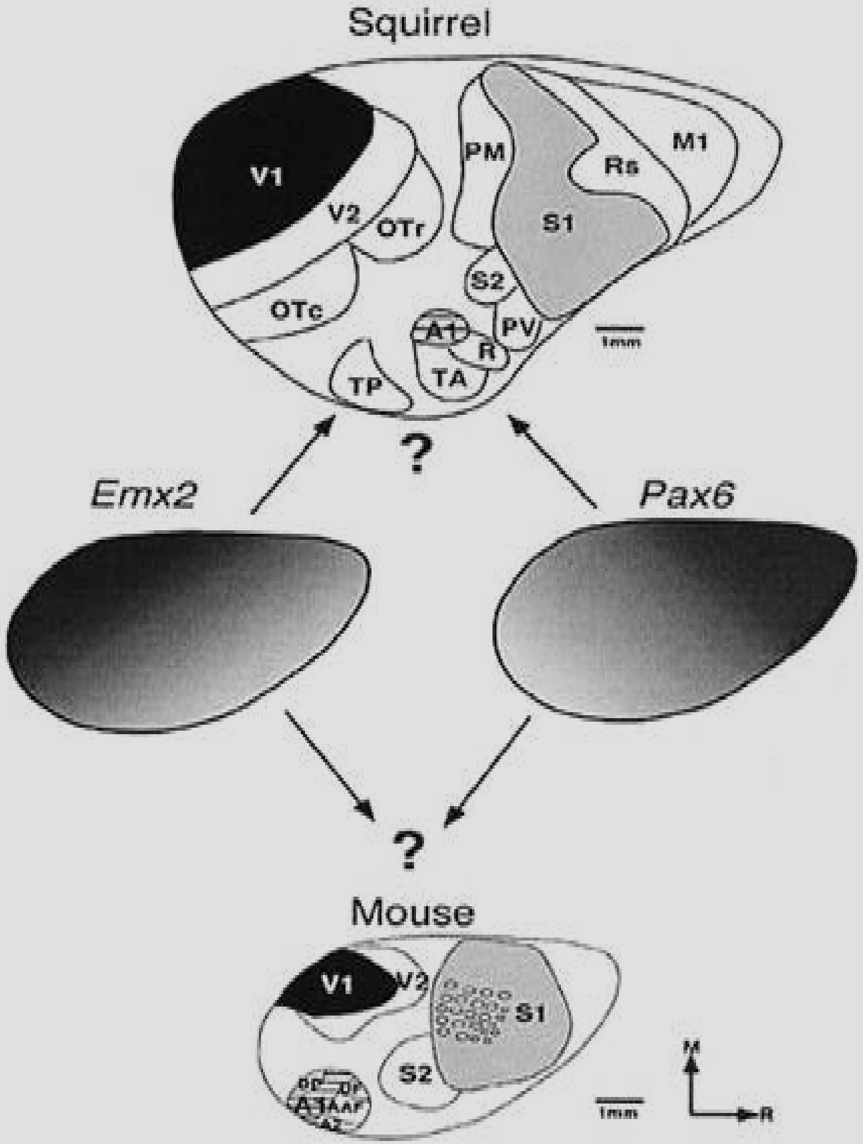


Fig. 4. The graded distribution of regulatory genes *Emx2* and *Pax6* in the mouse neocortex (middle figures), and the adult organization of the mouse (bottom) and squirrel (top) neocortex. While it seems plausible that graded expression patterns can assign a general rostral and caudal organization to incoming thalamic afferents, it is difficult to imagine how such a pattern can generate the precise organization observed in the adult mouse neocortex, and mediate major sensory domain shifts that are tied to the periphery. Further, if the common ancestor of rodents had graded expression patterns like those depicted in the middle illustrations, how are new areas added in some lineages of rodents such as visual areas in the squirrel and auditory areas in the mouse? [Middle figures are modified from Bishop et al., 2000. Subdivisions of the squirrel are from Kaas et al., 1972, 1989; Merzenich et al., 1976; Sur et al., 1978; Nelson et al., 1979; Krubitzer et al., 1986; Luethke et al., 1988; and Slutsky et al., 2000. Subdivisions from the mouse are from Woolsey, 1967; Woolsey and Van der Loos, 1970; Wagor et al., 1980; Carvell and Simmons, 1986 and Stiebler et al., 1997.]

L. Krubitzer and K.J. Huffman ´00

Aires homologues parmi les mammifères

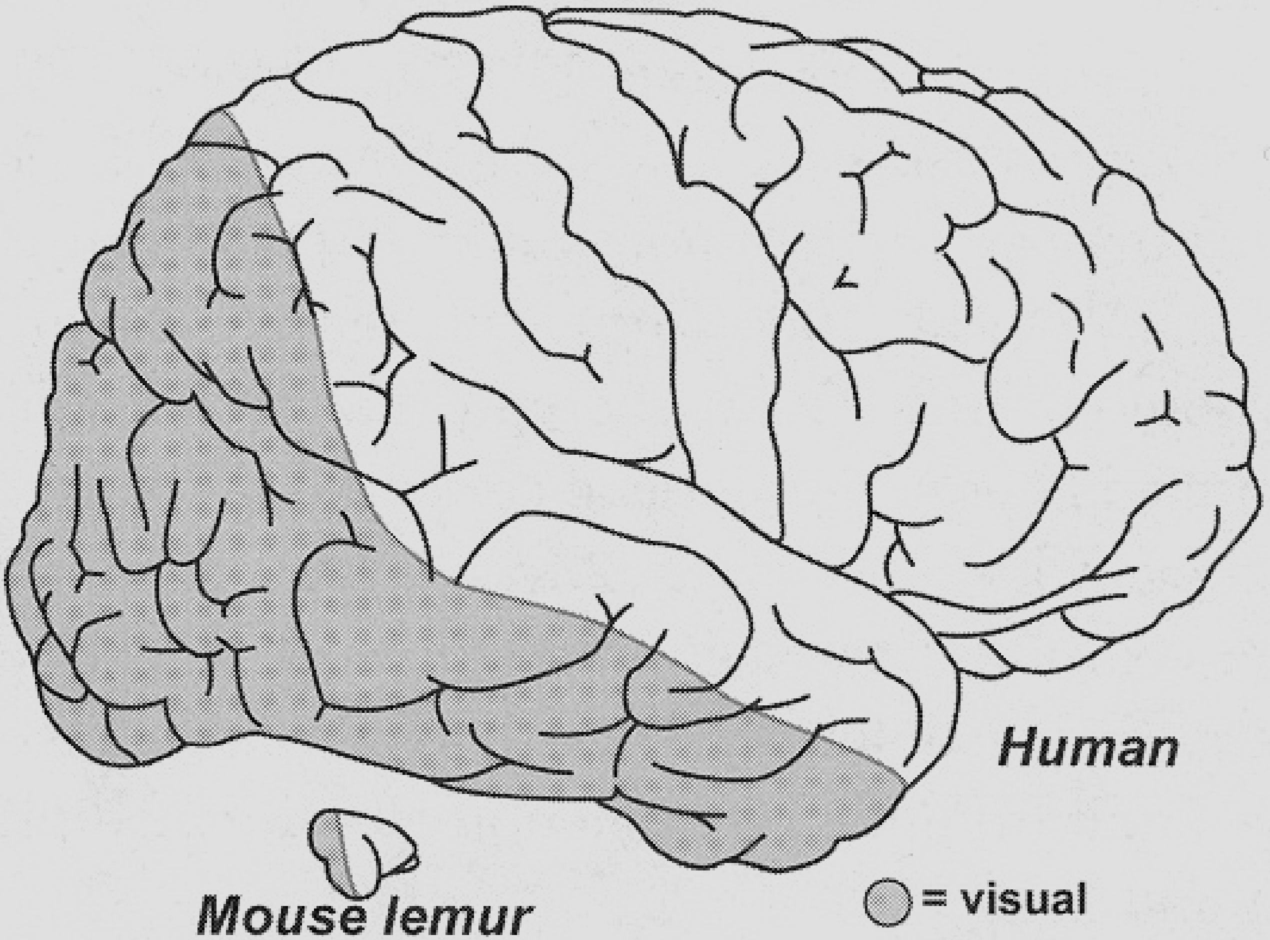
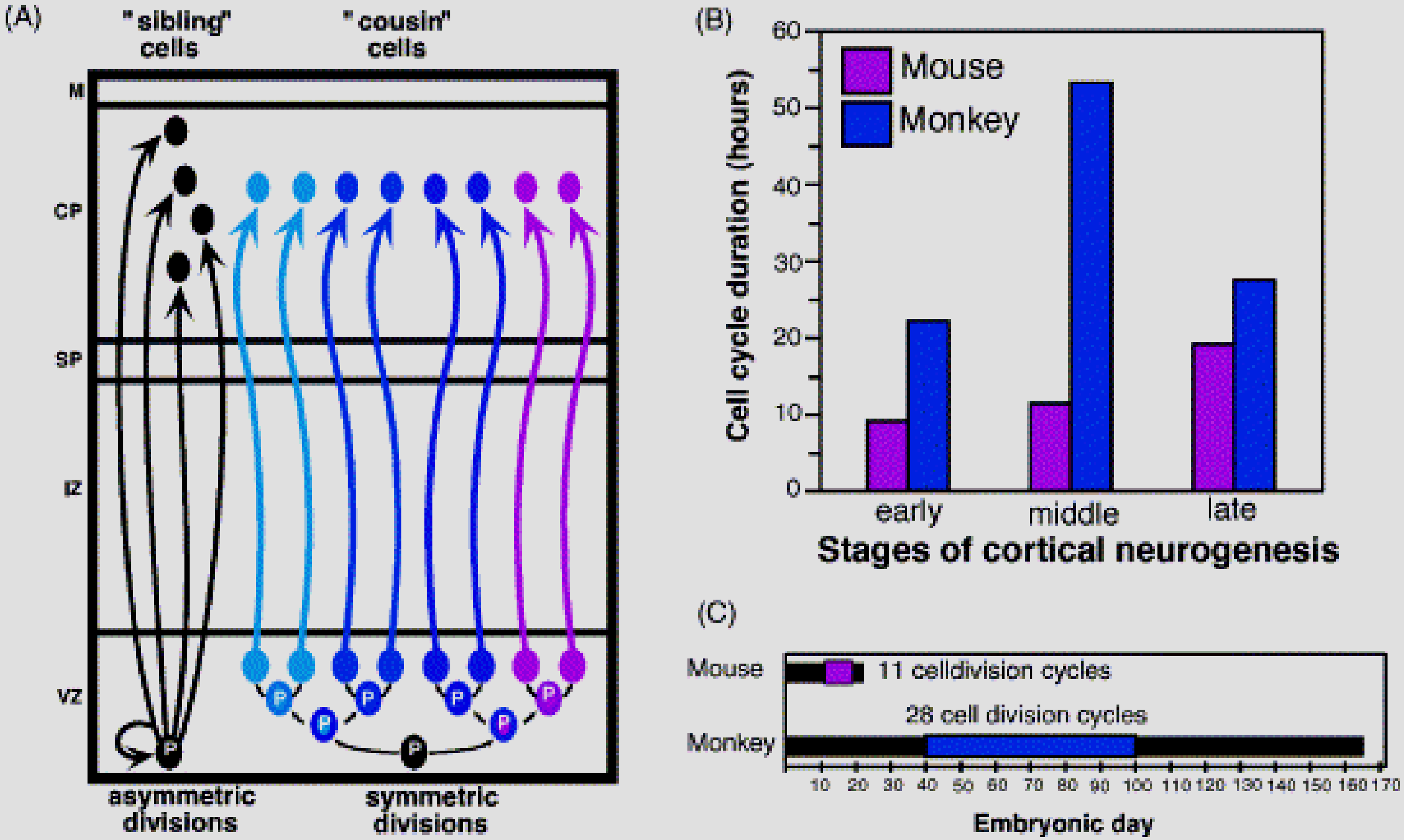


FIGURE 105.6. Size differences in primate brains. Our early primate ancestors were small, with small brains with few fissures, such as the mouse lemur brain (*lower left*). Smooth-brained members of the Euarchontoglires radiation (Fig. 105.1) gave rise to early primates with shallow lateral and calcarine fissures. The brain size and number of fissures increased dramatically in the course of evolving the human brain. The caudal regions of the lemur and human brain that are devoted to vision are shaded.

J.H. Kaas ´04

Aires homologues parmi les mammifères



Illustrations of how specific patterns of cell division in the ventricular zone (VZ) give rise to the patterns of clonally related neurons in the neocortex. In part A, asymmetric divisions from a single progenitor cell (P) (black arrows) generate "sibling" cells that migrate sequentially to different layers of the cortical plate (CP). This type of cell division determines cortical thickness. Symmetric divisions from a single progenitor cell (colored arrows) generate several progenitor cells that in turn simultaneously generate "cousin" cells that then migrate, in parallel, to the same cortical layer. This type of division determines cortical sheet size. Duration (B) and number (C) of cell cycle divisions differs dramatically in the mouse (pink) and the rhesus monkey (blue). In part C, black bars represent the length of gestation in the mouse (19 days) and the monkey (165 days). In the mouse (pink rectangle) neurogenesis lasts 6 days, from embryonic (E) day E11 to E17. In the monkey, neurogenesis lasts 60 days, from E40 to E100. The expanded duration and the increased number of cell cycles could be one mechanism involved in expansion of the primate neocortex. IZ, intermediate zone (white matter), M, marginal zone (layer I), SP, subplate zone (data used to construct this figure is taken from the work of [Kornack and Rakic, 1998] and [Kornack, 2000]).

L. Krubitzer and D.M. Kahn ´03

Aires homologues parmi les mammifères

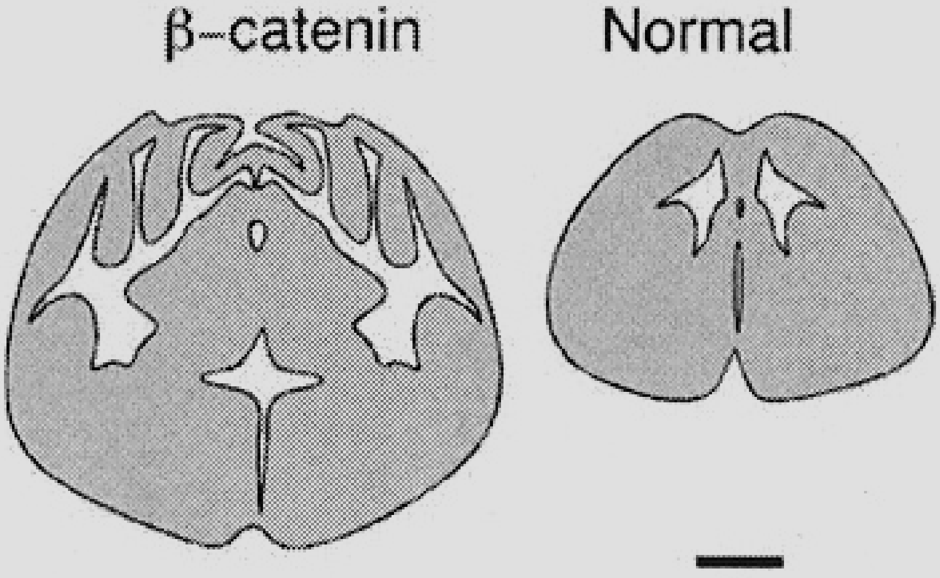


Fig. 4. An example of how changes in gene expression can dramatically alter the size of the cortical sheet. To the left is a coronal view of the cortex of a transgenic mouse in which the regulatory gene, *β-catenin*, was overexpressed, shown next to an age-matched normal mouse (right). In this study by Chenn and Walsh (2002), the animals that overexpressed *β-catenin* had massive increase in horizontal growth of the cortical sheet, which caused the normally lissencephalic cortex to became gyrencephalic. The results of this study indicated that the increased cortical size was due to a two-fold increase in the proportion of progenitor cells that re-entered the cell cycle and continued to divide (data used to construct this figure is taken from the work of Chenn and Walsh, 2002). Dorsal is to the top, scale bar = 1 mm.

L. Krubitzer and D.M. Kahn ´03

Homologies Cérébrales

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Aires homologues parmi les primates

Collicule superieur: hemichamp controlateral

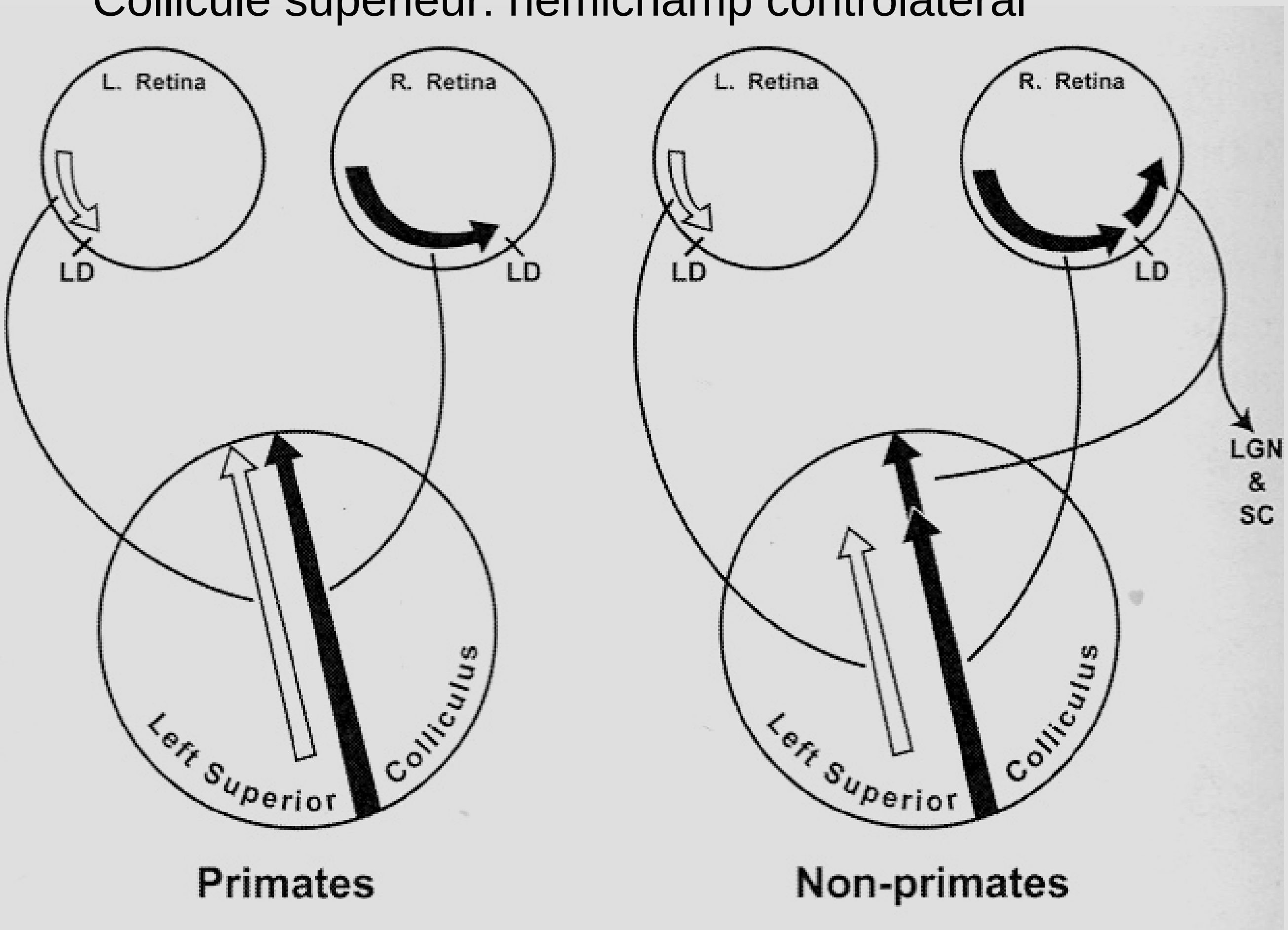
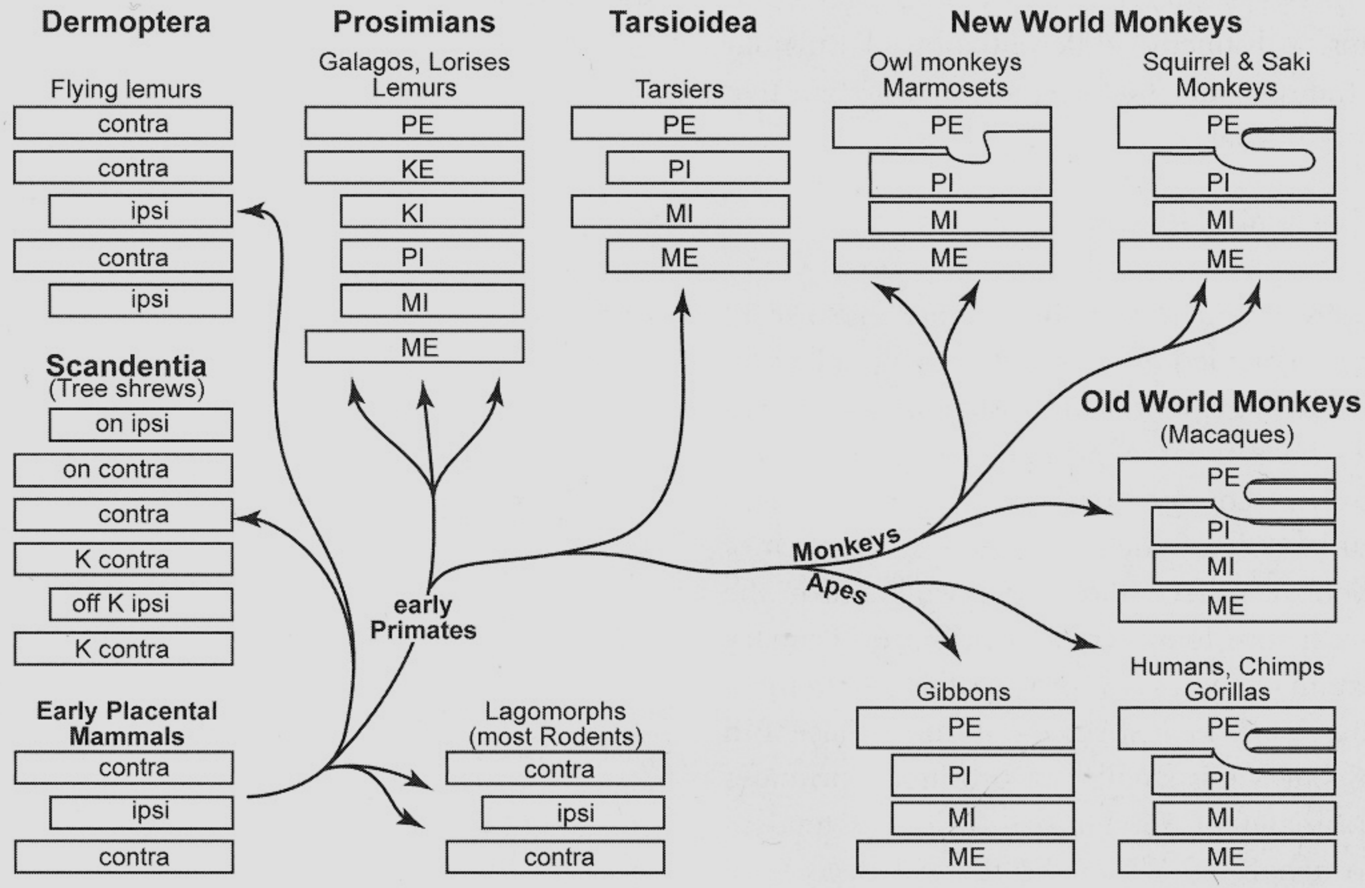


FIGURE 105.3. All primates share a unique type of retinotopic organization in the superior colliculus. In all primates, the left superior colliculus receives superimposed inputs from the nasal hemiretina of the right (R) eye and the temporal hemiretina of the left (L) eye, resulting in a representation of the right hemifield that is largely binocular. The right superior colliculus (SC) has a comparable pattern of inputs from the left and right eyes. In other studied mammals, the complete retina of the contralateral eye projects to the superior colliculus, even though the temporal retina also projects ipsilaterally to the LGN, as in primates. The temporal retina may also project weakly to the ipsilateral superior colliculus in a species-variable manner. Note that in nonprimate mammals, the superior colliculus represents the complete visual field of the contralateral eye, including the binocular part of the ipsilateral hemifield. LD, line of decussation of retinal projections to the two hemispheres.

J.H. Kaas ´04

Aires homologues parmi les primates

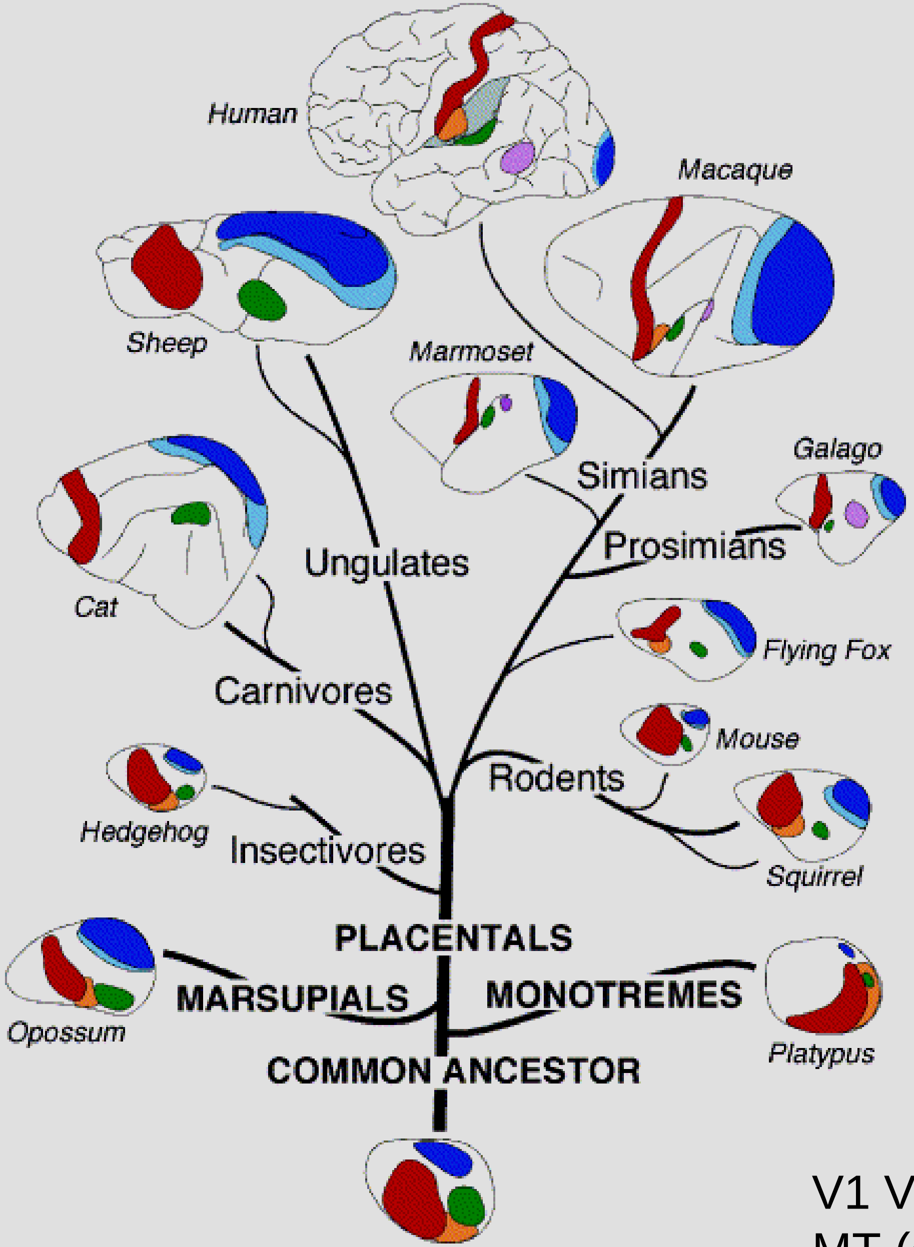


Quatre
Couches
Genouillees
2 Parvo
2 Magno

FIGURE 105.4. Laminar patterns of the dorsal LGN in primates. The schematics are of the laminar patterns in brain sections cut across layers that are stacked like slices of bread from ventral (or along the optic tract) to dorsal (near the pulvinar). Early mammals had a simple pattern of LGN lamination that segregated inputs from the ipsilateral retina in a central region between outer regions with inputs from the contralateral retina. All primates have a more elaborate pattern of four basic layers that evolved with the first primates. Close relatives of primates, tree shrews and flying lemurs, evolved different patterns of lamination. In flying lemurs, layers have been identified histologically and by having inputs from the contralateral (contra) or ipsilateral (ipsi) eye (Pettigrew et al., 1989). In tree shrews (Norton, 1982), microelectrode recordings suggest that M- and P-cell (termed Y and X) inputs are mixed in the same layers, unlike primates, while ON and OFF ganglion cell inputs are segregated in different layers (Norton, 1982), unlike in primates. Other layers appear to have K-cell inputs. The basic primate pattern of lamination includes two parvocellular (P) and two magnocellular (M) layers, with the longer (for the monocular field) outer (external) layers receiving from the contralateral retina (PE, ME) and the shorter inner or internal layers (PI, MI) from the ipsilateral eye. Present-day tarsiers may have a modified pattern, as there is evidence that the two M layers have a reversed pattern of input in regard to eye of origin, so that ME receives input from the ipsilateral retina (Pettigrew et al., 1989). All prosimians have an extra pair of koniocellular layers (KE and KI). In other primates, K cells are scattered between layers where they do not form distinct layers. In many anthropoid primates, the parvocellular layers divide to form sublayers and leaflets of sublayers. (Based on Kaas et al., 1978.)

J.H. Kaas ´04

Aires homologues parmi les primates



An evolutionary tree depicting the phylogenetic relationship of major orders of mammals and the cortical organization of some of the sensory fields that have been described in particular species.
Electrophysiological, anatomical, histochemical and molecular analyses have revealed that certain cortical regions, such as S1, S2, A1, V1, and V2, are common to all mammals and most likely are homologous areas that arose from a common ancestor. On the other hand, some regions, such as MT (pink), have been observed in only a few orders, such as primates, and likely evolved independently in these lineages. A comparative analysis of the neocortex, using the criteria described above, allows one to infer the organization of an unknown mammal, such as the common ancestor or human. If a number of species are compared, one can be fairly confident when assigning features of cortical organization to the unknown state, even in the absence of direct data. S1: primary somatosensory area (red), S2: second somatosensory area (orange), A1: auditory (green), V1: primary visual area (dark blue), V2: second visual area (light blue), rostral is left, medial is up.

V1 V2 communes aux mammiferes
MT (et V3) commune aux primates

L. Krubitzer and D.M. Kahn ´0

Homologies Cérébrales

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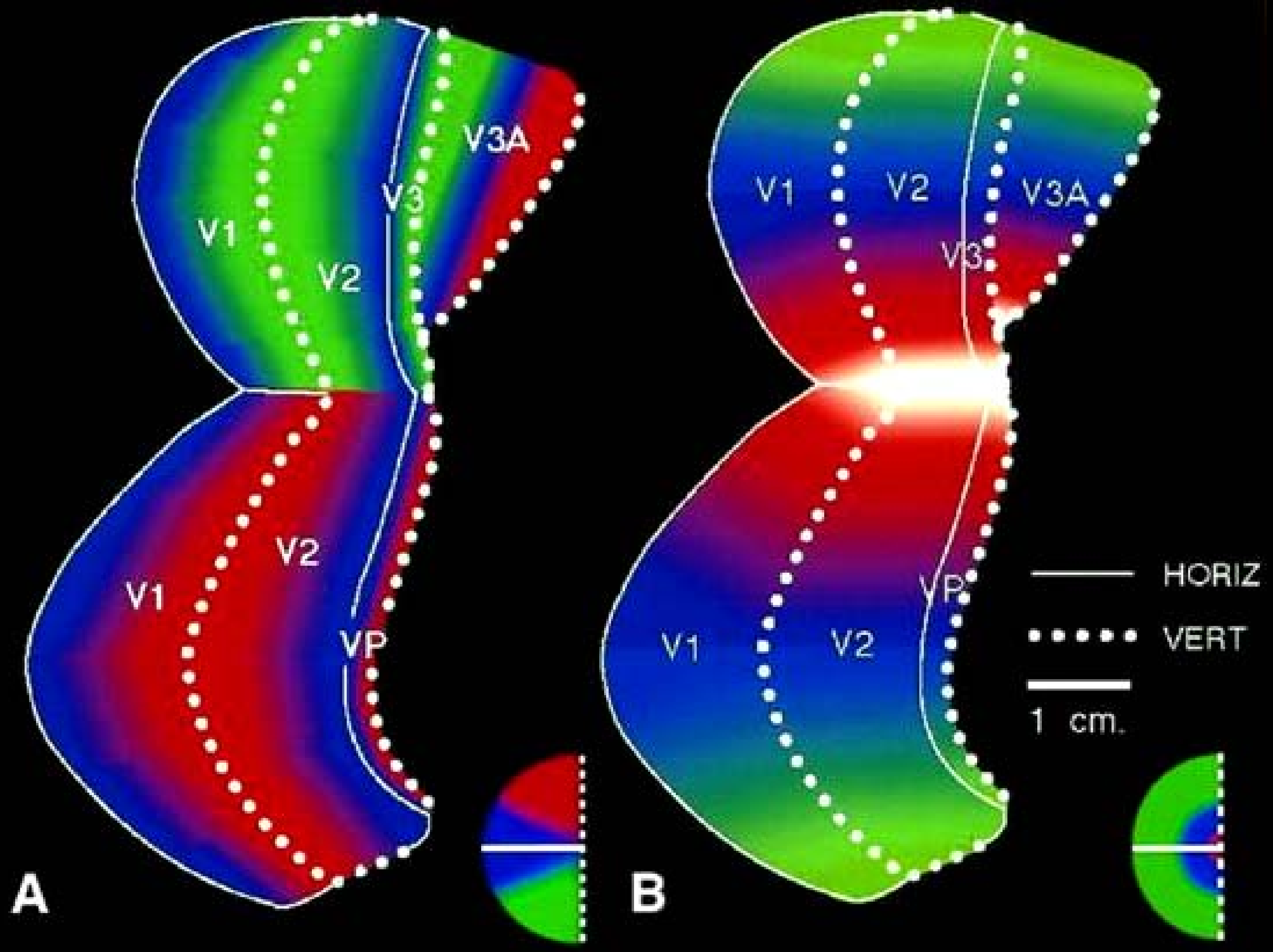
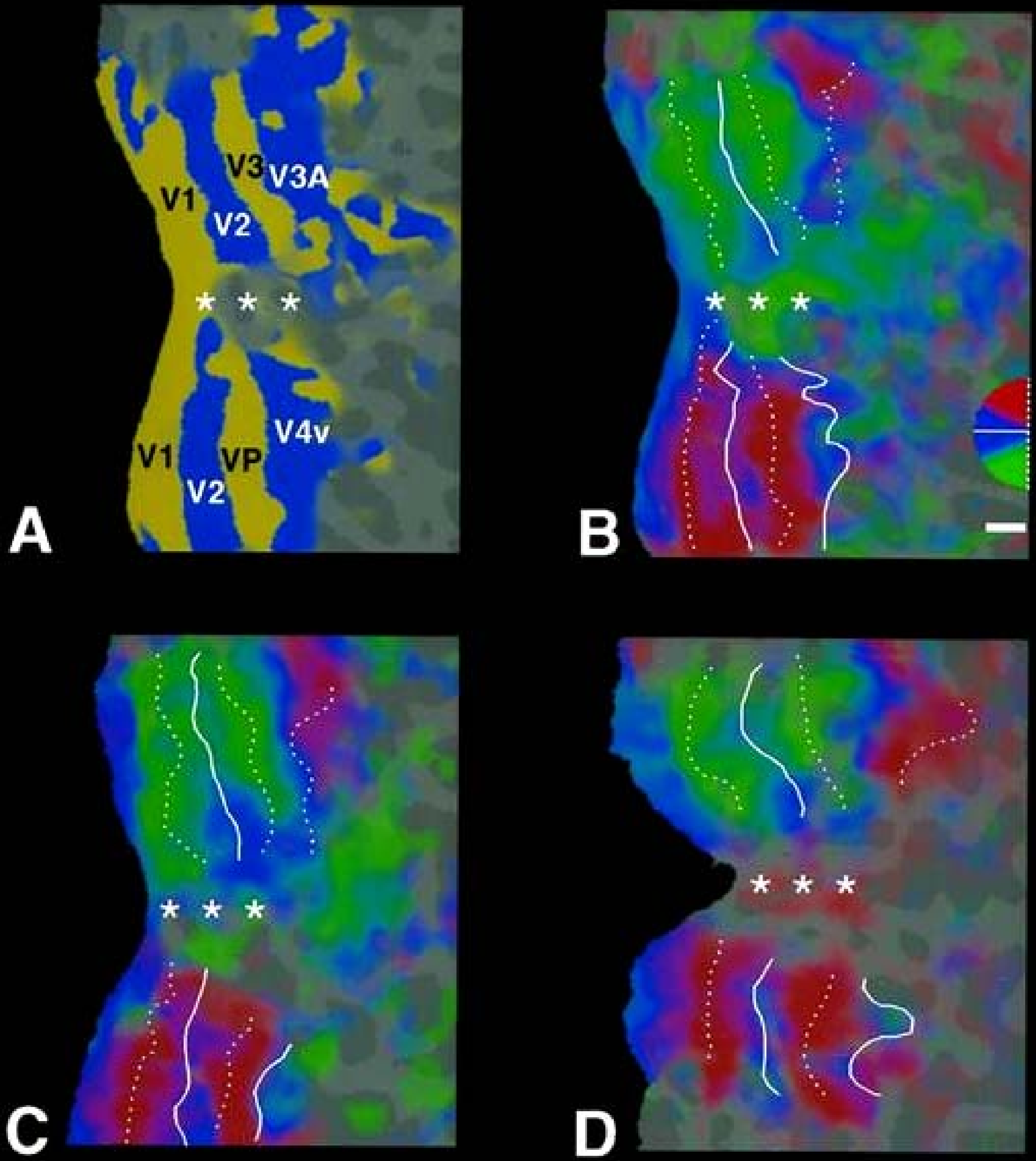
Aires retinotopiques



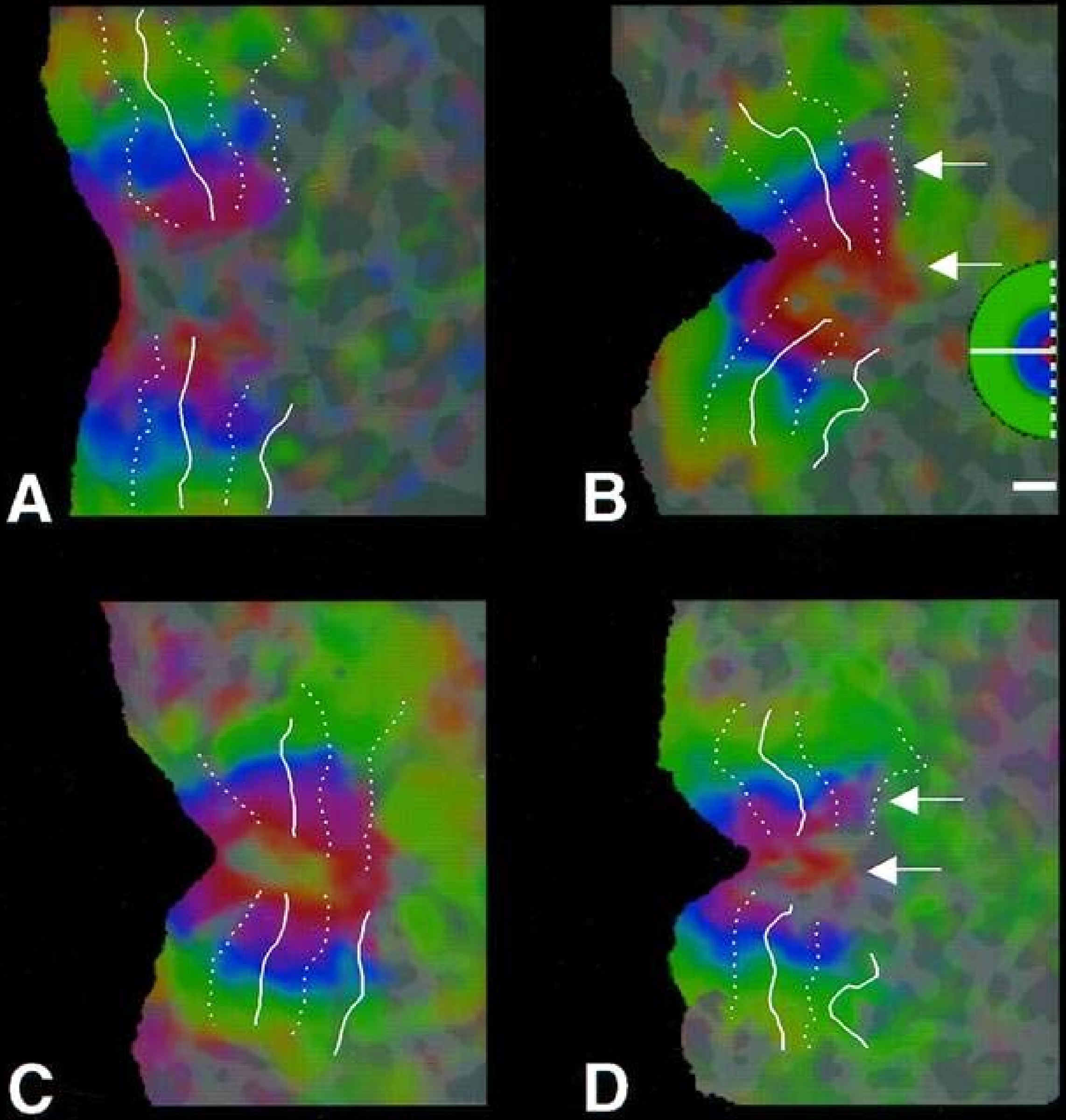
R.B.H. Tootell et al, ´97

Aires retinotopiques



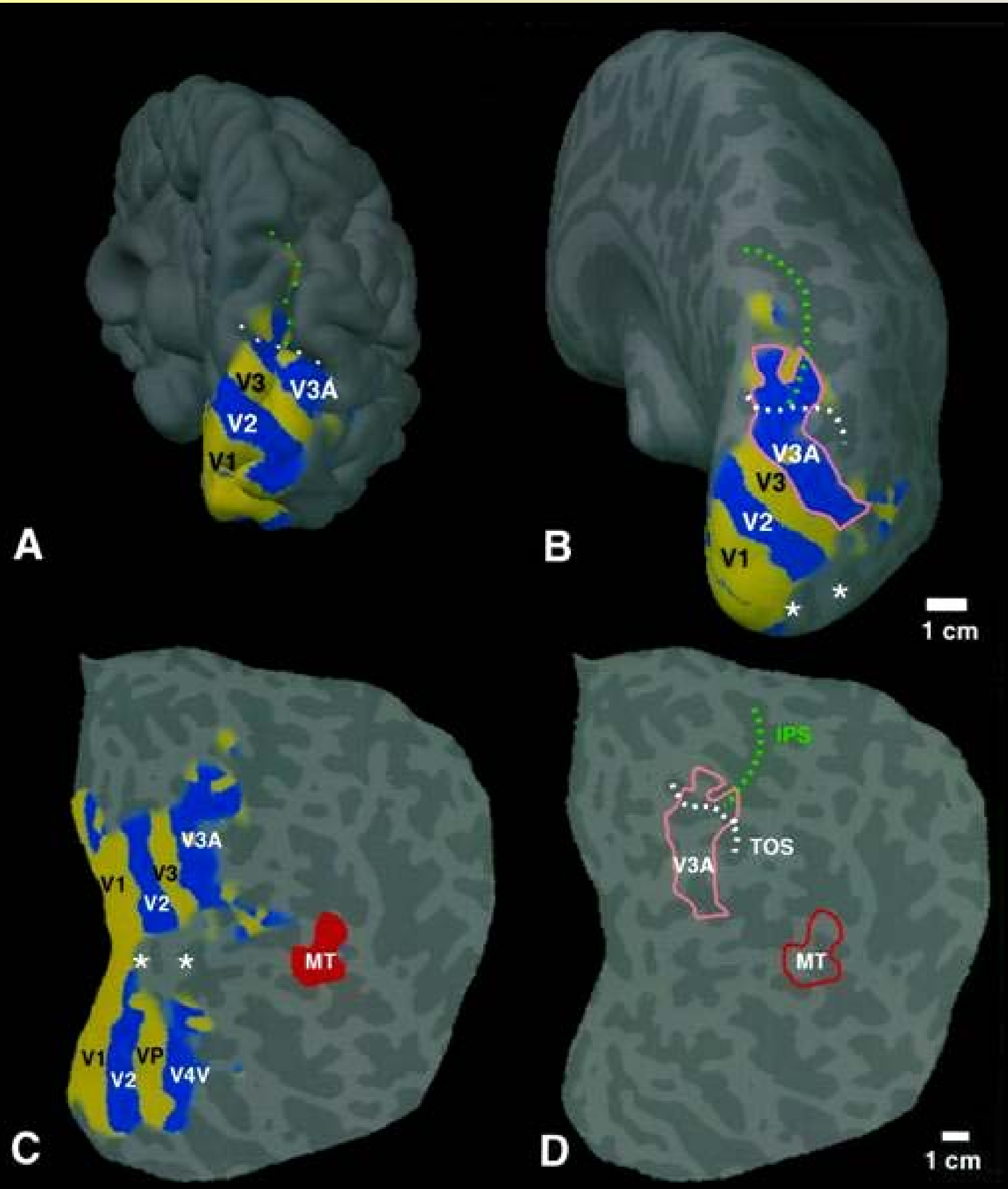
R.B.H. Tootell et al, ´97

Aires retinotopiques



R.B.H. Tootell et al, ´97

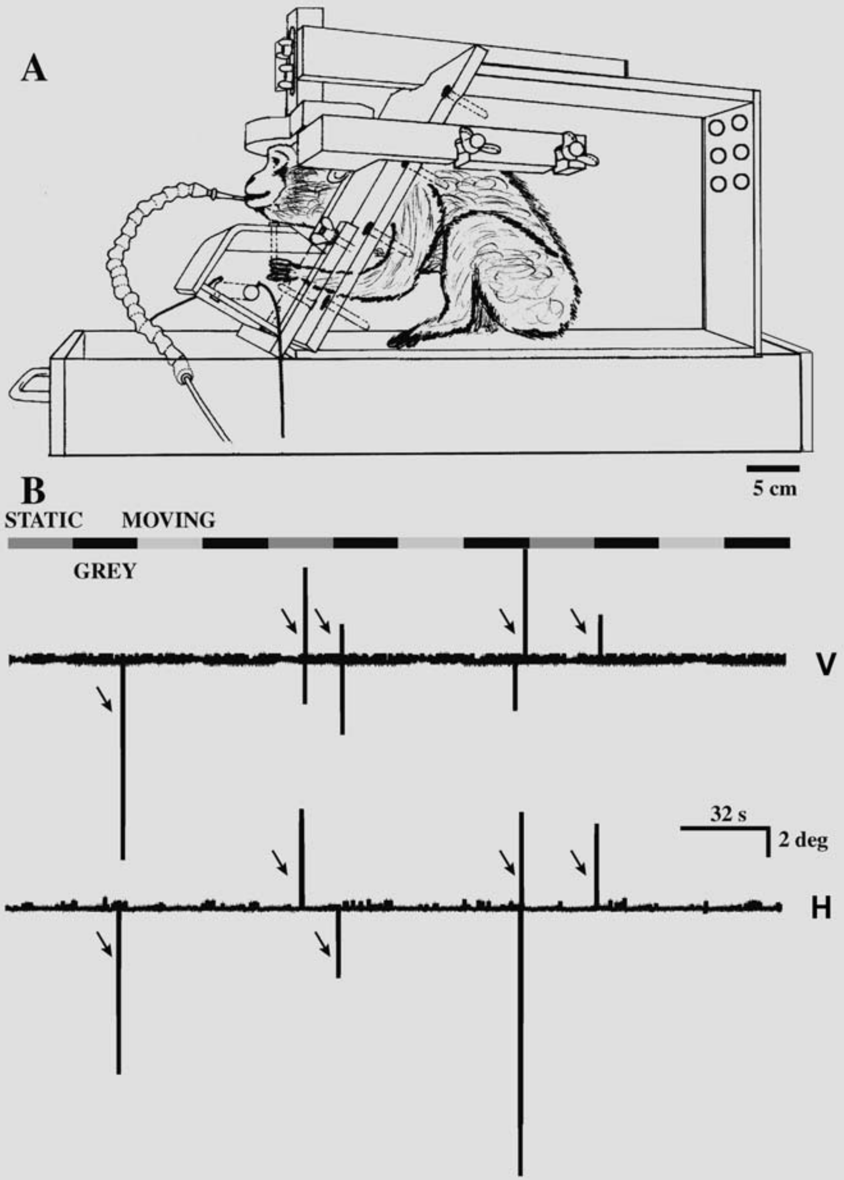
Aires retinotopiques

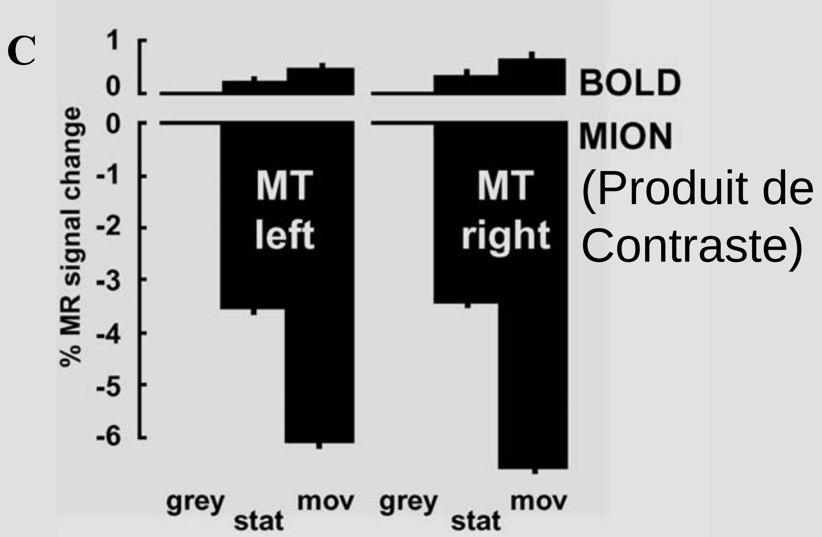


R.B.H. Tootell et al, ´97

Aires retinotopiques

IRMf primate non humain vigile





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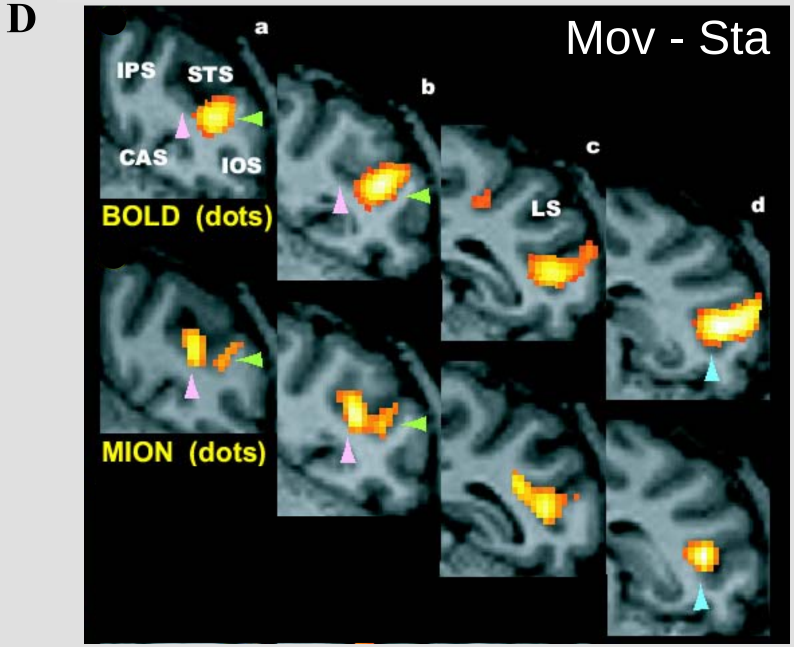

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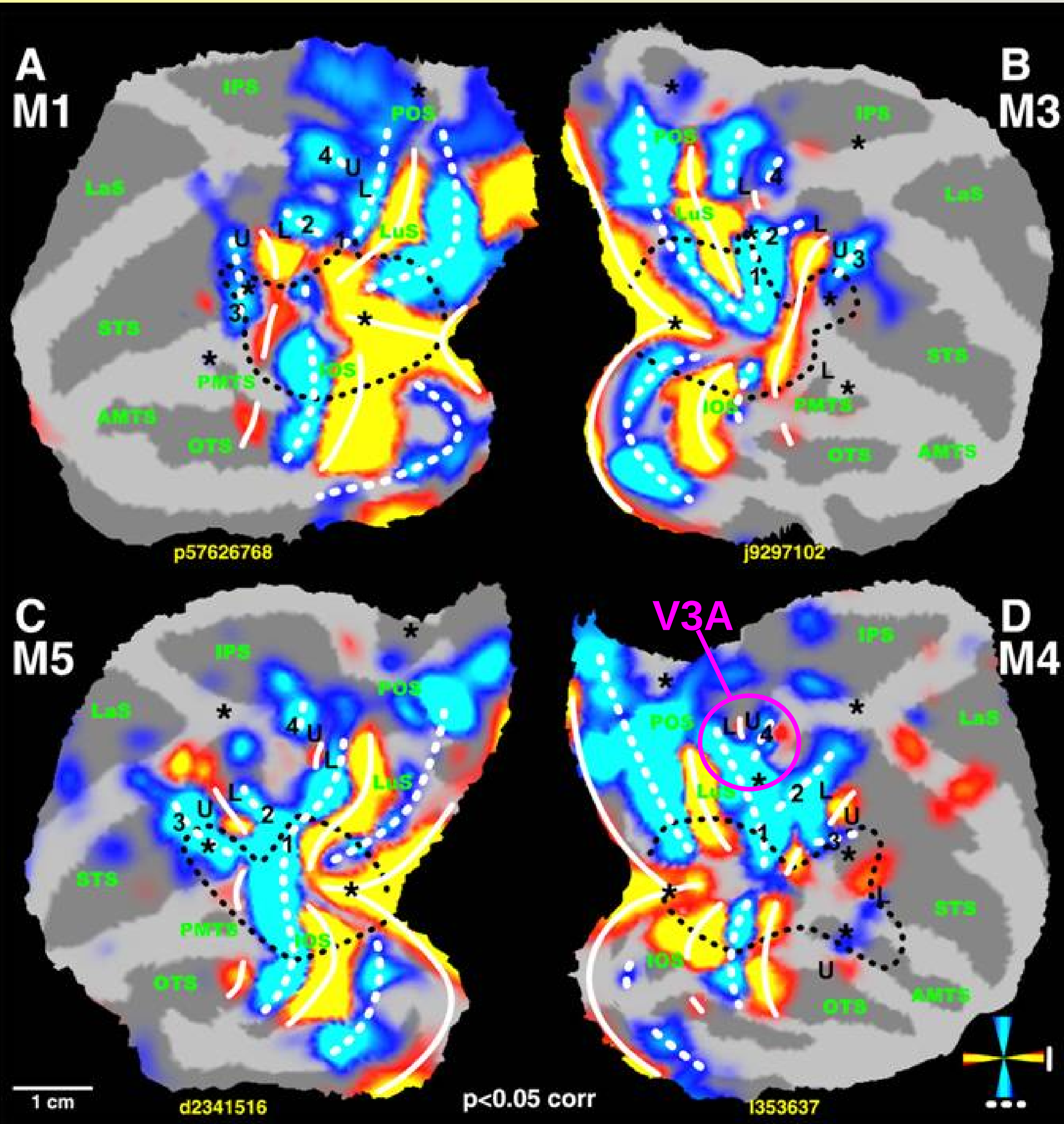
W. Vanduffel et al, Neuron, ´01

Aires retinotopiques

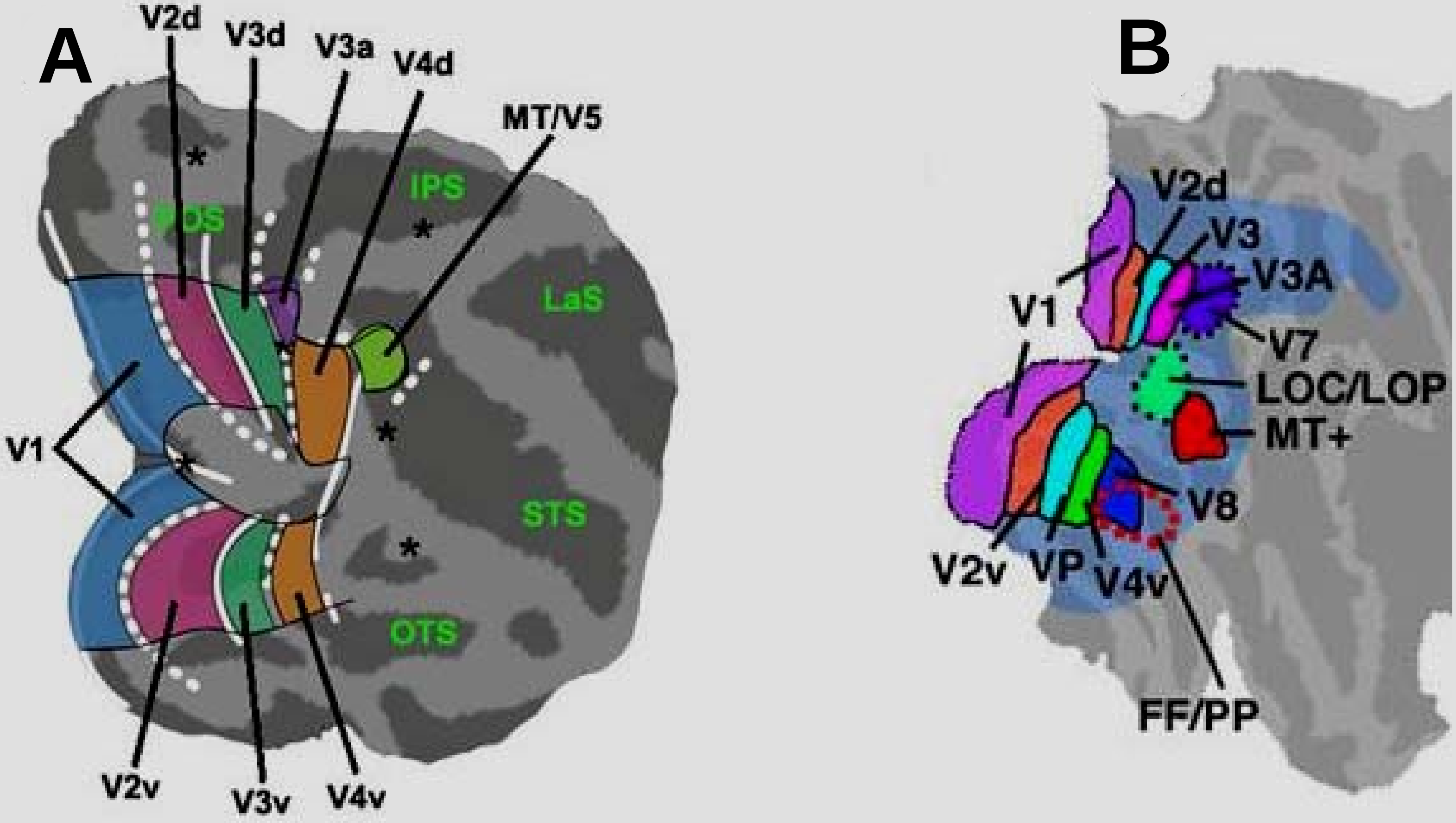


D. Fize et al, ´03

Aires retinotopiques

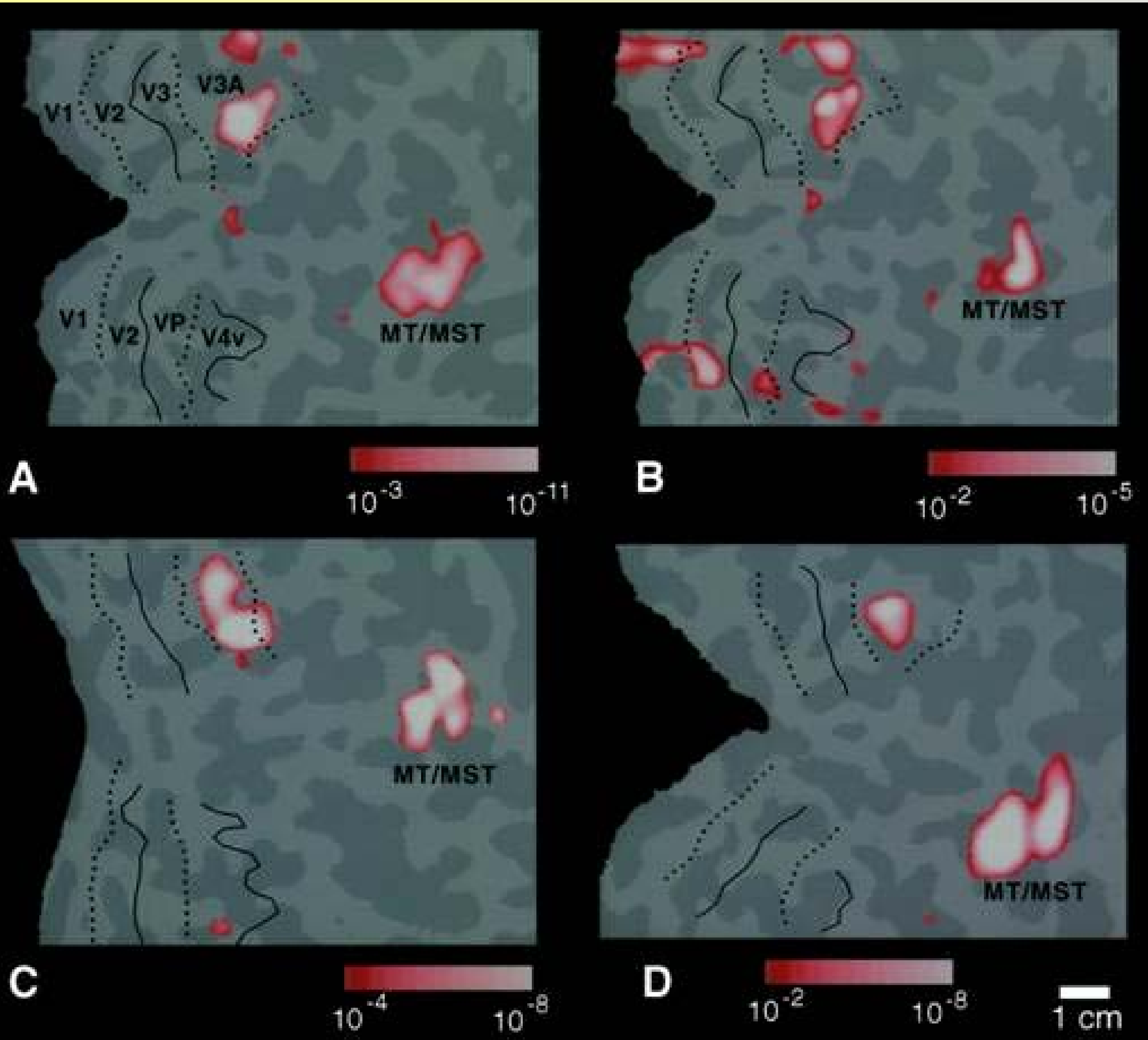
V1,V2,V3,V3a et V4v homologues; quid de V4d?

Macaque **Humain**



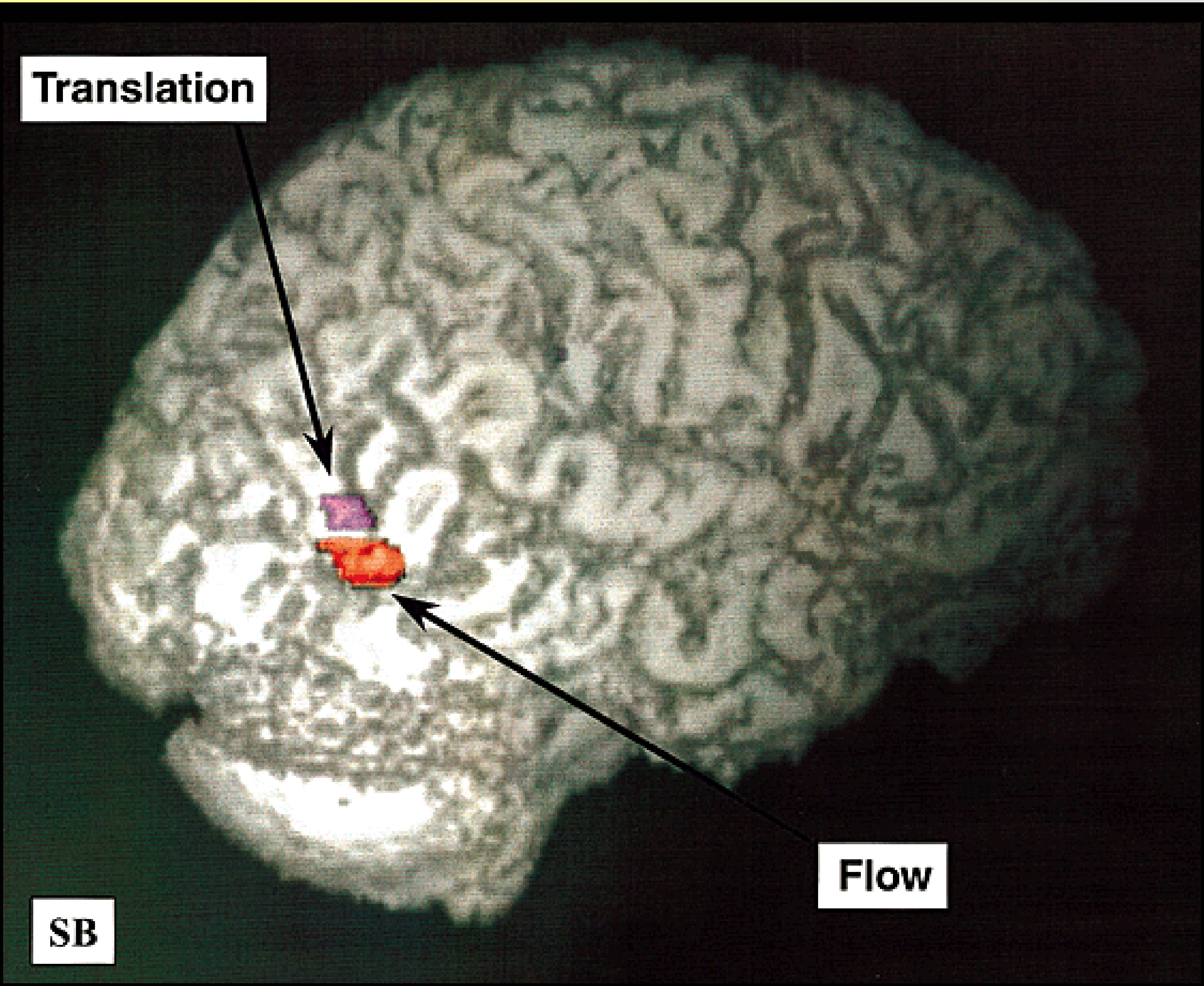
G. Orban et al, TICs ´04

Aires retinotopiques



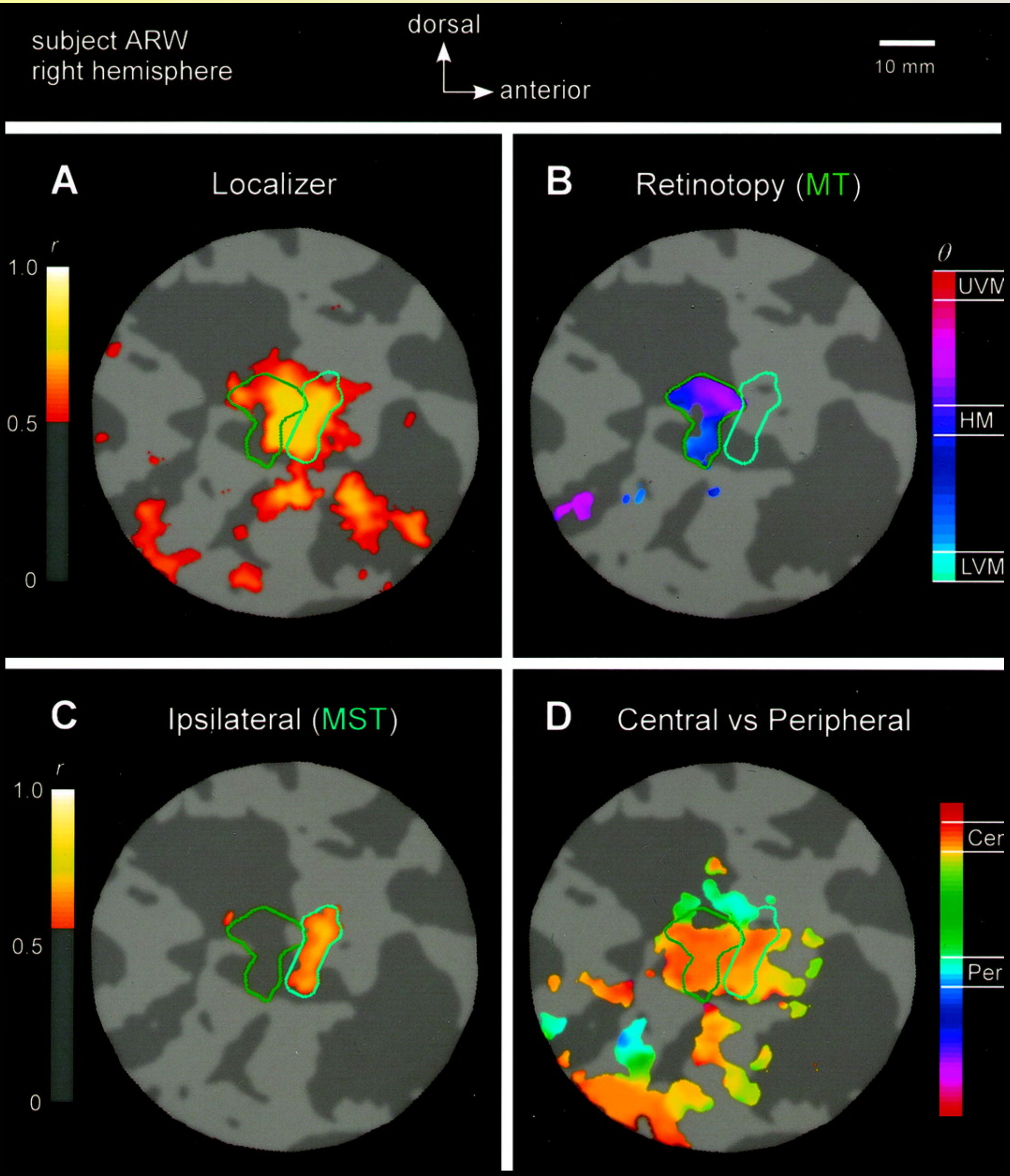
R.B.H. Tootell et al, ´97

hMT/V5+



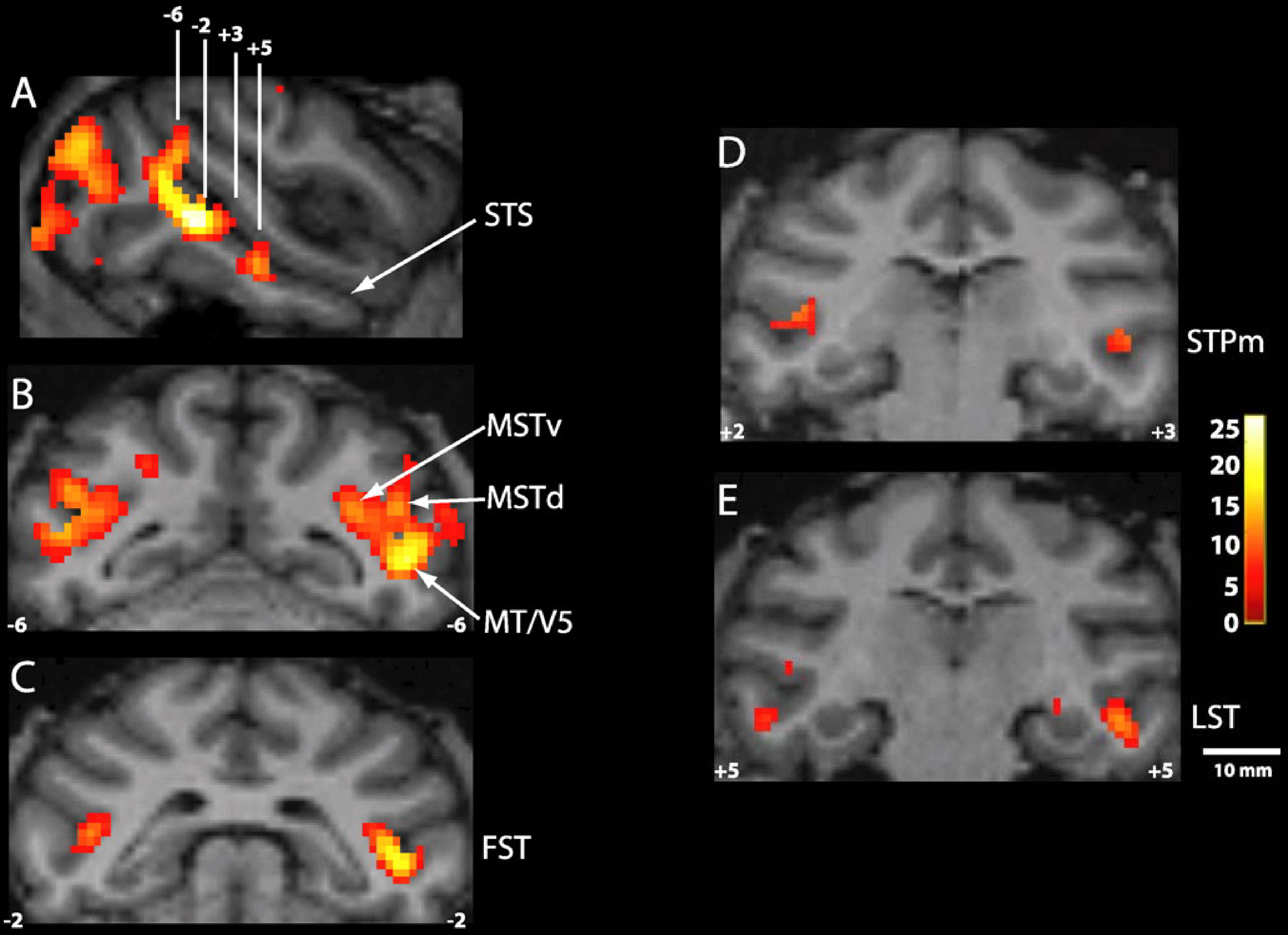
M.C. Morrone et al, Nature Neurosci, ´00

hMT/V5+



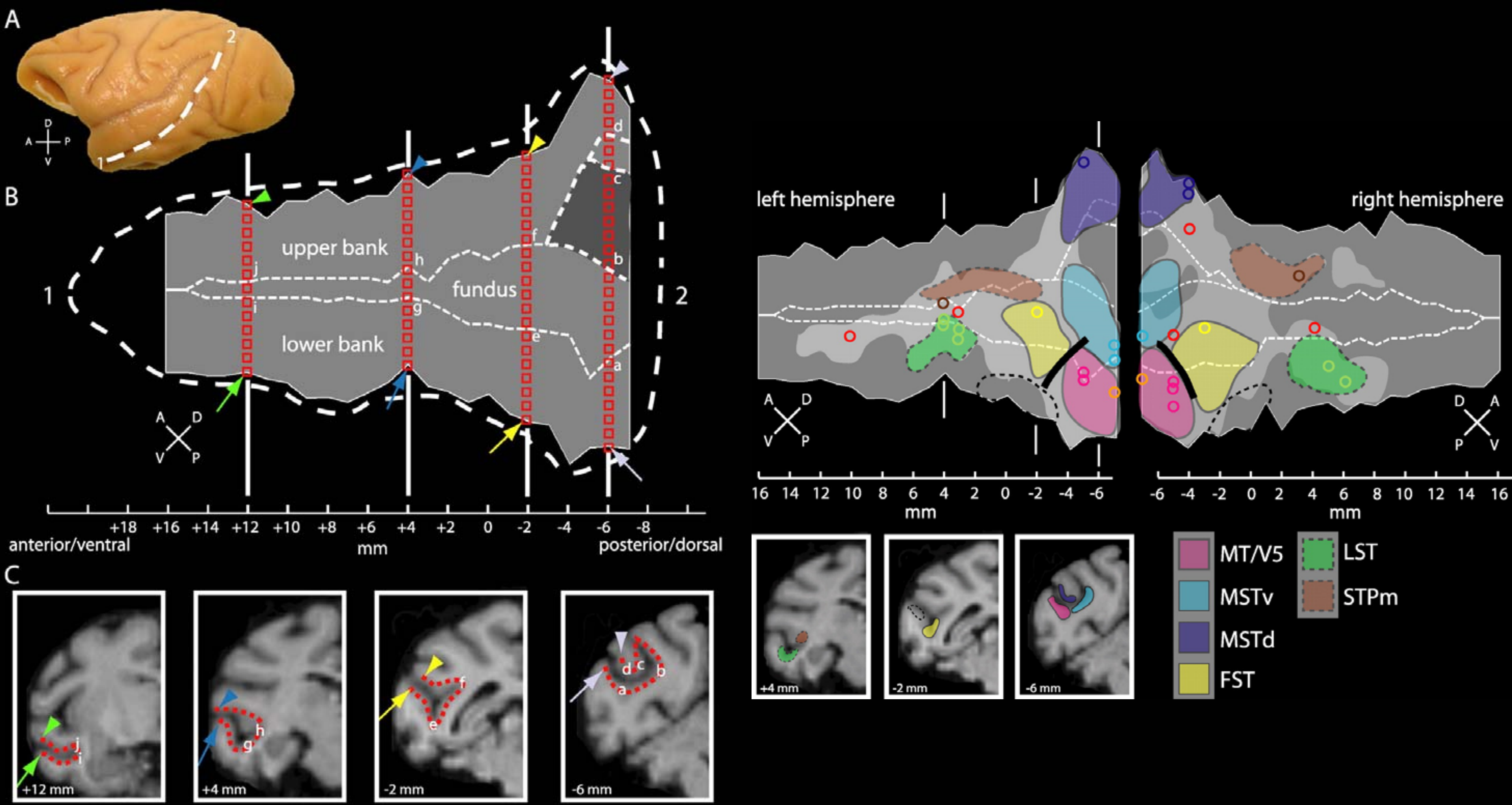
A.C. Hulk et al, Nature Neurosci, ´02

hMT/V5+



K. Nelissen et al, JoNS, ´06

hMT/V5+



K. Nelissen et al, JoNS, ´06

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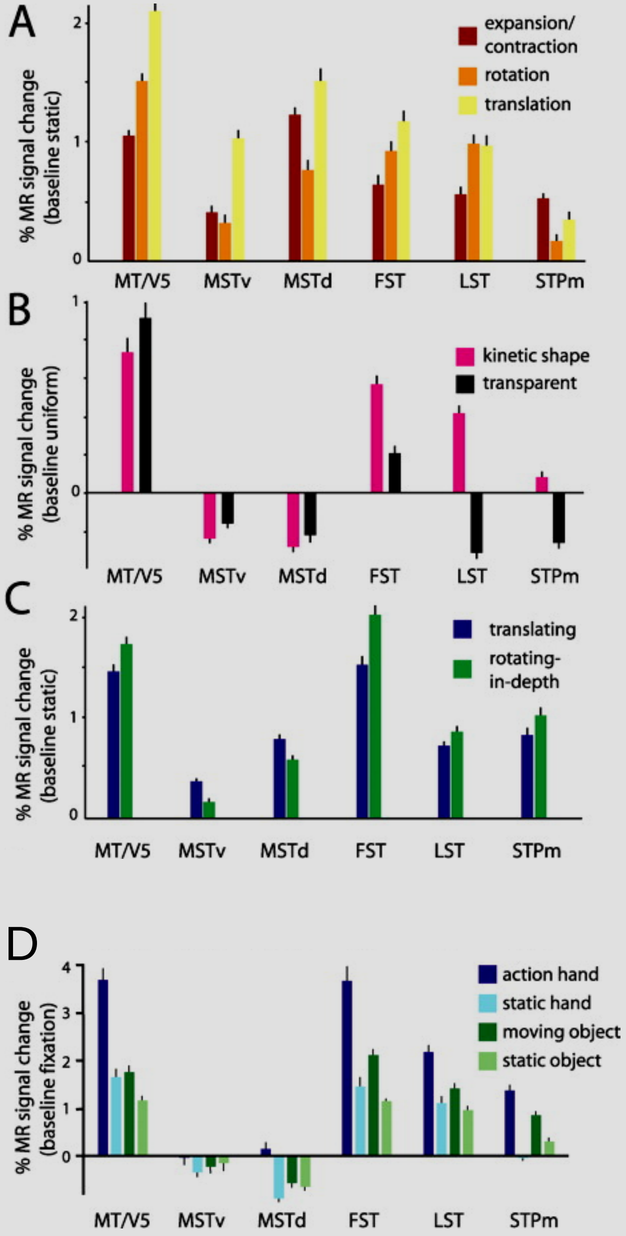

K. Nelissen et al, JoNS, ´06

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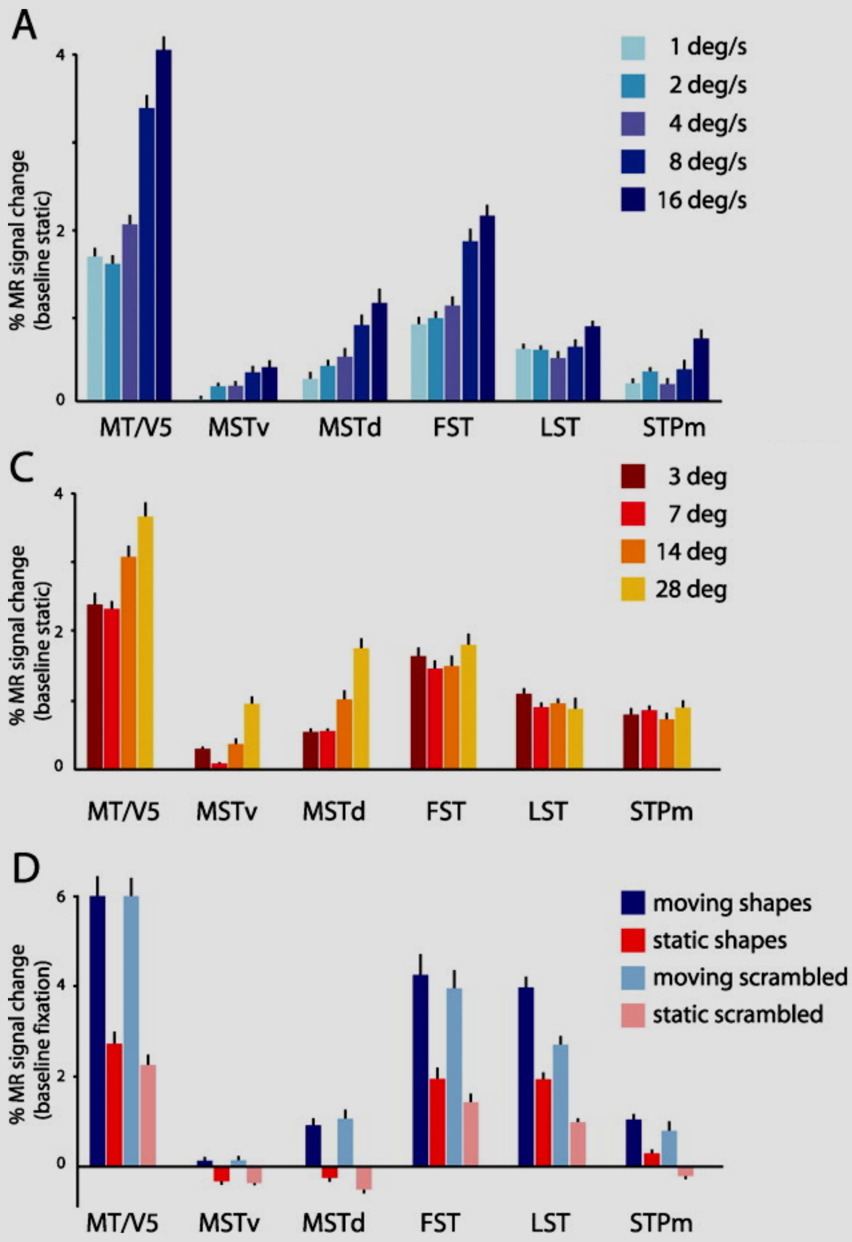
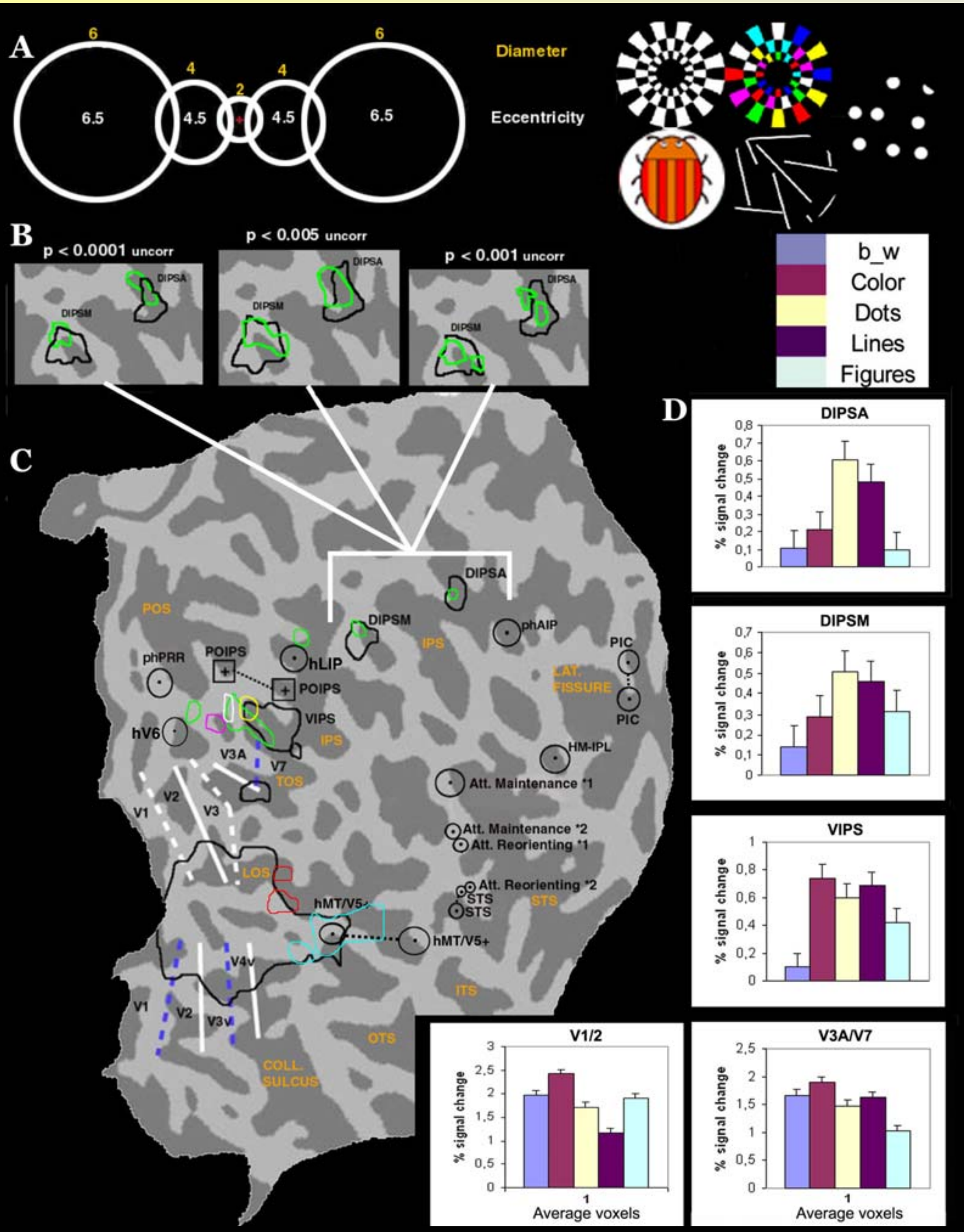


K. Nelissen et al, JoNS, ´06

Aires pariétales



G. Orban et al, Neuropsychologia, ´06

Aires pariétales

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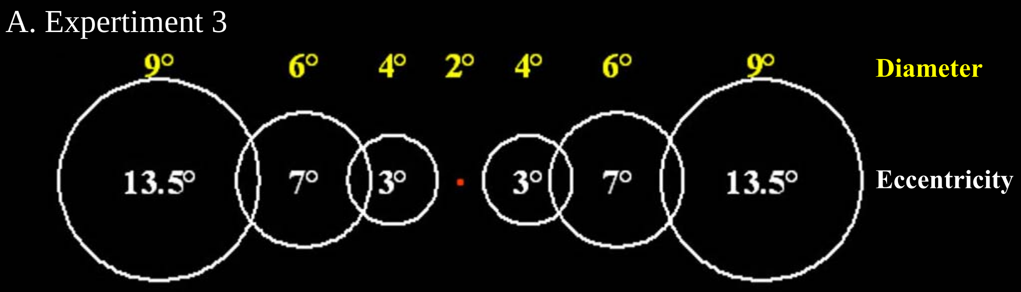

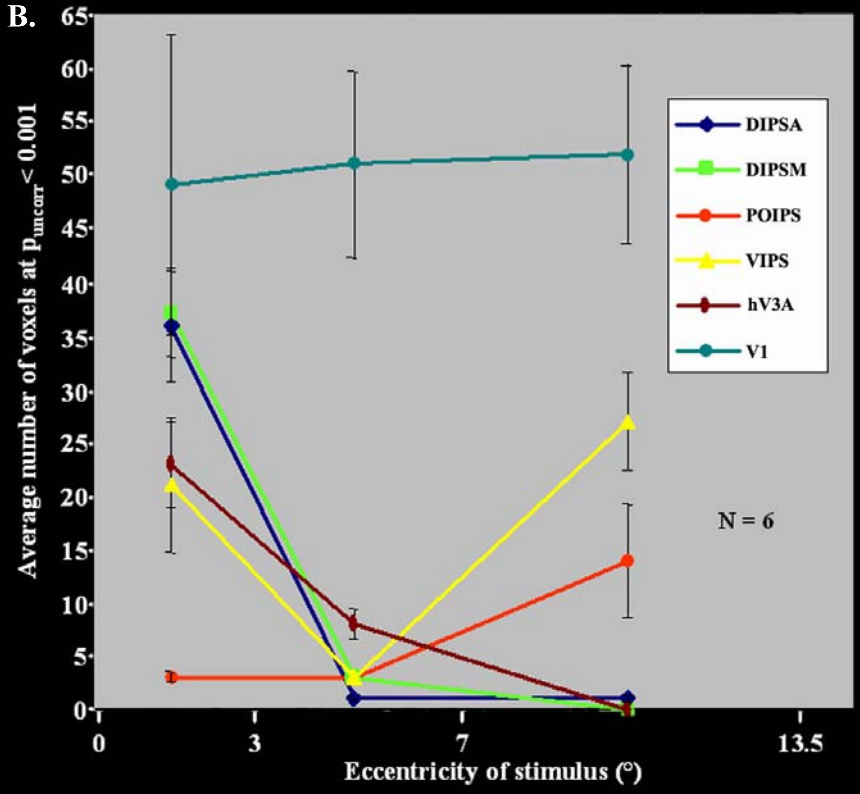

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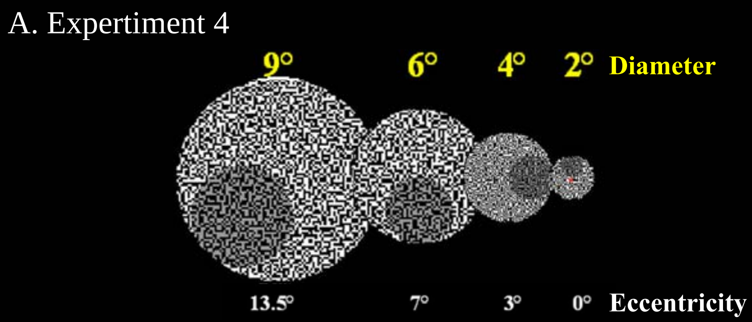
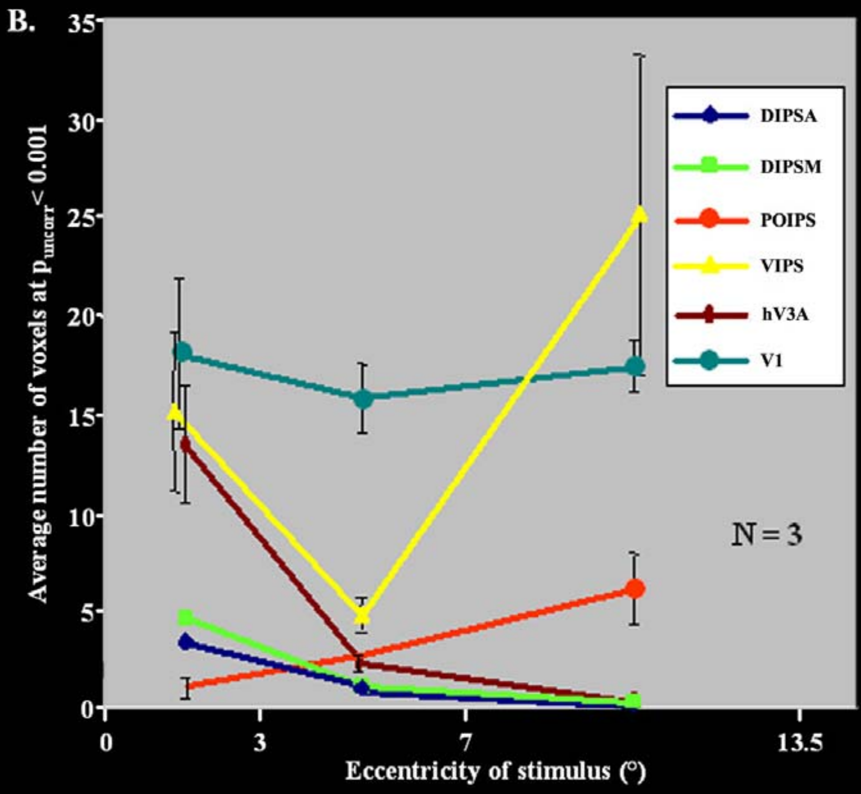
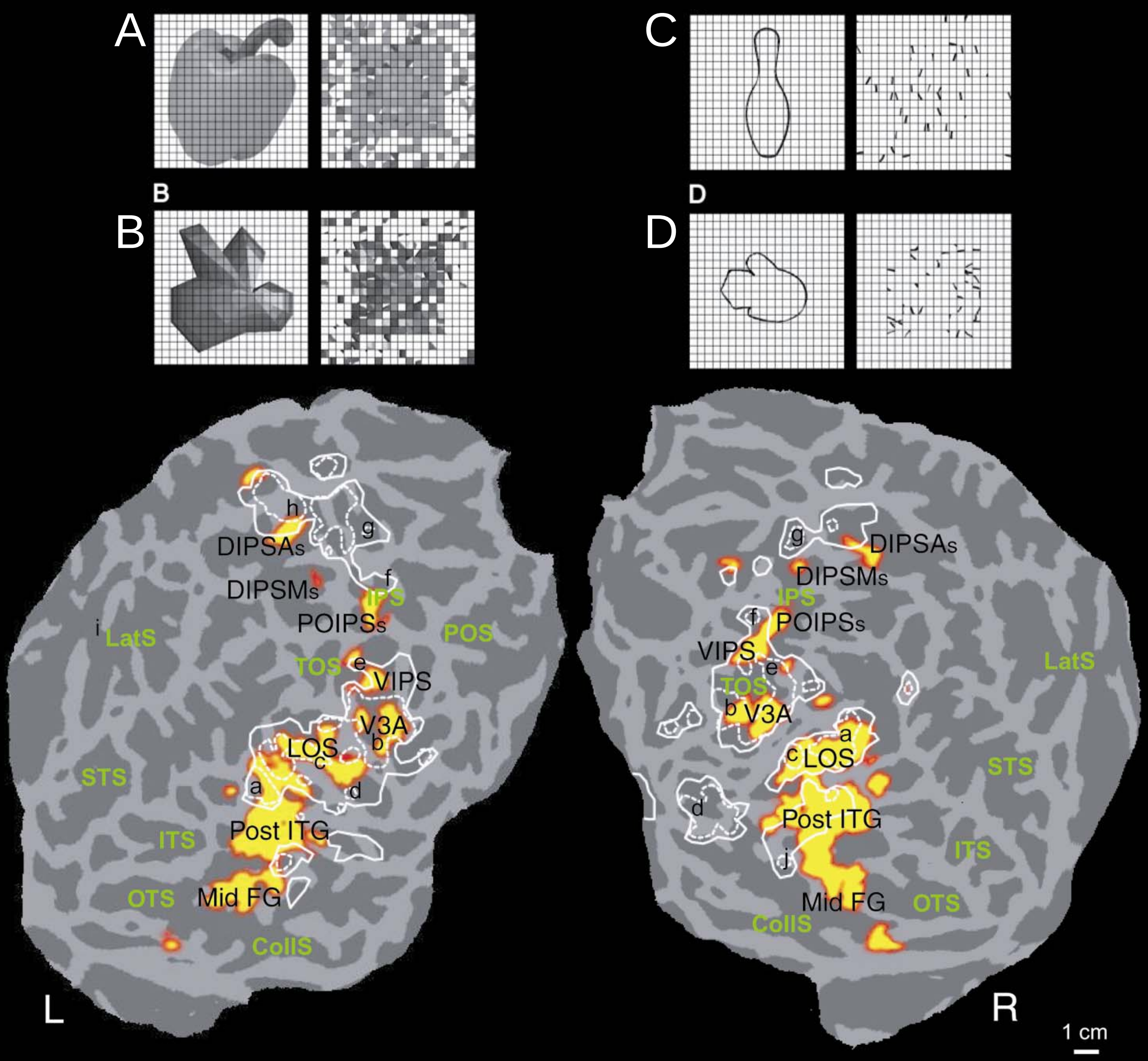




G. Orban et al, Neuropsychologia, ´06

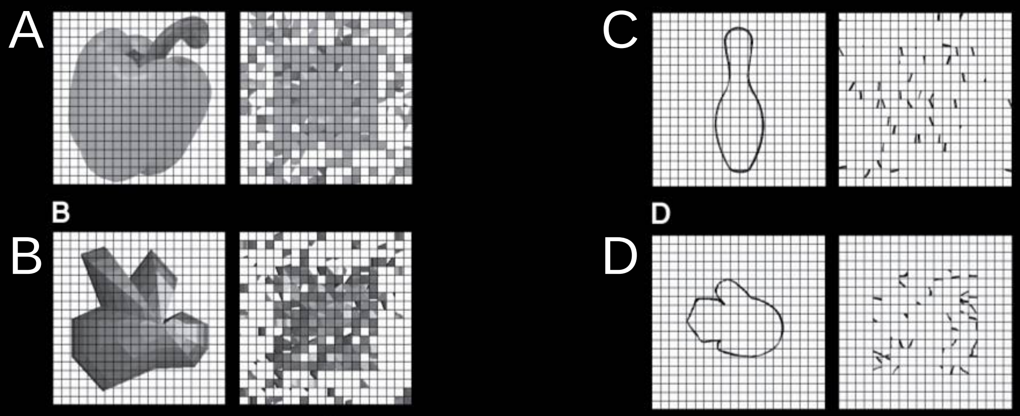
Aires pariétales

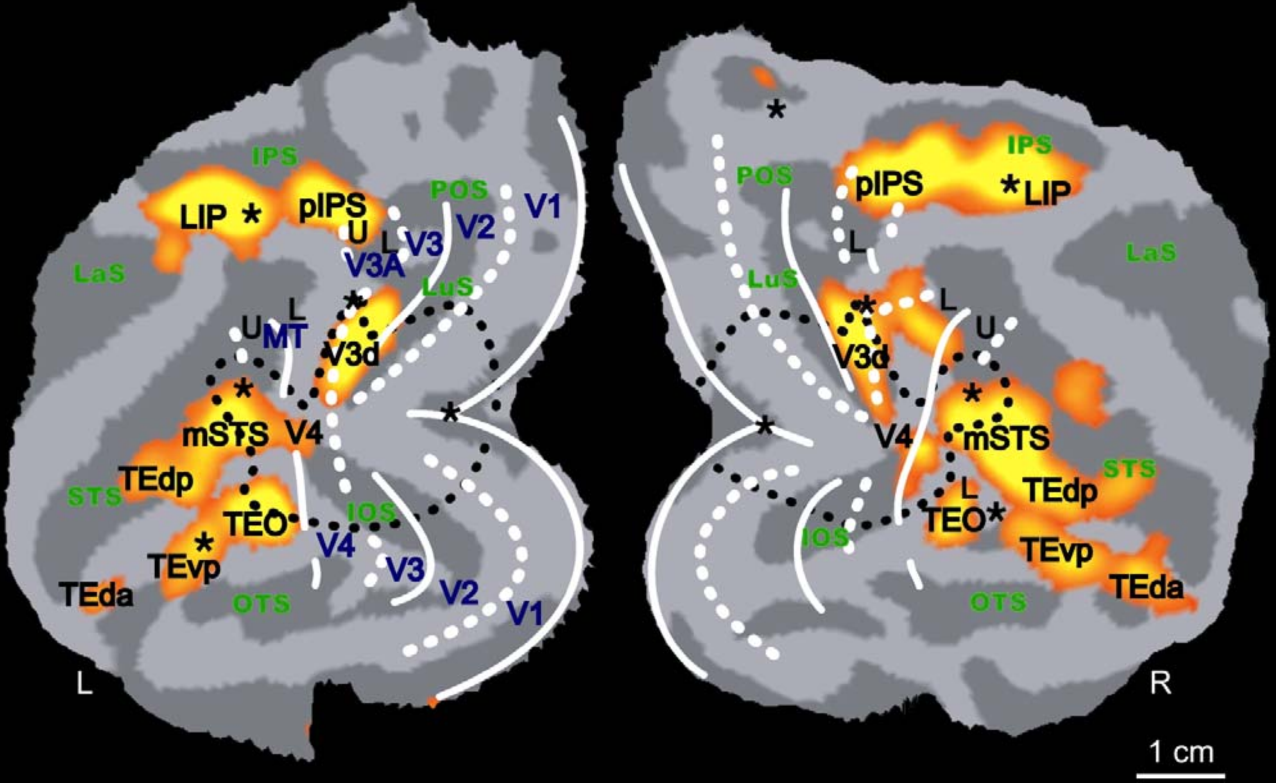
Anatomie fonctionnelle de la sensibilité à la forme 2D



K. Denys et al, JoNS, ´04

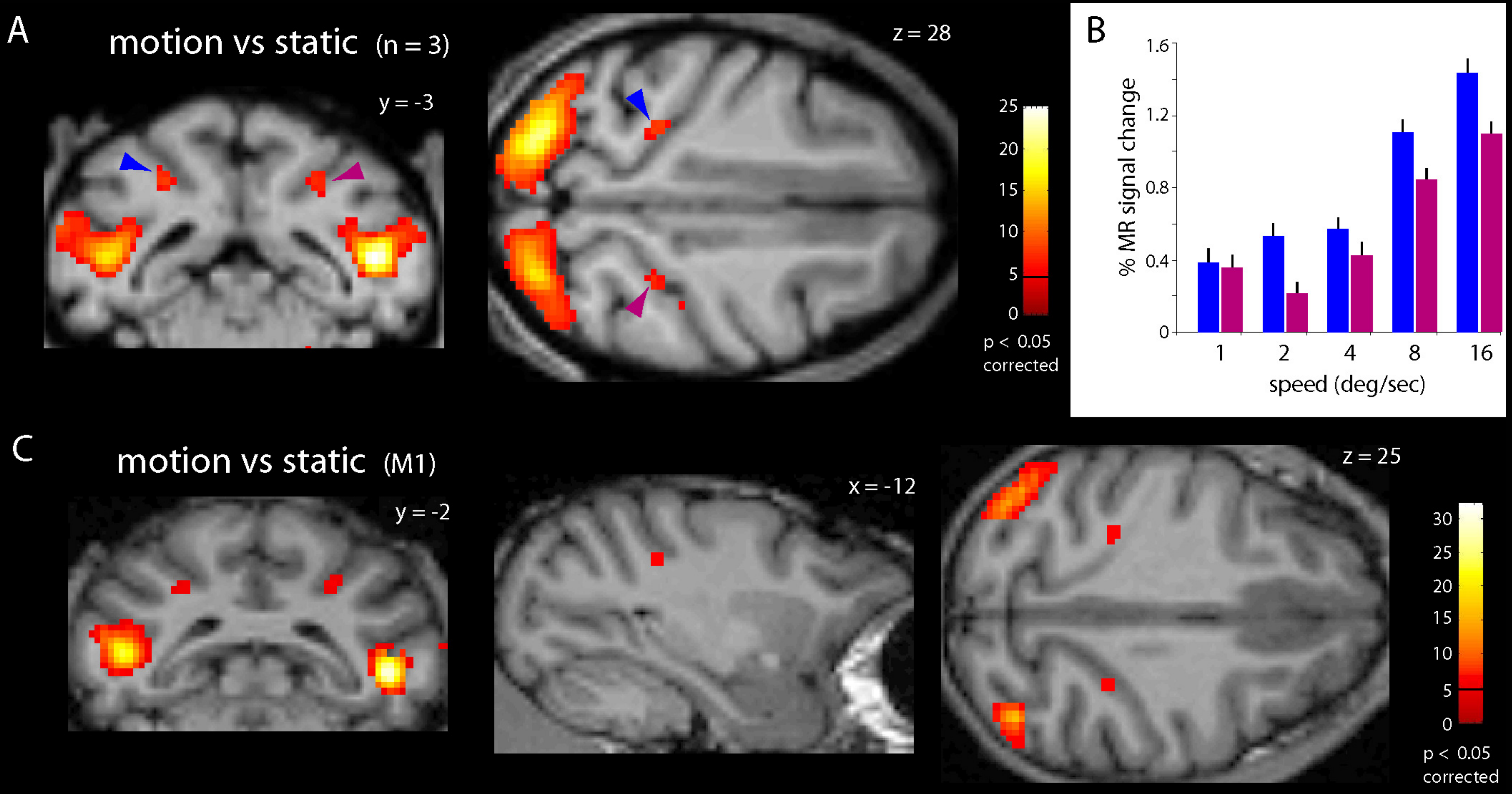
Anatomie fonctionnelle de la sensibilité à la forme 2D





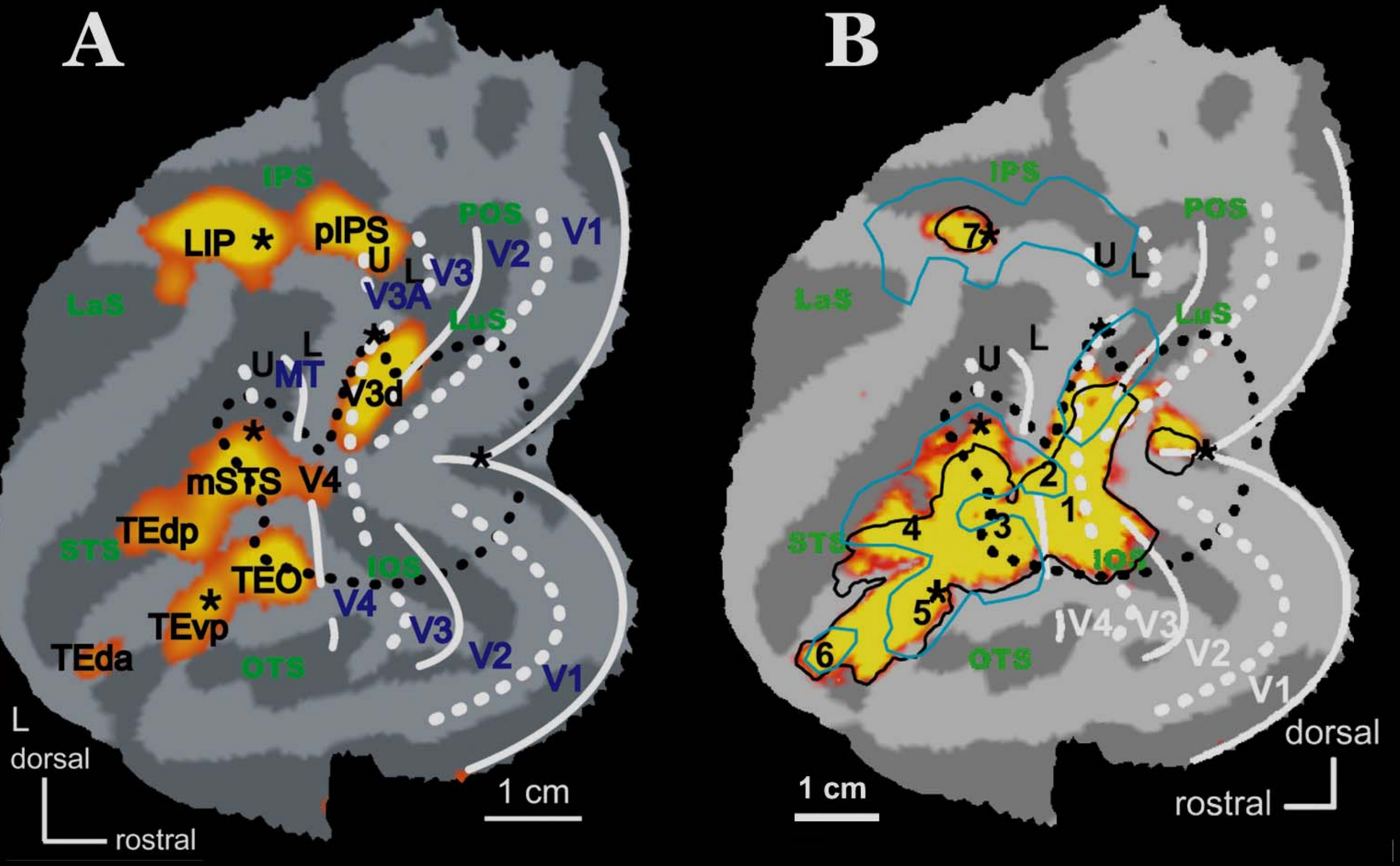
K. Denys et al, JoNS, ´04

Aires pariétales



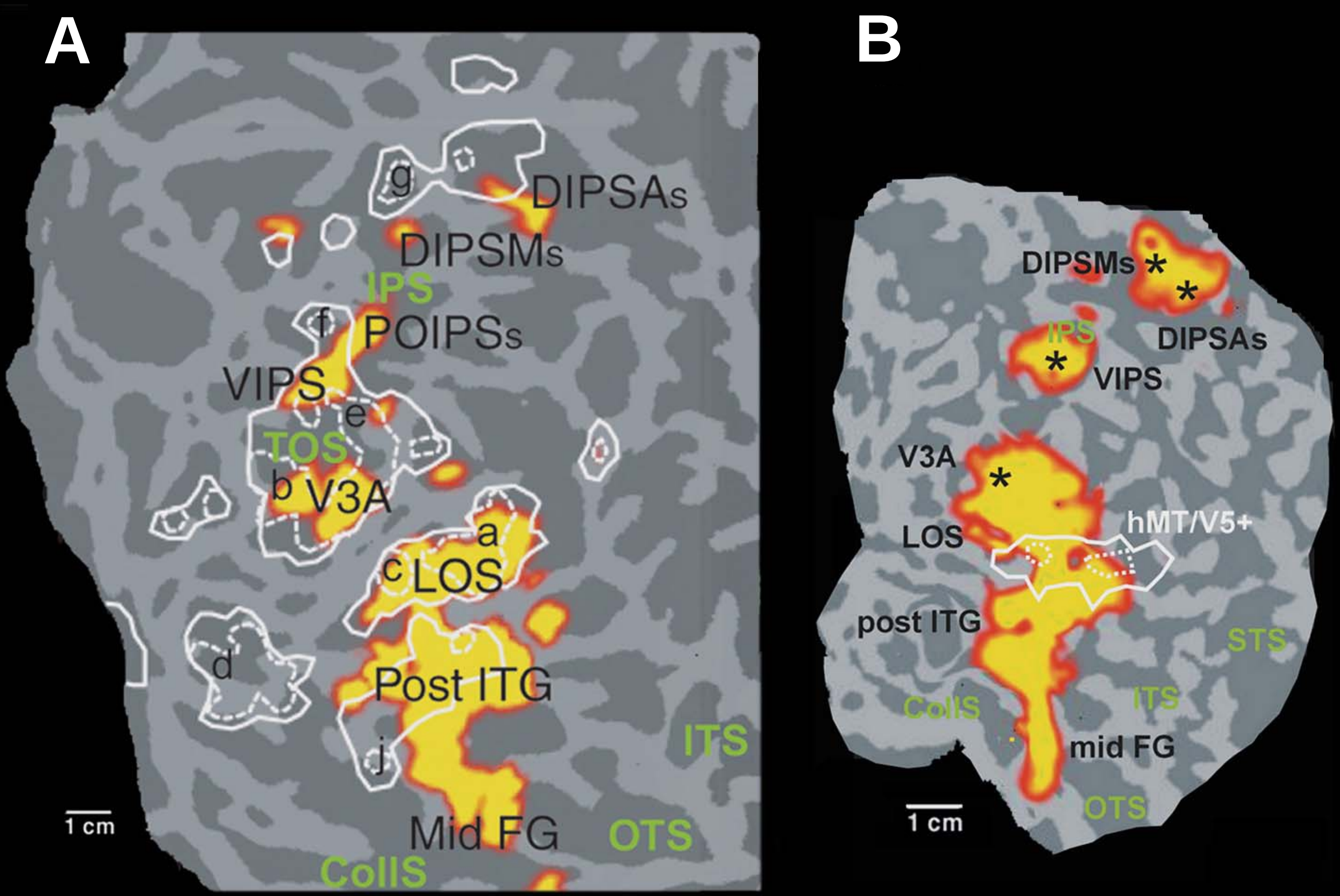
G. Orban et al, Neuropsychologia, ´06

Aires pariétales



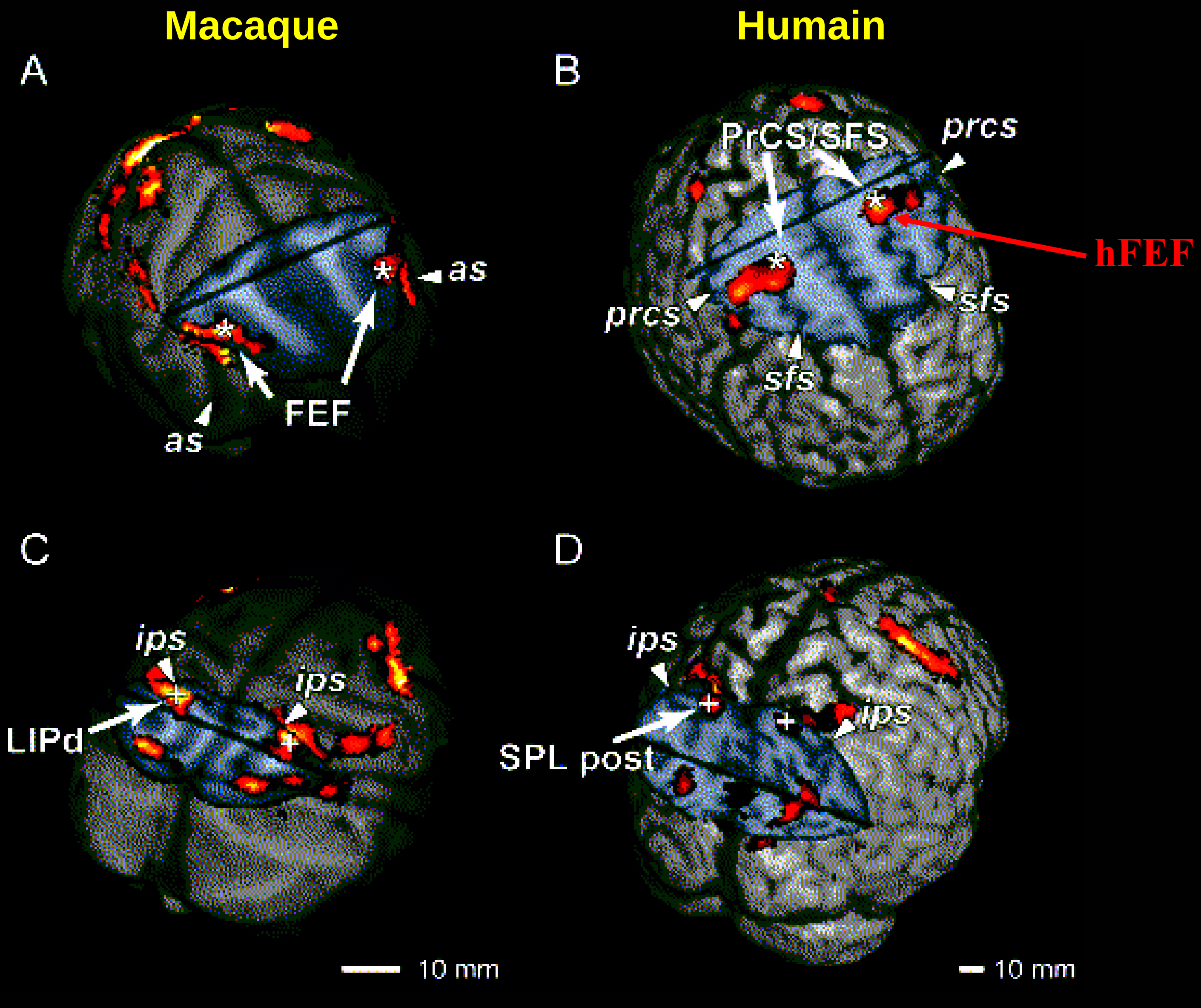
G. Orban et al, Neuropsychologia, ´06

Aires pariétales



G. Orban et al, Neuropsychologia, ´06

Anatomie fonctionnelle des mouvements oculaires



M. Koyama et al, Neuron, ´04

Correspondance fonctionnelle entre régions intrapariétales des primates non humain et humain

Macaque	Humain
Ant AIP	hAIP
Post AIP	DIPSA
Ant LIP	DIPSM
LIPd	hLIP
pIPS	POIPS
?	VIPS
V3A	hV3A

Orban ´07

Conclusions

- Homologies entre aires corticales humain-macaque sont difficiles à établir :
  Nécessité d’employer plusieurs critères (dont la position géographique)

- Homologies entre complexes d’aires plus faciles à établir
  qu’entre une aire individuelle

- Aires rétinotopiques : V1,V2,V3 et V3A homologues (~primates)
  Complexe MT/V5+ homologie du complexe pas encore
  des aires individuelles
  Aires pariétales : triade d’aires homologues centrées sur LIP (hypothèse)